ARTIFICIAL INTELLIGENCE RELATED INVENTIONS

Artificial Intelligence Patent Landscape

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About IP Pragmatics Limited

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IP Pragmatics helps our clients to create, progress and realise value from their intellectual property assets through the provision of integrated commercialisation and intellectual property management services. We are a specialist IP and technology management consultancy which combines intellectual property, technical and commercial expertise with a practical and pragmatic approach.

Over two-decades we have provided insightful IP analytics, technology scouting and transaction advisory services to SME, corporate and IP firm clients in over 20 countries. Our team is a unique blend of experienced ex-industry and IP specialists with active global industry networks and contacts. We use this collective expertise alongside extensive market, IP and scientific information resources, to provide analytical rigour and practical commercial insights.

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EXECUTIVE SUMMARY

The Royal Society provides expert, independent advice to policy-makers and to the general public, championing the contributions that science can make to economic prosperity, quality of life and environmental sustainability.

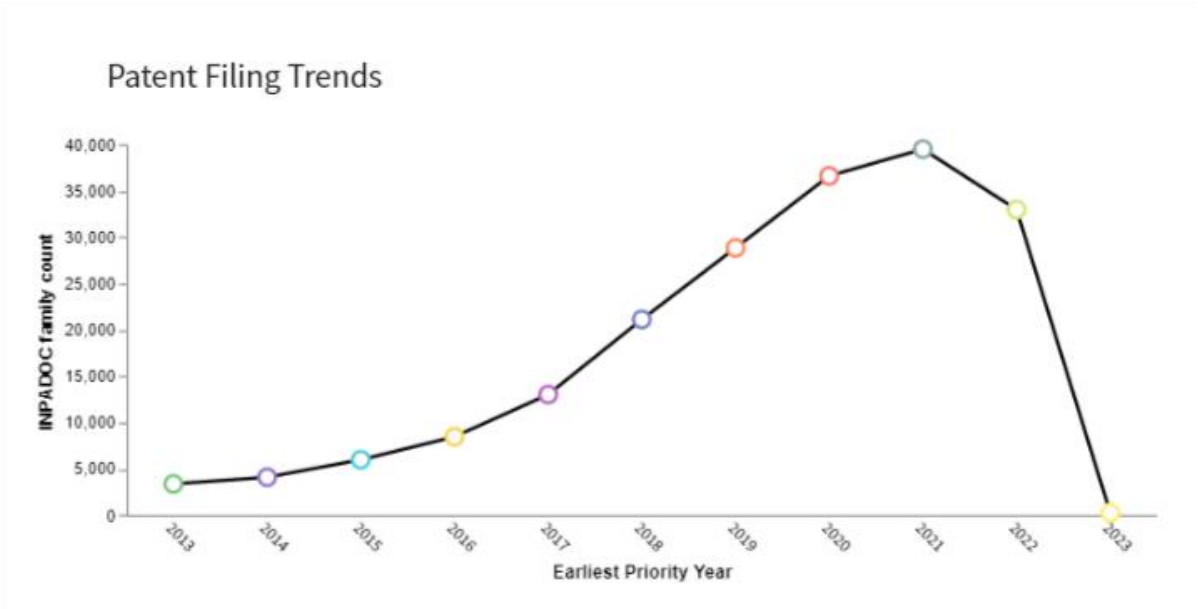
The Royal Society's *Disruptive Technology for Research* project aims to understand the landscape of data-driven and artificial intelligence-based technologies across different fields of scientific research. The project will further articulate the impact and risks data-driven technologies can have, outline cases of success and seeks to understand the factors that may have slowed adoption and how this might be improved. This work will look at different scientific fields as case studies to offer recommendations on how the UK government can best support the development, adoption, and uses of such technologies.

As part of this project, IP Pragmatics Ltd has been commissioned to undertake a patent landscape analysis for Artificial Intelligence (AI) related inventions to provide additional information and context to support the project's main aims. Information gleaned from this patent landscape analysis in terms of key trends, areas of invention and case studies will enable end users to have an overview of the current state of commercialisation for AI related inventions.

AI PATENT LANDSCAPE SUMMARY

The artificial intelligence (AI) patent landscape has grown significantly in the last 10 years, as indicated by the significant increase in the number of patents over this period.

- The last five years accounted for approximately 74% of the total patent landscape, which illustrates the significant developments and commercial interest within the field.



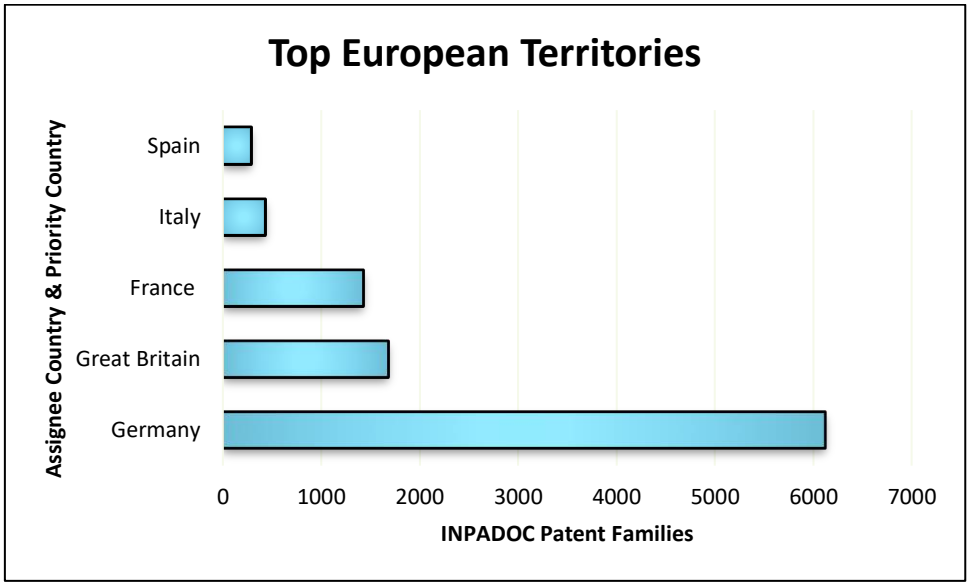
Source: Clarivate via Derwent Innovation (data for 2021-2023 is not complete given the 18-month delay from the priority filing date and the date of publication)

- A continuation of the positive patent filing trend is expected as the global AI market is forecast to expand at a compound annual growth rate (CAGR) of 37.3% from 2023 to 2030, from a market valuation of $136.55 billion in 2022.
- China dominates the patent landscape:
    - the majority of priority patent applications – an indicator of research and innovation – are filed in China, followed by US, Japan, and Korea. A more recent increase in AI patent filings has been observed in India.
    - an analysis of the territories in which applicants choose to subsequently file their applications - an indicator of key commercial markets – is led by China followed by US and Europe.

Great Britain ranks 10th in the AI patent landscape top list of countries

- where priority applications are filed
- as a key markets for AI patents
- it accounts for approximately 1.15% of the overall patent landscape.

In Europe, UK ranks second behind Germany. Great Britain is therefore one of the leading European players driving AI innovation within science and engineering research areas.



Defined by technology type, machine learning is the dominant AI sub-field of patenting activity, with neural networks forming the most prominent sub-category. Most innovation relating to training methods took place after 2016, wherein backpropagation is the leading neural network learning method, followed by unsupervised and reinforcement learning methods.

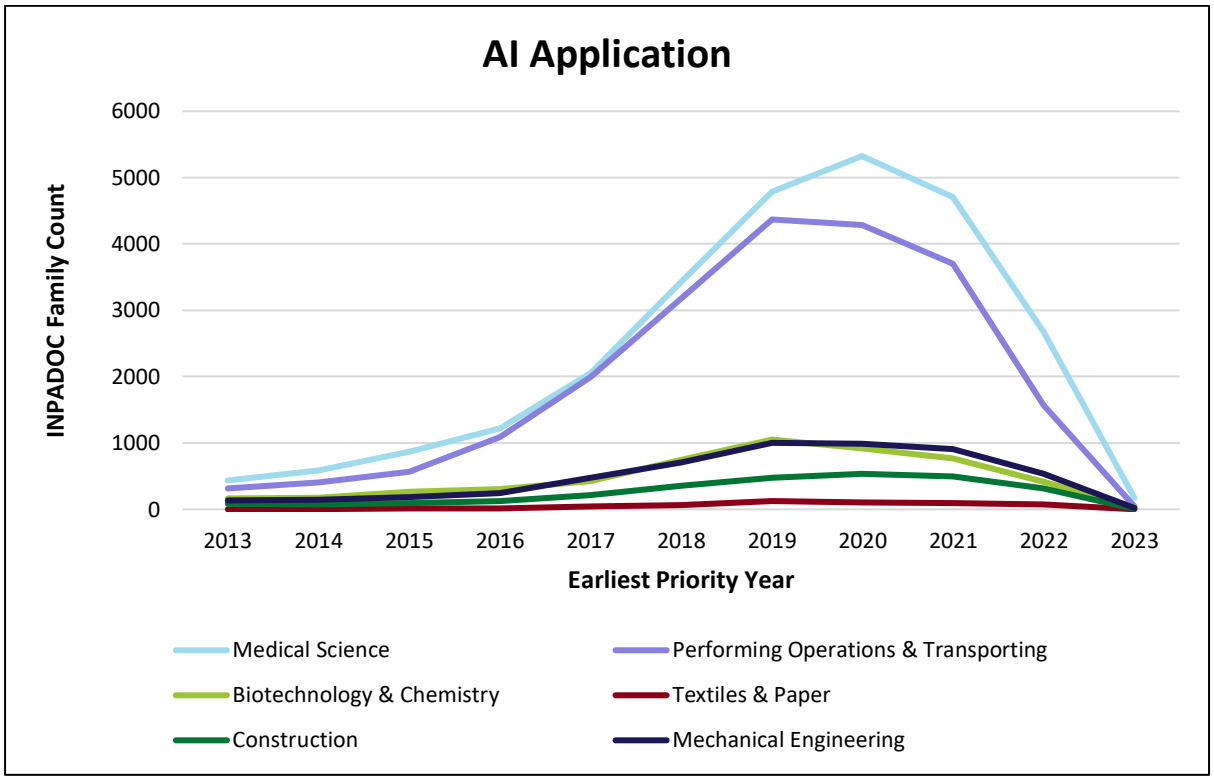
- The filing rate for backpropagation and unsupervised learning decreased in 2020 in contrast to reinforcement learning methods which has continued to increase in 2020.
- A number of neural network architectures have emerged since 2016, with combinations of neural networks emerging as the most prominent in the scientific and engineering fields. This

is closely followed by a continued increased interest in convolutional networks, and to a lesser extent recurrent networks.

Key AI patent applicants are commercial organisations; the top players include Siemens, IBM, and Samsung Electronics.

- The patent portfolio held by Canon established an early footing in the field of AI, but **Alphabet, Siemens, IBM, and Samsung are the most influential newcomers**. These also appear to be the most valuable in the scientific and engineering fields.
- Legal status analysis shows that this is a field with significant growth potential and commercial interest, demonstrated by the high proportion of granted and pending patent families, in combination with a low proportion of lapsed patent families.

The diversity of AI systems makes it adaptable for performing a wide array of tasks. In terms of the application of AI to scientific research, the medical sciences are the most active in relation to AI-related innovation, and advances in AI are improving healthcare and patient treatment outcomes and driving efficiencies across a wide range of medical and healthcare systems. Unsurprisingly, there is also a considerable level of activity across the transport industry, with autonomous vehicles and robots being the key focus.



Note: data for 2021-2023 is not complete given the 18-month delay from the priority filing date and the date of publication

AI PATENTS IN MEDICINE & PHARMACEUTICAL INVENTIONS

- A search generated a result of 7,745INPADOC patent families for the application of AI in medical preparations and pharmaceuticals, with an increase in the patent filing rate over the last 10 years.
- The patent landscape map shows **significant patenting activity related to genome analysis and medical imaging**, with significant interest also in **understanding disease pathology and protein structure**.
- **Key patents point to the importance of AI for improving the efficiency of diagnosis, prognosis, and therapeutic response prediction**. The technology is also having a significant impact on systems for identifying effective treatments, drug discovery and clinical trials.
- **Computer-aided diagnosis and image analysis represent the key research areas**, and **artificial neural networks are most frequently used for image analysis**. There also appears to be significant **interest in supervised data analysis for bioinformatics-related machine learning and data mining, as well as health risk assessment**.
- The significant interest in the use of AI in diagnostic technology in the pharmaceutical industry is expected, as the advent of pharmacogenomics has improved our understanding of disease risk and pathology, and facilitated the development of precision medicine and effective treatment.
- **Top AI patent applicants in this industry sector include Illumina, University Of California, and Roche**.
- Between 2016 and 2019 there was greater interest in filing patents using AI for image and nucleic acid analysis, which has been followed by more interest in developing AI-based platforms that leverage pharmacogenomic data and clinical trial datasets to enrich the portfolio of candidate drug response biomarkers and prediction of treatment responses.
- **Illumina filed the most patents in 2018**, following which the **growth in their patent portfolio appears to have slowed down**. **This trend was also observed in the patent filings of Siemens, Philips, Alphabet, and Fujifilm**. In contrast the patent portfolio held by Roche, University of California, and IBM have experienced continued growth. Interestingly, the patent filing rates by other key players such as Genesis Healthcare and Tata Sons spiked in 2019 and 2020.
- **AI patent portfolios held by Roche, University of California and IBM appear to be most valuable in this sector**. Siemens established an early footing in the field of medical treatment, with Harvard University and MIT being pioneers in the area. Most notably, **Alphabet is the most influential newcomer**.
- **Roche and Siemens dominate the image analysis sector**, with both companies also being **active in the development of pattern recognition systems**. Philips also holds a patent portfolio that follows a similar pattern to these companies. **Illumina also has a significant interest in pattern recognition systems, with a significant focus on cancer genetic analysis**. **Other key players in pattern recognition systems are Alphabet and IBM**, however the portfolios of the two technology companies are much more diversified.
- **Genesis Healthcare** appears to dominate the area relating to **analysis of biological material**, with patent filings exclusively in this area.

AI PATENTS IN MEDICAL TECHNOLOGY

- A search generated a result of 29,340 INPADOC patent families for the application of AI in medical technology, with an increase in the patent filing rate over the last 10 years.
- **Significant areas of patenting activity relate to medical imaging, surgery**, as well as considerable activity around understanding hard to treat cancers and health monitoring.
- AI has had the most significant impact on medical image analysis, diagnostics and health management, as well as computer-assisted surgical systems.
- **The most recent innovations focus on measurements for diagnostic purposes, computer-aided diagnosis, and image analysis**. While machine learning and neural network learning methods are dominant AI approaches, there also appears to be significant interest in systems for recognising patterns. **Neural networks comprising combinations of networks are surfacing within the AI patent landscape for medical technology**, **and artificial neural networks are emerging as the main tool for image analysis**, with significant innovation also focusing on algorithmic training methods.
- **Deep learning systems are a key area of research**, with particular interest in convolutional neural networks. There also appears to be significant interest in unsupervised learning, as well as medical imaging and physiological data.
- **The top players filing AI patents in this field include Philips, Siemens, and IBM.**
    - While Siemens led the field between 2015 and 2017, Philips emerged as the leading assignee in 2018. In this year, the number of patents held by Fujifilm increased significantly over its competitors such as Canon.
- **Siemens dominates most key areas**, with greatest focus on the image analysis sector, which also has significant competition from Philips, Fujifilm and Canon.
    - While most healthcare technology companies are heavily invested in image analysis and machine learning, **Samsung is more focused on measuring systems for diagnostic processes**, which also appears to be the focus of the University of Chandigarh.
    - **IBM dominates** the area of the patent landscape focusing on using **patient-specific data**.
- **The AI patent portfolios held by Siemens, Philips, and IBM appear to be most valuable**. Canon was one of the earliest patent filers, with IBM, Fujifilm, Samsung, and University of Chandigarh also well established. **Siemens is the most influential player, and Alphabet is quickly becoming an important player**.

AI PATENTS IN BIOTECHNOLOGY & CHEMICAL INVENTIONS

- A search generated a result of 15,012 INPADOC patent families for the application of AI in biotechnology and chemistry sectors, with a positive trend the patent filing rate over the last 10 years.
- Significant areas of AI patenting activity relate to relate to cancer, genomic data, gaseous emissions, with significant interest also in microcontrollers.
- **Key subject matter focuses on measuring processes involving nucleic acids and methods for recognising patterns**, with the emergence of supervised data analysis for bioinformatics-

related machine learning or data mining and ICT systems specially adapted for functional genomics or proteomics. **Combinations of neural networks form the core of new patent filings**, and artificial neural networks and algorithmic training methods appear to be the most common methods for image analysis.

- **Key patents also appear to relate to machine learning for environmentally controlled vertical farming systems, and crop health monitoring, assessment and prediction**. Moreover, AI has had a profound impact on the monitoring of bioreactors, genomic engineering, hydraulic fracturing and natural resource exploration using microbial/genetic information.
- **Leading applicants include International Business Machines Corp, University of Chandigarh, and Halliburton Co Holding.**
- **IBM became the leading patenting organisation in 2017, but Illumina emerged as the top assignee in 2018, while Genesis Healthcare exhibited the most significant increase in 2019.**
    - The rate of growth subsequently slowed down in 2020 and similar levels of patent activity were observed across the top parent organisations.
- **Siemens and Saudi Arabian Oil Company both established themselves early** in AI-related patenting activity while **IBM's patent portfolio is considered pioneering**. **Alphabet and Illumina represent new entrants** and have had the most significant impact on research. Nevertheless, **LG electronics has a more valuable patent portfolio** due to a much higher number of granted patent families.
- **LG Electronics, IBM, Schlumberger, Alphabet, Illumina and Deere dominate with patents relating to machine learning and neural network learning methods**.
    - **Genesis Healthcare leads AI-related innovation in the analysis of biological and chemical material**, while **Illumina appears to be the most significant player in cancer genetic analysis**, and **Deere driving innovation in methods for recognising patterns**.

AI PATENTS IN ENGINEERING & TRANSPORT

- A search generated a result of 45,454 INPADOC patent families for the application of AI in engineering sectors, which has experienced significant growth in the patent filing rate over the last 10 years.
- **Concentrated areas of patenting within the patent landscape relate to computer vision and vehicular environment, and robotics.**
- AI innovation is having the most **significant impact in relation to intelligent diagnosis systems for structural defects, autonomous vehicle control and machine learning systems for controlling robots.**
- **Machine learning, neural network learning methods, image analysis, and methods for recognising patterns patent classifications dominate, wherein AI appears to primarily be used to control vehicles and manipulators**.
    - Most patents have been filed between 2018 and 2021
    - Combinations of **neural networks and recurrent networks** are the most frequent neural networks used, with backpropagation being the leading neural network learning method.
    - There is also **significant patent activity relating to probabilistic graphical models**, while artificial neural networks and algorithmic training methods are the most

common AI systems being developed for image analysis within the engineering industry.

- **Key AI concepts in engineering research appear to focus on computer vision and microcontroller systems**, with particular interest in training models and reinforcement learning, as well as neural network neuron structure.
- **Top players include Bosch Robert, LG Electronics, and Siemens.**
    - Bosch and LG Electronics have significantly increased the number of patents filed with the majority of the patent portfolio held by LG Electronics originating in 2019. This is in contrast to other top players whose patent portfolios have increased more steadily over the last 10 years
    - Bosch and Toyota emerged as the most active patent applicants in 2020.
- Several players, such as **FANUC, established an early footing** in the engineering space, with **Hyundai and JAIN being the latest newcomers**. Important players include automotive manufacturers, such as Toyota and Mitsubishi, with Alphabet also emerging as a pioneer in the area. The portfolios of **Toyota, FANUC, and Siemens** are considered more valuable in the engineering field when based on the higher proportion of granted patent families held by these companies.
- **Ford and Toyota have also invested significantly in methods for recognising patterns**. In contrast, there appears to be **less interest from the automotive industry in image analysis, as this area is dominated by Siemens, Canon and Hitachi**. There also appears to be significant interest in programme-controlled manipulators, with substantial number of patents filed by Alphabet, FANUC and LG Electronics.

CONTENTS

1 METHODOLOGY

1.1 SEARCH STRATEGY

The search strategy was drafted utilising key search terms and classification codes to identify the overall patent landscape for artificial intelligence (AI) to help understand how AI is transforming scientific and engineering research. The search strings were drafted using IP Pragmatics' subscription landscape tool, Derwent Innovation, with additional analysis conducted in Orbit by Questel. The Derwent Innovation database contains full text patent information from all the major patent territories, bibliographic data from other territories (covered by International Patent Documentation (INPADOC)), plus augmented data added by Derwent World Patent Index, DWPI.

Searches were limited to the last 10 years to focus on recent trends, and keywords chosen to represent the AI technology areas currently dominating the research field. The chosen keywords were searched across the Title/Abstract/Claims fields, as these include the critical technical features of inventions. Other relevant keywords such as "robotics", "big data" or "speech recognition" were considered sub-topics of the key areas, hence were not included to keep the dataset focused. The appendix details the keywords that formed the basis of our searches.

Nevertheless, the wide variety of AI-related terminology presents a risk for keyword-based searching missing relevant patent data, hence the search strategy includes a combination of IPC/CPC codes and DWPI™ Manual Codes relating to AI, in order to broaden the coverage without compromising the accuracy of the dataset. The IPC/CPC codes and DWPI™ Manual Codes are technology indexing systems used to categorise patents based on subject matter.

The IPC/CPC codes and DWPI™ Manual Codes were also used to focus the analysis of AI applications within the natural sciences and engineering fields in order to provide more granular information on how AI is transforming research. Patent documents relating to ICT systems adapted for administrative, advertising, commercial, educational and financial purposes were excluded from our analysis given their lower impact on scientific research.

The total dataset generated was used to investigate the overall trends and geographical distribution of the AI patent landscape. A number of sub-searches were performed to permit more detailed insights on the identified key AI application areas, given the size and diversity of the patent landscape. Since patent filings in China dominate the patent landscape, we took an early decision in the search strategy to omit China-only applications, to avoid skewing the subsequent analysis of the AI patent landscape.

The Appendix of this report also lists the search codes used in the searching strategy, as well the definitions of IPC/CPC classifications and DWPI™ Manual Codes.

1.2 LANDSCAPE MAPS

Derwent Innovation can be used to generate sophisticated patent landscapes to visualise the relationship between patents in a common technology area based on key words within the claims and/or abstracts/text of individual patents within the searched field. The sets of INPADOC patent families identified in the patent landscape searches were mapped using Derwent Innovation's proprietary ThemeScape™ mapping tool to generate visual maps of patenting activity, where subject matter of high patenting activity is represented by "peaks" on the resulting map. Maps were generated for each of the different sectors.

1.3 FORWARD CITATION ANALYSIS

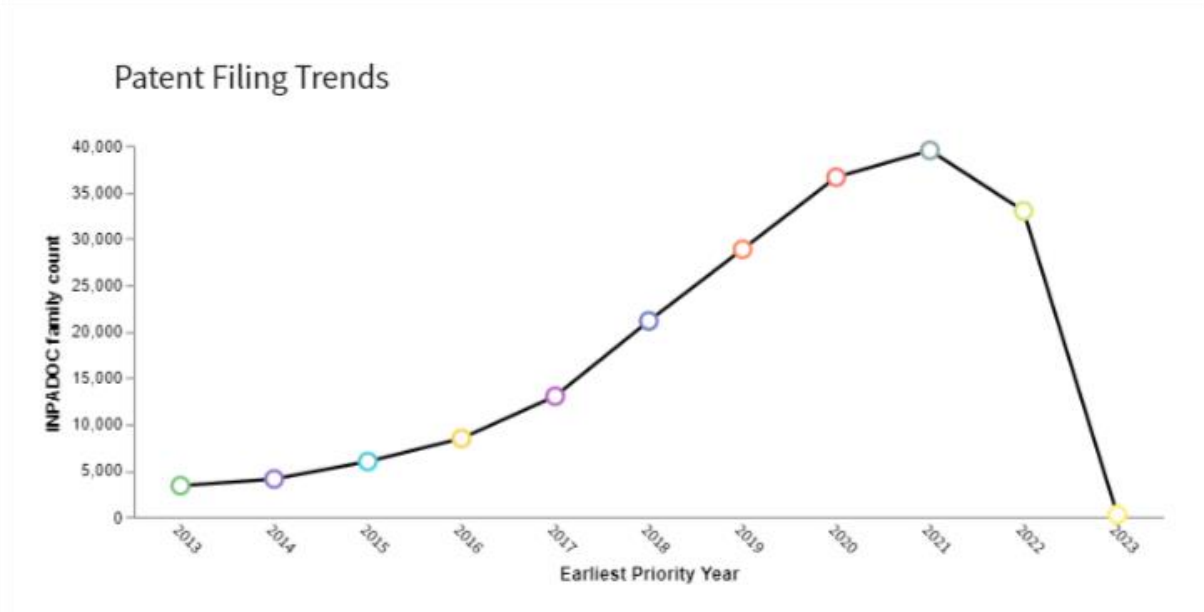
There are a number of metrics that can be used to determine key patents within the AI sector, these include: age of the patent from the priority date, independent claim count, first claim word count, as well as family size and breadth of international filings. A commonly used indicator is the number of times that a patent is cited by a later patent ("forward citation"), where more valuable patents tend to be cited more often than less valuable patents. In order to minimise bias, only non-self forward citations were examined, as assignees frequently cite their own patent families. The basic concept has broad recognition and has been extensively tested, since valuable patents are likely to encourage research and patenting in similar areas to capitalize on the potential economic reward. However, the age of patent families and technical domain also have an effect on the number of citations, and therefore the methodology for non-self forward citations corrects and accounts for these factors. The technology impact metric in Orbit by Questel provides a means to normalise the dataset, wherein an average patent family has a score of 1, which helps to identify key patent families.

2 AI PATENT FILING LANDSCAPE

2.1 FILING RATE

Patent filing trends offer a snapshot of the level of activity in the technology space over a given period. The artificial intelligence (AI) patent landscape has grown significantly in the last 10 years, as shown by the significant increase in the number of patents filed. There was a steady increase in patent filings for AI applications in science and engineering between 2013 and 2016, which has been followed by a steeper increase more recently. The last five years account for approximately 74% of the total patent landscape, which illustrates the significant developments and commercial interest within the field. This is be expected given the progress in the hardware and processing technology which has occurred over a similar time period, as the data needed to "teach" computers is no longer the bottleneck, with storage and processing power needed to execute deep learning now available, fast and cost-effectively[1].

Please note, 2021-2023 data given in the graph will not be complete, due to the 18-month delay between priority application and publication. Nevertheless, we can expect to see a continuation of the positive trend, given that the global AI market size is expected to expand at a compound annual growth rate (CAGR) of 37.3% from 2023 to 2030, from $136.55 billion in 2022[2].



Source: Clarivate via Derwent Innovation

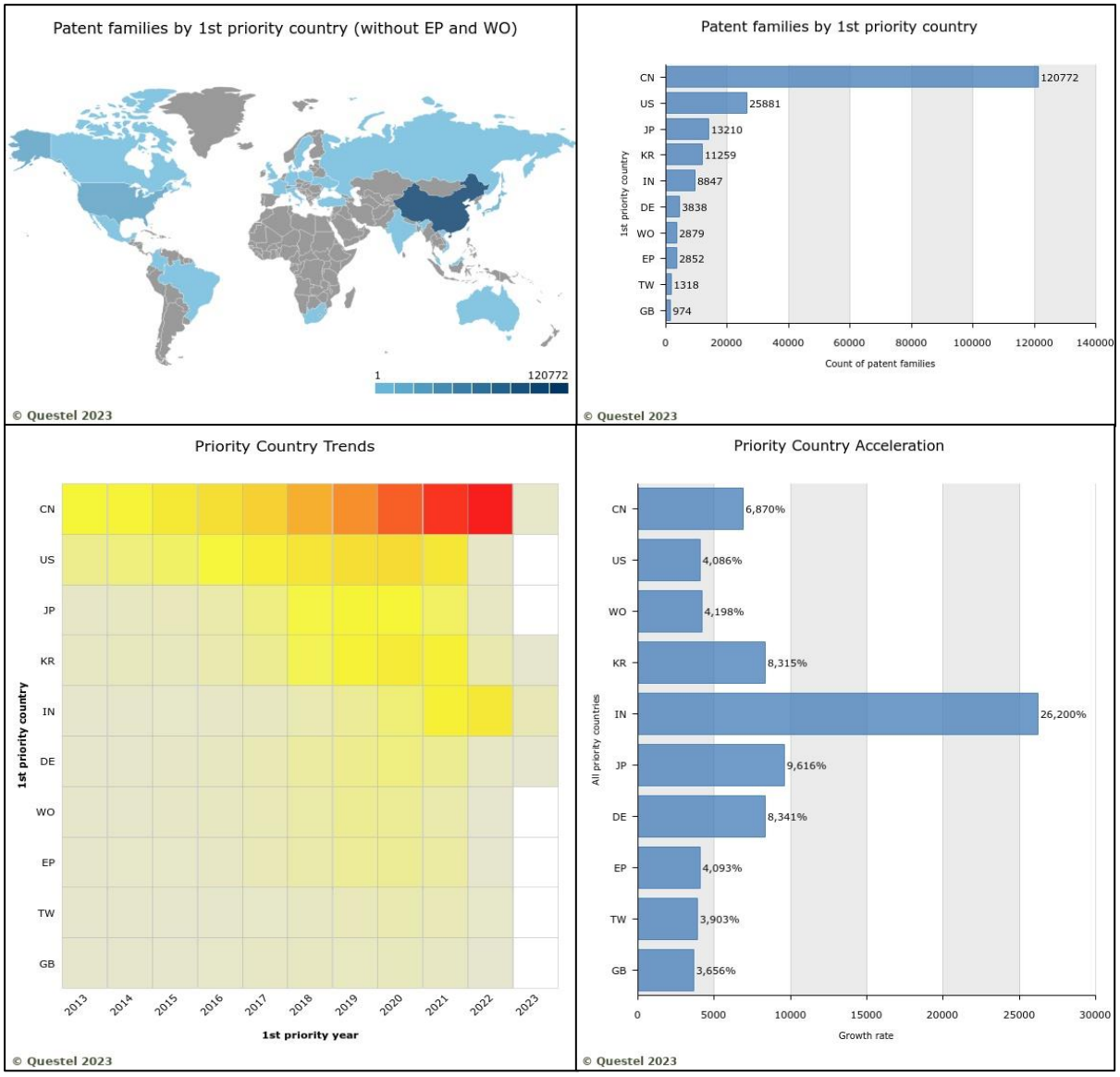
[1] https://www.theguardian.com/society/2017/sep/12/patients-illnesses-could-soon-bediagnosed-by-ai-nhs-leaders-say

[2] https://www.grandviewresearch.com/industry-analysis/artificial-intelligence-ai-market

2.2 PRIORITY FILING COUNTRIES

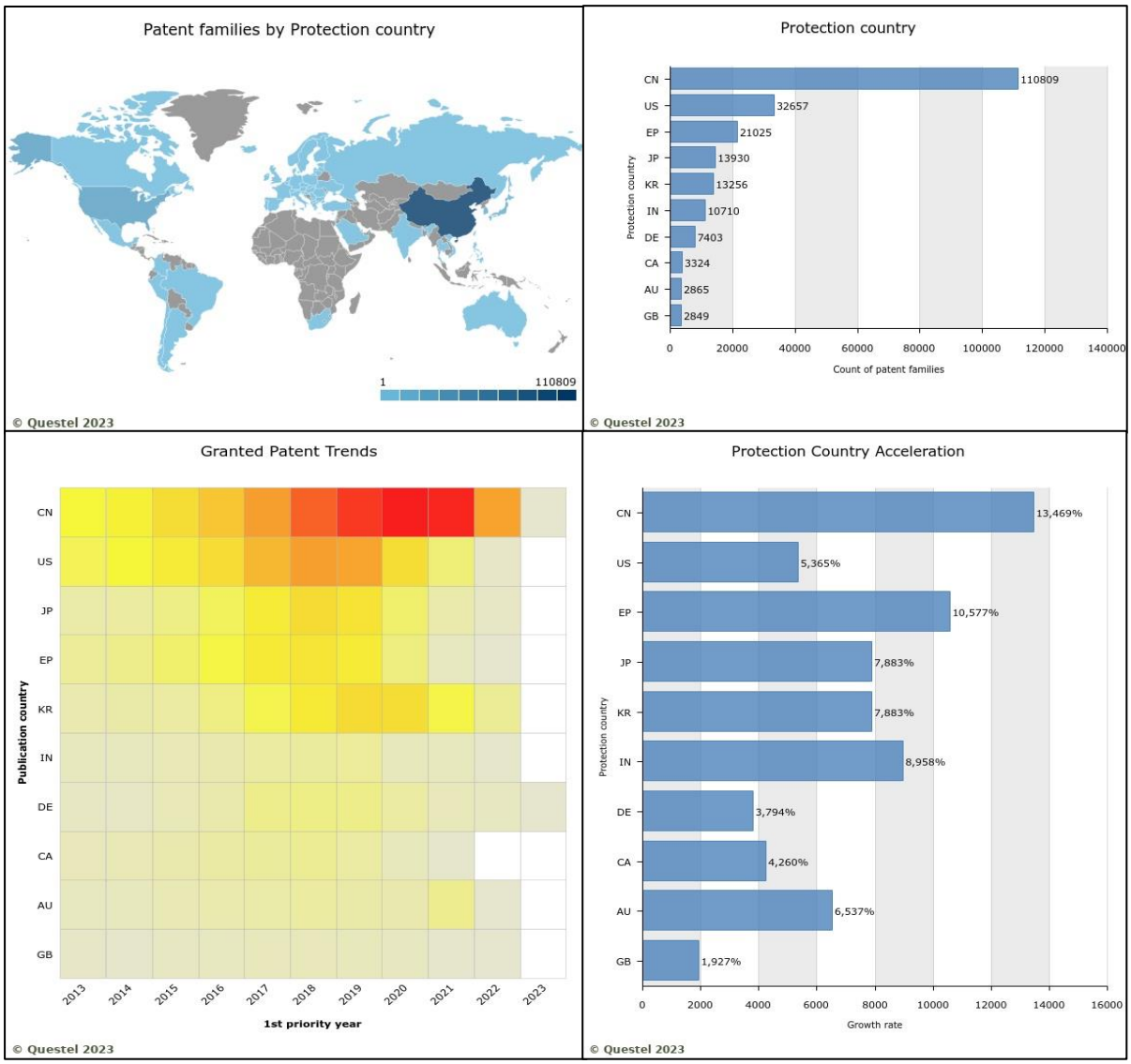
The top priority countries can be analysed to see where the patent applications are initially filed and claim their priority from. This can be a good indicator of the countries leading in research and innovation in a particular technology field, since organisations generally file patent applications first in the local territories where their research bases are located. Likewise, for universities the priority country will usually tend to be the country in which they are based.

The AI patenting landscape is dominated by China, which accounts for approximately 62% of the patent landscape. It is followed by US which represents approximately 13.2% of all priority applications. Japan constitutes approximately 6.75% of the patent landscape, while Korea accounts for approximately 5.75%. Interestingly, there appears to be a more recent increase in AI patent filings in India. **Great Britain represents a significantly smaller portion of the AI patent landscape, ranking 10th in the list, with approximately 0.5% of all priority applications (Section 2.4 has further analysis).**



2.3 PROTECTION COUNTRIES

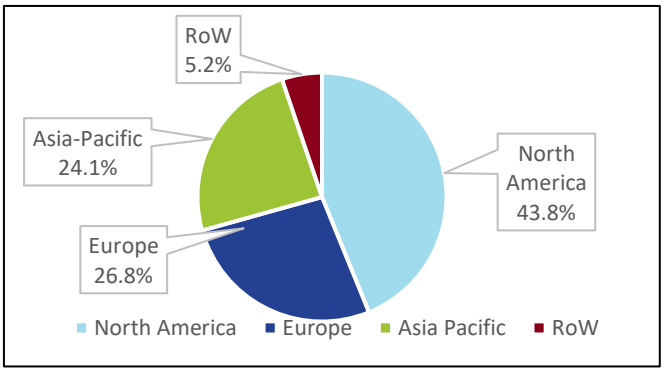
Similarly, we can look at the countries elected for patent protection (i.e. the jurisdictions of granted active patents including the countries where European patents are active). This is a good indicator of the leading markets in a given field. In this instance China is the leading jurisdiction, accounting for approximately 44.58% of all granted patents. It is followed by US which represents 13.3% of the patent landscape, and Europe which has approximately 8.45% of all granted patents. **Notably, despite most research taking place in Asia and North America, Europe represents a key major market**. However, the Chinese and US markets are growing at a faster pace than in Europe. **Great Britain ranks 10th in the analysis, accounting for approximately 1.15% of the patents granted.**



2.4 GREAT BRITAIN

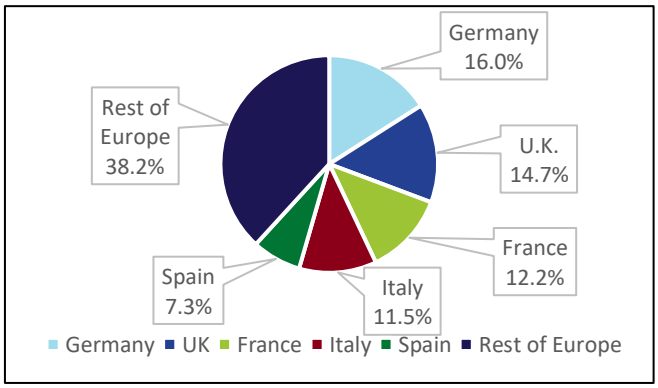
The use of AI in the science and engineering market is being driven primarily by the demand for AI technology to improve processes across key areas. It is therefore unsurprising to see a correlation between patent filing trends and global market shares[3]. North America represents the leading market, which is likely due to an interplay of a number of factors, such as the presence of many top science and technology companies, as well as a highly skilled workforce[3]. Interestingly, the Asia-Pacific region is predicted to have the highest compound annual growth rate (48.6%) between 2022 and 2027, in comparison to the US (43%) and Europe (46.5%)[3], which is also reflected in the granted patent trends shown in Section 2.3. The patent landscape also complements the reported increase in activities within the healthcare industry in China and India[3]. In a recent report by BCC, in Europe, UK has the second largest share of the AI in life sciences market after Germany, accounting for approximately 14.7% and having the highest predicted compound annual growth rate of 47.9% in the region[3]. As a result, the UK government has formed the "Office for Artificial Intelligence" to support the plan for continued growth.

Global Market Shares of Machine Learning in the Life Sciences, by Region, 2021 (%)



Source: BCC Research

European Market Shares of Machine Learning in the Life Sciences, by Country, 2021 (%)

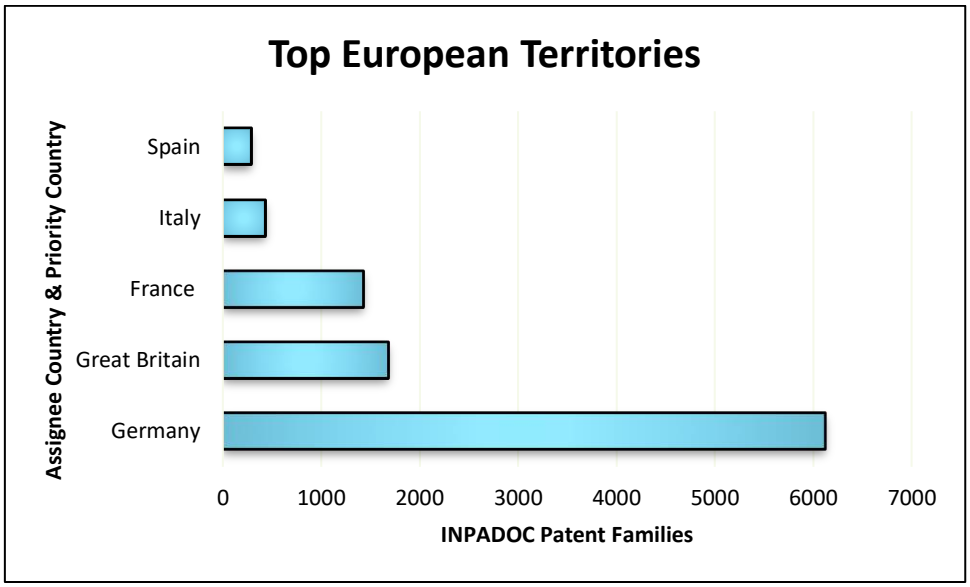


Source: BCC Research

[3] Global Markets for Machine Learning in the Life Sciences. October 2022. BCC Publishing Staff. Report Code: HLC284A

In Section 2.2 and 2.3, Great Britain is shown to represent a smaller portion of the AI patent landscape in science and engineering, in comparison to North America and Asia-Pacific regions. However, in Europe, it can be more difficult to estimate patent filing rates across individual territories, as applying for a regional European patent is a common IP strategy (it can be simpler and more cost-effective than obtaining individual national patents in the member states of the European Patent Convention). As a result of the international interest in AI within science and engineering, this route often provides more commercial and strategic advantages, as illustrated by a recent report, which found that "around 88% of AI-related patents first filed in the UK are also protected elsewhere, and this is in contrast with two big global players, the US and China, who have 53% and 19% respectively of patents protected in other jurisdictions."[4]

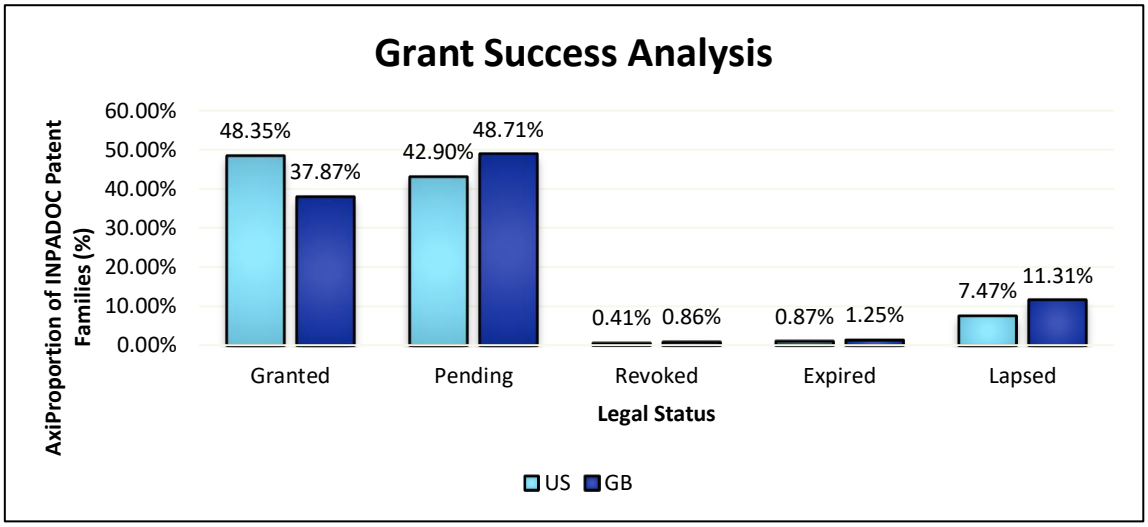
As a result, in order to provide a more accurate estimate of filing rates within each European country, the following graph incorporates data relating to assignee location, provided by Derwent Intelligence. The visualisation compares the number of patents filed in the top five European countries, where UK ranks second following Germany, which complements market data. The implementation of AI technology within the manufacturing sector in Germany appears to be the key factor driving the evident growth in innovation, as the manufacturing sector represents 25% of Germany's economy[3]. Great Britain is therefore one of the leading European players driving AI innovation within science and engineering research areas.



[4] https://www.potterclarkson.com/insights/patenting-ai-in-the-uk-trends-and-outlook/

In response to the gap in AI innovation when compared with the North American and Asia-Pacific regions, the UK government has set up a number of grants to help boost developments. For instance, the Life Sciences Innovative Manufacturing Fund includes £17 million in government funding, which is supported by additional private investment of £260 million to help fund life sciences manufacturing projects in both medical diagnostics and human medicines[5]. AI technology provides an important opportunity to grow the UK economy[6], hence such funding schemes will be imperative to help drive innovation and support UK's position as one of the leaders in science and engineering. As result, recent growth rate in UK patent filings has become similar to other key territories, such as the US, despite the UK representing a smaller portion of the patent landscape.

Although market differences are likely to be the primary factor driving the apparent differences in patent filing rates across the world, the various patent law and regulatory frameworks (including data protection) may also have an impact on innovation. For instance, the European Patent Convention and UKIPO follow similar approaches when assessing AI inventions, wherein computer programs and mathematical methods are excluded from patentability, unless such inventions provide a novel and inventive "technical effect"[7]. This is covered in more detail in Section 10 in this report. In addition, methods of treatment and diagnosis are generally not patentable in Europe, so that medical practitioners are not restricted at the point of care of a patient[8]. In contrast, the USPTO is reported to follow a more permissive approach in terms of patentable applications of AI and methods[9]. We can see that a higher proportion of patents in the US are granted than in the UK, where patents may also have faced increased regulatory challenges, as shown by the higher proportion of revoked patents.



[5] https://www.gov.uk/government/news/life-sciences-companies-supercharged-with-277-million-in-government-and-private-investment

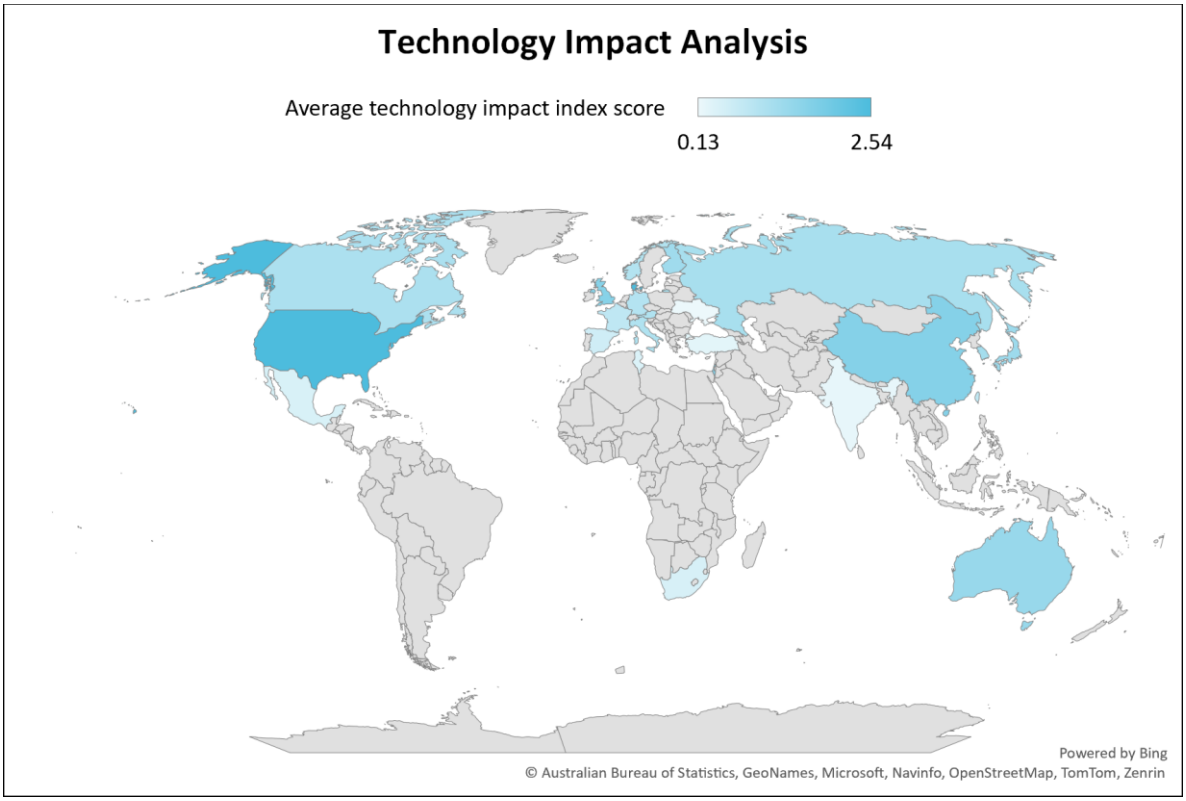
[6] https://www.gov.uk/government/news/initial-100-million-for-expert-taskforce-to-help-uk-build-and-adopt-next-generation-of-safe-ai

[7] https://cameronintellectualproperty.com/ai-patentability-in-europe-us-your-chances-before-epo-uspto/

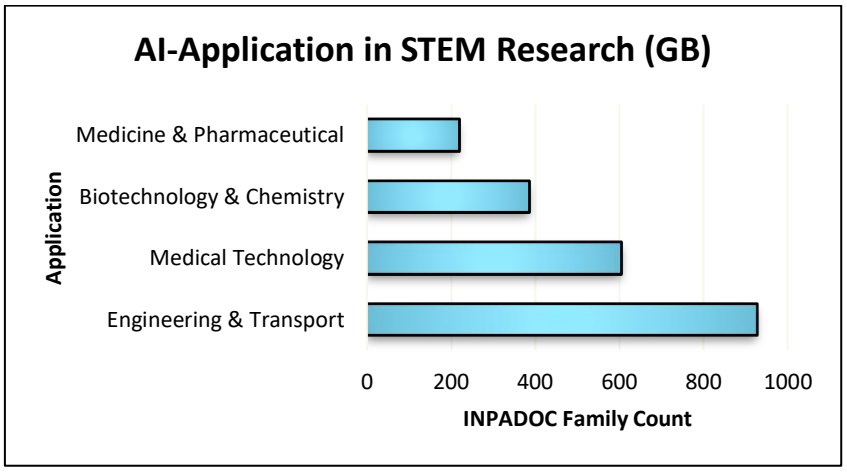
[8] https://www.vennershipley.co.uk/insights-events/patentability-of-methods-of-treatment-and-diagnosis/#:~:text=This%20has%20led%20to%20the,the%20human%20or%20animal%20body%E2%80%A6%E2%80%9D

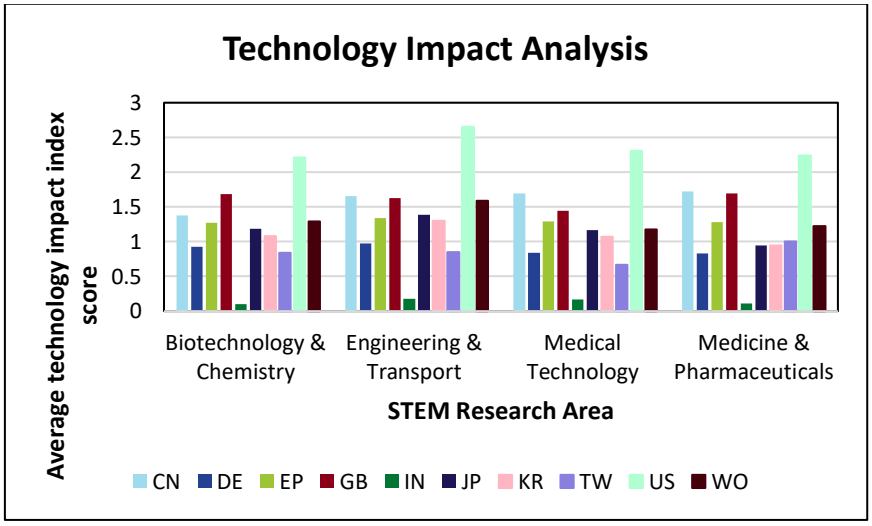
[9] https://cameronintellectualproperty.com/ai-patentability-in-europe-us-your-chances-before-epo-uspto/

Nevertheless, a quantitative comparison of patent filings in each country provides a very little insight into the quality of AI innovation within science, technology, engineering, and mathematics (STEM) research, as it does not consider the impact of patent filings on the patent landscape. In order to investigate the impact of AI innovation in each country, the "Average Technology Index Score" (provided by Orbit by Questel) was utilised, as described in Section 1.3. Interestingly, although China has filed significantly more patents than any other territory, the patent filings in US appear to have a higher technological impact on the landscape. Similarly, despite India exhibiting the most significant growth rate in AI patent filings in the science and engineering sectors, the innovation does not appear to have a significant impact. In contrast, although the UK represents a smaller portion of the patent landscape, research and innovation by UK organisations appears to be having a profound impact, as the UK is amongst the highest ranking in world. In particular, the UK has a higher impact than Canada, Germany, France, Japan, Korea, and Australia. Please note, the graph does not show EP and WO patent filings, which are common patent filing strategies, and can therefore have an effect on the analysis.



Although the UK is one of the leaders in AI innovation within the science and engineering sectors, the following chart investigates areas of strength and weakness of patents filed by UK organisations. It can be observed that in the UK a higher proportion of patent filings are focused on the engineering and transport sectors, which appears to be driven by patent filings by major industry players, such as BP, Jaguar Land Rover, BAE Systems, and Rolls Royce, with significant interest also from the University of Oxford, University of London, and Cambridge University. The limitations in the patentability of treatment and diagnostic methods in the UK may have also contributed to lower interest in medical technology. Since patent law is more similar in Europe, comparable trends can also be observed in the region. In contrast, patent activity relating to medical technology is higher in China, US, India, Korea, and Japan. Biotechnology and medicine fields are also represented less in the UK. In response, the government has opened a number of centres of excellence dedicated to developing AI technology in healthcare, such as the Artificial Intelligence Centre for Value-Based Healthcare and the London Medical Imaging[10], in order to keep the UK competitive in these areas. As a result, it can be observed in the following figures that UK patent filings are making a significant impact in science and engineering, based on the technology impact index score.





[10] https://www.gov.uk/government/news/artificial-intelligence-to-help-save-lives-at-five-new-technology-centres

3 AI PATENTING TRENDS

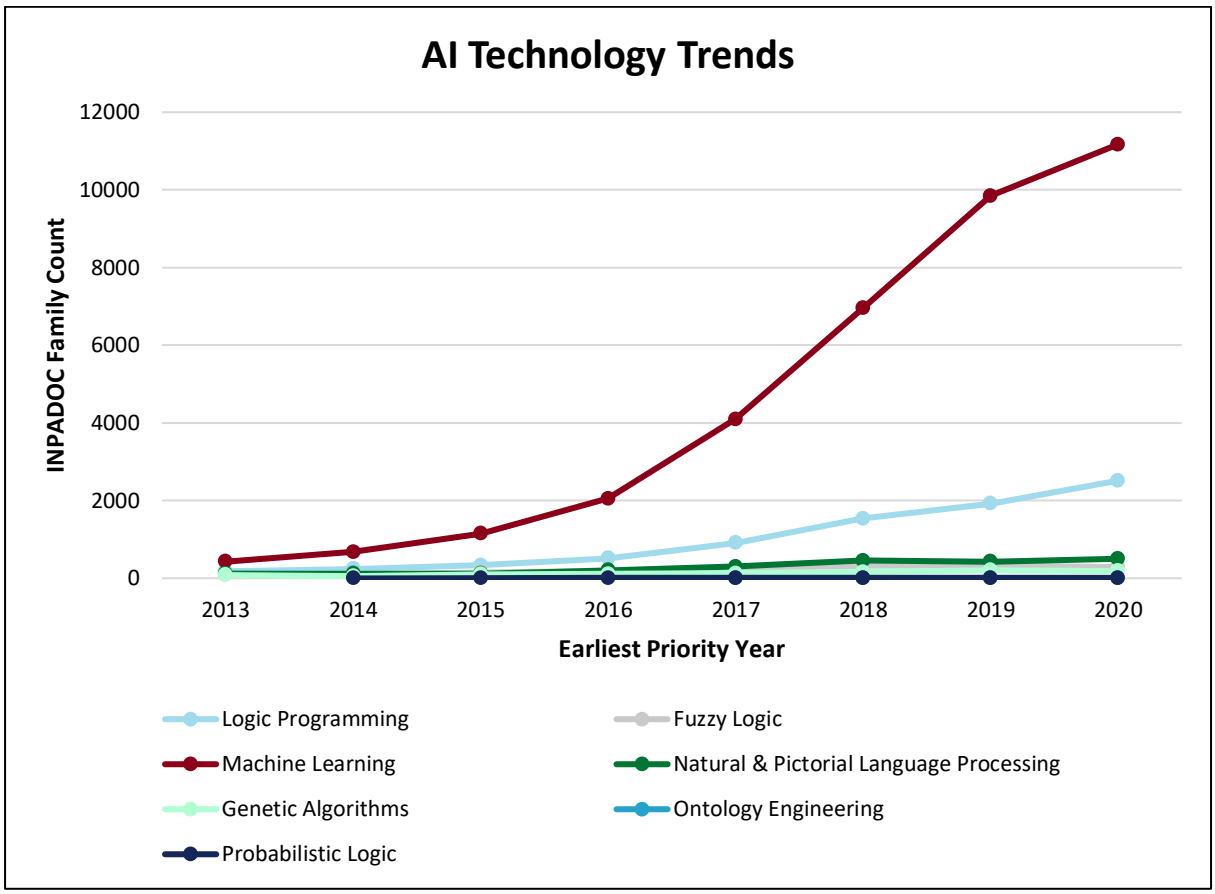
Whilst the data shows China dominating the AI patent landscape, it is important to highlight that a large proportion of the patents are filed exclusively in China. Since most of these patent applications do not reach national phase, these are unlikely to have an impact on the wider scientific and engineering community. Therefore, our search strategy hereon in the report omits China-only applications, in order to provide a more accurate picture of the AI patent landscape and eliminate any analysis bias that may be generated through retaining domestic China-only applications.

Please note, 2021-2023 data were omitted from the graphical representations, since data for these years will be incomplete due to the 18-month delay between priority application and publication.

The AI patent filing trends are not affected by the exclusion of China-only applications from the dataset.

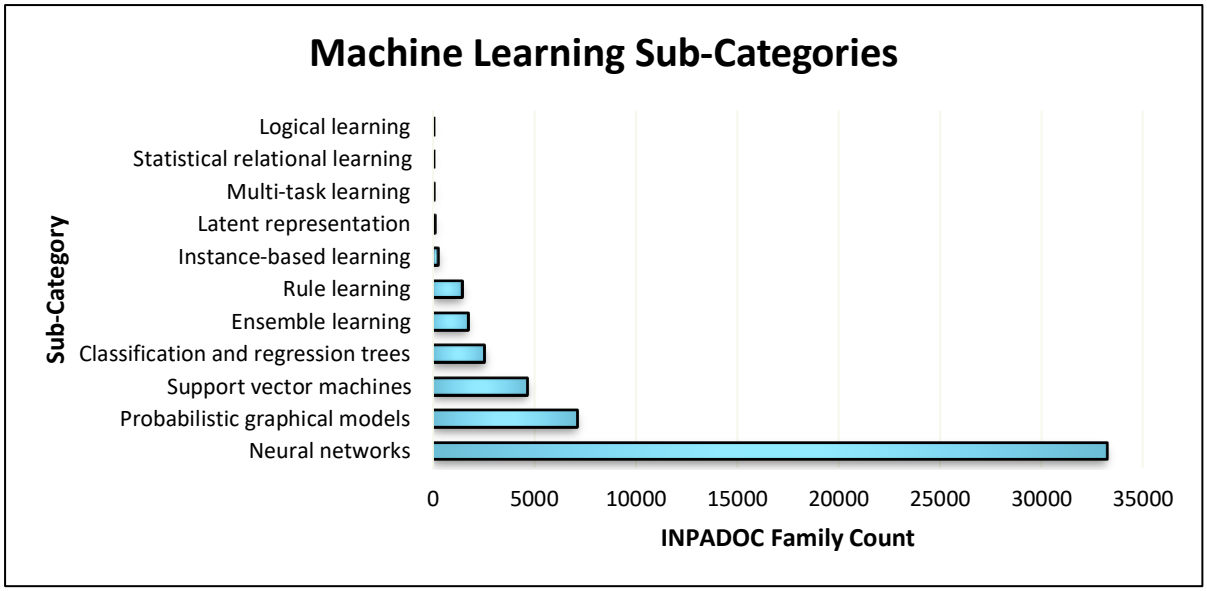
3.1 FILING RATE BY AI TECHNOLOGY

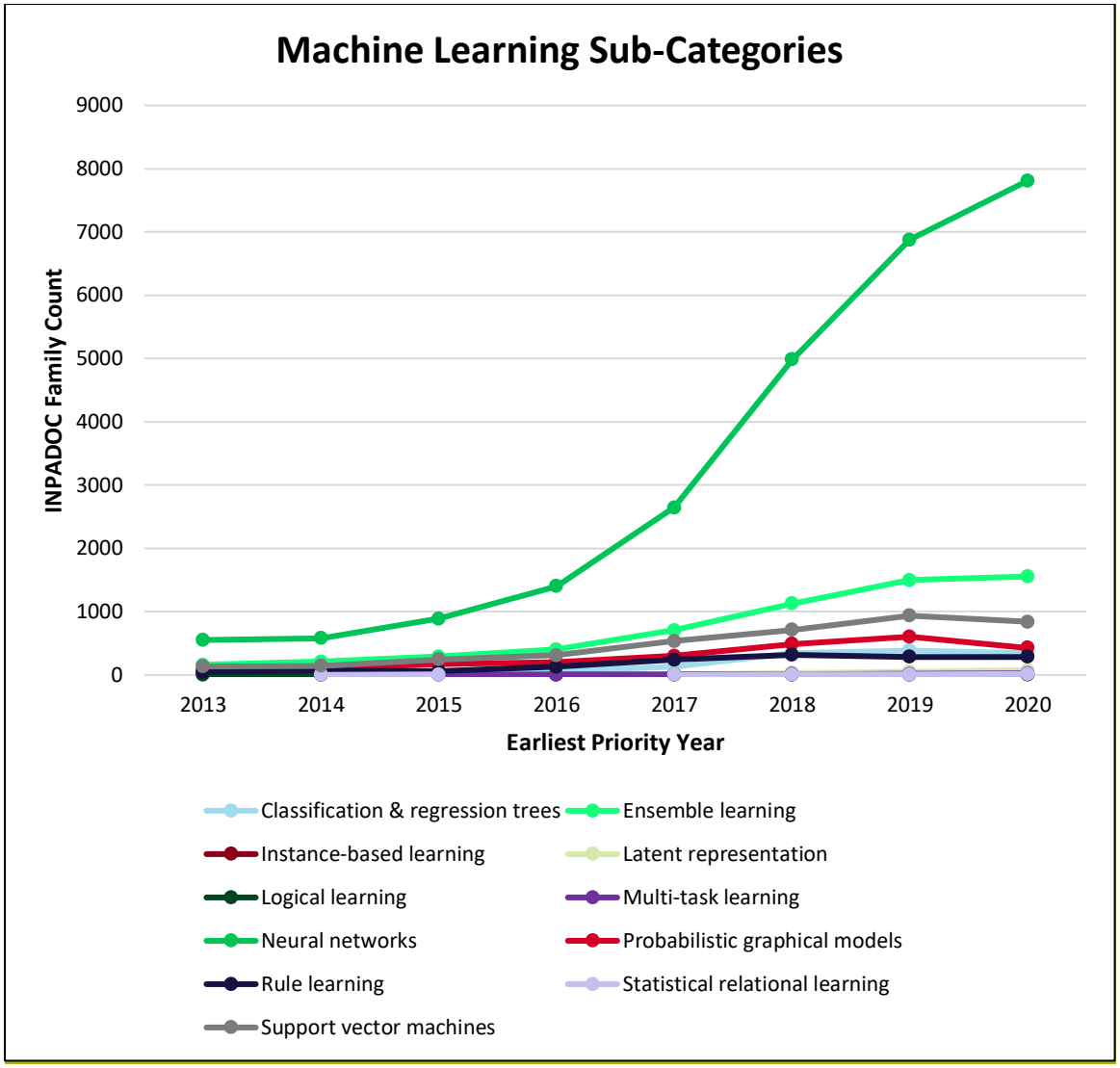
Technology filing trends were investigated to gain an understanding of the technology areas driving the rapid growth of AI patent activity. Machine learning is the dominant AI technique:



3.1.1 MACHINE LEARNING

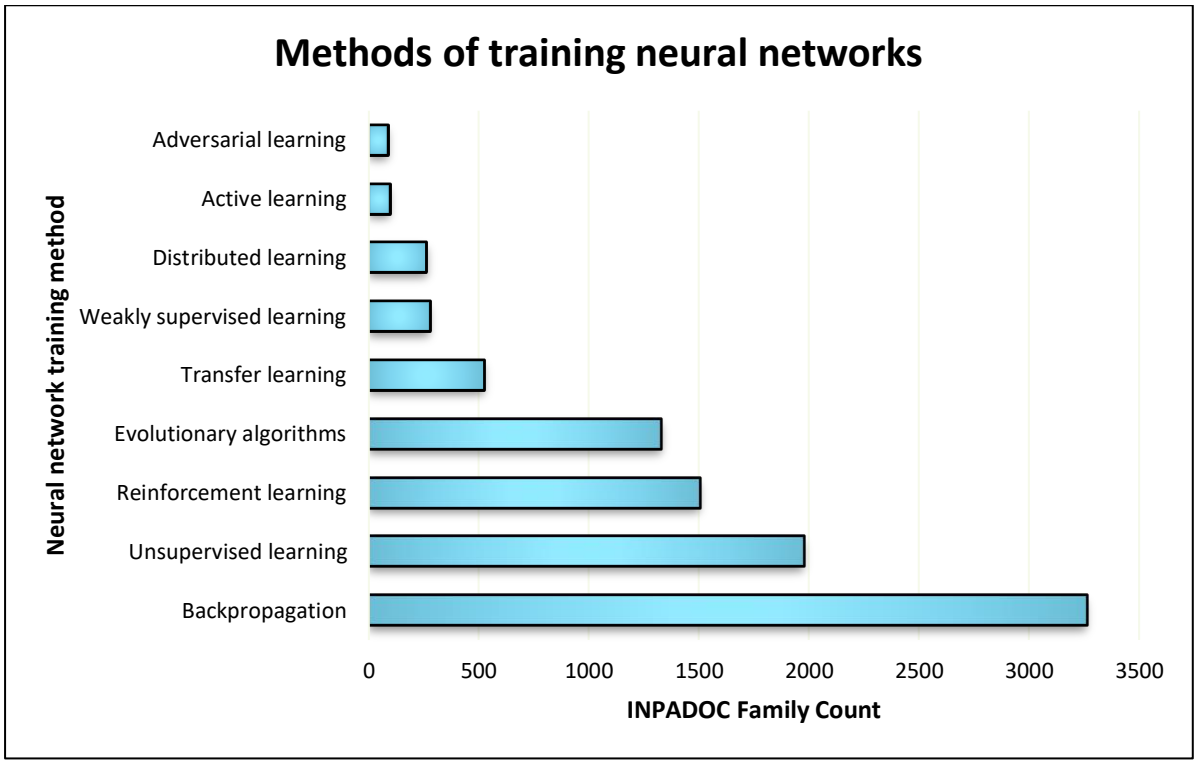
Machine learning constitutes a wide array of systems that comprise “learning” methods that leverage the power of data to improve functional performance. Neural networks form the most significant pool of patents within machine learning, which has shown a significant increase in the patent filing rate between 2013 and 2020. It is followed by ensemble machine learning methods which has also experienced continued growth over the period of our analysis. Interestingly, the patent filing rate for other key methods experienced a slower rate of growth in 2020 than in previous years.

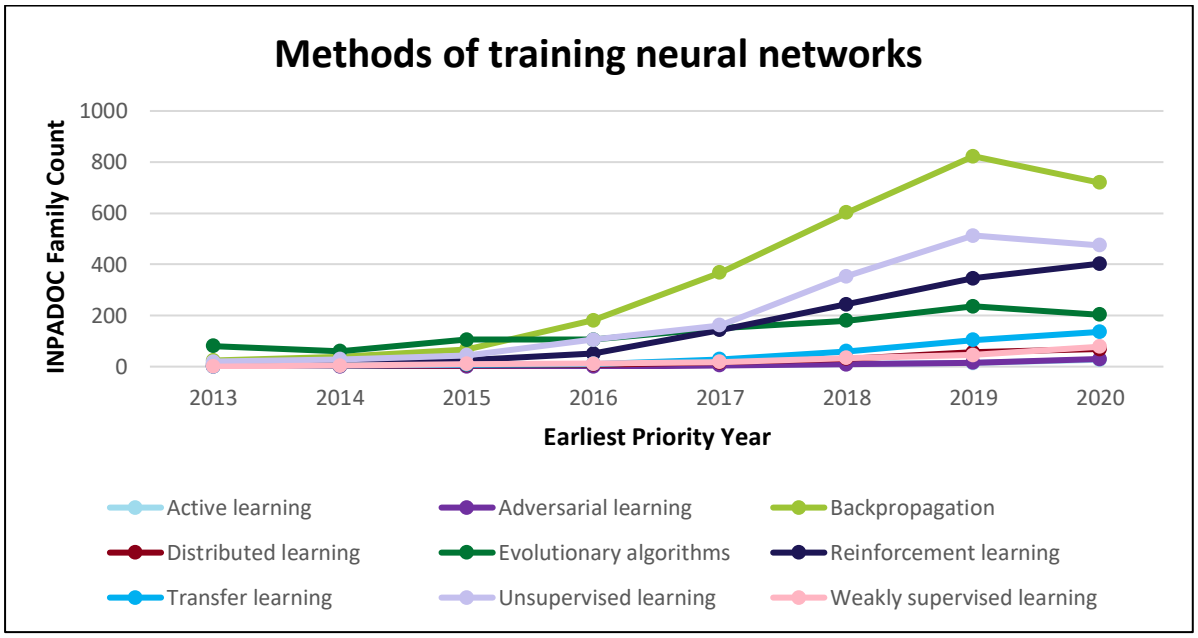



Machine Learning Sub-Categories
INPADOC Family Count
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2013
2014
2015
2016
2017
2018
2019
2020
Earliest Priority Year
Classification & regression trees
Ensemble learning
Instance-based learning
Latent representation
Logical learning
Multi-task learning
Neural networks
Probabilistic graphical models
Rule learning
Statistical relational learning
Support vector machines

3.1.2 NEURAL NETWORK LEARNING METHODS

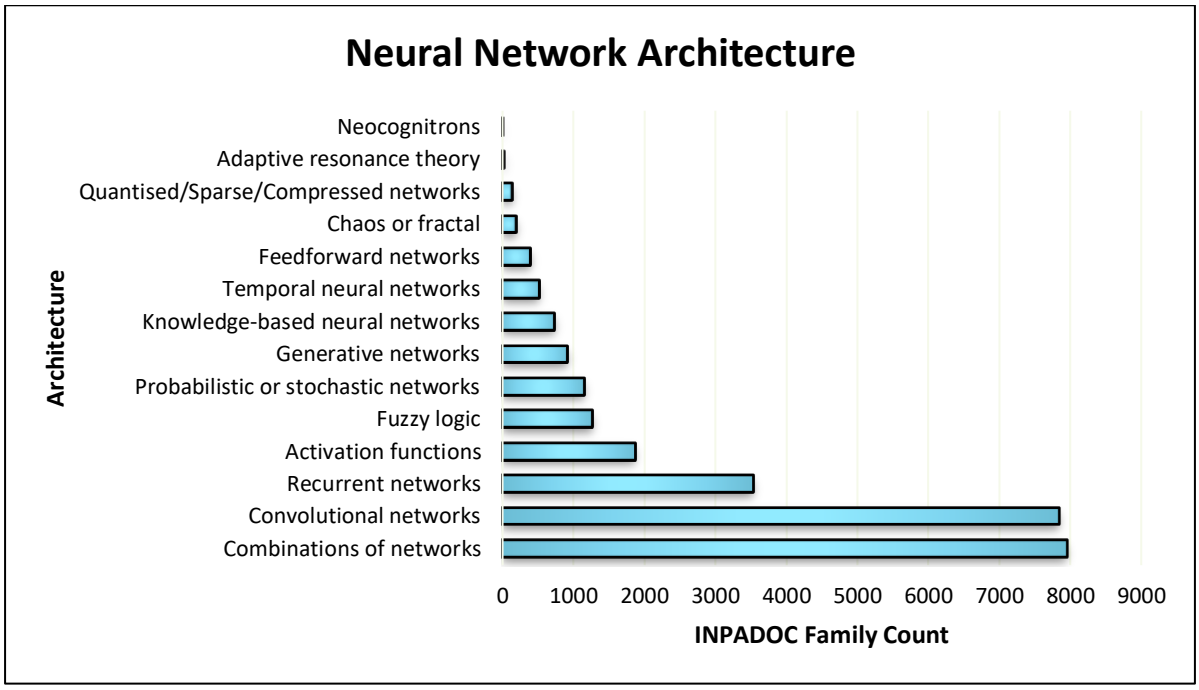
As already mentioned, neural networks form the largest sub-division of machine learning. Neural networks represent an efficient means to solve problems and carry out tasks that can be used in various situations. As a result, multiple methods have been developed to train neural networks to optimise performance. Much of the innovation relating to training methods took place after 2016, with backpropagation emerging as the leading method patented. It is followed by unsupervised and reinforcement learning methods. While the filing rate for backpropagation and unsupervised learning decreased in 2020 compared to 2019, reinforcement learning methods have continued to increase.

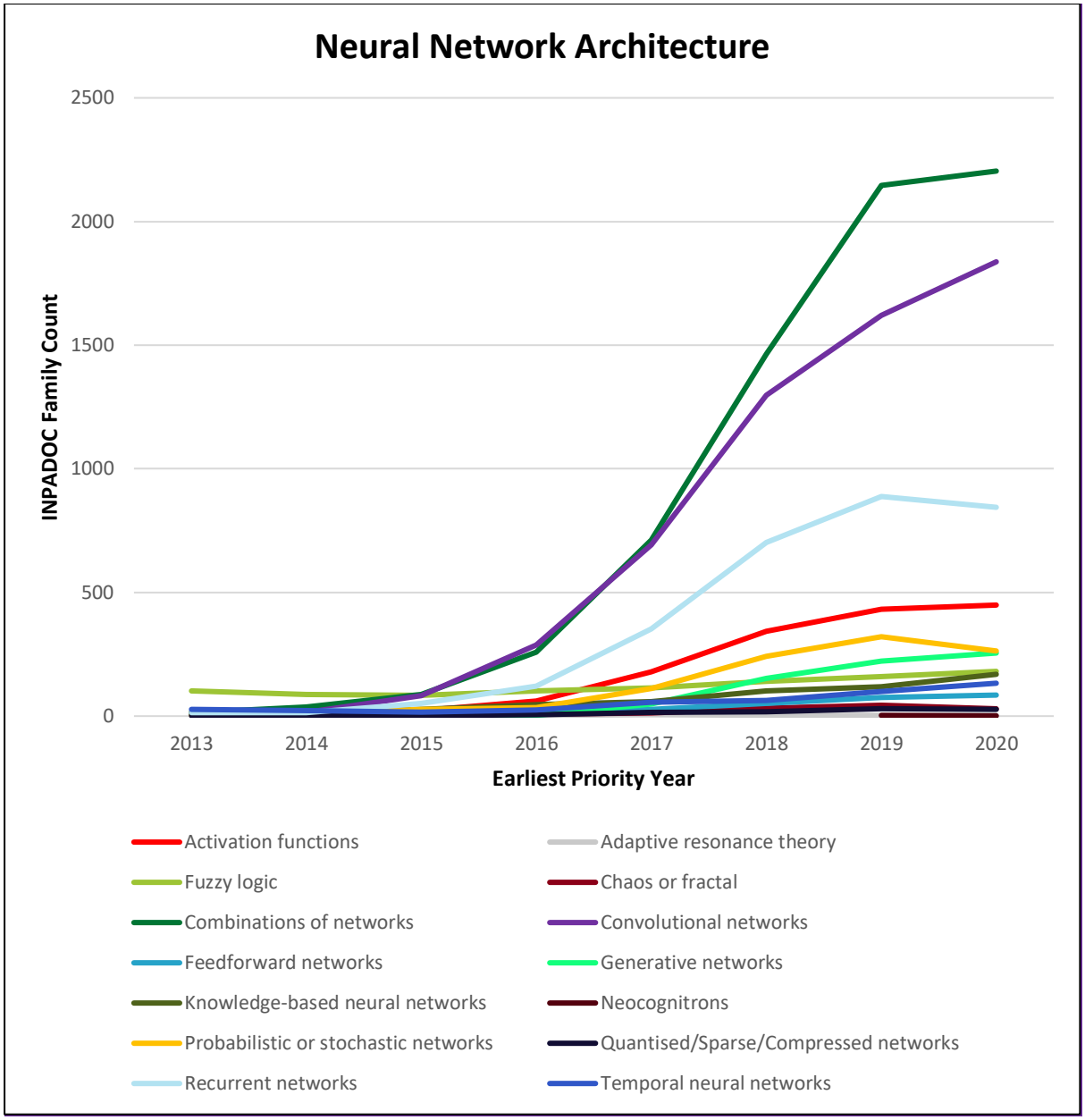




3.1.3 NEURAL NETWORK ARCHITECTURE

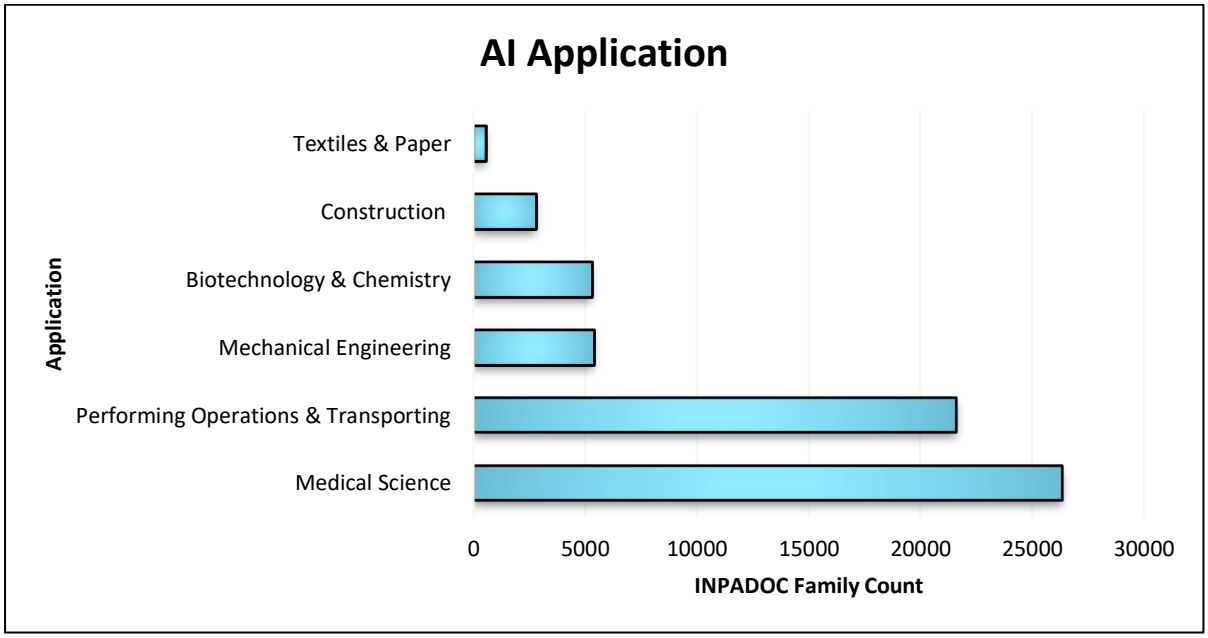
Neural networks function by passing data through the layers of an artificial neuron designed to mimic the processing power of a human brain. The architecture of neural networks is made up of an input, output, and hidden layer. The configuration can have a profound effect on the efficiency of the neural network to perform a given task, hence neural networks are comprised of a wide array of structures. A number of neural network layouts have emerged since 2016; combinations of networks are the most prominent in the scientific and engineering fields. This is closely followed by the continued interest in convolutional networks, and to a lesser extent recurrent networks.

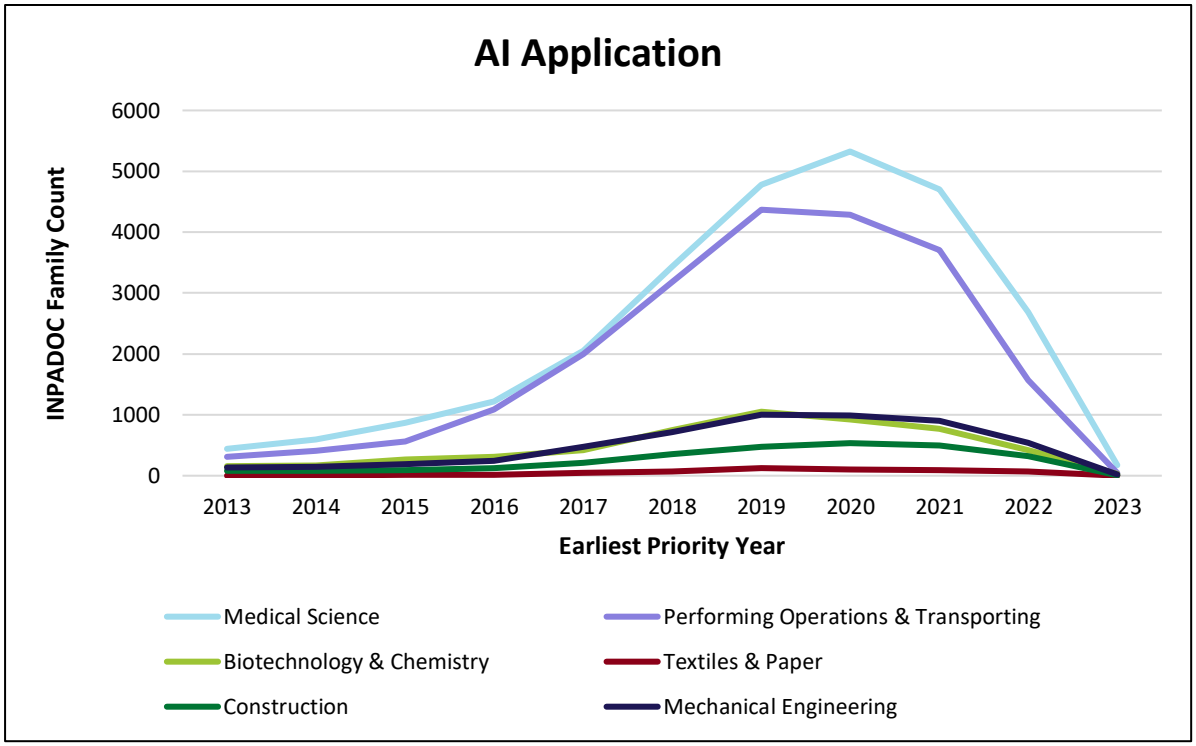



Neural Network Architecture
INPADOC Family Count
2500
2000
1500
1000
500
0
2013
2014
2015
2016
2017
2018
2019
2020
Earliest Priority Year
Activation functions
Adaptive resonance theory
Fuzzy logic
Chaos or fractal
Combinations of networks
Convolutional networks
Feedforward networks
Generative networks
Knowledge-based neural networks
Neocognitrons
Probabilistic or stochastic networks
Quantised/Sparse/Compressed networks
Recurrent networks
Temporal neural networks

3.2 AI APPLICATIONS

It is clear that the diversity of AI systems makes it adaptable for performing a wide array of tasks. In terms of the application of AI to scientific research, the medical sciences are the most active in relation to AI-related innovation, and advances in AI are improving healthcare and patient treatment outcomes and driving efficiencies across a wide range of medical and healthcare systems. Unsurprisingly, there is also considerable level of activity across the transport industry, with autonomous vehicles and robots being the key focus.





Note: data for 2021-2023 is not complete given the 18-month delay from the priority filing date and the date of publication

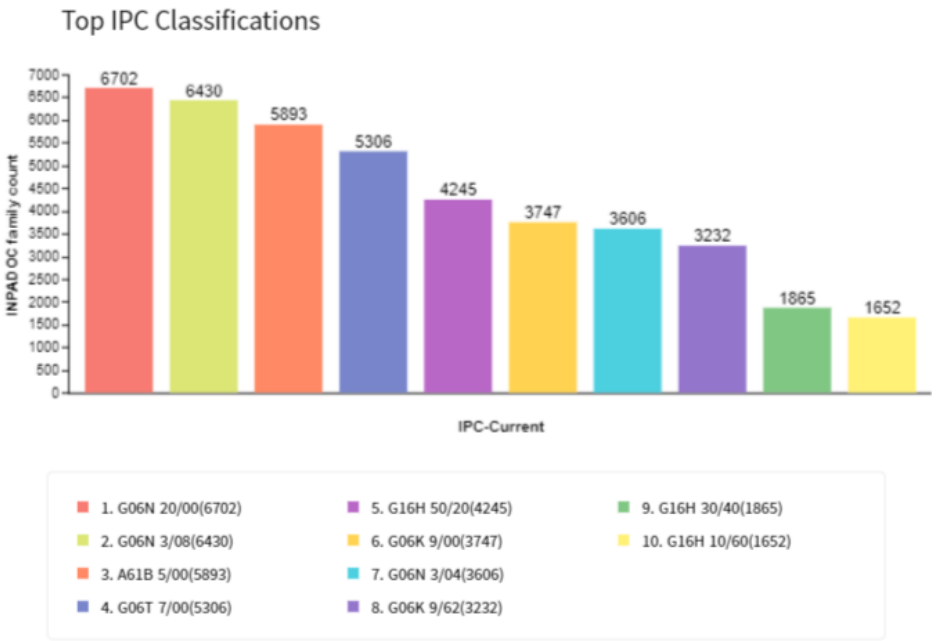
3.3 TOP CLASSIFICATIONS

3.3.1 IPC CLASSIFICATIONS

Classification analysis can provide further insights into the areas driving the growth of AI in the scientific and engineering industries. The International Patent Classification (IPC) provides a hierarchical system of language independent symbols for the classification of patents and utility models according to the different areas of technology to which they pertain. The IPC divides technology into eight sections with approximately 70,000 subdivisions. The relevant IPC symbols are displayed on each patent document, of which more than 1,000,000 were issued each year in the last 10 years.

In order to verify the relevance of the patents listed, and to look in more detail at the areas of technical focus, an analysis of the top 10 current IPC codes from the patent landscape was performed (see table below). As mentioned, IPC codes are a mechanism of categorising the patents by detailed subject matter and have been used in part to frame the search strategy, so there will be some bias towards the top-level codes we used in the search in these results.

Each patent is typically classified according to one or more IPCs as the subject matter may cover a number of technology fields. The top 10 IPC listing highlights and explains the most frequent IPC codes identified within the patent families listed:



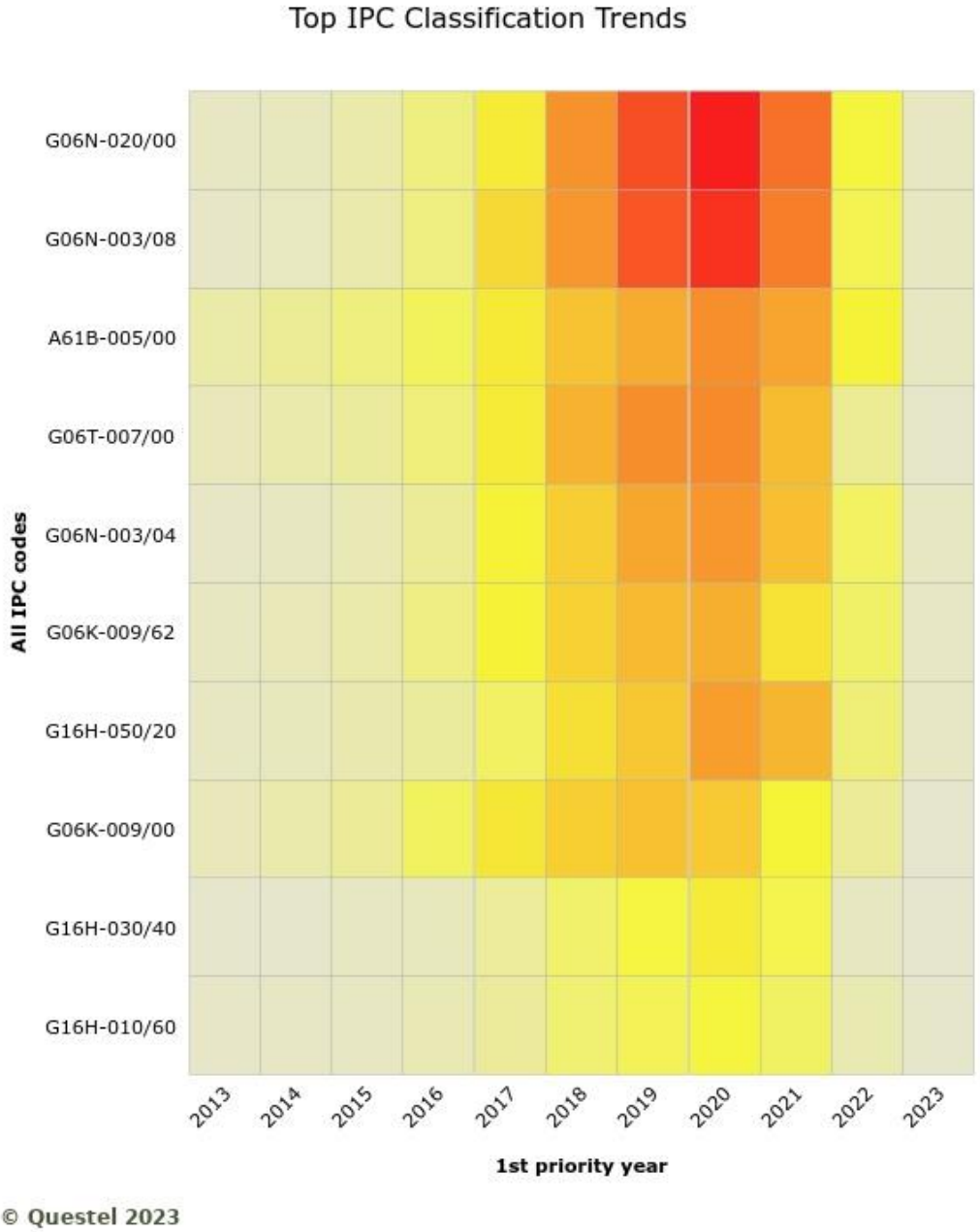
Source: Clarivate via Derwent Innovation

Rank	IPC	Number of Families	Definition	
1	G06N20/00	6702	G06N20/00	Machine learning
2	G06N3/08	6430	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/08	Learning methods
3	A61B5/00	5893	A61B5/00	Measuring for diagnostic purposes; Identification of persons
4	G06T7/00	5306	G06T7/00	Image analysis
5	G16H50/20	4245	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/20	for computer-aided diagnosis, e.g. based on medical expert systems
6	G06K9/00	3747	G06K9/00	Methods or arrangements for recognising patterns
7	G06N3/04	3606	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/04	Architecture, e.g. interconnection topology
8	G06K9/62	3232	G06K9/00	Methods or arrangements for recognising patterns
			G06K9/62	Methods or arrangements for pattern recognition using electronic means
9	G16H30/40	1865	G16H30/00	ICT specially adapted for the handling or processing of medical images
			G16H30/40	for processing medical images, e.g. editing
10	G16H10/60	1652	G16H10/00	ICT specially adapted for the handling or processing of patient-related medical or healthcare data
			G16H10/60	for patient-specific data, e.g. for electronic patient records

The majority of the top 10 IPCs are within the G06N classifications groups, which broadly covers the fields of computational models, thereby verifying the relevance of the patents picked up by the search strategy. The top AI related IPCs relate to machine learning (G06N20/00), neural networks learning methods (G06N3/08), and image analysis (G06T7/00).

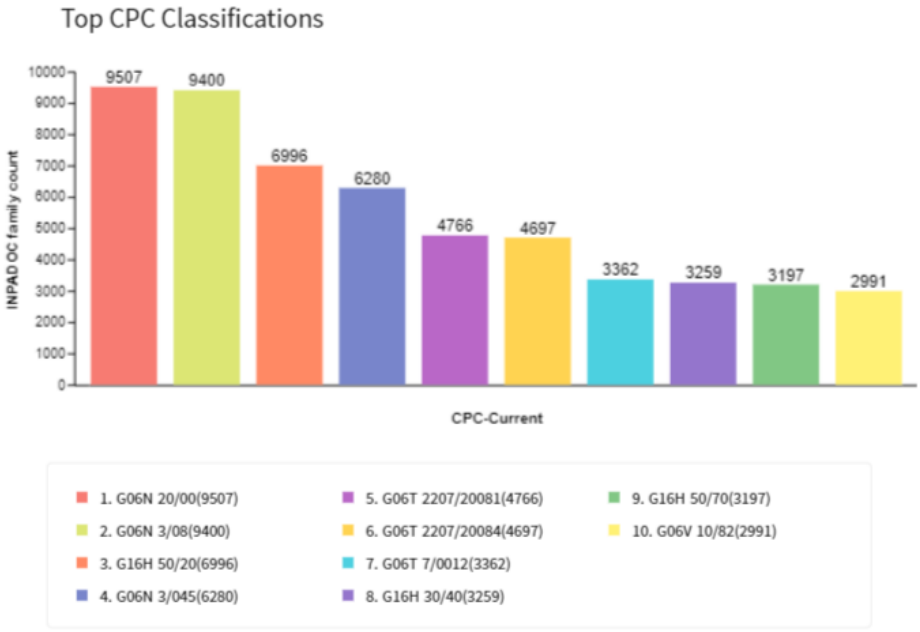
Our classification analysis reveals that AI technology is most frequently applied to: measuring for diagnostic purposes (A61B5/00), computer-aided diagnosis (G16H50/20) and for the processing of medical images (G16H30/40).

To see how the patent landscape has evolved over the last 10 years, we looked at how the filing rates have changed for the different AI technologies. 2016 represents the year with the most technological diversity, as many of the technologies were represented equally. **Machine learning (G06N20/00) and neural network learning methods (G06N3/08) are emerging as the two leading areas of patenting activity**. **A significant increase in the number of patent filings between 2019 and 2020 have also been observed in the fields of image analysis (G06T7/00) and computer-aided diagnosis (G16H50/20).** Interestingly, despite the significant increase in patent filings relating to image analysis and computer-aided diagnosis, as well as measuring for diagnostic purposes (A61B5/00), a parallel increase has not been reflected in patent filings relating to the processing of medical images (G16H30/40) or patient-specific data (G16H10/60). This difference suggests that AI patent applications have recently evolved to provide assistance in more skilled or complex tasks, such as diagnosis.



3.3.2 CPC CLASSIFICATIONS

The Cooperative Patent Classification (CPC) is based on the IPC, but gives a more specific level of detail, as IPCs provide less granularity than CPCs on the technology classifications. The relevant CPC classifications were analysed to provide more detailed information on the key areas of interest for patent protection.



Source: Clarivate via Derwent Innovation

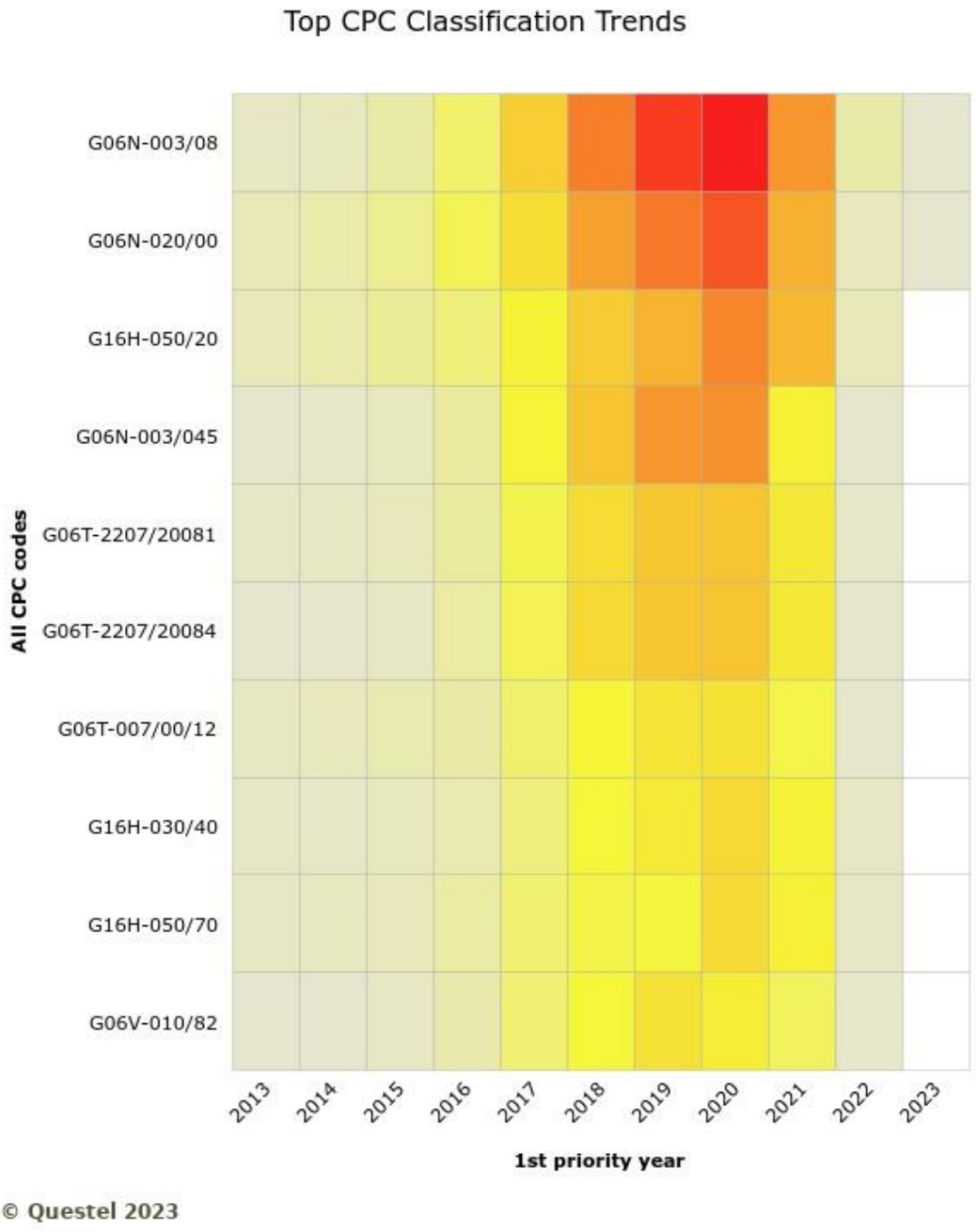
Rank	CPC	Number of Families	Definition	
1	G06N20/00	9507	G06N20/00	Machine learning
2	G06N3/08	9400	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/08	Learning methods
3	G16H50/20	6996	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/20	for computer-aided diagnosis, e.g. based on medical expert systems
4	G06N3/045	6280	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/04	Architecture, e.g. interconnection topology
			G06N3/045	Combinations of networks

Rank	CPC	Number of Families	Definition
5	G06T2207/20081	4766	G06T2207/00 Indexing scheme for image analysis or image enhancement G06T2207/20 Special algorithmic details G06T2207/20081 Training; Learning
6	G06T2207/20084	4697	G06T2207/00 Indexing scheme for image analysis or image enhancement G06T2207/20 Special algorithmic details G06T2207/20084 Artificial neural networks [ANN]
7	G06T7/0012	3362	G06T7/00 Image analysis G06T7/0002 Inspection of images, e.g. flaw detection G06T7/0012 Biomedical image inspection
8	G16H30/40	3259	G16H30/00 ICT specially adapted for the handling or processing of medical images G16H30/40 for processing medical images, e.g. editing
9	G16H50/70	3197	G16H50/00 ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics G16H50/70 for mining of medical data, e.g. analysing previous cases of other patients
10	G06V10/82	2991	G06V10/00 Arrangements for image or video recognition or understanding G06V10/70 using pattern recognition or machine learning G06V10/82 using neural networks

Analysis of the top CPC classifications reaffirms the same technology fields identified by top IPC classifications, such as machine learning (G06N20/00), neural networks learning methods (G06N3/08) and computer-aided diagnosis (G16H50/20). In addition, **CPC analysis reveals that images are primarily analysed using artificial neural networks (G06T2207/20084)**. **It also uncovers that there is significant interest in combining neural networks (G06N3/045)**, which appears to help AI systems to accurately perform more complex tasks[11]. This may help to explain the emergence of AI patent applications in more technically demanding areas, such as computer-aided diagnosis (G16H50/20).

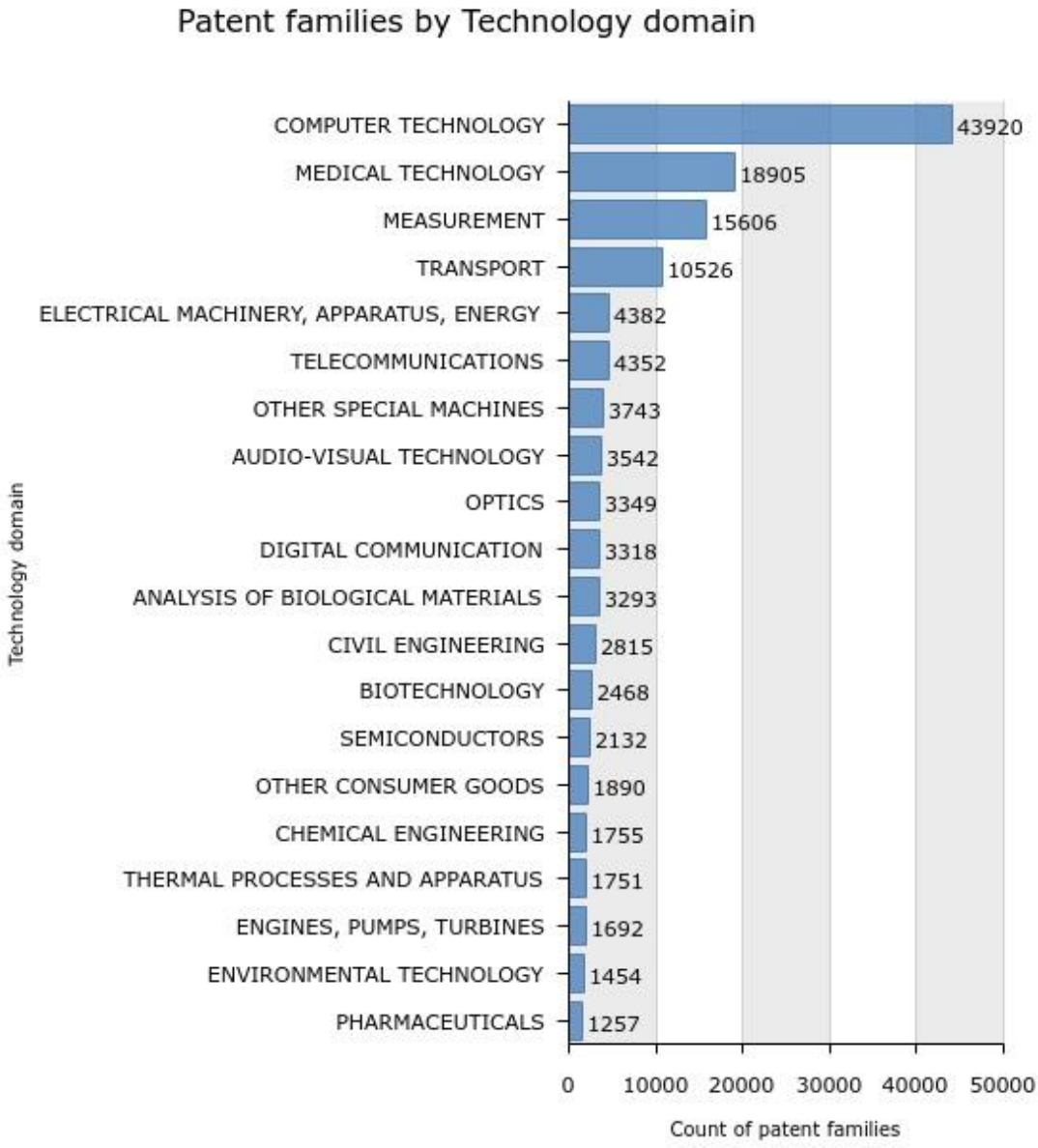
[11] https://www.sciencedirect.com/science/article/abs/pii/S0893608096000986

The CPC classification trend analysis also reveals the recent emergence of image analysis using artificial neural networks (G06T2207/20084) and neural networks having combinations of networks (G06N3/045). There have also been small increases in the number of patent filings relating to: the mining of medical data (G16H50/70), biomedical image inspection (G06T7/0012), and pattern recognition (G06V10/82).



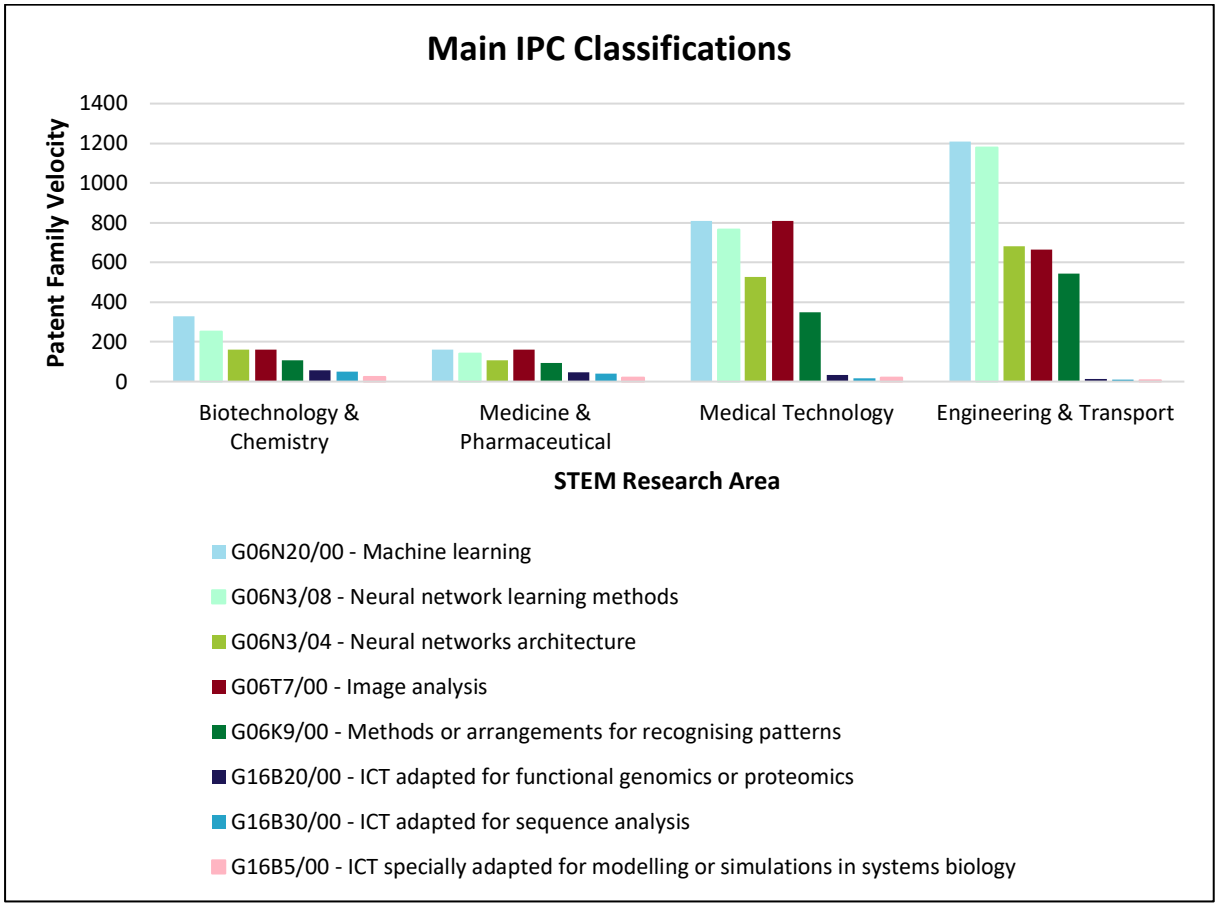
3.3.3 TECHNOLOGICAL DOMAINS

International Patent Classification (IPC) codes can also be used to identify the technical domains of the AI patent landscape, since IPC codes are grouped into 35 technology fields. The analysis helps to visualise the diversity of the patent landscape and identify the main applications of AI. **The main areas for the application of AI technologies are in medical technology, measurement, transport and electrical machinery.**

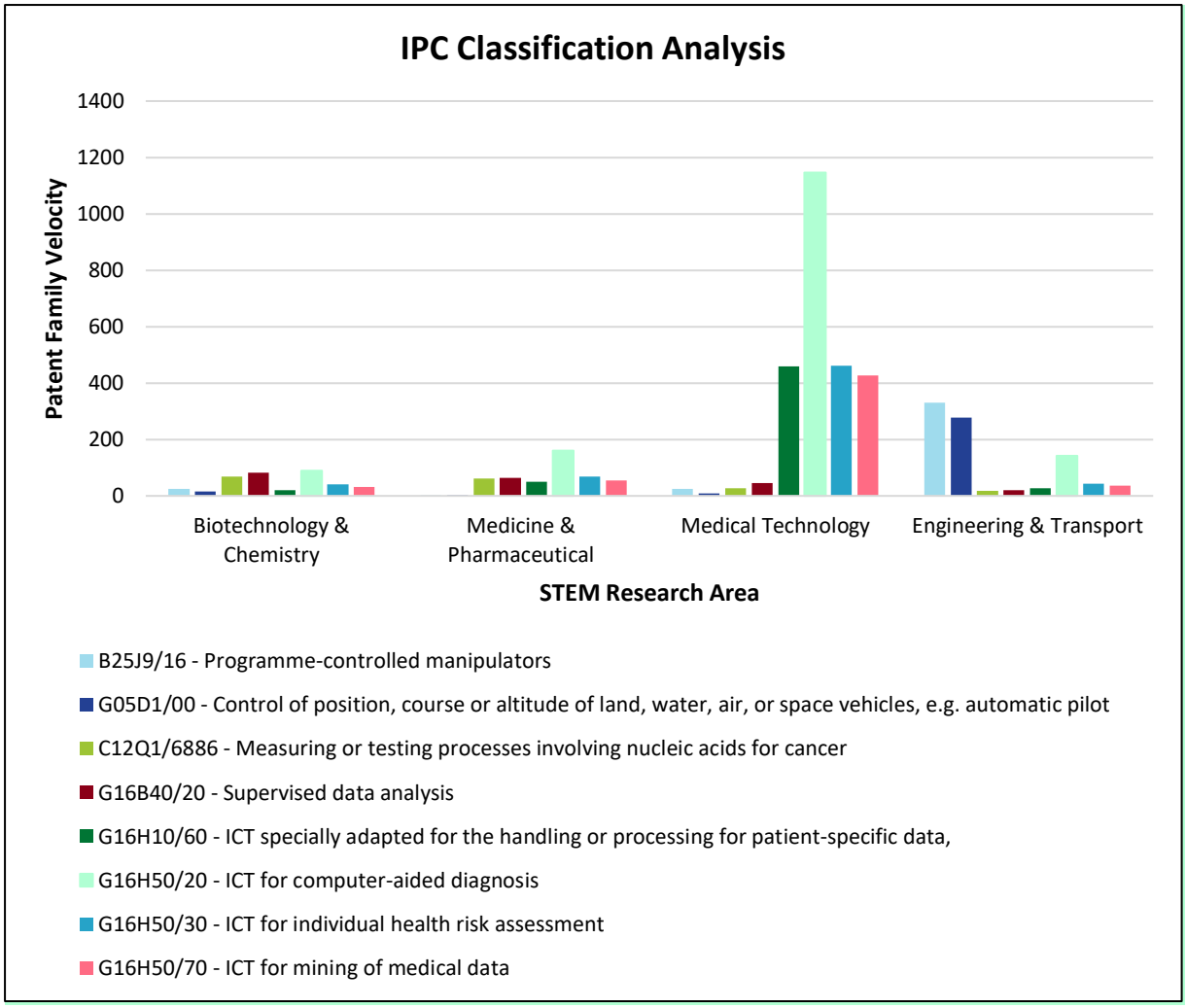


3.3.4 CLASSIFICATION ANALYSIS

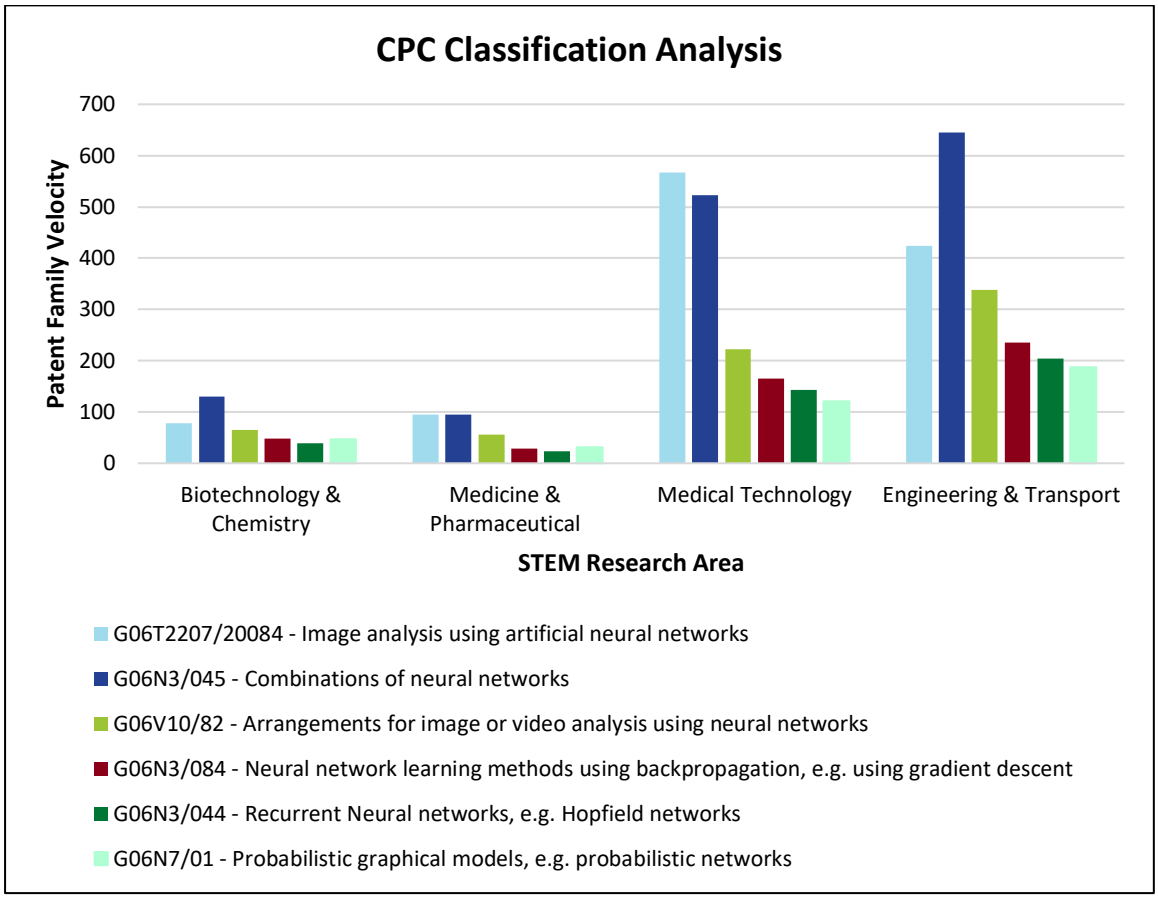
The main areas of AI innovation across the patent landscape relate to machine learning (G06N20/00), neural network learning methods (G06N3/08), image analysis (G06T7/00), and methods for recognizing patterns (G06K9/00). However, a number of AI systems appear to have emerged in specific areas of the STEM patent landscape, as shown in the following graph summarizing the main areas of growth by comparing patent family velocity, which corresponds to the average count of patent families filed in the last 5 years. It can be observed that machine learning systems and neural networks ranked the highest across the key STEM research areas, however image analysis patent filings are more concentrated in the medical technology segment of the patent landscape, while bioinformatic ICT systems are more represented in biotechnology & chemistry and medicine & pharmaceuticals.



The analysis of more focused IPC classifications reveals that computer aided diagnostics are the main focus of recent innovation within medical technology, while program-controlled manipulators and AI-controlled vehicles were the main areas driving innovation in the engineering & transport sectors. Interestingly, in biotechnology & chemistry supervised data analysis was the main area of focus, which appears to be primarily used for biostatistics and bioinformatics-related machine learning or data mining. This area also appears to score highly in the medicine & pharmaceuticals segment, however ICT systems adapted for health risk assessment scored higher, along with computer-aided diagnostics.

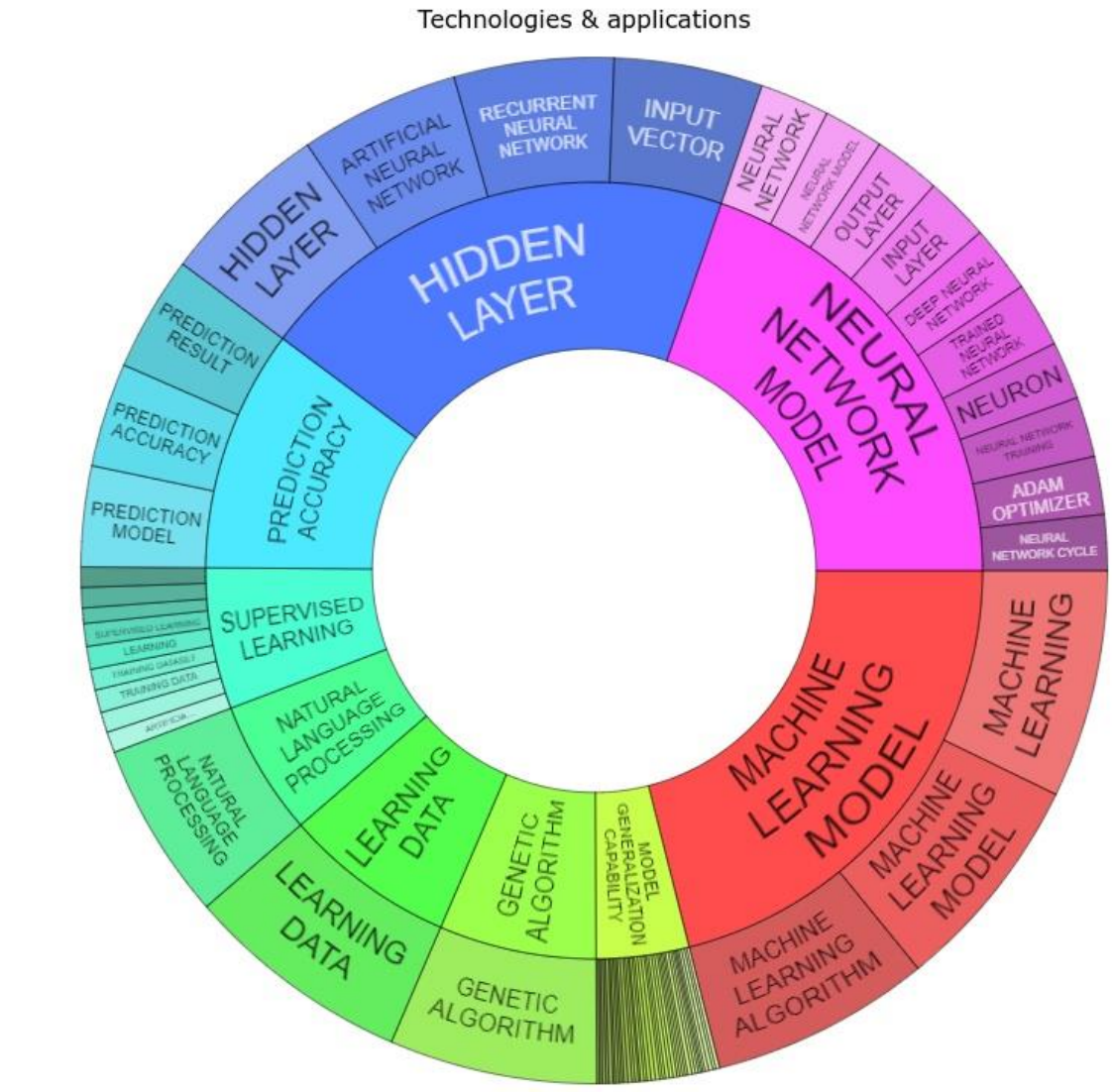


A more in-depth analysis of top CPC classifications reveals additional information regarding top AI systems across the STEM research areas. It can be seen that combinations of neural networks are the main focus of recent patent filings in biotechnology & chemistry and engineering & transport sectors of the patent landscape, while image analysis using artificial neural networks is the dominant technology focus in medical technology. Interestingly, in medicine & pharmaceutical sectors both areas have very similar levels of interest, likely due to equal need improvement in our understanding of disease pathology and development of new therapeutic solutions.



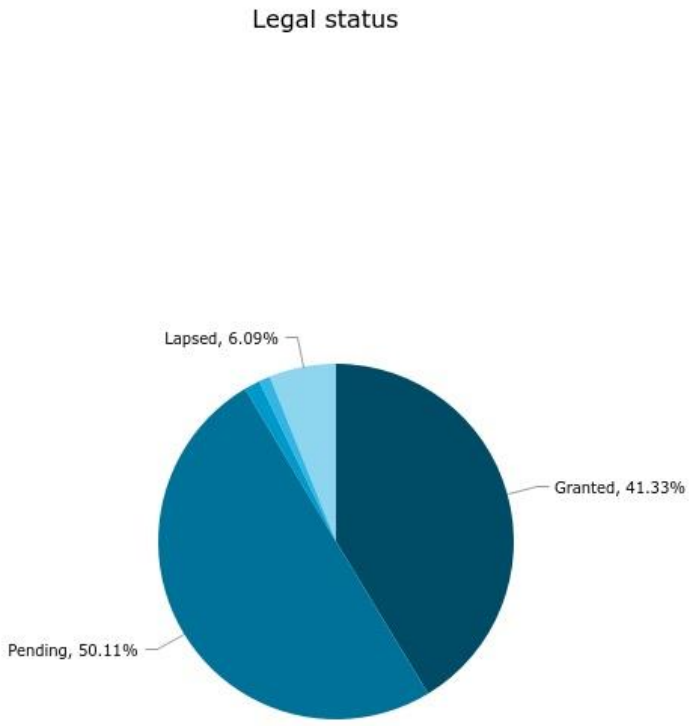
3.4 KEY AI PATENT LANDSCAPE CONCEPTS

The following figure illustrates the distribution of the main concepts across the AI patent landscape, which provides additional depth to key research areas identified from classification analysis. Neural networks and machine learning models are key concepts within the AI patent landscape, with a significant focus on the hidden layers which form neural networks. It can also be observed that a smaller number of patent filings are directed towards supervised learning, natural language processing and genetic algorithms.



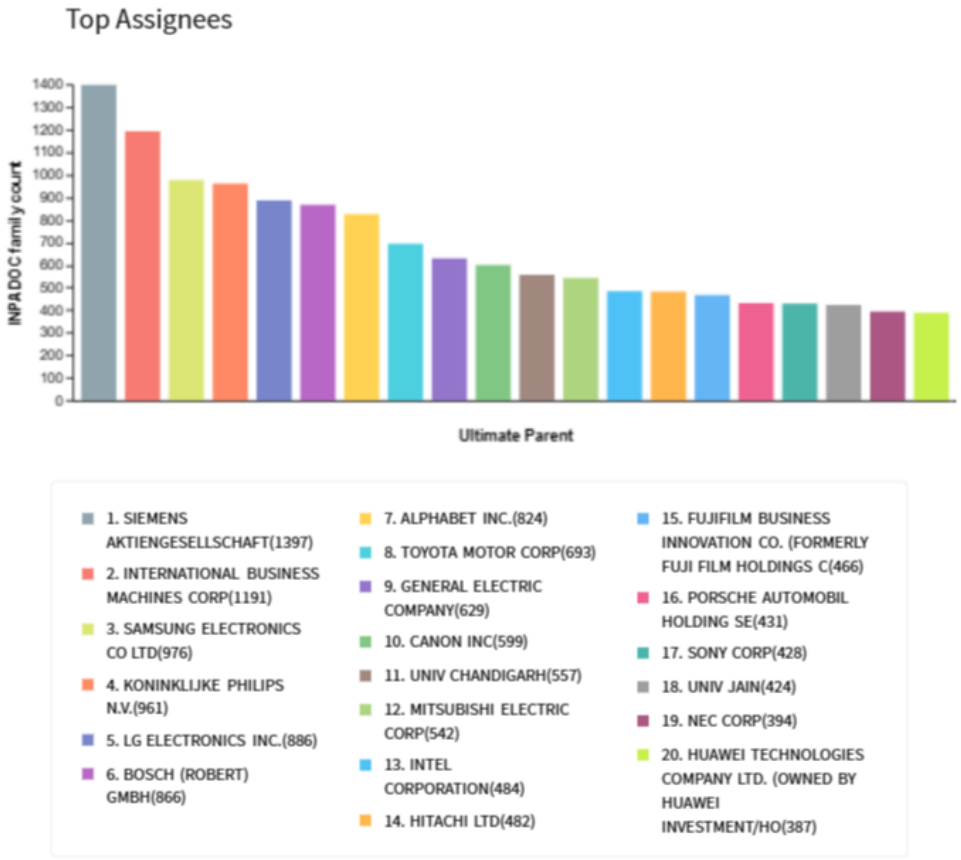
3.5 GLOBAL GRANT SUCCESS

An assessment of the proportion of granted patents compared to patent applications can give additional insight into market entry and competition. The following graph compares the legal status of patent families picked up by the search strategy in the overall AI patent landscape, in order to provide a benchmark for comparing AI applications in each scientific field. The high number of granted patent families and low proportion of lapsed patent families implies there is significant commercial interest in AI. The higher number of pending patent applications also shows that despite the great interest, AI remains a fast-growing area with significant space for innovation.



3.6 TOP ASSIGNEES OVERALL

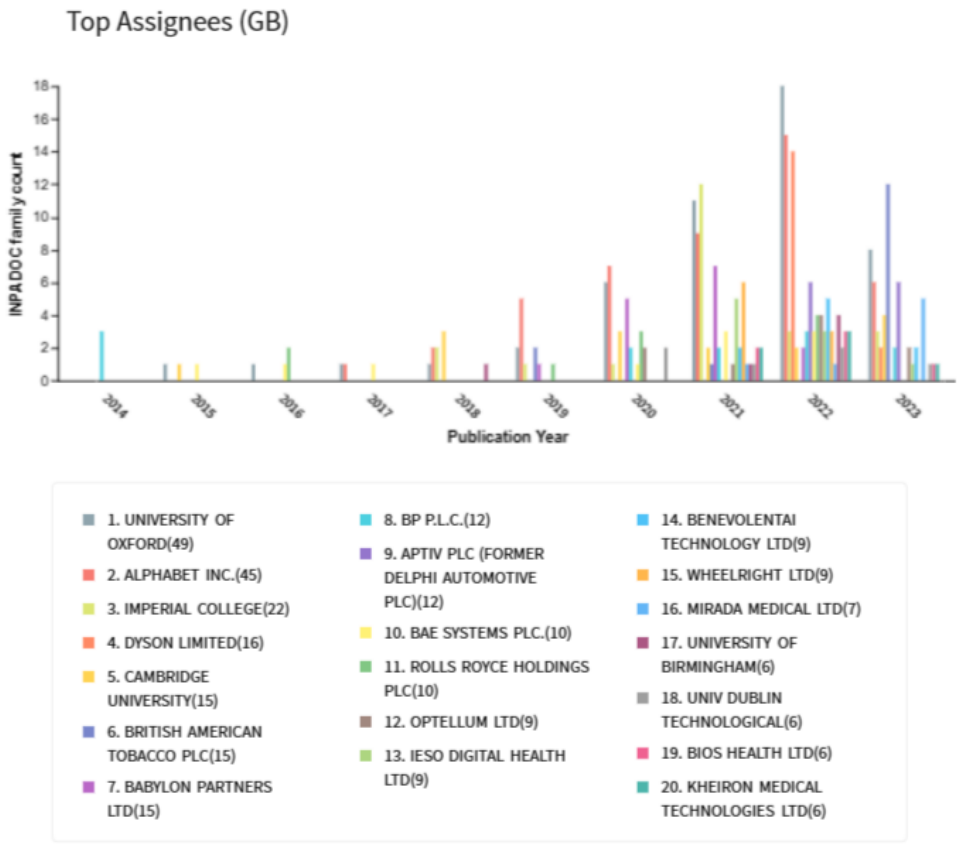
The following section of the report highlights the top 20 assignees for the number of patents relating to AI within the overall scientific and engineering research space, representing both the top industry and academic groups in terms of patenting activity. The analysis can provide useful insights to support an effective intellectual property commercialization strategy, as it can help to gauge the commercial interest and maturity of key areas identified. Commercial organisations make up most of the top assignees, thereby indicating the significant commercial interest in AI. Considering the global geographic distribution of patent filings, it is no surprise to see major international corporations dominate.



Rank	Assignee/Applicant	Document Count	Organisation Type	Country
1	SIEMENS AKTIENGESELLSCHAFT	1397	Commercial	Germany
2	INTERNATIONAL BUSINESS MACHINES CORP	1191	Commercial	US
3	SAMSUNG ELECTRONICS CO LTD	976	Commercial	Korea
4	KONINKLIJKE PHILIPS N.V.	961	Commercial	Netherlands
5	LG ELECTRONICS INC.	886	Commercial	Korea
6	BOSCH ROBERT GMBH	866	Commercial	Germany
7	ALPHABET INC.	824	Commercial	US
8	TOYOTA MOTOR CORP	693	Commercial	Japan
9	GENERAL ELECTRIC COMPANY	629	Commercial	US
10	CANON INC	599	Commercial	Japan
11	UNIV CHANDIGARH	557	Academic	India
12	MITSUBISHI ELECTRIC CORP	542	Commercial	Japan
13	INTEL CORPORATION	484	Commercial	US
14	HITACHI LTD	482	Commercial	Japan
15	FUJIFILM BUSINESS INNOVATION CO	466	Commercial	Japan
16	PORSCHE AUTOMOBIL (VOLKSWAGEN)	431	Commercial	Germany
17	SONY CORP	428	Commercial	Japan
18	UNIV JAIN	424	Academic	India
19	NEC CORP	394	Commercial	Japan
20	HUAWEI TECHNOLOGIES COMPANY LTD	387	Commercial	China

GREAT BRITAIN

The top patent filing UK organisations include:



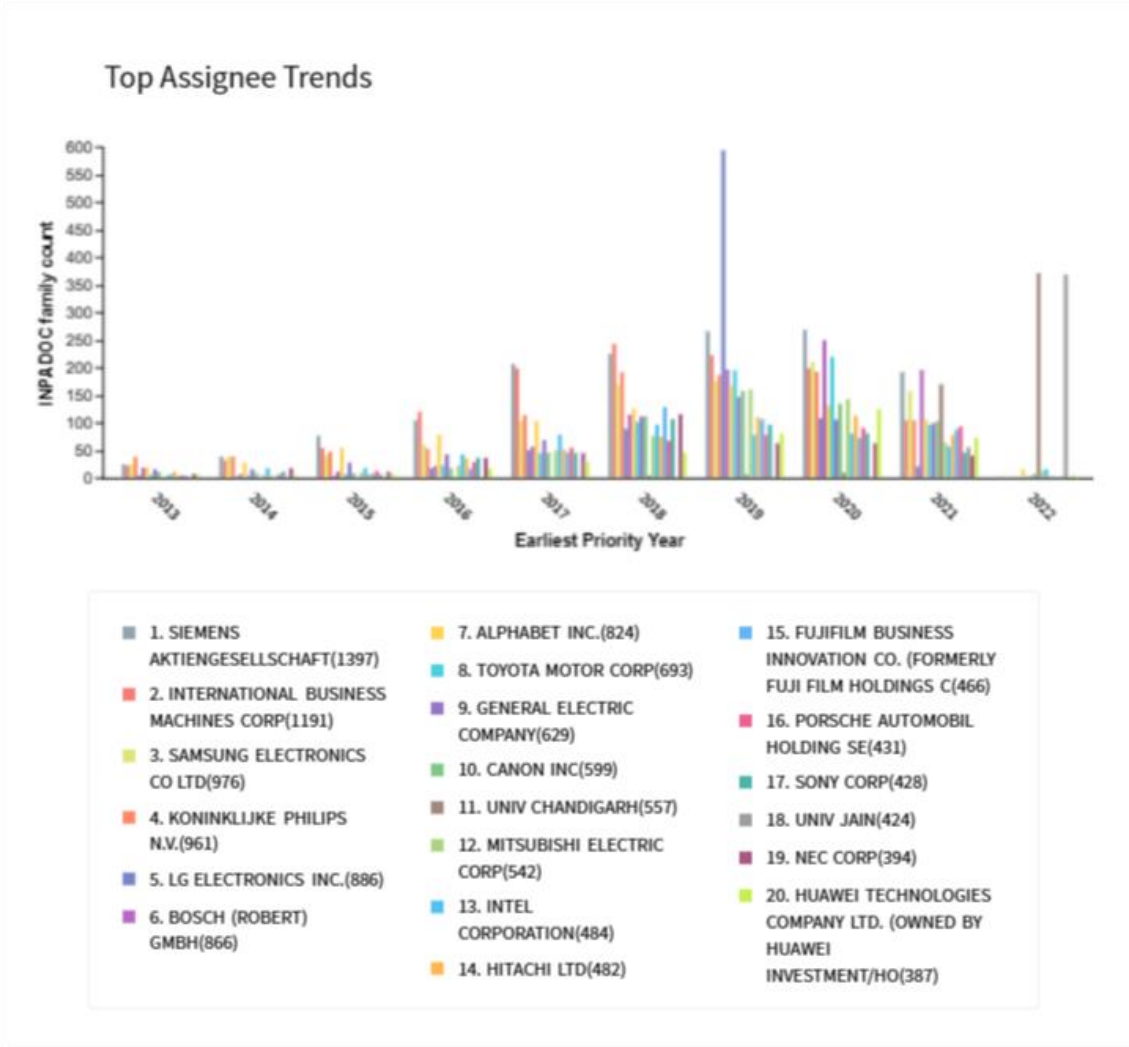
Source: Clarivate via Derwent Innovation

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
1	UNIVERSITY OF OXFORD	49	Academic	GB
2	ALPHABET INC. (DEEPMIND TECH LTD)	45	Commercial	GB
3	IMPERIAL COLLEGE	22	Academic	GB
4	DYSON LIMITED	16	Commercial	GB
5	CAMBRIDGE UNIVERSITY	15	Academic	GB
6	BRITISH AMERICAN TOBACCO PLC	15	Commercial	GB
7	BABYLON PARTNERS LTD	15	Commercial	GB
8	BP P.L.C.	12	Commercial	GB
9	APTIV PLC	12	Commercial	GB
10	BAE SYSTEMS PLC.	10	Commercial	GB
11	ROLLS ROYCE HOLDINGS PLC	10	Commercial	GB
12	OPTELLUM LTD	9	Commercial	GB
13	IESO DIGITAL HEALTH LTD	9	Commercial	GB

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
14	BENEVOLENTAI TECHNOLOGY LTD	9	Commercial	GB
15	WHEELRIGHT LTD	9	Commercial	GB
16	MIRADA MEDICAL LTD	7	Commercial	GB
17	UNIVERSITY OF BIRMINGHAM	6	Academic	GB
18	UNIV DUBLIN TECHNOLOGICAL	6	Academic	GB
19	BIOS HEALTH LTD	6	Commercial	GB
20	KHEIRON MEDICAL TECHNOLOGIES LTD	6	Commercial	GB

3.6.1 FILING TRENDS AMONGST TOP ASSIGNEES

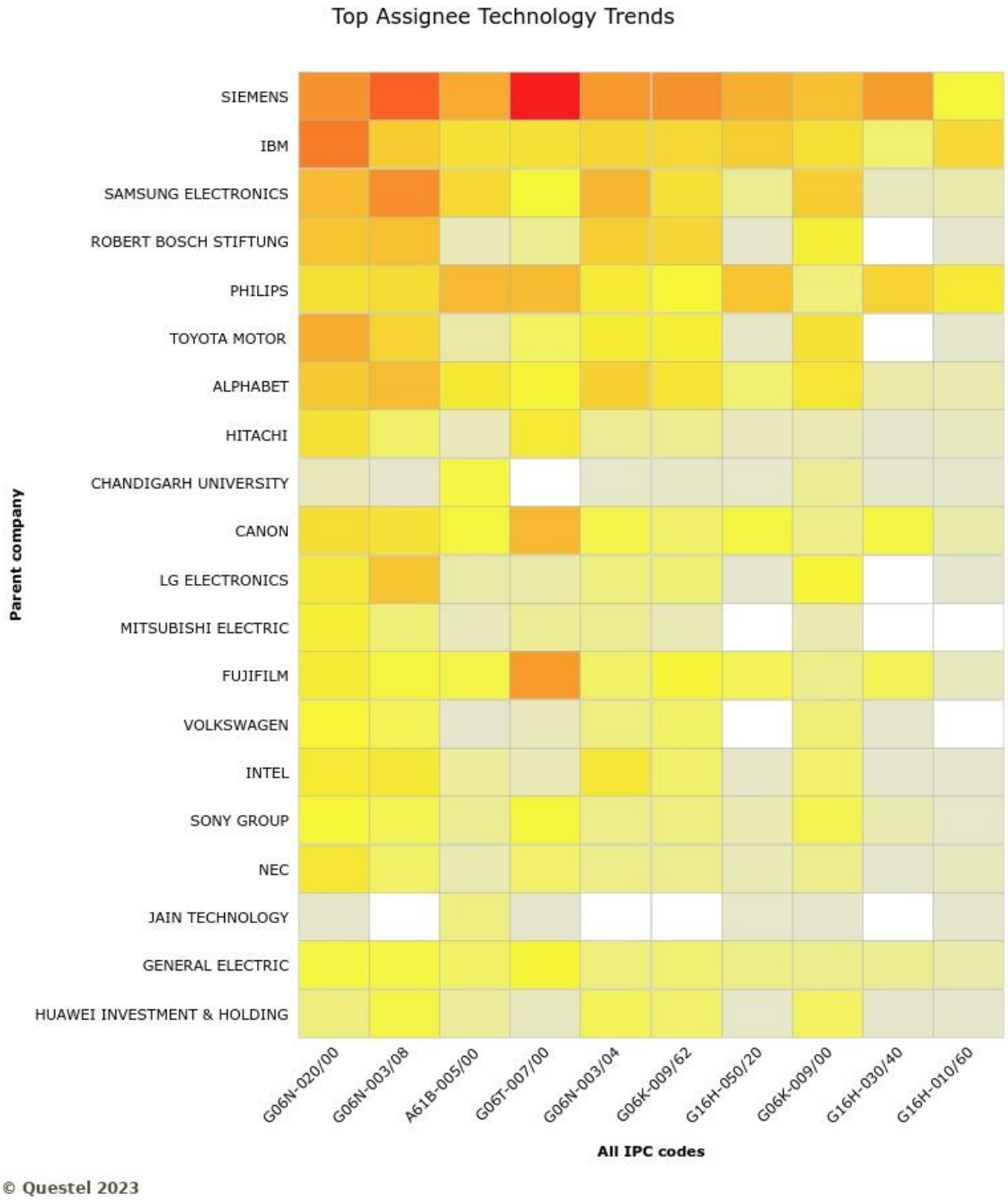
It can also be useful to analyse the annual patent filing trend among the top assignees, in order to understand the level of interest of key players. AI-related patent portfolios held by the top 20 assignees all experienced growth over the last 10 years. Please note, 2021-2023 data given in the graph will not be complete, due to the 18-month delay between priority application and publication.



Source: Clarivate via Derwent Innovation

3.6.2 TECHNOLOGICAL FOCUS

The patents filed by the top assignees across the leading IPC classifications can provide further insights regarding their key areas of interest within the patent landscape. The patent portfolio held by Siemens is the most diverse, and dominates areas relating to image analysis (G06T7/00 & G06K9/62) and pattern recognition (G06K9/62). Siemens also leads in the patenting of neural network learning methods (G06N3/08), however this area is more competetive, with significant activity also from Samsung, Alphabet and LG Electronics. One area which Siemens does not appear to dominate in in machine learning (G06N20/00), which is led by IBM.

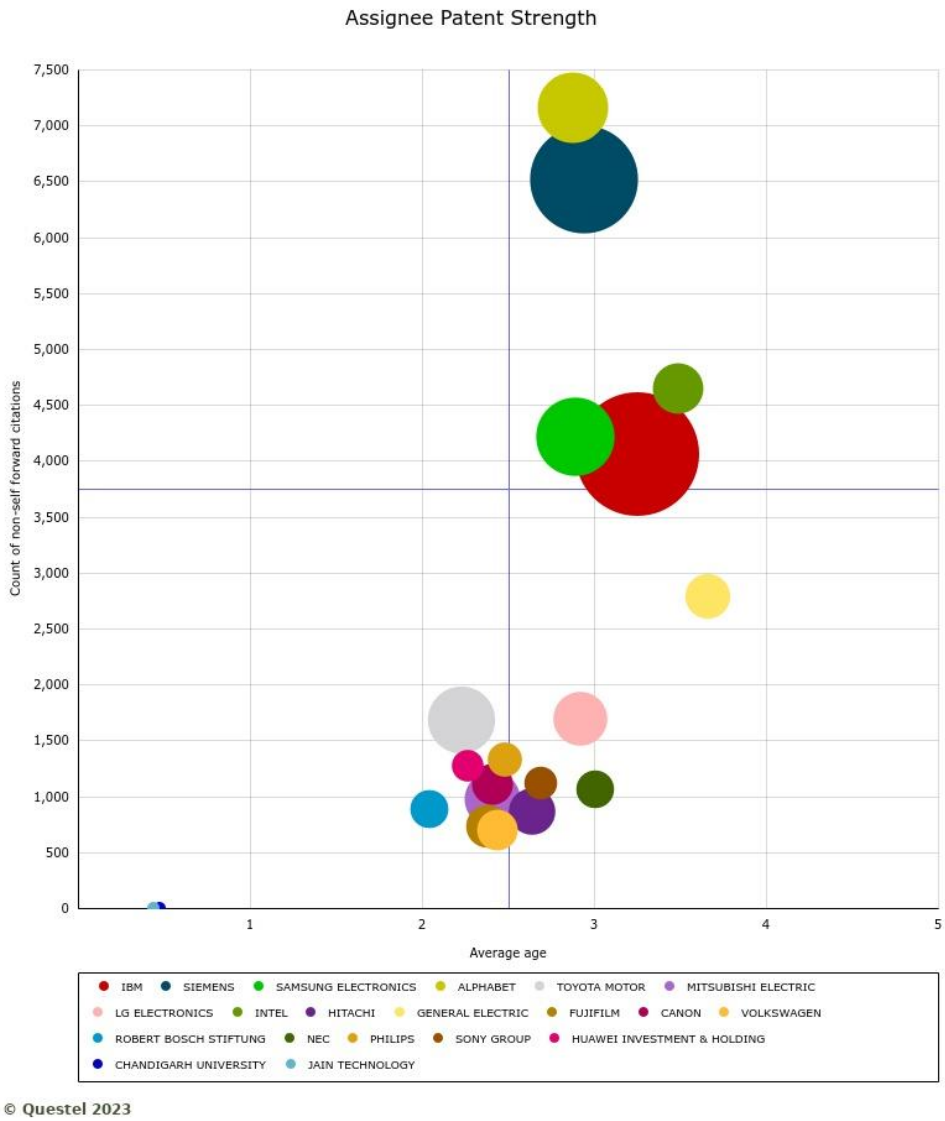


3.6.3 PATENT PORTFOLIO STRENGTH

The strength of an assignee's patent portfolio can be benchmarked by comparing the number of forward citations (vertical axis) relative to the average age of the portfolio (horizontal axis). Forward citations are where a patent is referred to by a later filed patent.

Portfolios positioned further to the right side of this graph correspond to pioneers in the area studied. A position at the top right is indicative of a pioneer with a strong impact on the field studied (potential blocking player). The portfolios further to the left side of this chart are the portfolios of the newcomers. A position at the top left corresponds to a later entrant into the space who quickly became important in the field (strong impact). The size of the bubbles corresponds to the number of families that have at least one family member issued. The larger the bubble, the greater the crowd/competition potential within the sector.

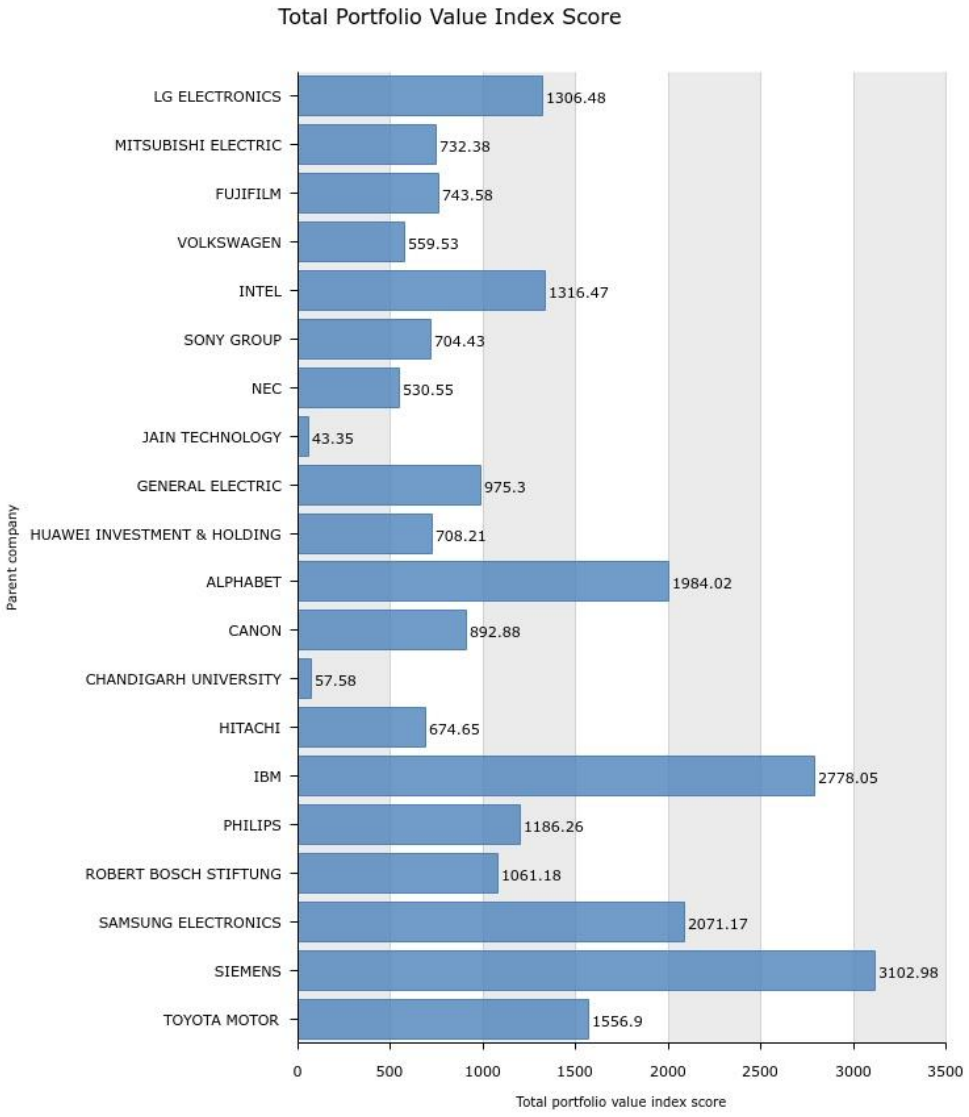
Of the top 20 parent organisations, the patent portfolio held by General Electric established an early footing in the field of AI. However, the analysis indicates that Alphabet, Siemens, IBM, Samsung and Intel are the most influential players in area.



3.6.4 PATENT PORTFOLIO VALUE

The integration of complex patent data with economic indicators can also highlight the value of the patents of the key players in AI. Scores are based upon the geographical distribution of granted and pending patent families using the GDP of the territories targeted by each patent portfolio. The number of non-self forward citations (technological impact) of each patent portfolio is also combined along with the remaining life of each patent portfolio to provide a headline metric of the portfolio value of each assignee.

A global analysis of the top 10 parent organisations suggests the AI patent portfolios held by Siemens, IBM, and Samsung are the most valuable across the scientific and engineering fields. All top 10 companies are likely to be targeting similar high GDP markets, and since AI is a relatively young field, most of the patent portfolios will have a significant amount of term remaining. Therefore, the patent portfolios held by Siemens, IBM, and Samsung are likely to be more valuable due to a high number of non-self patent citations and a greater impact in the AI field.

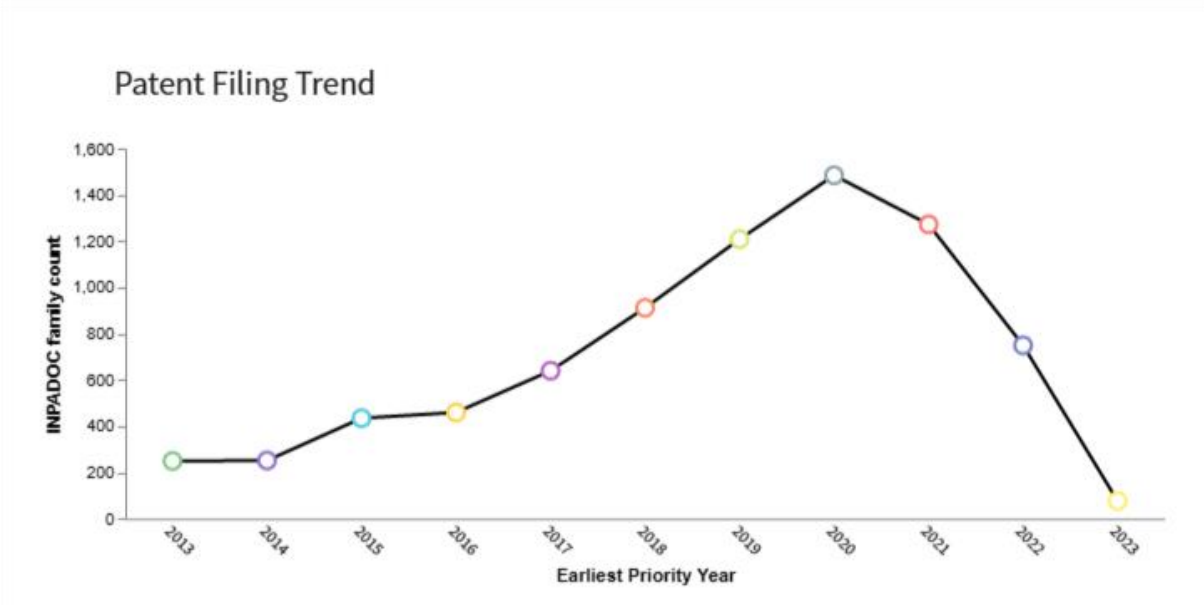


4 MEDICINE & PHARMACEUTICAL AI PATENT LANDSCAPE

The key search terms and classification codes outlined in Section 1.1 were used to understand how AI is transforming research in the pharmaceutical industry.

4.1 FILING RATE

Patent filing trend analysis indicates significant growth in the application of AI technologies for medicinal preparations and pharmaceuticals. The last five years account for approximately 62% of the total patent landscape. Please note, 2021-2023 data given in the graph will not be complete, due to the 18-month delay between priority application and publication.

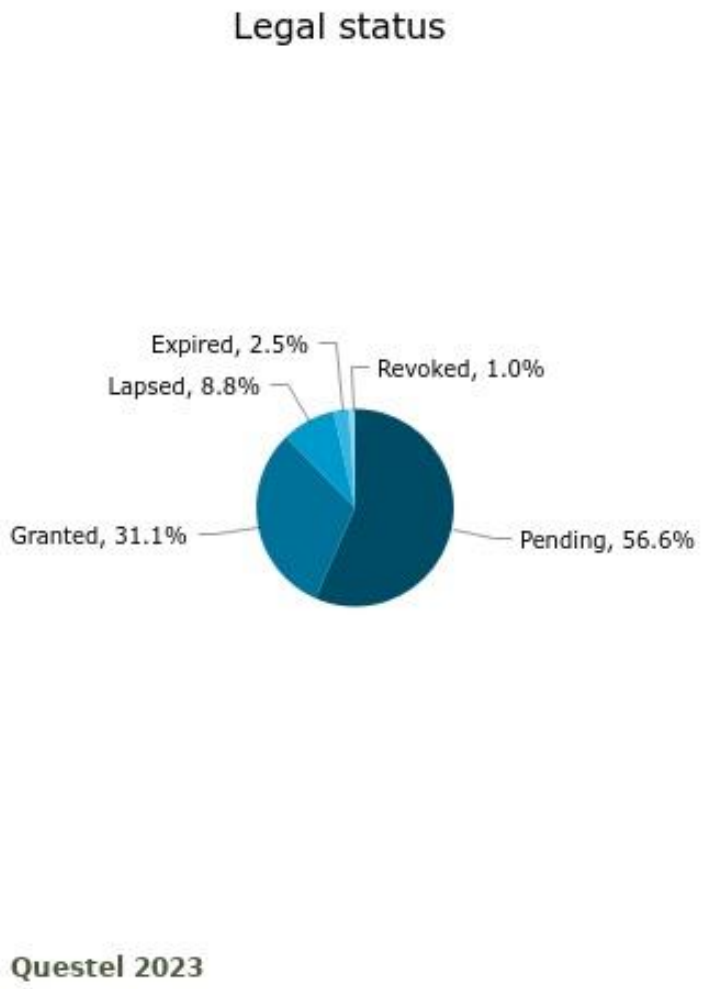


Source: Clarivate via Derwent Innovation

4.1.1 GLOBAL GRANT SUCCESS

In addition to the filing trends, we can look at the proportion of granted patents compared to patent applications to assess the maturity and competition in the sector. The following graph compares the legal status of patent families picked up by the search strategy.

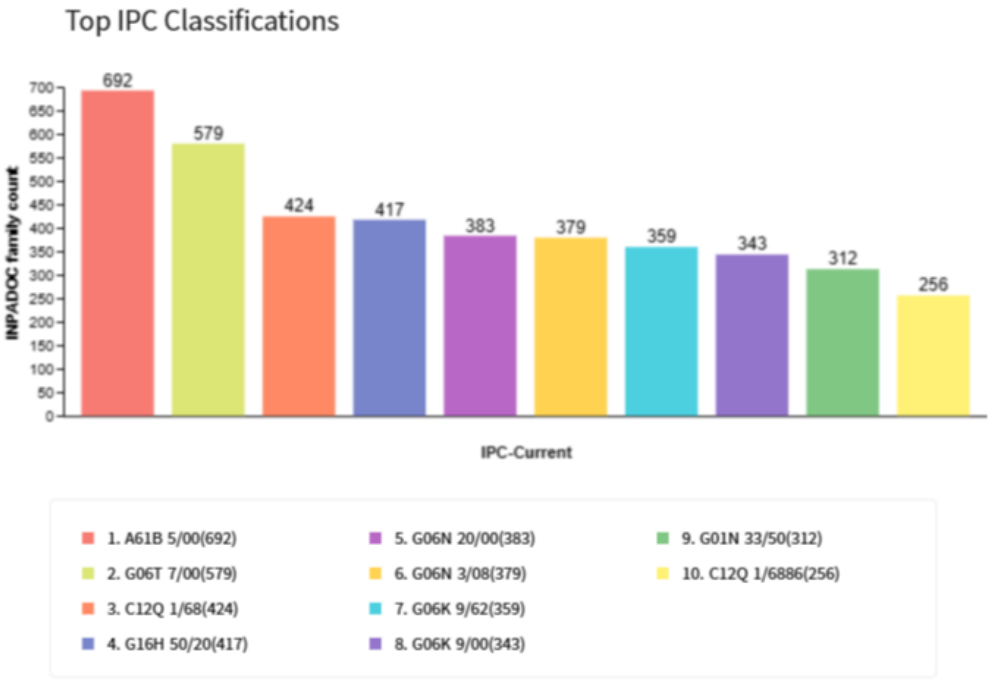
AI technologies for use in the pharmaceutical industries is a relatively new development, as evidenced by the low number of expired patents and a high proportion of pending patent applications. The high number of granted patent families and low proportion of lapsed patent families also suggests a significant commercial interest in AI within the pharmaceutical sector.



4.2 CLASSIFICATIONS

4.2.1 IPC CLASSIFICATIONS

The top AI IPCs relate to image analysis (G06T7/00), machine learning (G06N20/00), and neural network learning methods (G06N3/08), as well as methods or arrangements for recognising patterns (G06K9/00). Analysis of classification codes reveals that AI technology is most frequently applied to: measuring for diagnostic purposes (A61B5/00), measuring processes involving nucleic acids (C12Q1/68), and computer-aided diagnosis (G16H50/20). The significant interest in AI for diagnostic technology in the pharmaceutical industry is expected, as the advent of pharmacogenomics has improved our understanding of disease risk and pathology, which has facilitated the development of precision medicine and improved treatments.



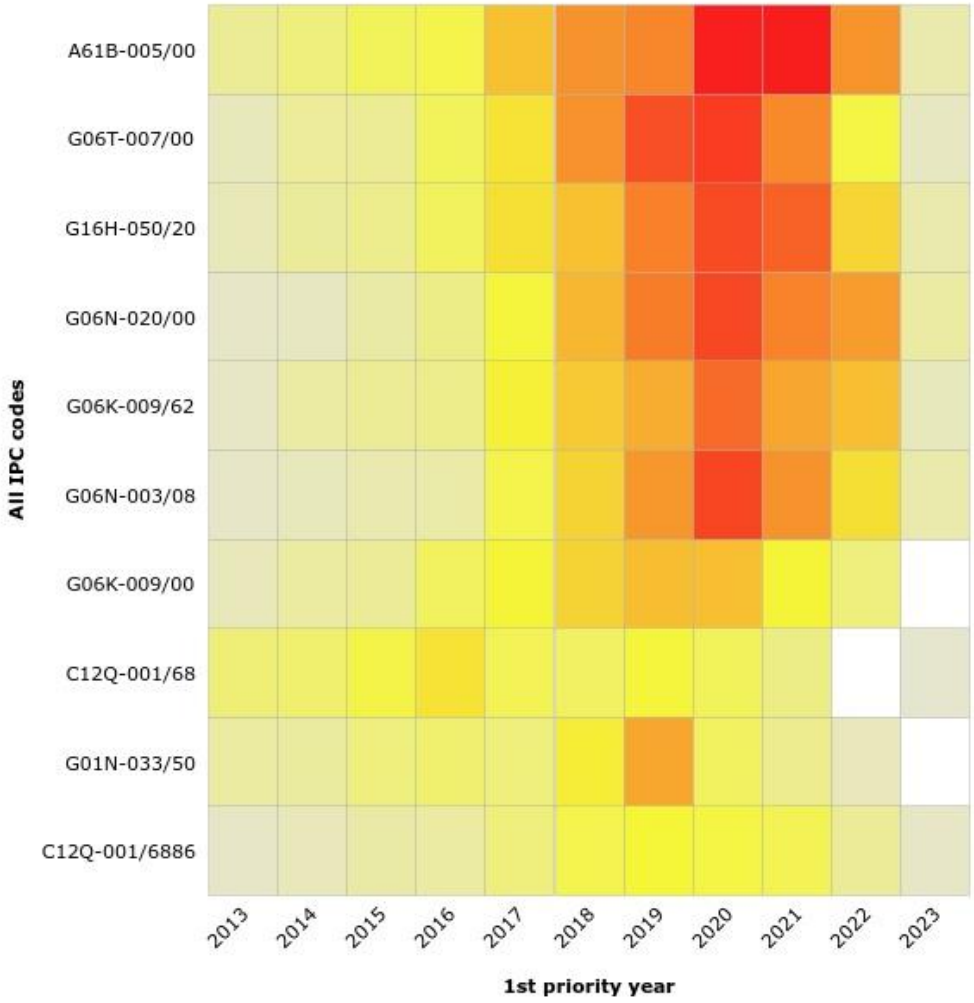
Source: Clarivate via Derwent Innovation

Rank	IPC	Number of Families	Definition	
1	A61B5/00	692	A61B5/00	Measuring for diagnostic purposes; Identification of persons
2	G06T7/00	579	G06T7/00	Image analysis
3	C12Q1/68	424	C12Q1/00 C12Q1/68	Measuring or testing processes involving enzymes, nucleic acids or microorganisms; Compositions therefor; Processes of preparing such compositions involving nucleic acids
4	G16H50/20	417	G16H50/00 G16H50/20	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics for computer-aided diagnosis, e.g. based on medical expert systems

Rank	IPC	Number of Families	Definition	
5	G06N20/00	383	G06N20/00	Machine learning
6	G06N3/08	379	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/08	Learning methods
7	G06K9/62	359	G06K9/00	Methods or arrangements for recognising patterns
			G06K9/62	Methods or arrangements for pattern recognition using electronic means
8	G06K9/00	343	G06K9/00	Methods or arrangements for recognising patterns
9	G01N33/50	312	G01N33/00	Investigating or analysing materials by specific methods not covered by groups G01N1/00 - G01N31/00
			G01N33/48	Biological material, e.g. blood, urine
			G01N33/50	Chemical analysis of biological material, e.g. blood, urine; Testing involving biospecific ligand binding methods; Immunological testing
10	C12Q1/6886	256	C12Q1/00	Measuring or testing processes involving enzymes, nucleic acids or microorganisms; Compositions therefor; Processes of preparing such compositions
			C12Q1/68	involving nucleic acids
			C12Q1/6876	Nucleic acid products used in the analysis of nucleic acids, e.g. primers or probes
			C12Q1/6883	for diseases caused by alterations of genetic material
			C12Q1/6886	for cancer

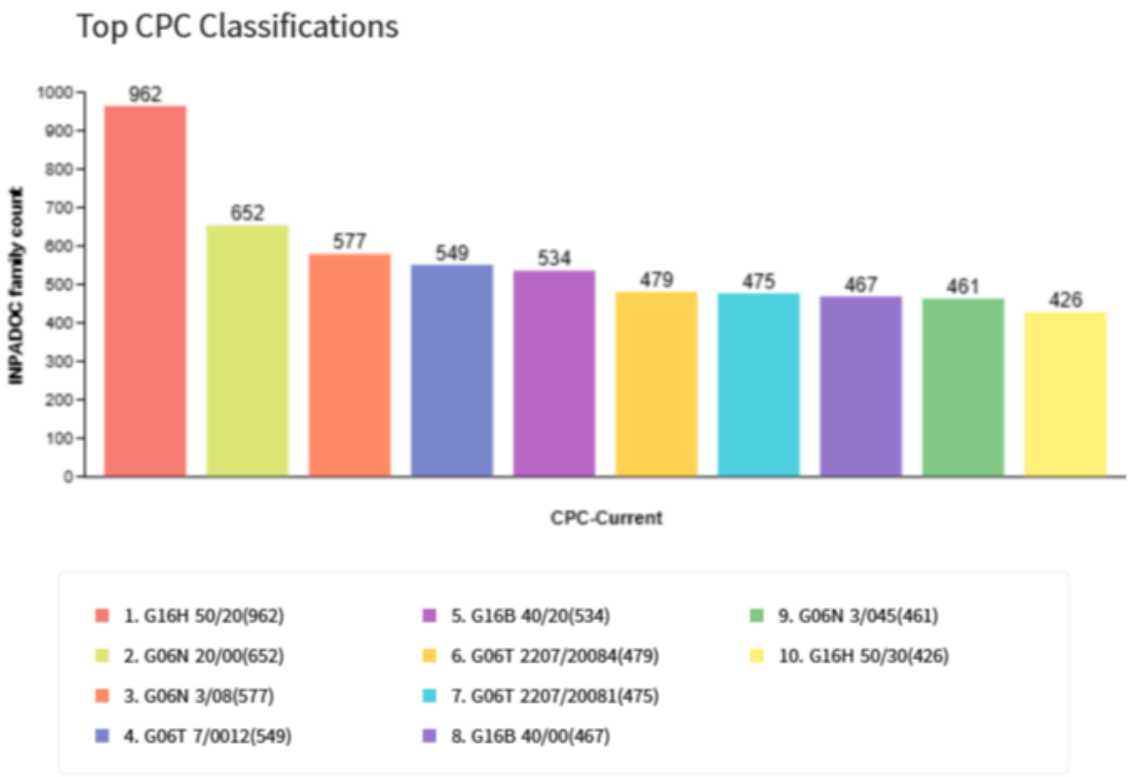
A closer look at the evolving filing trends reveals most patents were filed from 2018. Machine learning (G06N20/00) and neural network learning methods (G06N3/08) have emerged as the two dominant AI systems, with a significant increase in patent filings in image analysis (G06T7/00) as well.

Top IPC Classification Trends



4.2.2 CPC CLASSIFICATIONS

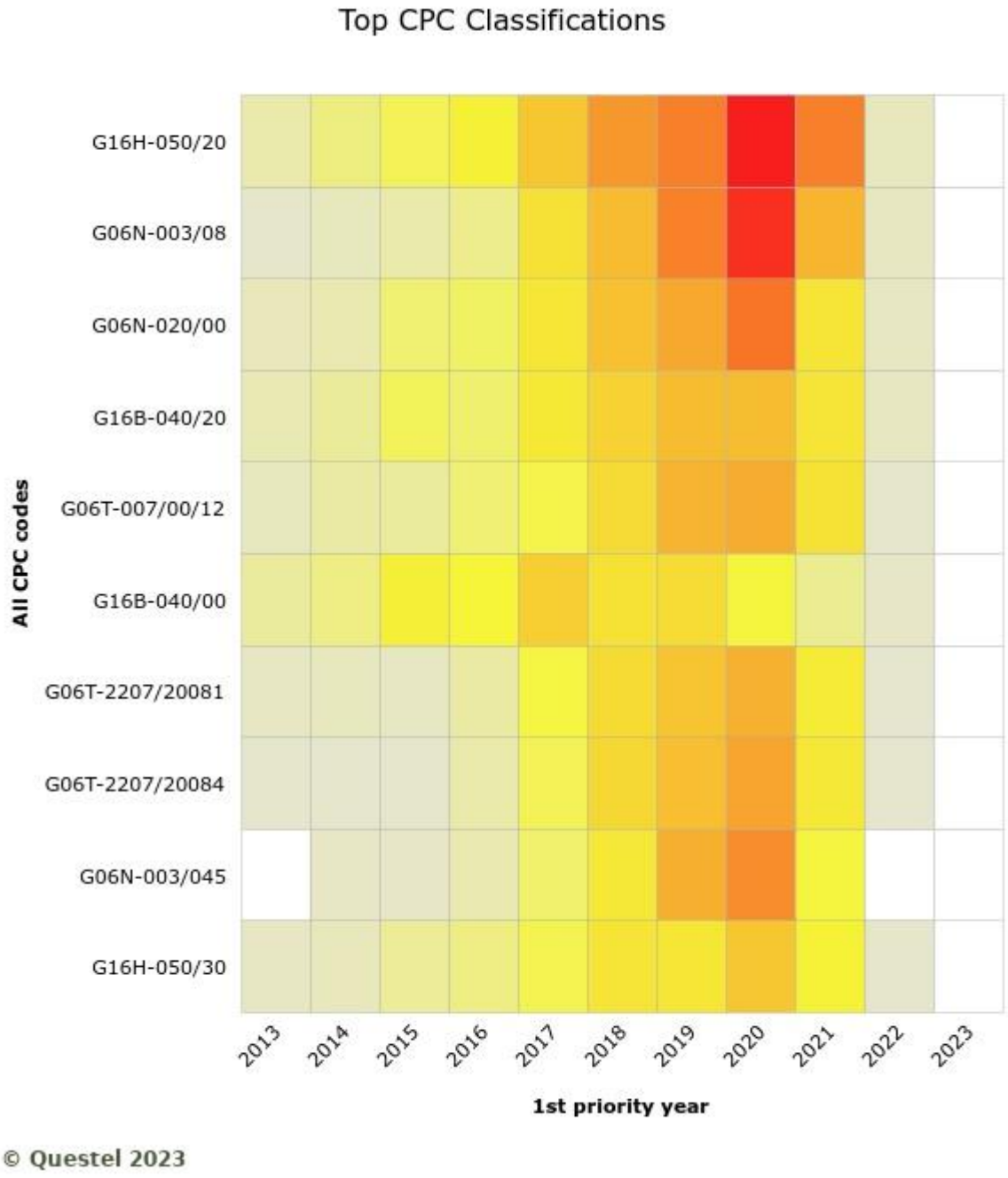
An analysis of the top CPC classifications points to computer-aided diagnosis based on medical expert systems (G16H50/20) as the most frequently used CPC classification. The classifications of machine learning (G06N20/00) and learning methods for neural networks (G06N3/08) are also highly ranked. Interestingly, the patent landscape analysis suggests that artificial neural networks (G06T2207/20084) are most frequently used for image analysis, while supervised data analysis is employed for bioinformatics-related machine learning or data mining (G16B40/20) patents. Patents that fall under the classification of health risk assessment (G16H50/30) are also prominent. Technologies for neural networks employed in the medical treatment and pharmaceutical industries often comprise of combinations of networks (G06N3/045).



Source: Clarivate via Derwent Innovation

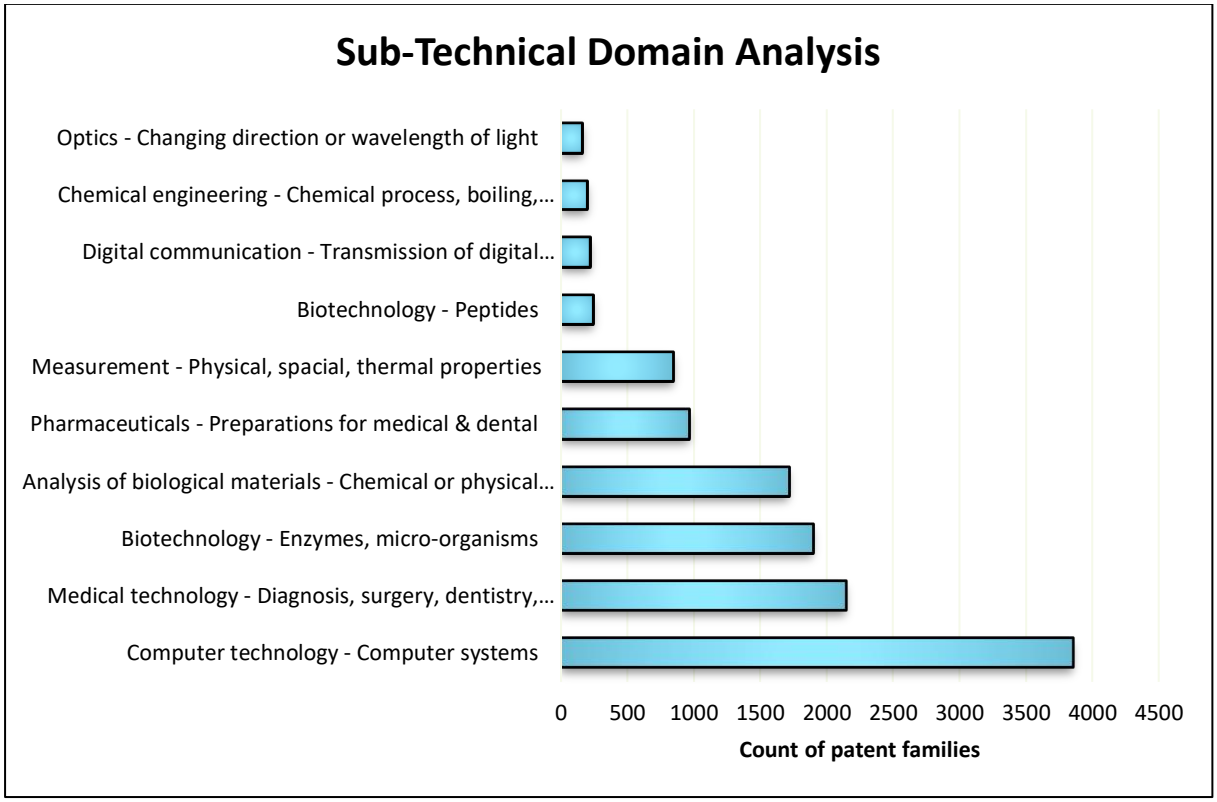
Rank	CPC	Number of Families	Definition	
1	G16H50/20	962	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/20	for computer-aided diagnosis, e.g. based on medical expert systems
2	G06N20/00	652	G06N20/00	Machine learning
3	G06N3/08	577	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/08	Learning methods
4	G06T7/0012	549	G06T7/00	Image analysis
			G06T7/0002	Inspection of images, e.g. flaw detection
			G06T7/0012	Biomedical image inspection
5	G16B40/20	534	G16B40/00	ICT specially adapted for biostatistics; ICT specially adapted for bioinformatics-related machine learning or data mining, e.g. knowledge discovery or pattern finding
			G16B40/20	Supervised data analysis
6	G06T2207/20084	479	G06T2207/00	Indexing scheme for image analysis or image enhancement
			G06T2207/20	Special algorithmic details
			G06T2207/20084	Artificial neural networks [ANN]
7	G06T2207/20081	475	G06T2207/00	Indexing scheme for image analysis or image enhancement
			G06T2207/20	Special algorithmic details
			G06T2207/20081	Training; Learning
8	G16B40/00	467	G16B40/00	ICT specially adapted for biostatistics; ICT specially adapted for bioinformatics-related machine learning or data mining, e.g. knowledge discovery or pattern finding
9	G06N3/045	461	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/04	Architecture, e.g. interconnection topology
			G06N3/045	Combinations of networks
10	G16H50/30	426	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/30	for calculating health indices; for individual health risk assessment

The CPC classification trend analysis confirms the previously identified IPC trends, which show the recent emergence of key areas. While computer-aided diagnosis based on medical expert systems (G16H50/20) represents the leading area of innovation since 2016, the graphic below indicates that since 2020 there is a growing interest in learning methods for neural networks (G06N3/08) over machine learning (G06N20/00). Neural networks having combinations of networks (G06N3/045) also appear to be emerging as the leading type of neural network.



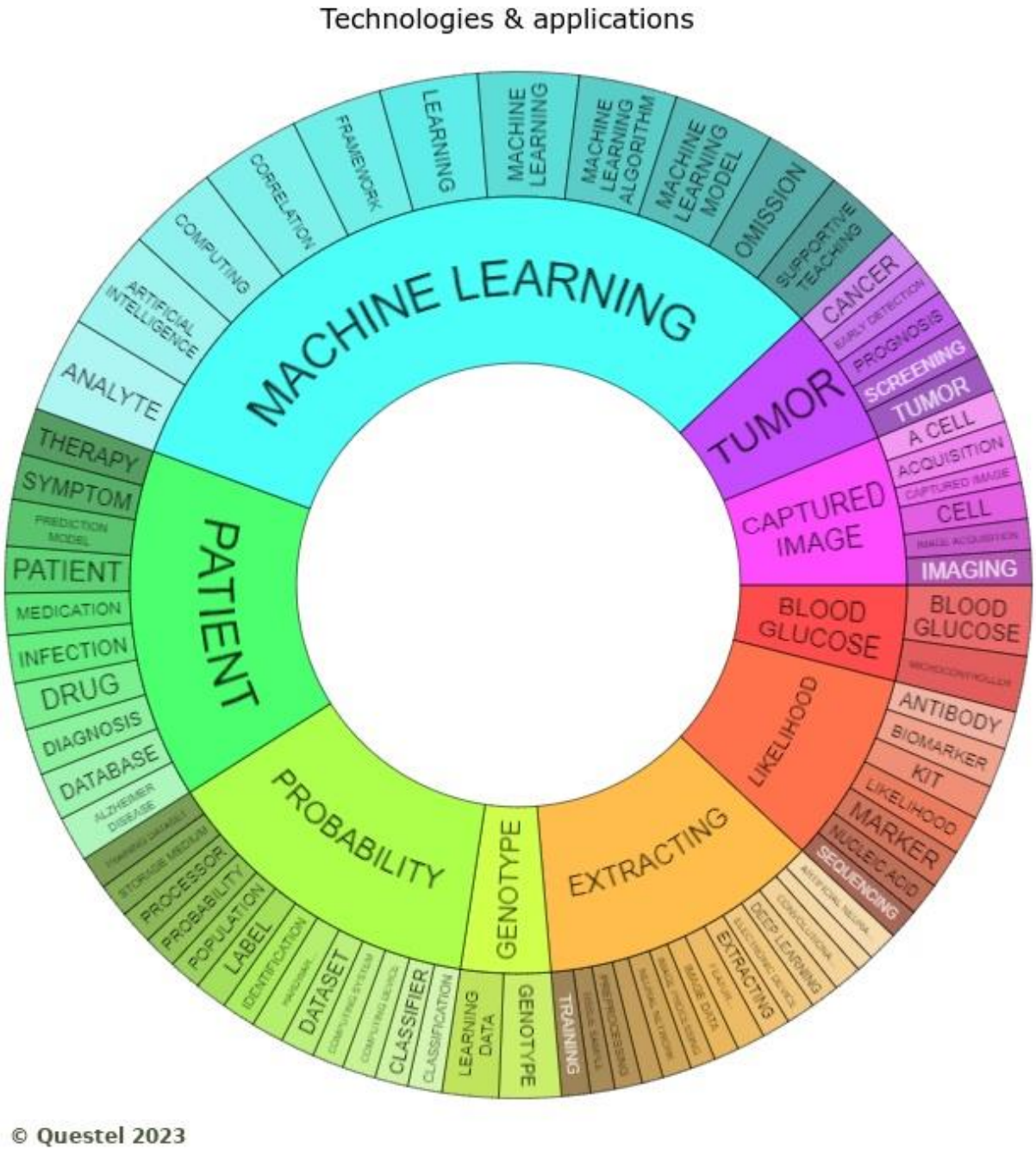
4.2.3 SUB-TECHNICAL DOMAINS

Sub-technical domains are based on IPC codes, which have been grouped into 177 sub-technology fields. An analysis provides further information on the applications of AI within the medical treatment and pharmaceutical industries. Most of the innovation relates to the computer systems themselves, diagnosis, surgical and therapeutic equipment, as well as pharmaceuticals, enzymes and micro-organisms.



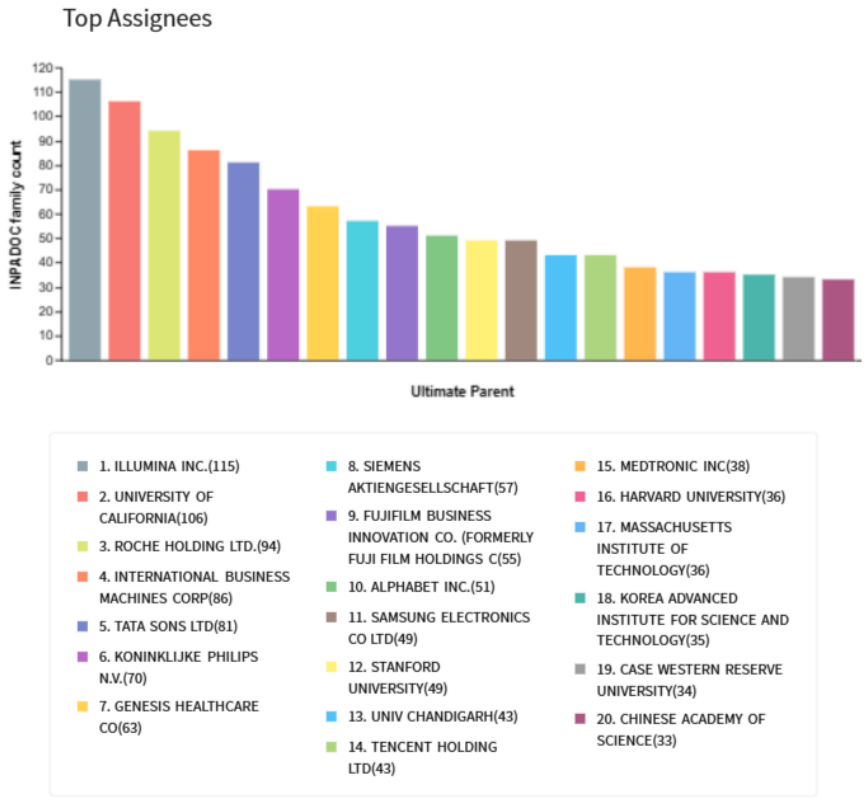
4.3 LANDSCAPE CONCEPTS

The following figure illustrates the distribution of the main concepts across the AI patent landscape in the pharmaceutical industry, highlighting the importance of machine learning models, and patient and genotype data. Image analysis, blood glucose data, as well as tumour biomarkers for screening, diagnosis and prognosis are all prominent concepts within the pharmaceutical AI patent landscape.



4.4 TOP ASSIGNEES

The top 20 assignees for the number of patents filed to AI-based technologies relevant to pharmaceutical research are presented in the following figure:



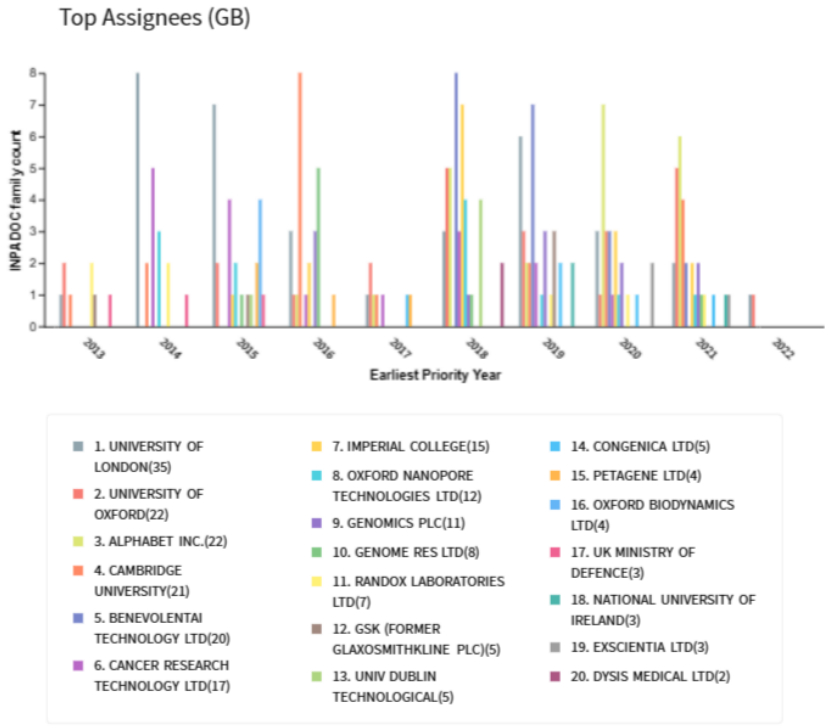
Source: Clarivate via Derwent Innovation

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
1	ILLUMINA INC.	115	Commercial	US
2	UNIVERSITY OF CALIFORNIA	106	Academic	US
3	ROCHE HOLDING LTD.	94	Commercial	Switzerland
4	INTERNATIONAL BUSINESS MACHINES CORP	86	Commercial	US
5	TATA SONS LTD	81	Commercial	India
6	KONINKLIJKE PHILIPS N.V.	70	Commercial	Netherlands
7	GENESIS HEALTHCARE CO	63	Commercial	GB
8	SIEMENS AKTIENGESELLSCHAFT	57	Commercial	Germany
9	FUJIFILM BUSINESS INNOVATION CO	55	Commercial	Japan
10	ALPHABET INC.	51	Commercial	US
11	STANFORD UNIVERSITY	49	Academic	US
12	SAMSUNG ELECTRONICS CO LTD	49	Commercial	Korea
13	TENCENT HOLDING LTD	43	Commercial	China

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
14	UNIV CHANDIGARH	43	Academic	India
15	MEDTRONIC INC	38	Commercial	US
16	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	36	Academic	US
17	HARVARD UNIVERSITY	36	Academic	US
18	KOREA ADVANCED INSTITUTE FOR SCIENCE AND TECHNOLOGY	35	Academic	Korea
19	CASE WESTERN RESERVE UNIVERSITY	34	Academic	US
20	CHINESE ACADEMY OF SCIENCE	33	Academic	China

GREAT BRITAIN

The top patent filing UK organisations include:



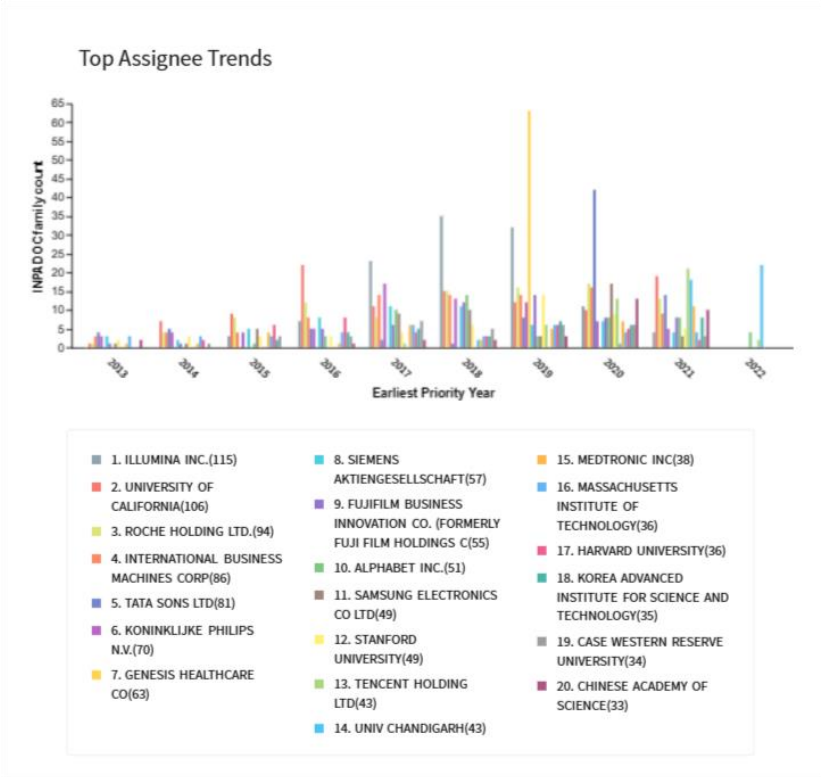
Source: Clarivate via Derwent Innovation

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
1	UNIVERSITY OF LONDON	35	Academic	GB
2	UNIVERSITY OF OXFORD	22	Academic	GB
3	ALPHABET INC. (DEEPMIND TECH LTD)	22	Commercial	GB
4	CAMBRIDGE UNIVERSITY	21	Academic	GB
5	BENEVOLENTAI TECHNOLOGY LTD	20	Commercial	GB

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
6	CANCER RESEARCH TECHNOLOGY LTD	17	Commercial	GB
7	IMPERIAL COLLEGE	15	Academic	GB
8	OXFORD NANOPORE TECHNOLOGIES LTD	12	Commercial	GB
9	GENOMICS PLC	11	Commercial	GB
10	GENOME RES LTD	8	Commercial	GB
11	RANDOX LABORATORIES LTD	7	Commercial	GB
12	GSK	5	Commercial	GB
13	UNIV DUBLIN TECHNOLOGICAL	5	Academic	GB
14	CONGENICA LTD	5	Commercial	GB
15	PETAGENE LTD	4	Commercial	GB
16	OXFORD BIODYNAMICS LTD	4	Commercial	GB
17	UK MINISTRY OF DEFENCE	3	Commercial	GB
18	NATIONAL UNIVERSITY OF IRELAND	3	Academic	GB
19	EXSCIENTIA LTD	3	Commercial	GB
20	DYSIS MEDICAL LTD	2	Commercial	GB

4.4.1 FILING TRENDS

Of the top assignees, Illumina filed the most patents in 2018, after which the growth in their patent portfolio appears to have slowed down. This trend is also seen in Siemens, Philips, Alphabet, and Fujifilm. In contrast, the patent portfolios held by Roche, University of California, and IBM have all experienced continued growth. Interestingly, the patent filing rates of Genesis Healthcare and Tata Sons spiked significantly in 2019 and 2020. **The analysis of patent filing trends shows that between 2016 and 2019 there was more interest in image and nucleic acid analysis, which has been replaced by more interest in developing AI-based platforms that leverage pharmacogenomic data and clinical trial datasets to enrich the portfolio of candidate drug response biomarkers.** Please note, 2021-2023 data given in the graph will not be complete, due to the 18-month delay between priority application and publication.



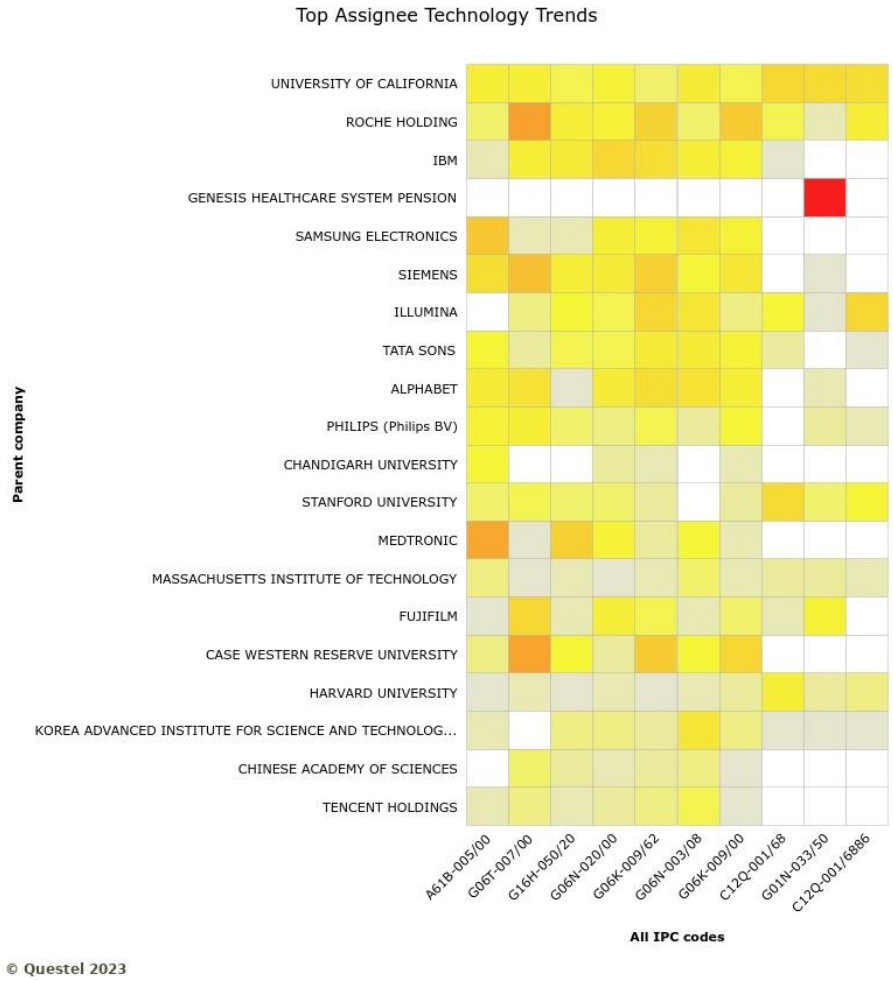
Source: Clarivate via Derwent Innovation

4.4.2 TECHNOLOGY FOCUS

Roche and Siemens dominate the image analysis sector, with both companies also being active in the development of pattern recognition systems (G06K9/00). Philips also holds patent portfolios that follows a similar patent filing pattern to a lesser extent. While Illumina also appears to have significant activity in pattern recognition systems (G06K9/00), IPC classification assessment suggests this is in relation to cancer genetic analysis (C12Q1/6886), as the company appears to have filed the most patents in this area. Alphabet and IBM also have significant interest in patents to pattern recognition systems, however the portfolios of these two technology companies are much more diversified.

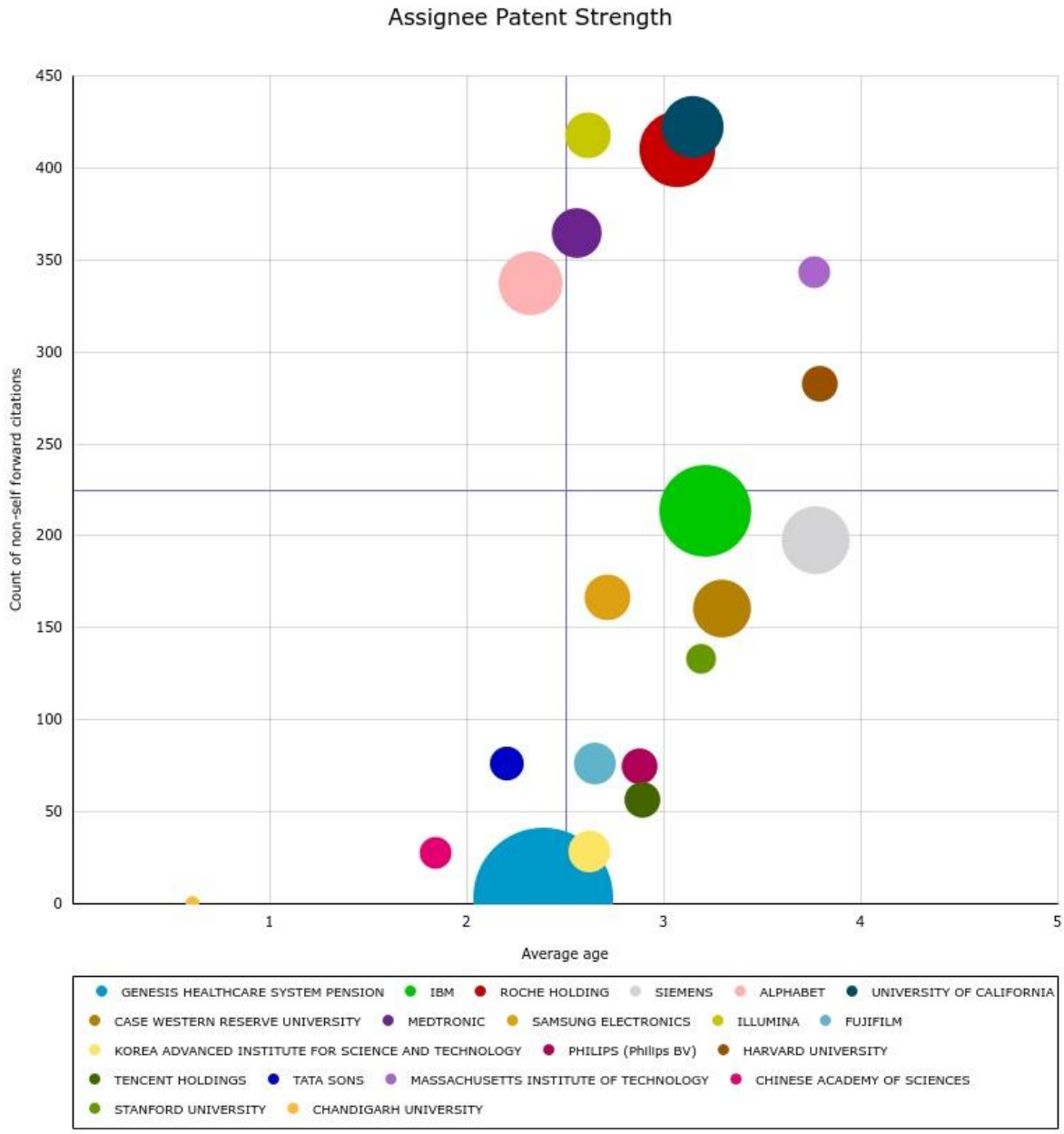
The patent portfolio held by the University of California exhibits a focus in nucleic acid analysis (C12Q1/68). In contrast, Genesis Healthcare appear to dominate the area of the patent landscape relating to analysis of biological material (G01N33/50), with patent filings exclusively in this area.

Pattern recognition systems for imaging and genome data are important applications of AI within the pharmaceutical field.



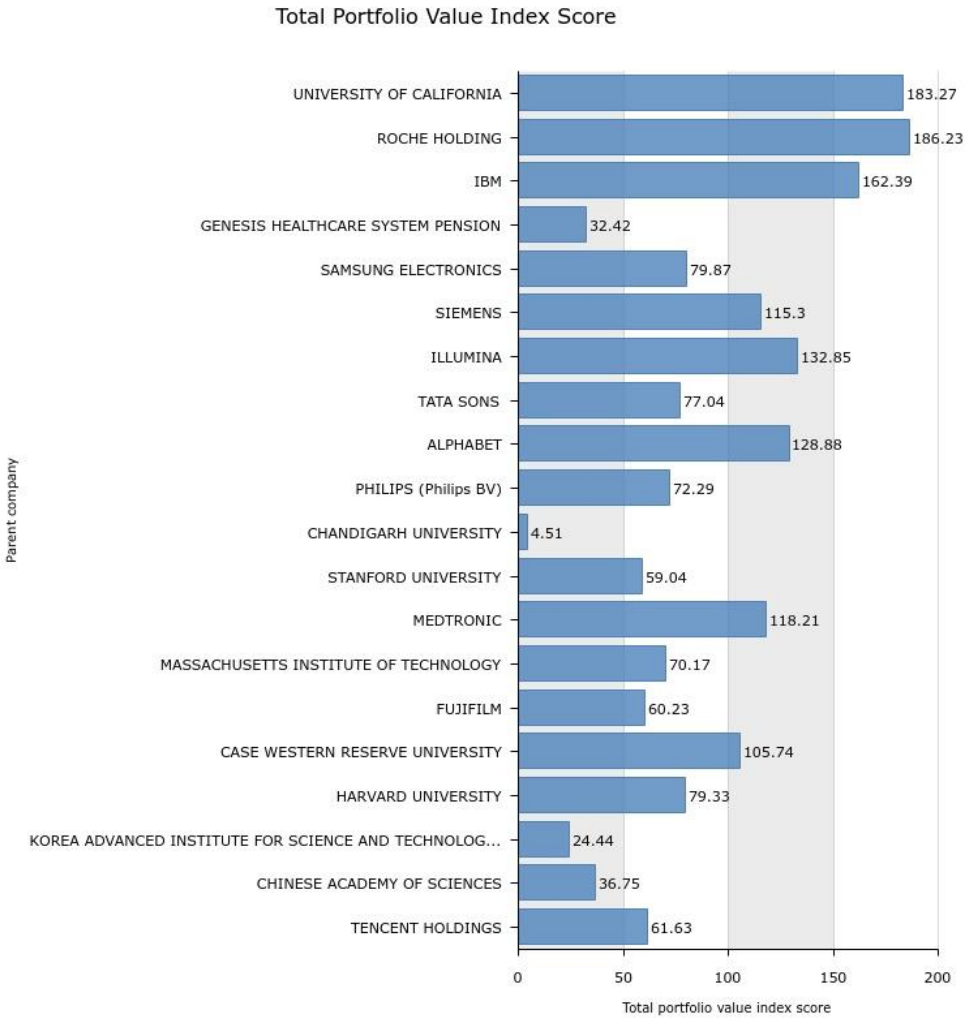
4.4.3 PATENT PORTFOLIO STRENGTH

Siemens established an early footing in the field of medical treatment, with Harvard University and MIT being pioneers in the area. Most notably, Alphabet is the most influential newcomer.



4.4.4 PATENT PORTFOLIO VALUE

The basis of patent portfolio value scores was introduced in Section 4.6.4 of this report. An analysis of the top 20 parent organisations suggests the most valuable AI patent portfolios are held by Roche, University of California and IBM.



4.5 LANDSCAPE MAP

We used the Derwent Themescape tool on the patent landscape dataset, mapping one representative patent from each of the INPADOC families. The resulting map is shown below, with some broad subject areas highlighted. This allows us to identify some key areas of interest in the field, represented by the highest "peaks" on the map.

Although landscaping is not a precise tool, it is useful to identify clusters of activity on the map which facilitates the analysis of both trends and also to identify similar patents or potential competitors. This can be a way to visualise and start to identify both potential freedom to operate issues around a patent estate and/or to identify potential collaborators and licensees who have similar patented technologies and interests.

In this instance, the landscape map was used to identify areas of high patent coverage and areas of low patent coverage, as well as gain insight into the position of the patent portfolios of the top 10 assignees, as illustrated in Figure 1 below. **The patent landscape map shows a concentration of patenting activity in the areas of research that relate to genome analysis and medical imaging, with significant activity in using AI to understand disease pathology and protein structure.**

Figure 1 legend:

Company	Colour
Illumina Inc.	
University Of California	
Roche Holding Ltd.	
International Business Machines Corp	
Tata Sons Ltd	
Koninklijke Philips N.V.	
Genesis Healthcare Co	
Siemens Aktiengesellschaft	
Fujifilm Business Innovation Co	
Alphabet Inc.	

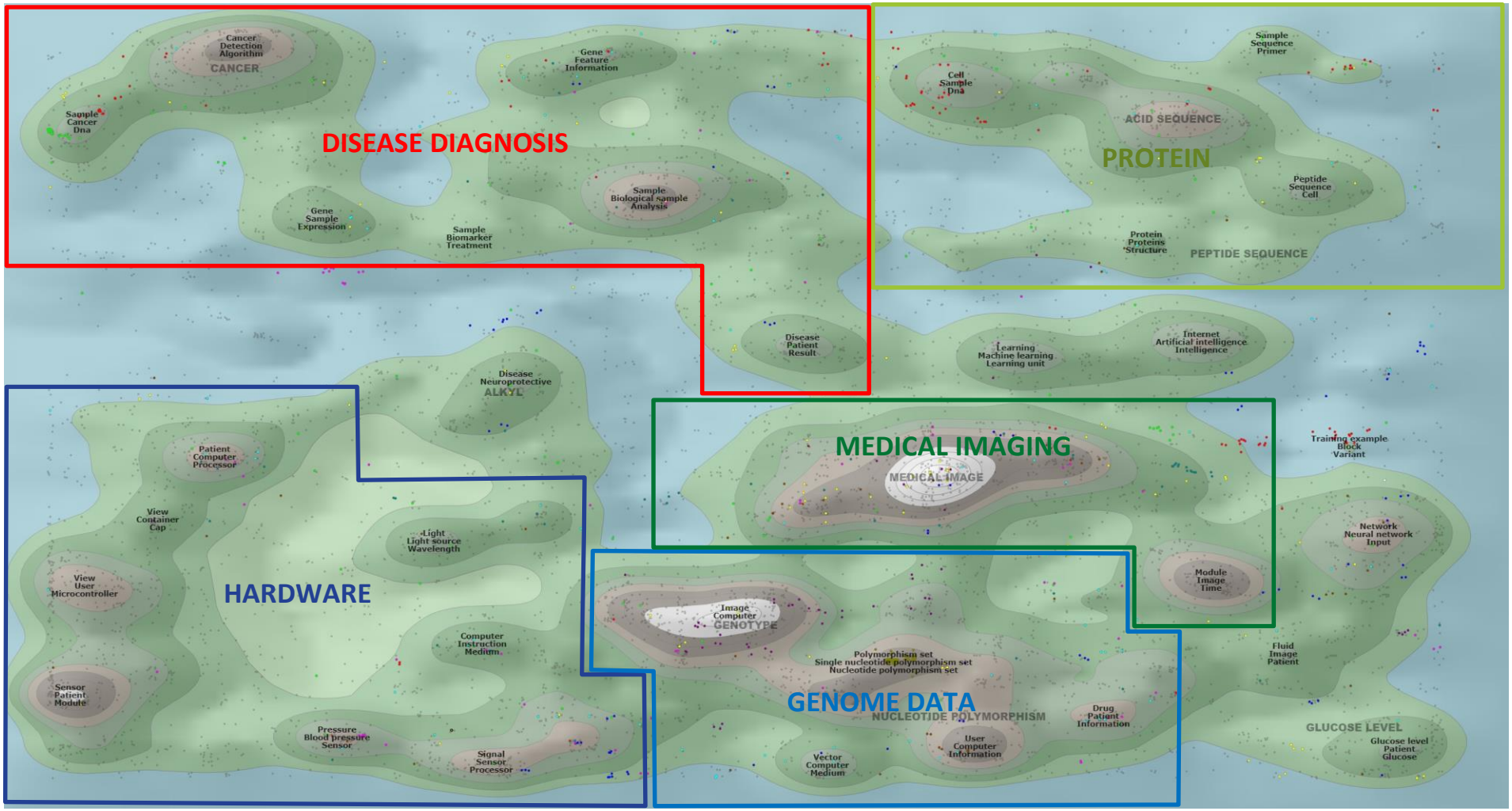


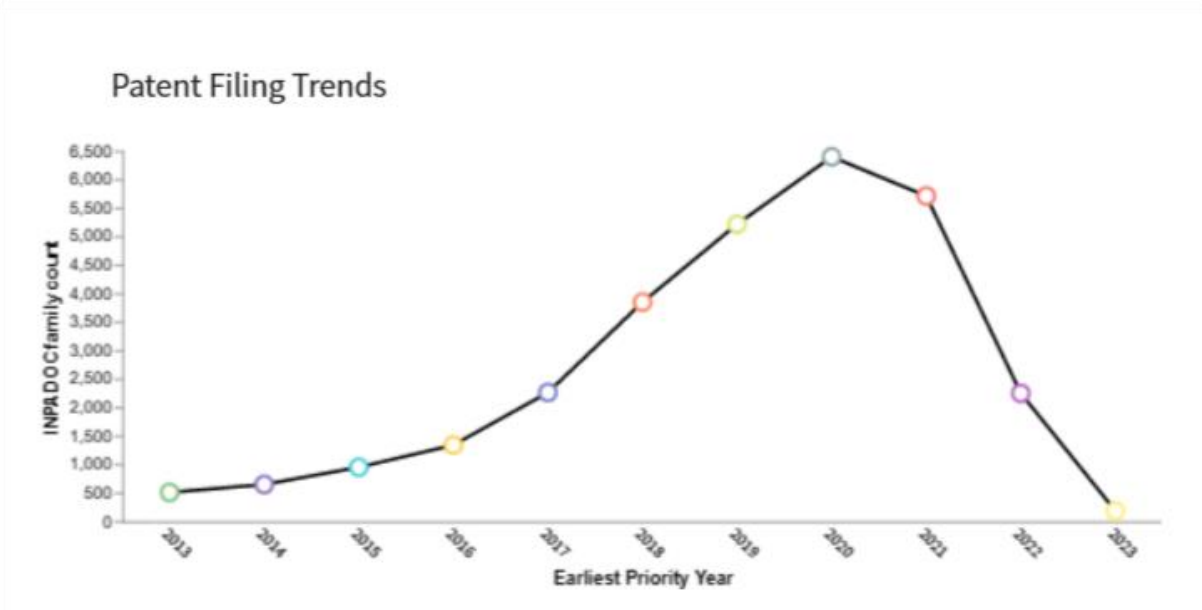
Figure 1. AI technologies in the pharmaceutical space (Source: Clarivate via Derwent Innovation). Each dot indicates the location of an INPADOC patent family on the map. The map has been overlaid with the key areas under which the patents fall on the map.

5 MEDICAL TECHNOLOGY AI PATENT LANDSCAPE

The key search terms and classification codes outlined in Section 1.1 were used understand how AI is transforming medical technology.

5.1 FILING RATE

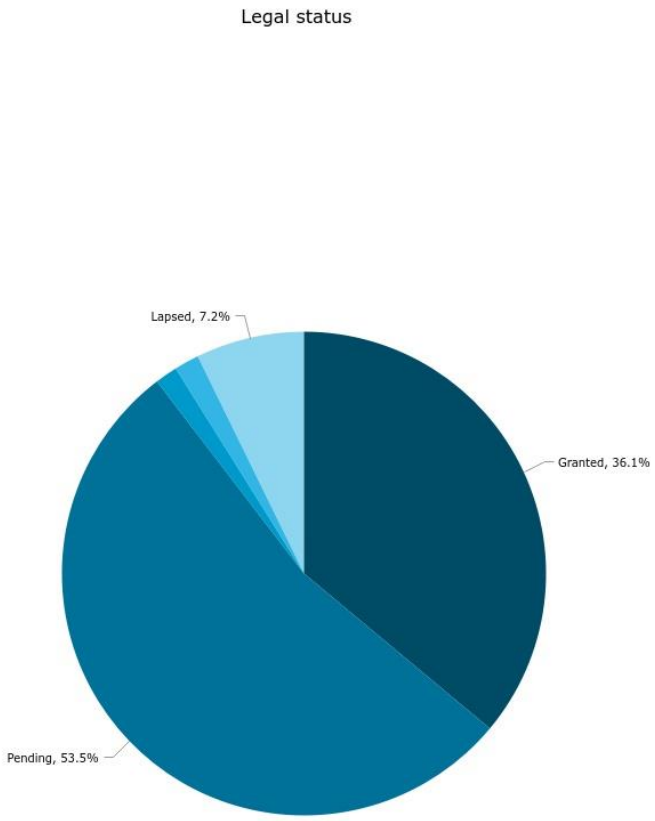
Within the field of AI and medical technology, the last five years account for approximately 67% of the total patent landscape. Please note, 2021-2023 data given in the graph will not be complete, due to the 18-month delay between priority application and publication.



Source: Clarivate via Derwent Innovation

5.1.1 GLOBAL GRANT SUCCESS

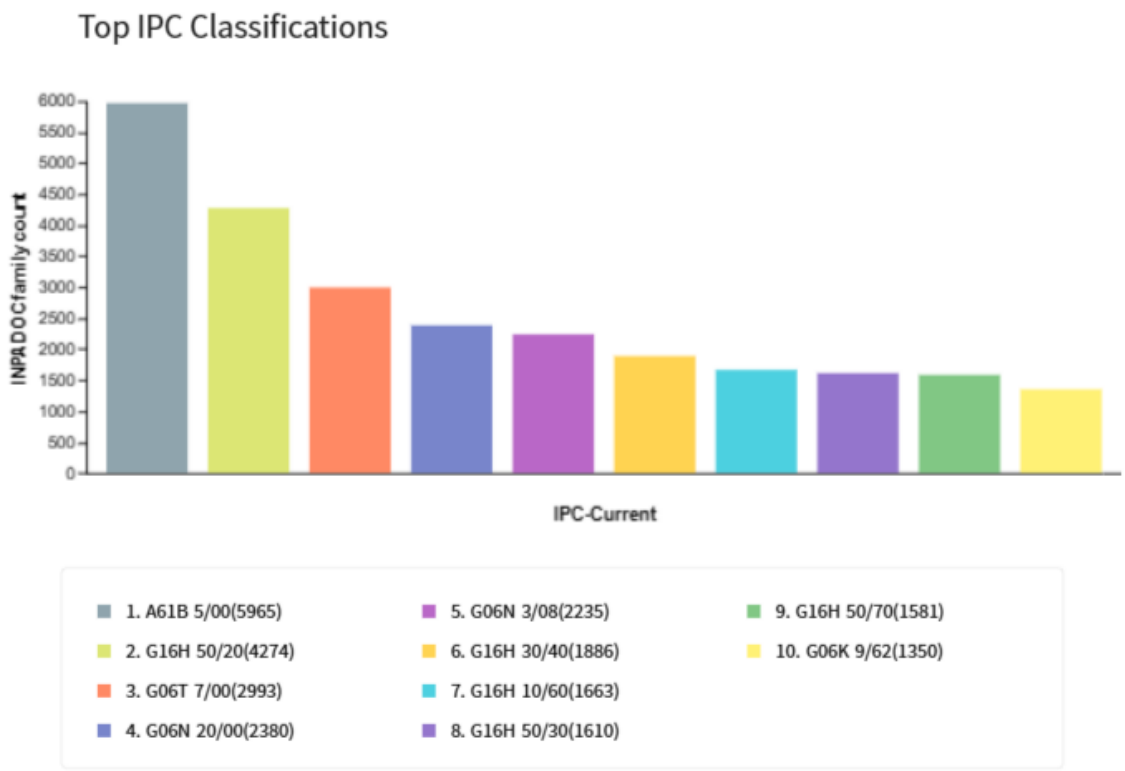
The following graph illustrates the legal status of the patent families picked up by the search strategy. The high number of granted patent families and low proportion of lapsed patent families the commercial interest in using AI within the medical technology space. Over half of the patent families are pending which also suggests that this remains fast-growing area with significant space for innovation.



5.2 CLASSIFICATIONS

5.2.1 IPC CLASSIFICATIONS

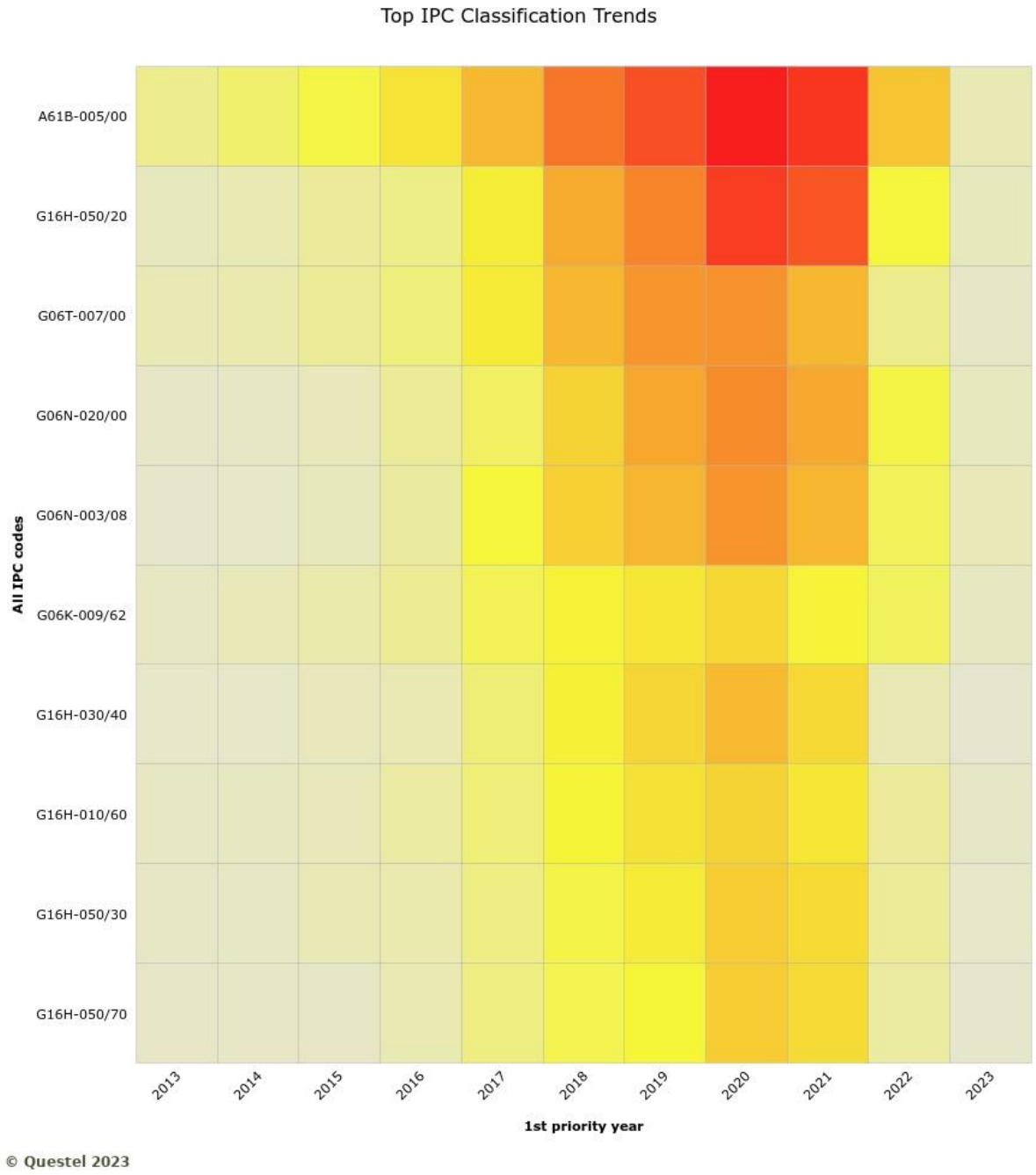
The top AI IPCs for medical technologies relate to measuring for diagnostic purposes (A61B5/00), computer-aided diagnosis based on medical expert systems (G16H50/20), and image analysis (G06T7/00). Machine learning (G06N20/00) and neural network learning methods (G06N3/08) are common AI models applied in this domain, with interest also in systems for recognising patterns (G06K9/62). The top AI IPCs also include patents related to health risk assessment (G16H50/30) and mining of medical data (G16H50/70).



Source: Clarivate via Derwent Innovation

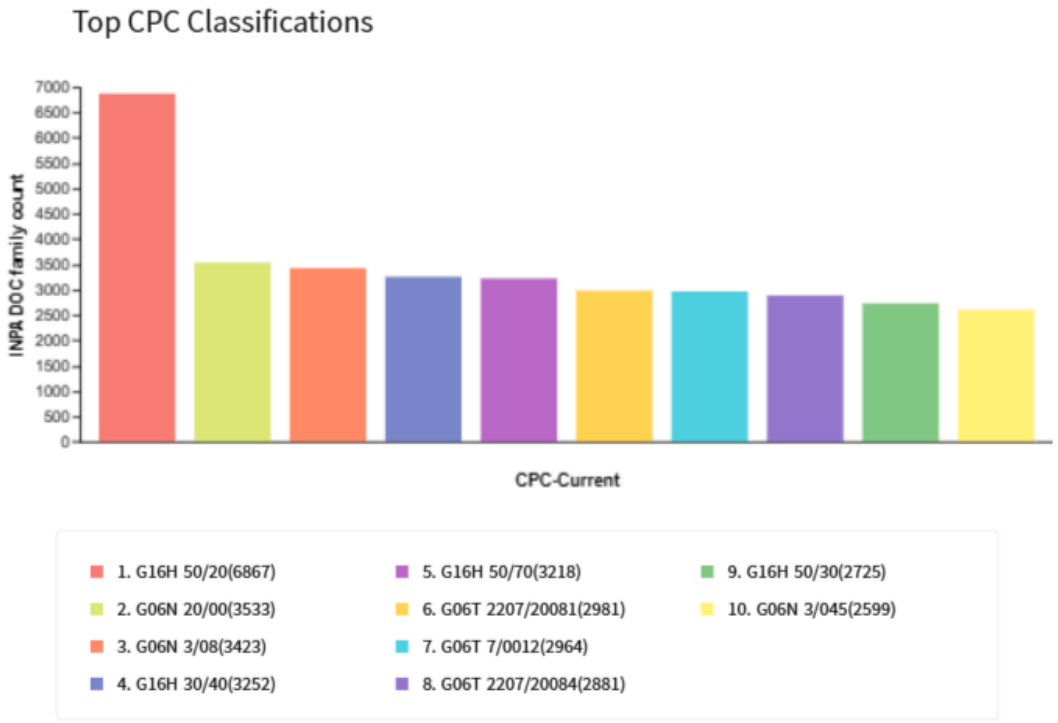
Rank	IPC	Number of Families	Definition	
1	A61B5/00	5965	A61B5/00	Measuring for diagnostic purposes; Identification of persons
2	G16H50/20	4274	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/20	for computer-aided diagnosis, e.g. based on medical expert systems
3	G06T7/00	2993	G06T7/00	Image analysis
4	G06N20/00	2380	G06N20/00	Machine learning
5	G06N3/08	2235	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/08	Learning methods
6	G16H30/40	1886	G16H30/00	ICT specially adapted for the handling or processing of medical images
			G16H30/40	for processing medical images, e.g. editing
7	G16H10/60	1663	G16H10/00	ICT specially adapted for the handling or processing of patient-related medical or healthcare data
			G16H10/60	for patient-specific data, e.g. for electronic patient records
8	G16H50/30	1610	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/30	for calculating health indices; for individual health risk assessment
9	G16H50/70	1581	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/70	for mining of medical data, e.g. analysing previous cases of other patients
10	G06K9/62	1350	G06K9/00	Methods or arrangements for recognising patterns
			G06K9/62	Methods or arrangements for pattern recognition using electronic means

Most AI-medical technology patent filings were made from 2019 onwards, with most patent classification areas experiencing growth. Until recently, AI applications for measuring processes for diagnostic purposes (A61B5/00) dominated the patent landscape, however it appears that AI technology has improved sufficiently to enable the emergence of computer-aided diagnosis (G16H50/20). Patenting in areas relating to health risk assessment (G16H50/30) and mining of medical data (G16H50/70) have also emerged recently in 2020. While AI has been heavily used in image analysis (G06T7/00) since 2018, AI has started to be increasingly used for the processing of medical images (G16H30/40). Interestingly, there did not appear to be a significant increase in patent filings relating to systems for pattern recognition (G06K9/62), which suggests that AI has evolved to perform much more complex tasks.



5.2.2 CPC CLASSIFICATIONS

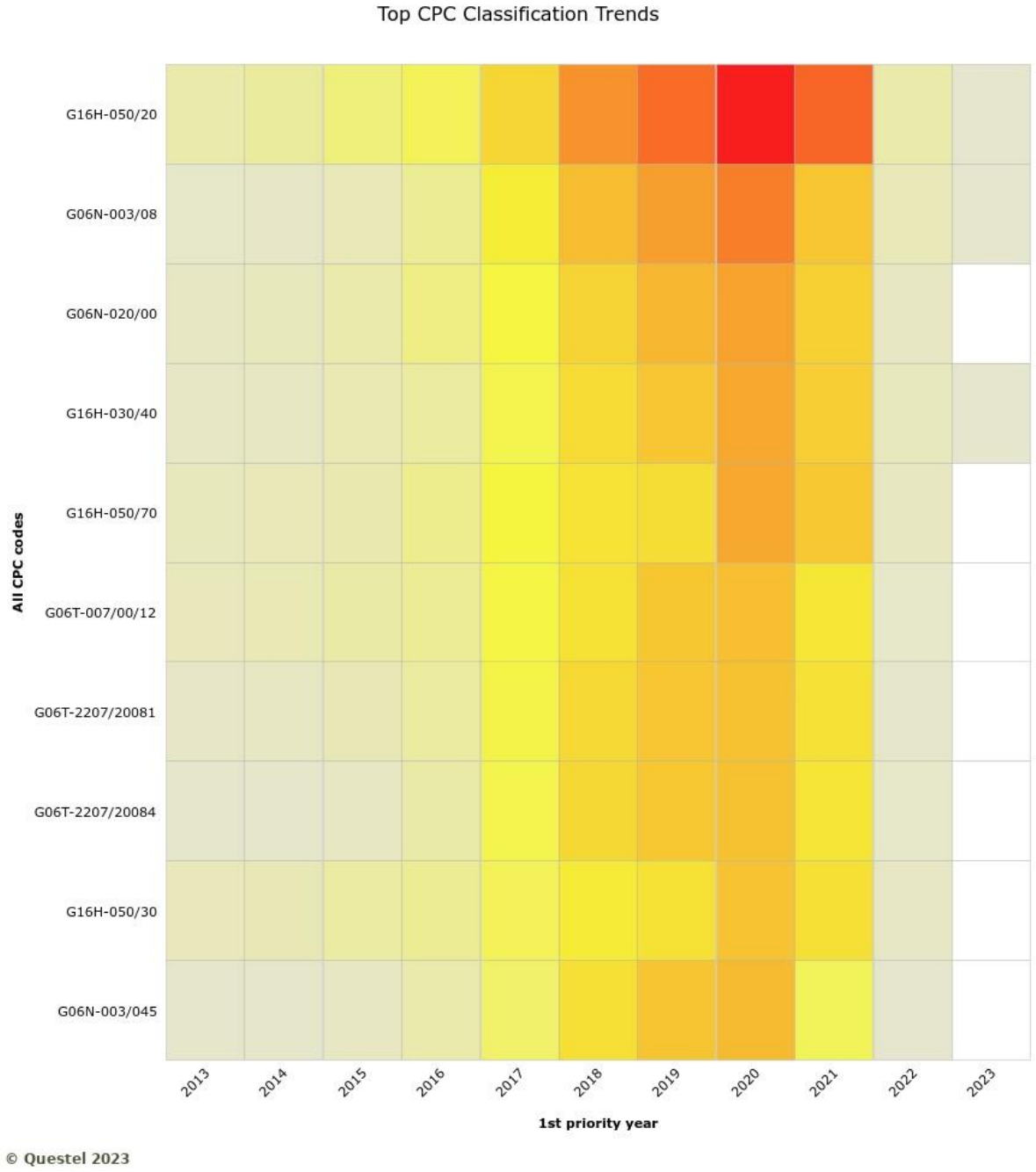
The analysis of top CPC classifications showed similar key trends identified by the top IPC classifications. Additional key patenting areas of interest include: algorithmic training methods for image analysis (G06T2207/20081), biomedical image inspection (G06T7/0012) which encompass computer-aided detection of disease abnormalities, artificial neural networks for image analysis (G06T7/0012), and combinations of neural networks (G06N3/045).



Source: Clarivate via Derwent Innovation

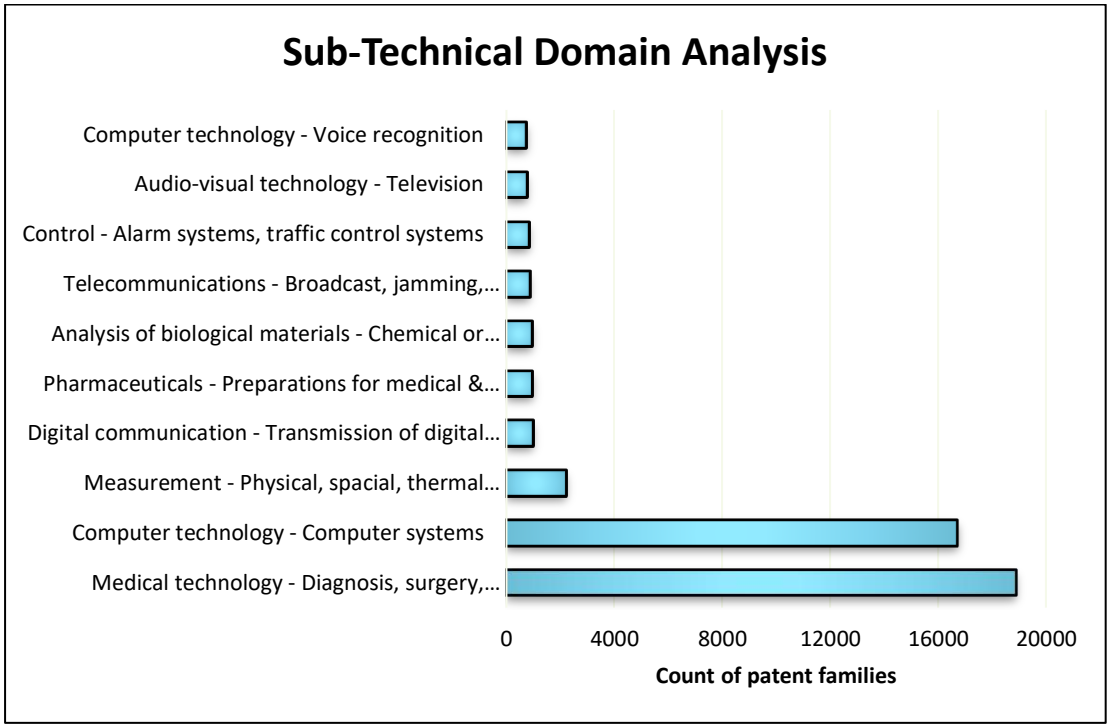
Rank	CPC	Number of Families	Definition	
1	G16H50/20	6867	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/20	for computer-aided diagnosis, e.g. based on medical expert systems
2	G06N20/00	3533	G06N20/00	Machine learning
3	G06N3/08	3423	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/08	Learning methods
4	G16H30/40	3252	G16H30/00	ICT specially adapted for the handling or processing of medical images
			G16H30/40	for processing medical images, e.g. editing
5	G16H50/70	3218	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/70	for mining of medical data, e.g. analysing previous cases of other patients
6	G06T2207/20081	2981	G06T2207/00	Indexing scheme for image analysis or image enhancement
			G06T2207/20	Special algorithmic details
			G06T2207/20081	Training; Learning
7	G06T7/0012	2964	G06T7/00	Image analysis
			G06T7/0002	Inspection of images, e.g. flaw detection
			G06T7/0012	Biomedical image inspection
8	G06T2207/20084	2881	G06T2207/00	Indexing scheme for image analysis or image enhancement
			G06T2207/20	Special algorithmic details
			G06T2207/20084	Artificial neural networks [ANN]
9	G16H50/30	2725	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/30	for calculating health indices; for individual health risk assessment
10	G06N3/045	2599	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/04	Architecture, e.g. interconnection topology
			G06N3/045	Combinations of networks

The CPC classification trend analysis confirms the previously identified IPC trends, which show the recent emergence of some specific key areas. While growth was experienced in all the top CPC classifications, inventions to computer-aided diagnosis based on medical expert systems (G16H50/20) continues to be leading patenting area. Neural networks comprised of combinations of networks (G06N3/045) are emerging now as an important type of neural network. Similarly, patents classed under artificial neural networks (G06T2207/20084) are emerging as the main tool for image analysis, with a lot of innovation focused on algorithmic training methods (G06T2207/20081).



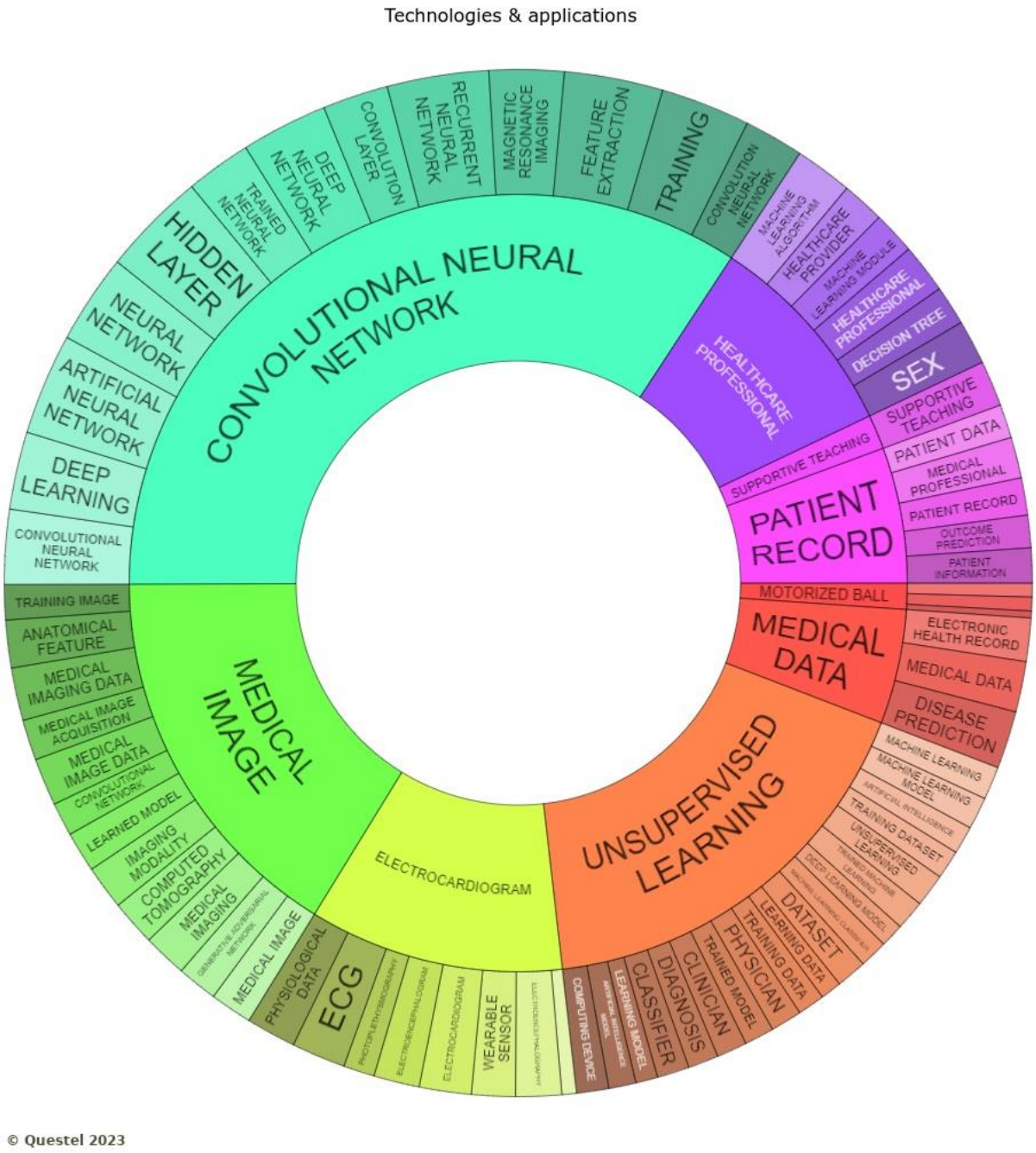
5.2.3 SUB-TECHNICAL DOMAINS

Further analysis into the 177 sub-technology fields showed that most innovation appears to relate to diagnosis, surgery, dentistry, therapy devices, and pharmaceuticals, and overlap between different fields. Patents to measurement devices and digital communication systems also feature highly.



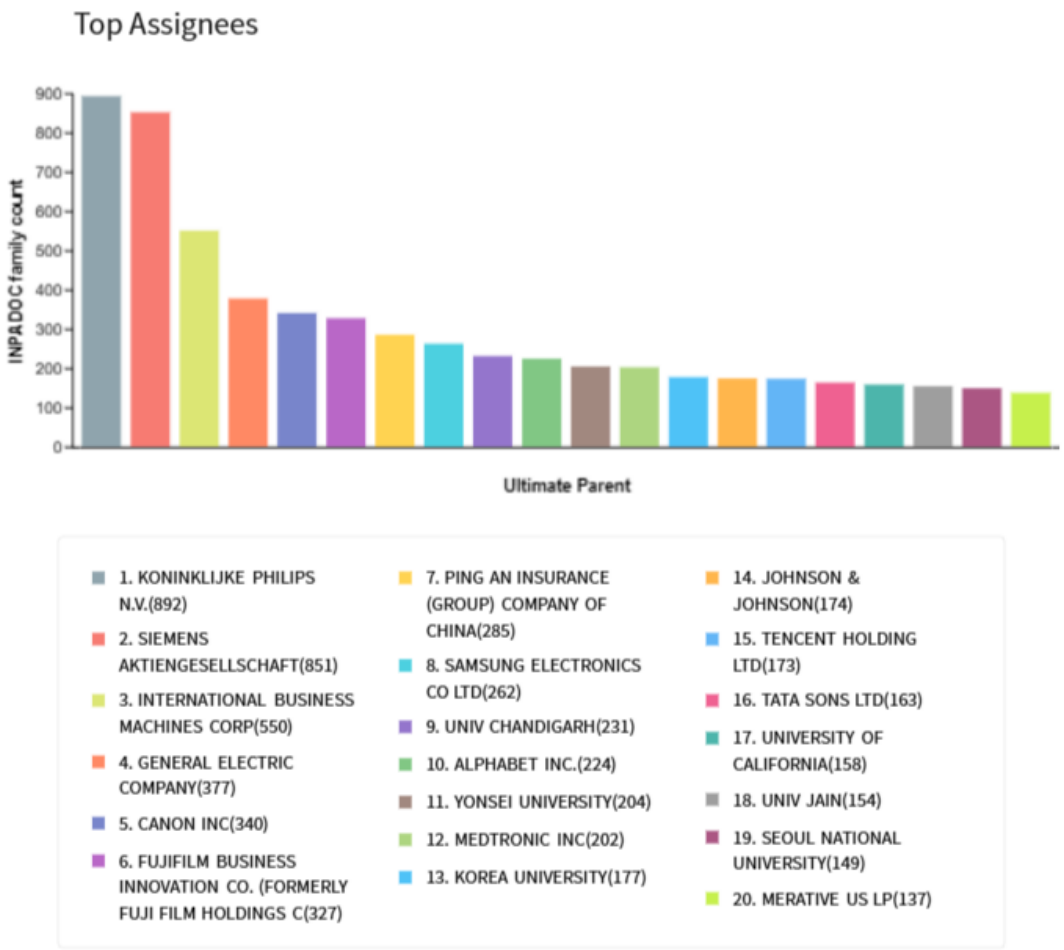
5.3 LANDSCAPE CONCEPTS

The following figure illustrates the grouping and distribution of the main concepts across the AI patent landscape in the medical technology industry. Key patent concepts focus on deep learning systems, with particular interest in convolutional neural networks. There also appears to be significant interest in unsupervised learning, as well as medical imaging and physiological, medical and patient data:



5.4 TOP ASSIGNEES

The top 20 assignees in terms of number of patents filed AI related technologies in the medical technology area are mainly commercial organisations, and considering the significant growth in the patent landscape, it is no surprise see major international corporations dominate this patent landscape.

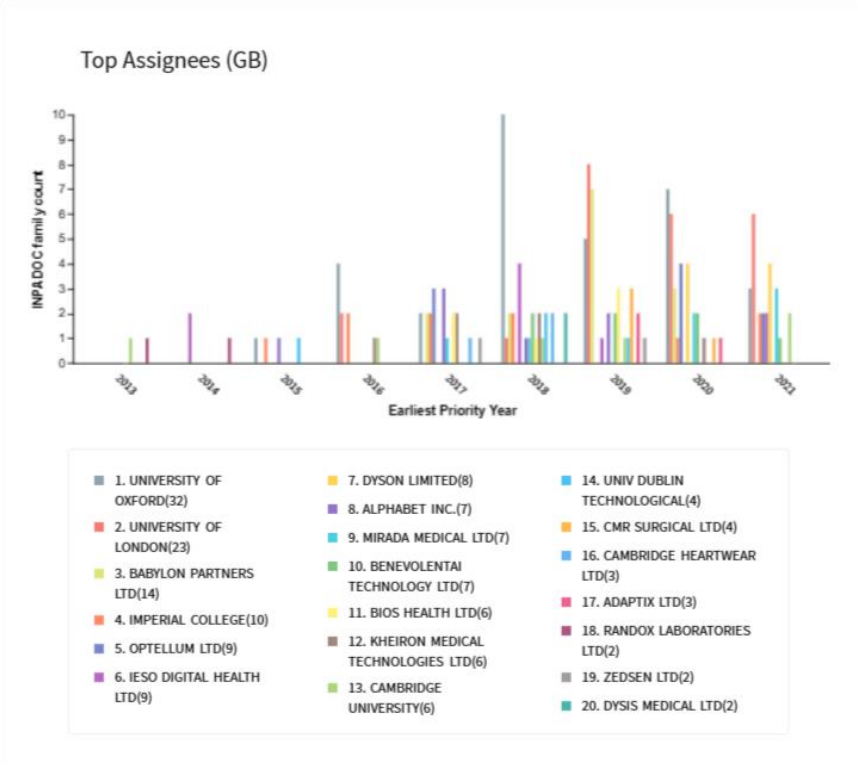


Source: Clarivate via Derwent Innovation

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
1	KONINKLIJKE PHILIPS N.V.	892	Commercial	Netherlands
2	SIEMENS AKTIENGESELLSCHAFT	851	Commercial	Germany
3	INTERNATIONAL BUSINESS MACHINES CORP	550	Commercial	US
4	GENERAL ELECTRIC COMPANY	377	Commercial	US
5	CANON INC	340	Commercial	Japan
6	FUJIFILM BUSINESS INNOVATION CO	327	Commercial	Japan
7	PING AN INSURANCE	285	Commercial	China
8	SAMSUNG ELECTRONICS CO LTD	262	Commercial	Korea
9	UNIV CHANDIGARH	231	Academic	India
10	ALPHABET INC.	224	Commercial	US
11	YONSEI UNIVERSITY	204	Academic	Korea
12	MEDTRONIC INC	202	Commercial	US
13	KOREA UNIVERSITY	177	Academic	Korea
14	JOHNSON & JOHNSON	174	Commercial	US
15	TENCENT HOLDING LTD	173	Commercial	China
16	TATA SONS LTD	163	Commercial	India
17	UNIVERSITY OF CALIFORNIA	158	Academic	US
18	UNIV JAIN	154	Academic	India
19	SEOUL NATIONAL UNIVERSITY	149	Academic	Korea
20	MERATIVE US LP	137	Commercial	US

GREAT BRITAIN

The top patent filing UK organisations include:

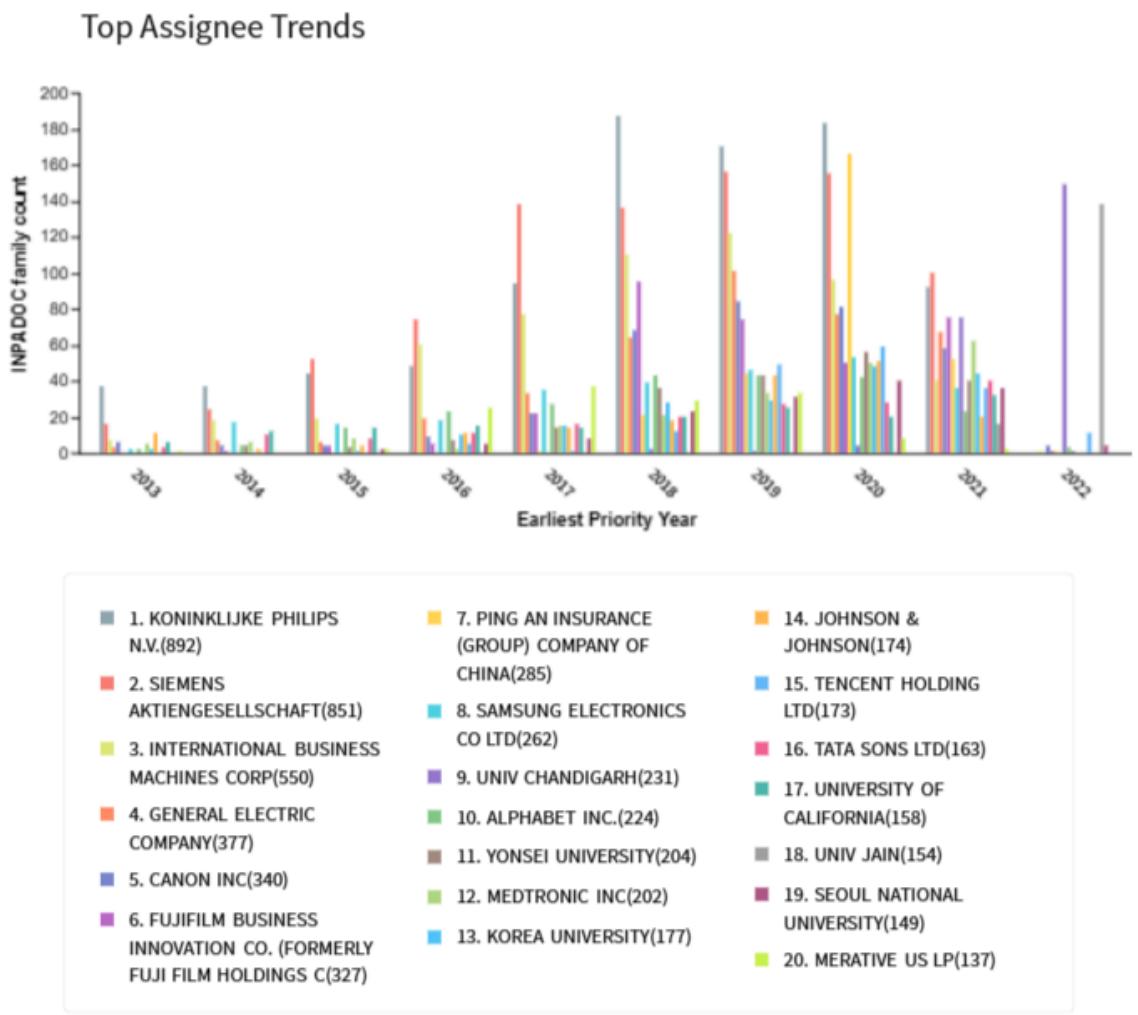


Source: Clarivate via Derwent Innovation

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
1	UNIVERSITY OF OXFORD	32	Academic	GB
2	UNIVERSITY OF LONDON	23	Academic	GB
3	BABYLON PARTNERS LTD	14	Commercial	GB
4	IMPERIAL COLLEGE	10	Academic	GB
5	OPTELLUM LTD	9	Commercial	GB
6	IESO DIGITAL HEALTH LTD	9	Commercial	GB
7	DYSON LIMITED	8	Commercial	GB
8	ALPHABET INC. (DEEPMIND TECH LTD)	7	Commercial	GB
9	MIRADA MEDICAL LTD	7	Commercial	GB
10	BENEVOLENTAI TECHNOLOGY LTD	7	Academic	GB
11	BIOS HEALTH LTD	6	Commercial	GB
12	KHEIRON MEDICAL TECHNOLOGIES LTD	6	Commercial	GB
13	CAMBRIDGE UNIVERSITY	6	Academic	GB
14	UNIV DUBLIN TECHNOLOGICAL	4	Academic	GB
15	CMR SURGICAL LTD	4	Commercial	GB
16	CAMBRIDGE HEARTWEAR LTD	3	Commercial	GB
17	ADAPTIX LTD	3	Commercial	GB
18	RANDOX LABORATORIES LTD	2	Commercial	GB
19	ZEDSEN LTD	2	Commercial	GB
20	DYSIS MEDICAL LTD	2	Commercial	GB

5.4.1 FILING TRENDS

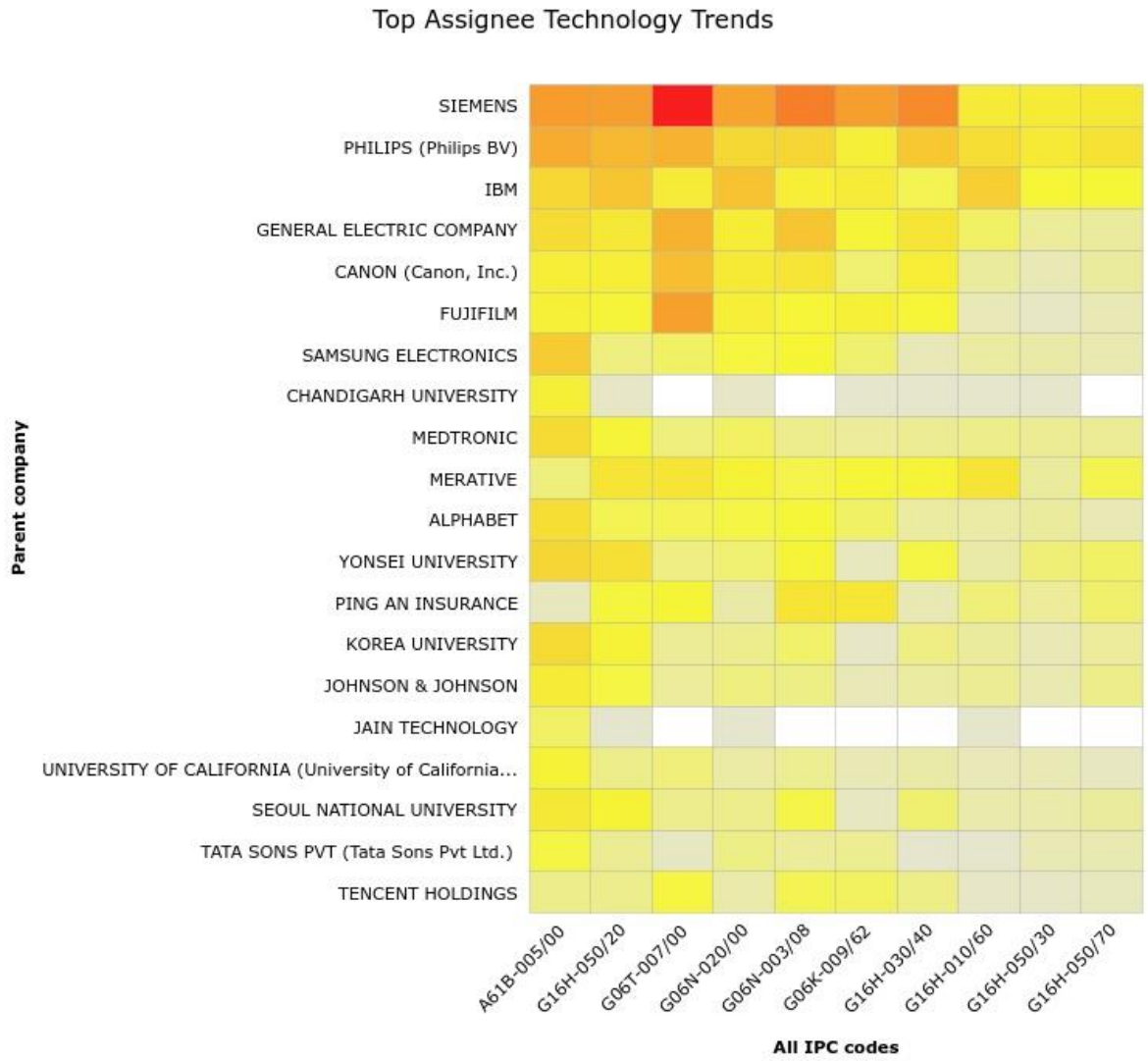
Companies such as Philips and Siemens have increased the number of patents filed in this field significantly. Siemens led the field between 2015 and 2017 before Philips emerged as the leading assignee in 2018. In 2018, the number of patents held by Fujifilm that year overtook its competitors, such as Canon, but has since been followed by a period of slower growth. Again, 2021-2023 data will not be complete, due to the 18-month delay between priority application and publication.



Source: Clarivate via Derwent Innovation

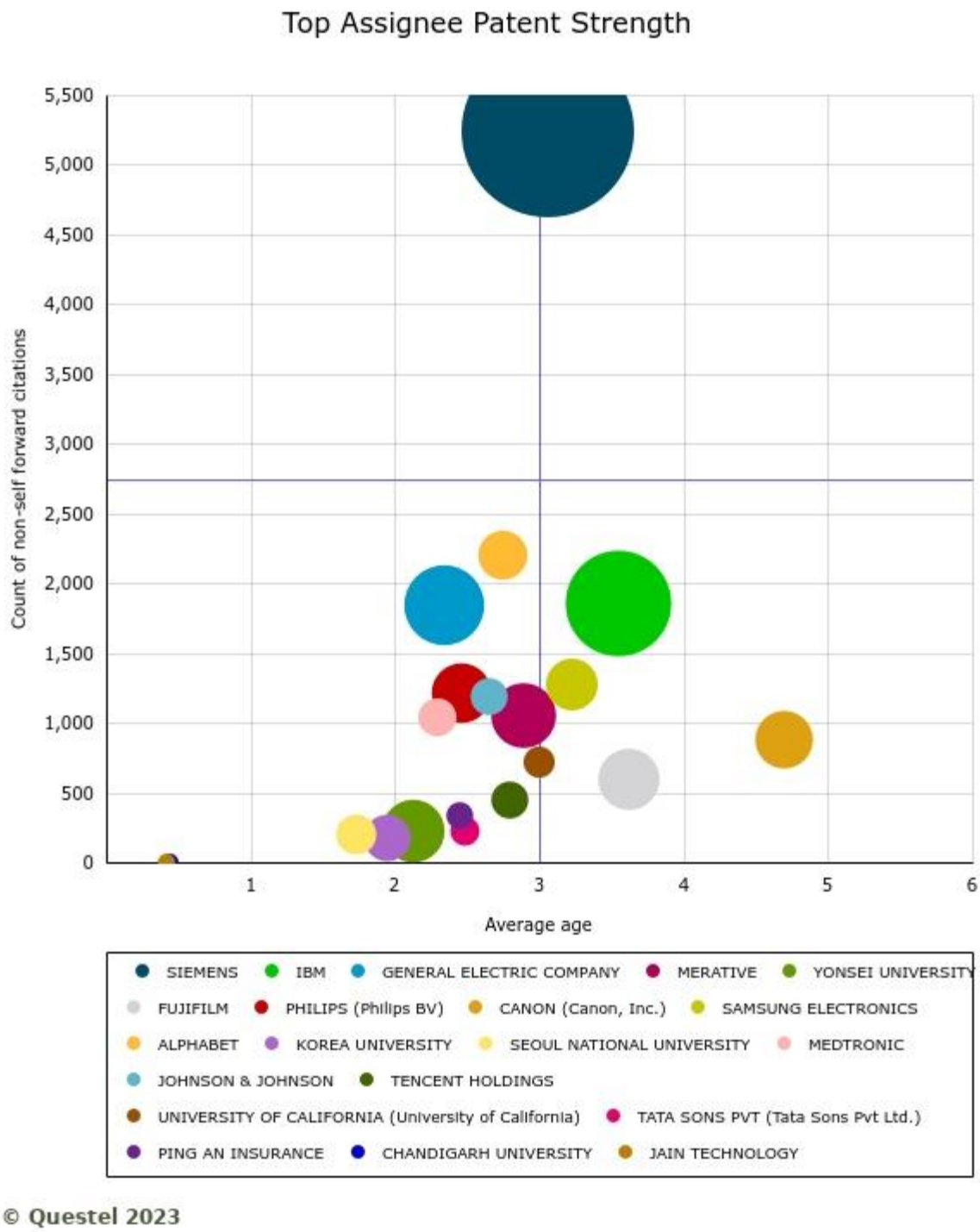
5.4.2 TECHNOLOGY FOCUS

The patents filed by the top assignees across the top IPC classifications can provide further insights into key areas of development. Siemens dominates most key areas, and has a greater focus on the image analysis sector (G06T7/00), but has significant competition in this technology area from Philips, Fujifilm and Canon. While most healthcare technology companies are heavily invested in image analysis and machine learning, Samsung is more focused on measuring systems for diagnostic processes (A61B5/00), which also appears to be the focus of the University of Chandigarh. In contrast IBM dominates the area of the patent landscape focusing on using patient-specific data (G16H10/60).



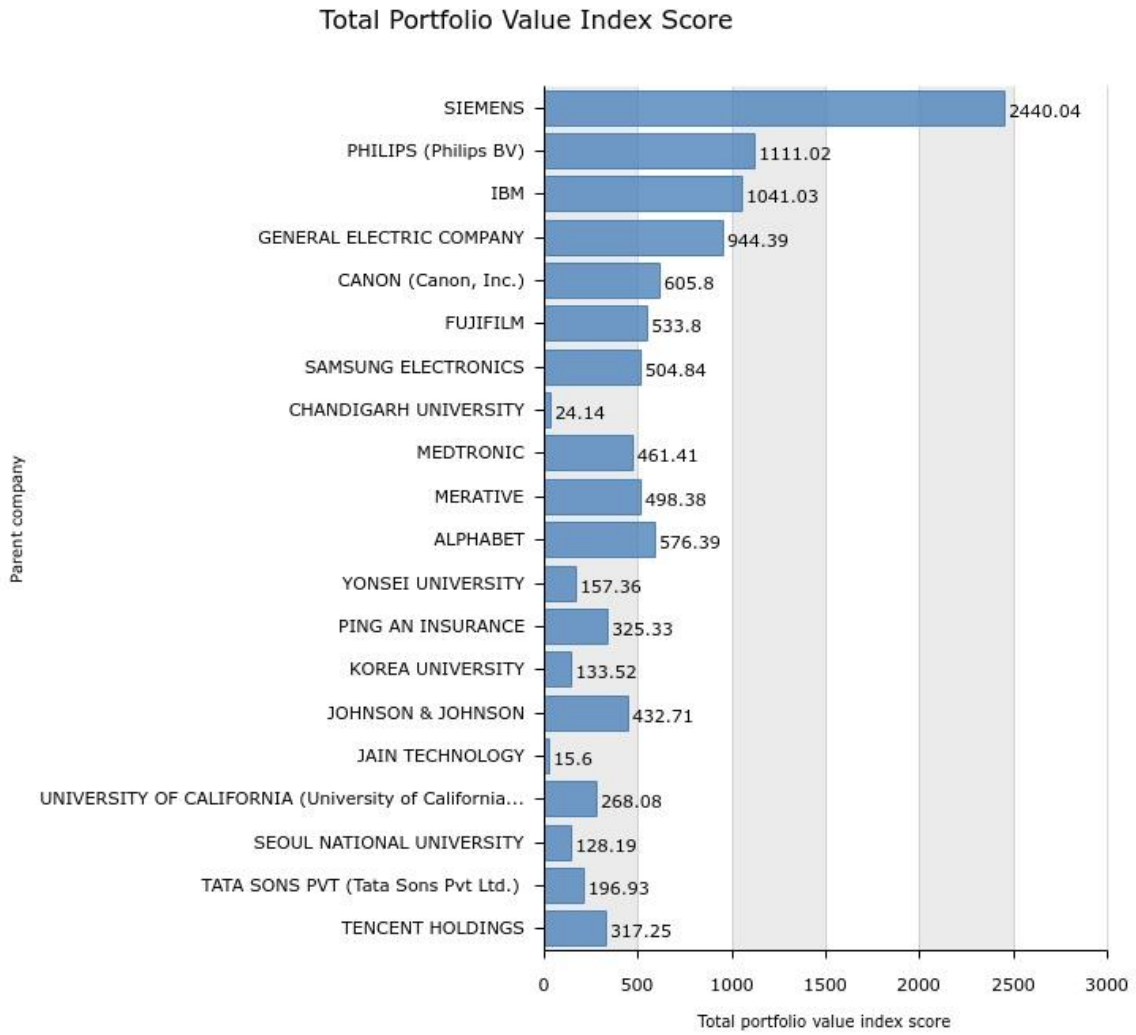
5.4.3 PATENT PORTFOLIO STRENGTH

Canon established an early footing in the field of patenting AI related medical technology, with IBM, Fujifilm, Samsung, and University of Chandigarh also being well established in the area. Siemens is the most influential player, while Alphabet is quickly becoming an important player.



5.4.4 PATENT PORTFOLIO VALUE

The AI patent portfolios held by Siemens, Philips, and IBM are considered to be most valuable within the field of medical technology.



5.5 LANDSCAPE MAP

We applied Derwent Innovation's proprietary ThemeScape™ mapping tool to generate a landscape map visualise areas of high patent coverage and areas of low patent coverage, as well as gain an insight into the position of the patent portfolios of the top 10 assignees identified. **More concentrated areas of patenting were observed in relation to medical imaging, surgery, with significant activity also in using AI to understand hard to treat cancers and health monitoring.**

Figure 2 legend:

Company	Colour
Koninklijke Philips N.V.	
Siemens Aktiengesellschaft	
International Business Machines Corp	
General Electric Company	
Canon Inc	
Fujifilm Business Innovation Co	
Ping An Insurance	
Samsung Electronics Co Ltd	
Univ Chandigarh	
Alphabet Inc.	

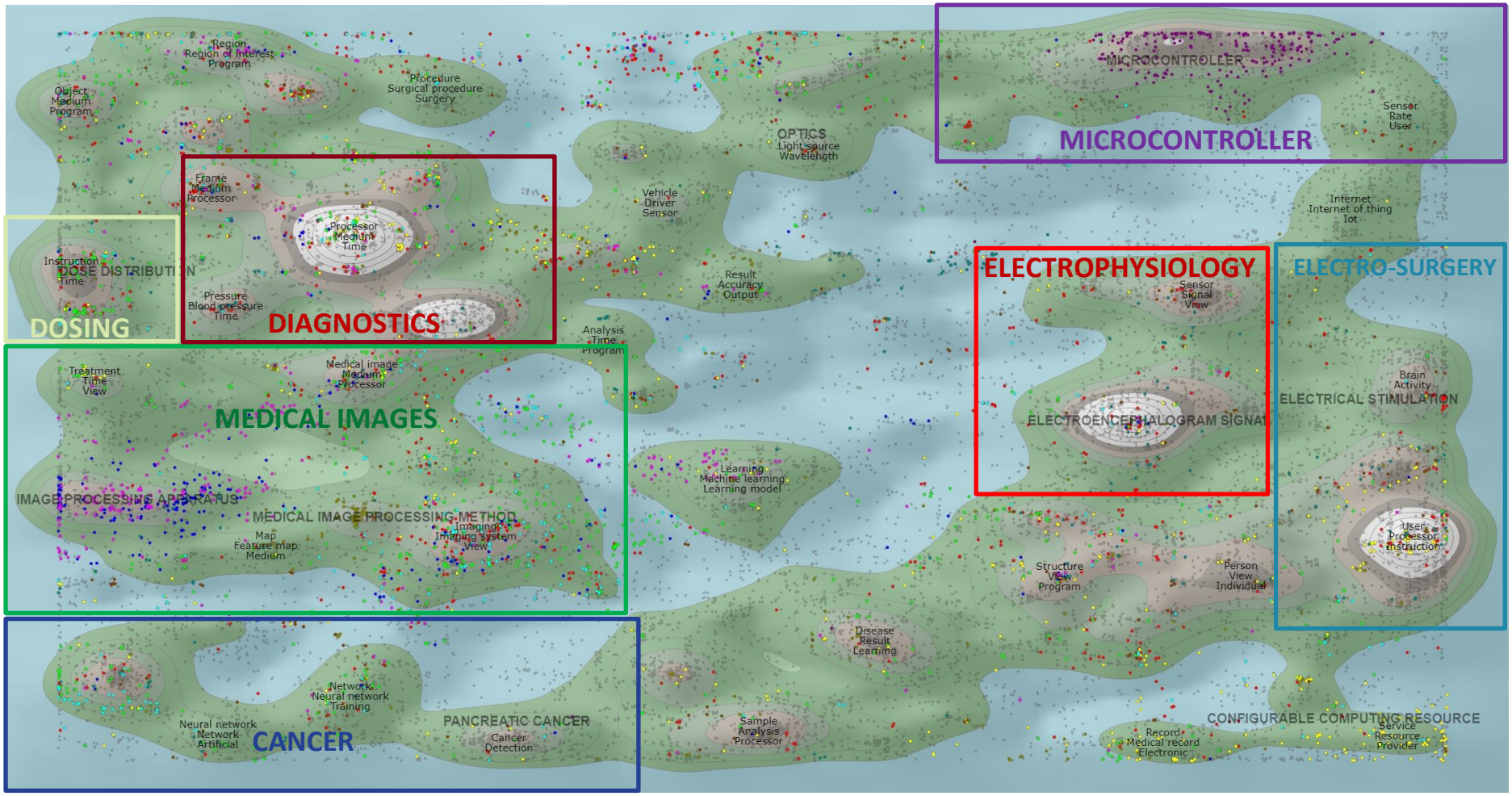


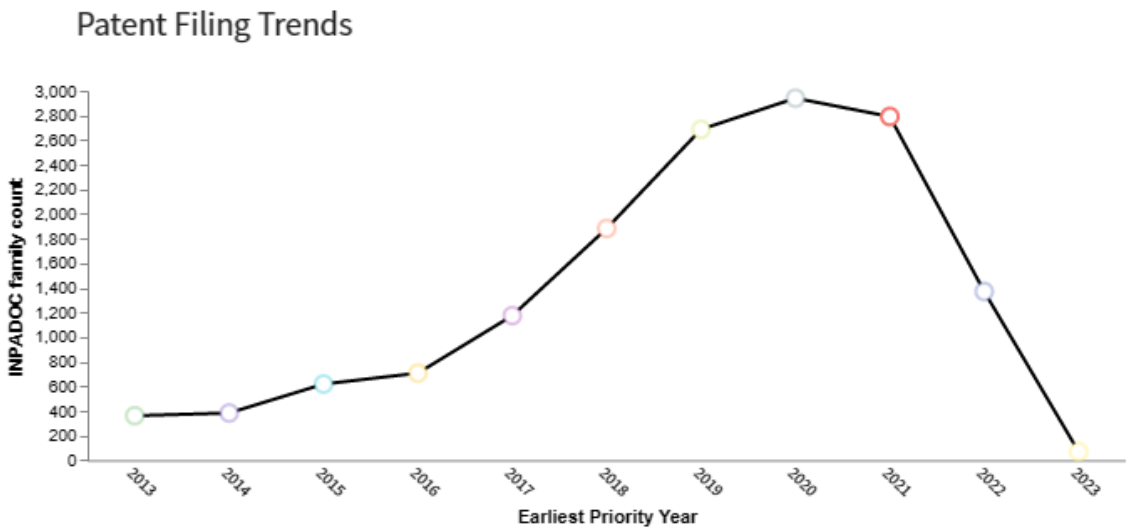
Figure 2. AI medical technology (Source: Clarivate via Derwent Innovation). Each dot indicates the location of an INPADOC patent family on the map. The map has been overlaid with the key areas in which the patents fall on the map.

6 BIOTECHNOLOGY & CHEMICAL AI PATENT LANDSCAPE

The key search terms and classification codes outlined in Section 1.1 were used to understand how AI is facilitating research in biotechnology and chemical sectors.

6.1 FILING RATE

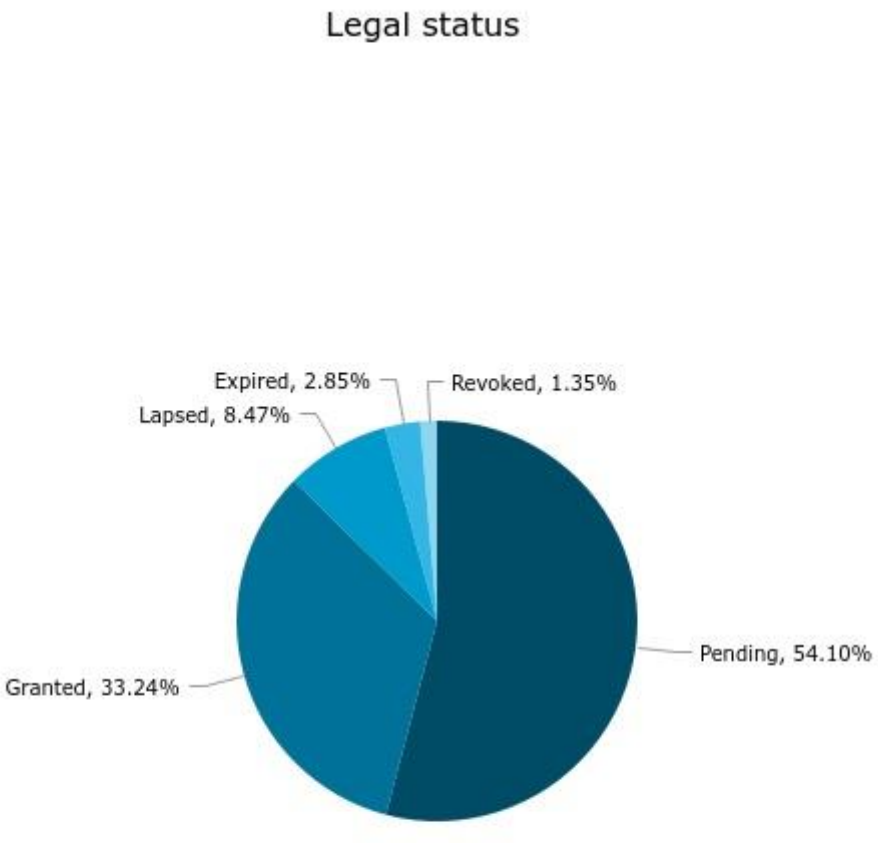
The last five years account for approximately 66% of the total patent landscape, which illustrates the significant growth in AI related technologies within biotechnology and chemical research and industries. Please note, 2021-2023 data given in the graph will not be complete, due to the 18-month delay between priority application and publication.



Source: Clarivate via Derwent Innovation

6.1.1 GLOBAL GRANT SUCCESS

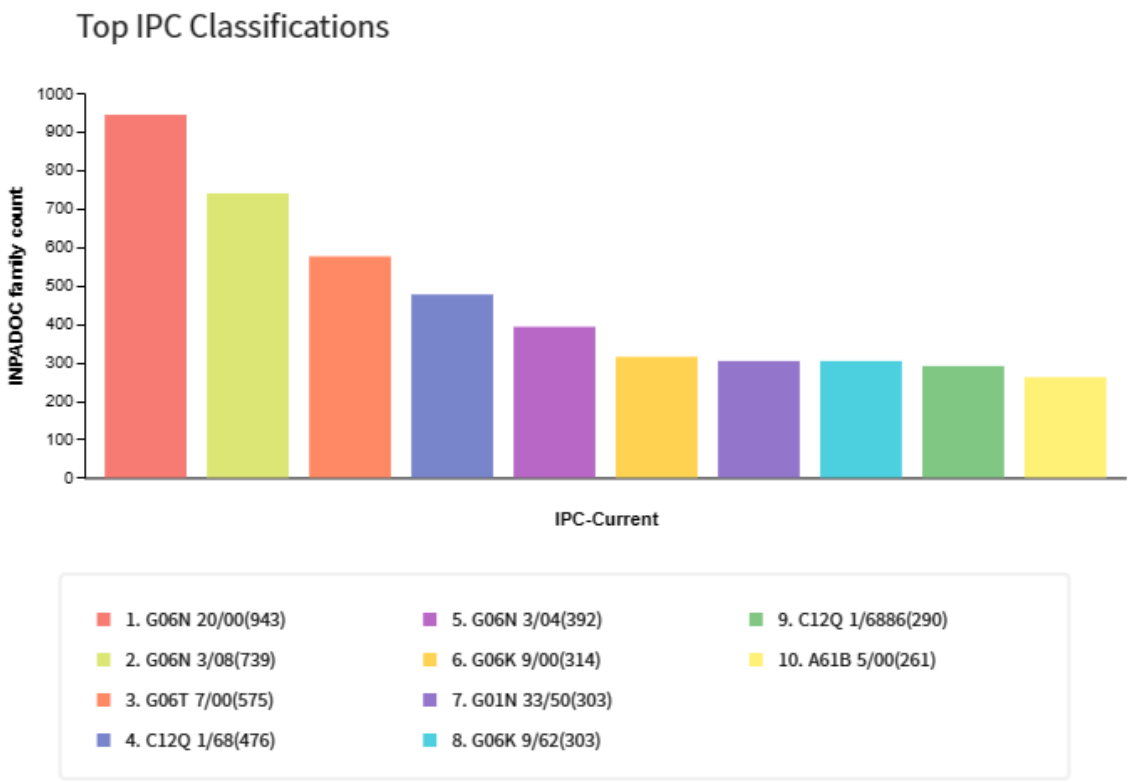
Similarly, as for other scientific fields, the chart shows a low proportion of lapsed patent families indicating that AI for research in biotechnology and chemistry is valuable and industrially important, and that this is a growth area for patents with significant space for innovation given the greater proportion of pending patent applications.



6.2 CLASSIFICATIONS

6.2.1 IPC CLASSIFICATIONS

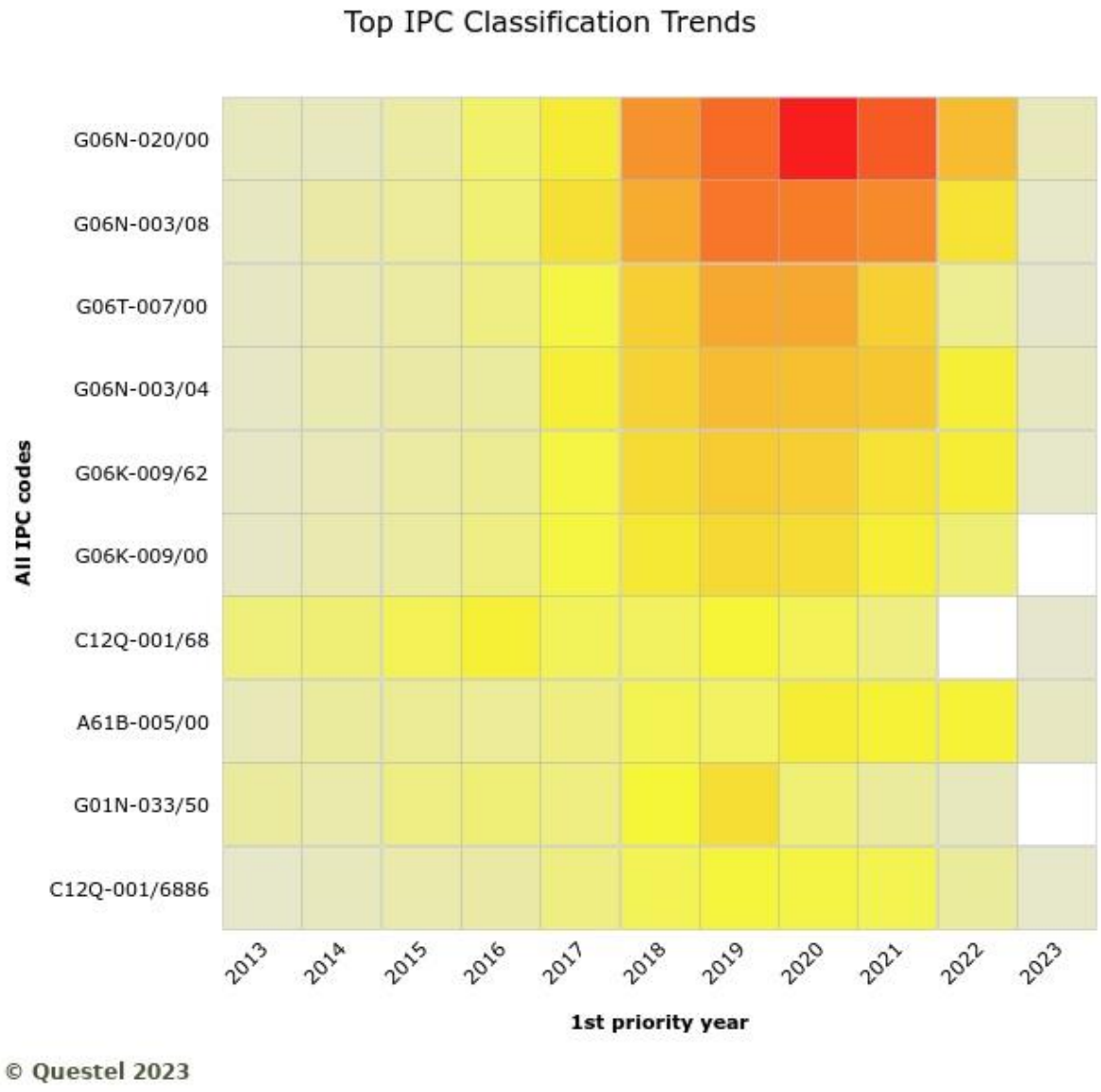
The top AI IPCs relate to machine learning (G06N20/00), neural network learning methods (G06N3/08) and image analysis (G06T7/00). Measuring processes involving nucleic acids (C12Q1/68 and C12Q1/6886) also captures many of the patents in biotechnology and chemistry, which may help to explain the substantial number of recent patent filings being classified under methods for recognising patterns (G06K9/00), as new systems are being developed to process the increasing amount of data being developed from improvements in sequencing technology.



Source: Clarivate via Derwent Innovation

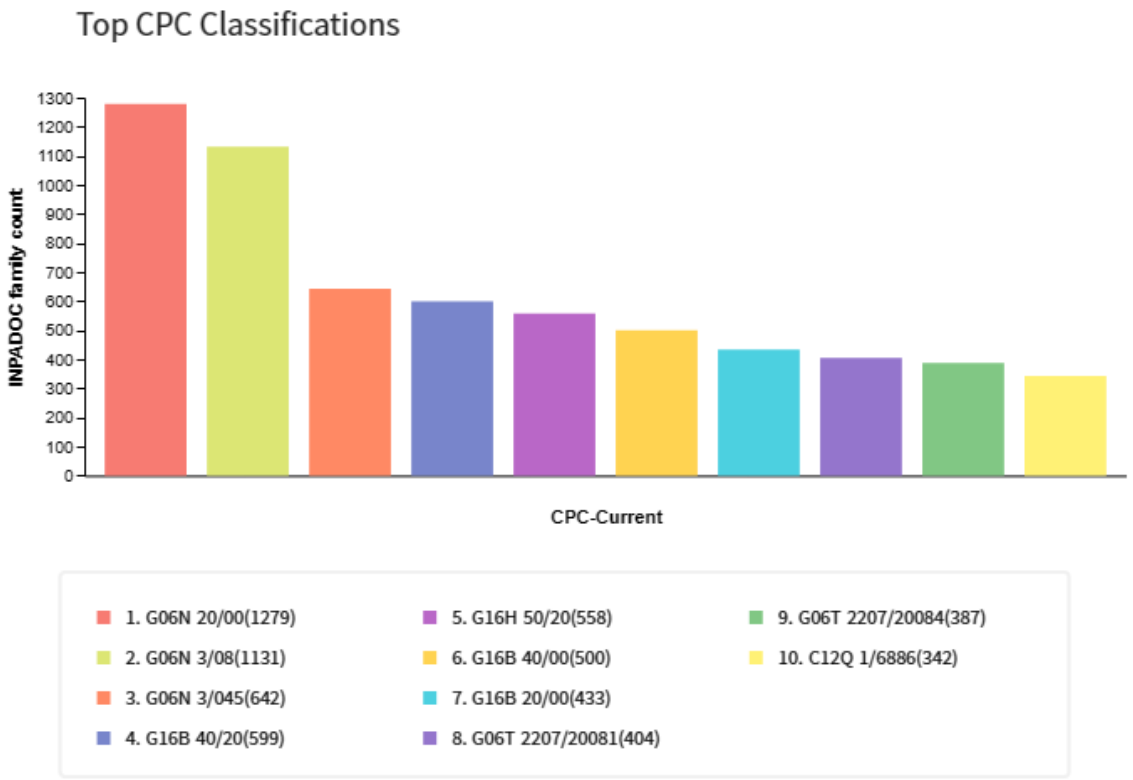
Rank	IPC	Number of Families	Definition	
1	G06N20/00	943	G06N20/00	Machine learning
2	G06N3/08	739	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/08	Learning methods
3	G06T7/00	575	G06T7/00	Image analysis
4	C12Q1/68	476	C12Q1/00	Measuring or testing processes involving enzymes, nucleic acids or microorganisms; Compositions therefor; Processes of preparing such compositions
			C12Q1/68	involving nucleic acids
5	G06N3/04	392	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/04	Architecture, e.g. interconnection topology
6	G06K9/00	314	G06K9/00	Methods or arrangements for recognising patterns
7	G01N33/50	303	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/30	for calculating health indices; for individual health risk assessment
8	G06K9/62	303	G06K9/00	Methods or arrangements for recognising patterns
			G06K9/62	Methods or arrangements for pattern recognition using electronic means
9	C12Q1/6886	290	C12Q1/00	Measuring or testing processes involving enzymes, nucleic acids or microorganisms; Compositions therefor; Processes of preparing such compositions
			C12Q1/68	involving nucleic acids
			C12Q1/6876	Nucleic acid products used in the analysis of nucleic acids, e.g. primers or probes
			C12Q1/6883	for diseases caused by alterations of genetic material
			C12Q1/6886	for cancer
10	A61B5/00	261	A61B5/00	Measuring for diagnostic purposes; Identification of persons

Most of the patents were filed after 2018, with machine learning (G06N20/00) and neural network learning methods (G06N3/08) emerging as the leading AI systems. Most of the top IPC classifications have experienced increases in patent filings.



6.2.2 CPC CLASSIFICATIONS

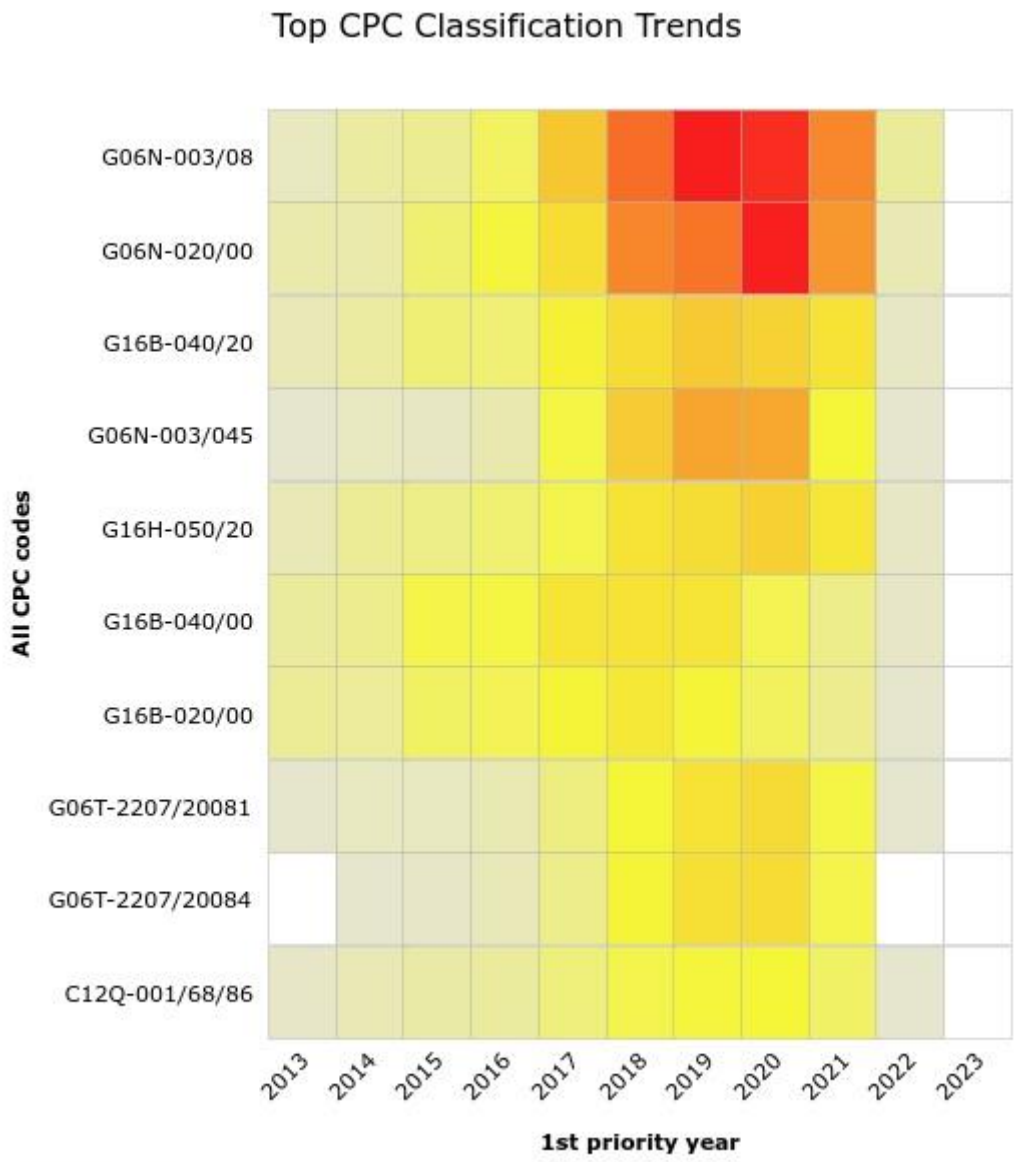
The analysis of top CPC classifications reiterates the dominance of machine learning (G06N20/00) and neural network learning methods (G06N3/08) in biotechnology and chemistry research areas. It also shows a more granular level of detail, as combinations of neural networks (G06N3/045) appear to be the most common type of neural networks utilised. While IPC classification analysis identified significant interest in methods for recognising patterns (G06K9/00), CPC classification analysis shows that this is likely to be bioinformatics-related and involves supervised data analysis (G16B40/20), with interest also in ICT systems specially adapted for functional genomics or proteomics (G16B20/00). In terms of the previously identified interest in image analysis (G06T7/00), CPC classification analysis reveal a substantial number of these patents relate to artificial neural networks for image analysis (G06T2207/20084) and algorithmic training methods for image analysis (G06T2207/20081).



Source: Clarivate via Derwent Innovation

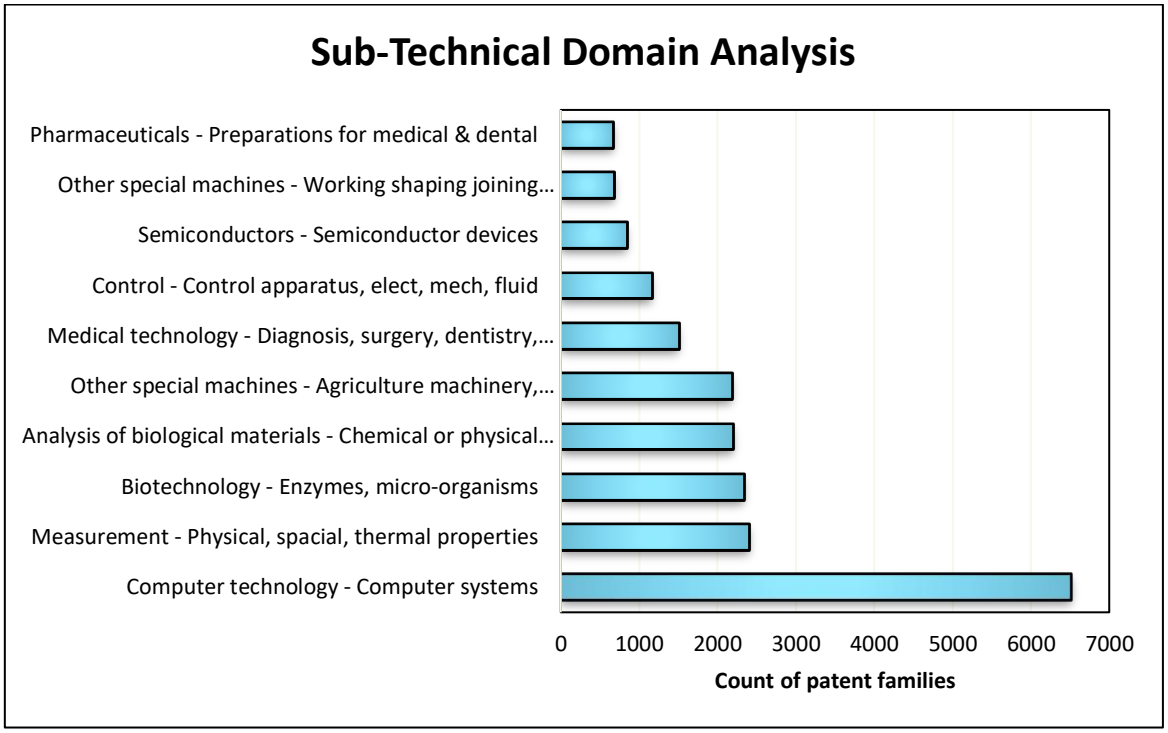
Rank	CPC	Number of Families	Definition	
1	G06N20/00	1279	G06N20/00	Machine learning
2	G06N3/08	1131	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/08	Learning methods
3	G06N3/045	642	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/04	Architecture, e.g. interconnection topology
			G06N3/045	Combinations of networks
4	G16B40/20	599	G16B40/00	ICT specially adapted for biostatistics; ICT specially adapted for bioinformatics-related machine learning or data mining, e.g. knowledge discovery or pattern finding
			G16B40/20	Supervised data analysis
5	G16H50/20	558	G16H50/00	ICT specially adapted for medical diagnosis, medical simulation or medical data mining; ICT specially adapted for detecting, monitoring or modelling epidemics or pandemics
			G16H50/20	for computer-aided diagnosis, e.g. based on medical expert systems
6	G16B40/00	500	G16B40/00	ICT specially adapted for biostatistics; ICT specially adapted for bioinformatics-related machine learning or data mining, e.g. knowledge discovery or pattern finding
7	G16B20/00	433	G16B20/00	ICT specially adapted for functional genomics or proteomics, e.g. genotype-phenotype associations
8	G06T2207/20081	404	G06T2207/00	Indexing scheme for image analysis or image enhancement
			G06T2207/20	Special algorithmic details
			G06T2207/20081	Training; Learning
9	G06T2207/20084	387	G06T2207/00	Indexing scheme for image analysis or image enhancement
			G06T2207/20	Special algorithmic details
			G06T2207/20084	Artificial neural networks [ANN]
10	C12Q1/6886	342	C12Q1/00	Measuring or testing processes involving enzymes, nucleic acids or microorganisms; Compositions therefor; Processes of preparing such compositions
			C12Q1/68	involving nucleic acids
			C12Q1/6876	Nucleic acid products used in the analysis of nucleic acids, e.g. primers or probes
			C12Q1/6883	for diseases caused by alterations of genetic material
			C12Q1/6886	for cancer

Over the period, the CPC classification trends show a similar patent filing profile to the IPC classification trends. Patents classed as having combinations of neural networks (G06N3/045) have also experienced a significant growth in the number of patent filings since 2018.



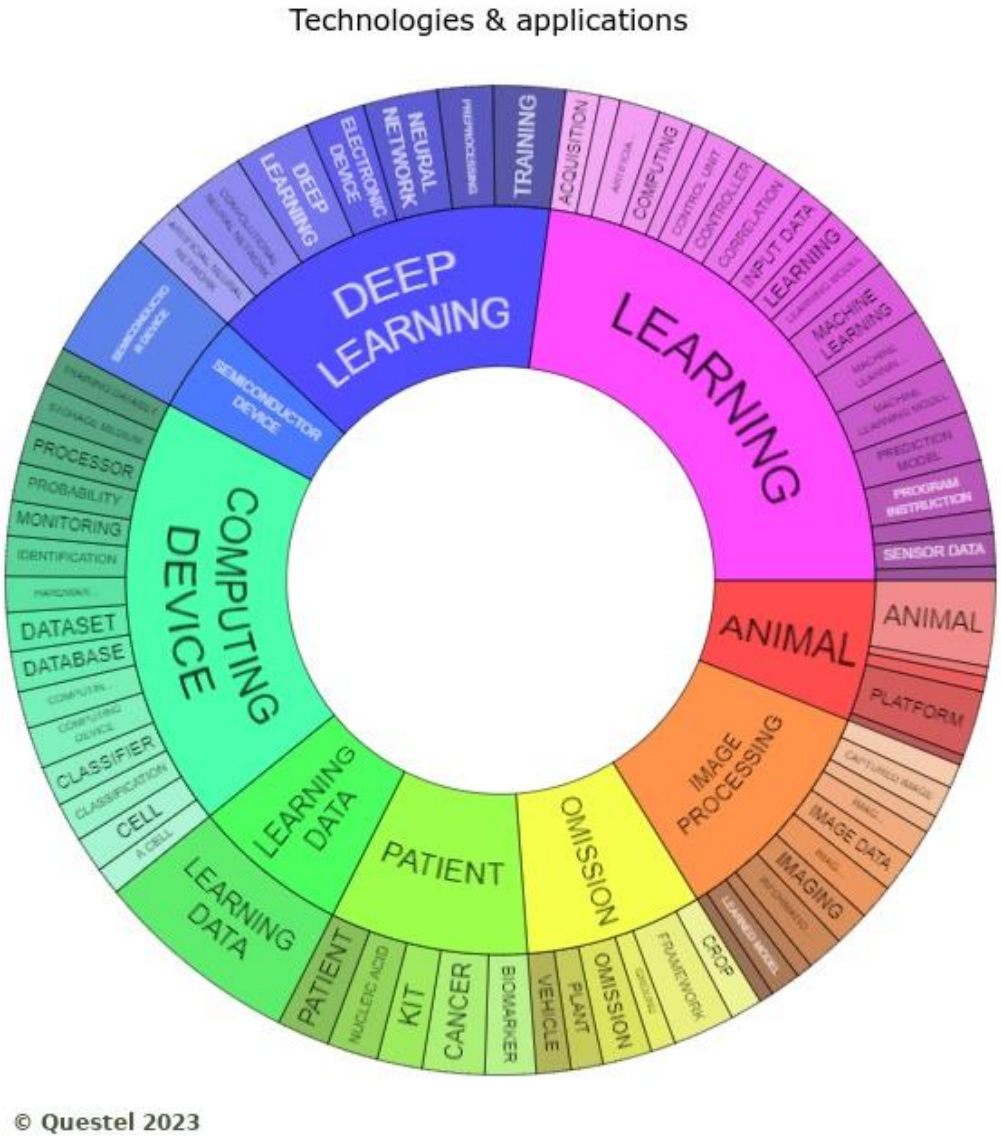
6.2.3 SUB-TECHNICAL DOMAINS

Most of the innovation appears to relate to domains relating to measurement apparatus, as well as enzyme and micro-organism biotechnology. AI-enabled agriculture machinery, medical technology and pharmaceuticals also feature.



6.3 LANDSCAPE CONCEPTS

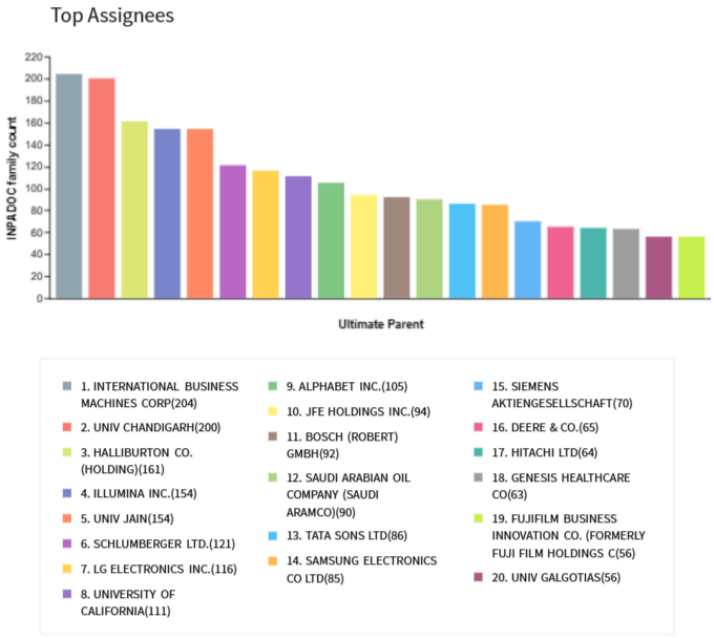
The following figure illustrates the distribution of the main concepts across the AI patent landscape in R&D in the biotechnology and chemistry industries; the main innovation concepts feature machine learning and deep learning systems, as well as databases and learning data. The patent landscape also includes significant patent activity in image processing, which also appears to be driving the design of new proteins and drugs [12].



[12] https://www.technologyreview.com/2022/12/01/1064023/biotech-labs-are-using-ai-inspired-by-dall-e-to-invent-new-drugs/

6.4 TOP ASSIGNEES

The top 20 assignees in terms of number of patents filed to AI inventions within biotechnology and chemistry R&D are mostly by commercial organisations.

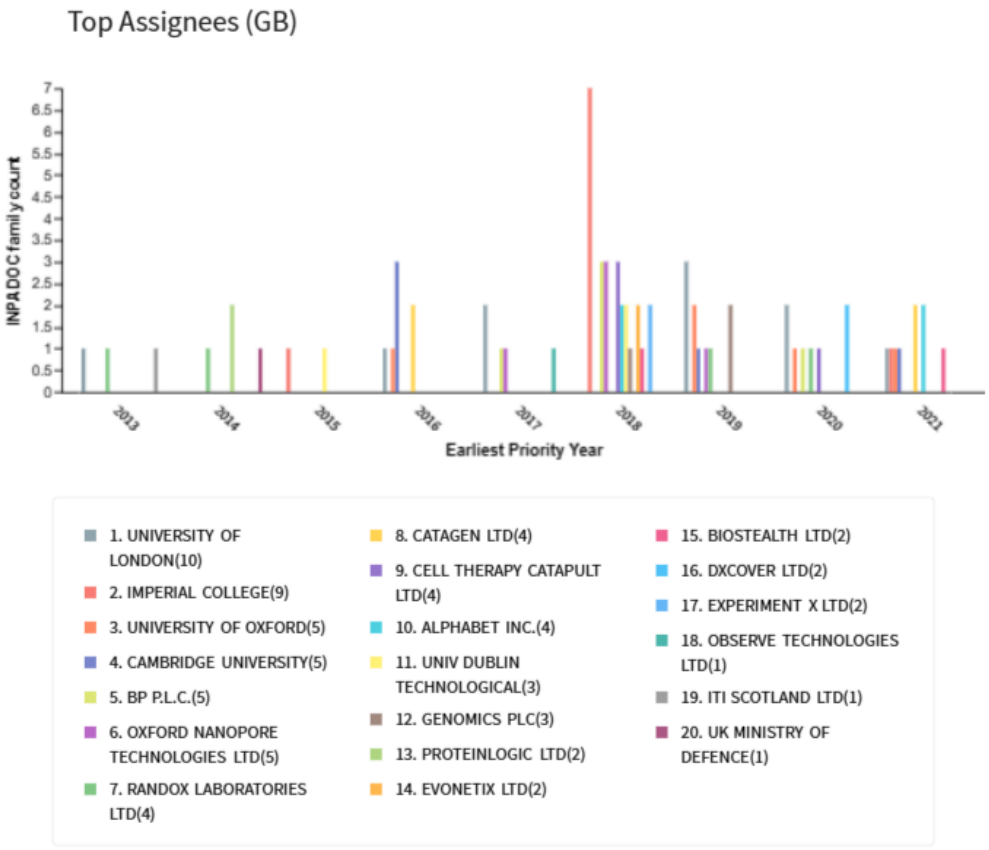


Source: Clarivate via Derwent Innovation

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
1	INTERNATIONAL BUSINESS MACHINES CORP	204	Commercial	US
2	UNIV CHANDIGARH	200	Academic	India
3	HALLIBURTON CO HOLDING	161	Commercial	US
4	ILLUMINA INC.	154	Commercial	US
5	UNIV JAIN	154	Academic	India
6	SCHLUMBERGER LTD.	121	Commercial	US
7	LG ELECTRONICS INC.	116	Commercial	Korea
8	UNIVERSITY OF CALIFORNIA	111	Academic	US
9	ALPHABET INC.	105	Commercial	US
10	JFE HOLDINGS INC.	94	Commercial	Japan
11	BOSCH ROBERT GMBH	92	Commercial	Germany
12	SAUDI ARABIAN OIL COMPANY	90	Commercial	Saudi Arabia
13	TATA SONS LTD	86	Commercial	India
14	SAMSUNG ELECTRONICS CO LTD	85	Commercial	Korea
15	SIEMENS AKTIENGESELLSCHAFT	70	Commercial	Germany
16	DEERE & CO.	65	Commercial	US
17	HITACHI LTD	64	Commercial	Japan
18	GENESIS HEALTHCARE CO	63	Commercial	US
19	FUJIFILM BUSINESS INNOVATION CO	56	Commercial	Japan
20	UNIV GALGOTIAS	56	Academic	India

GREAT BRITAIN

The top patent filing UK organisations include:



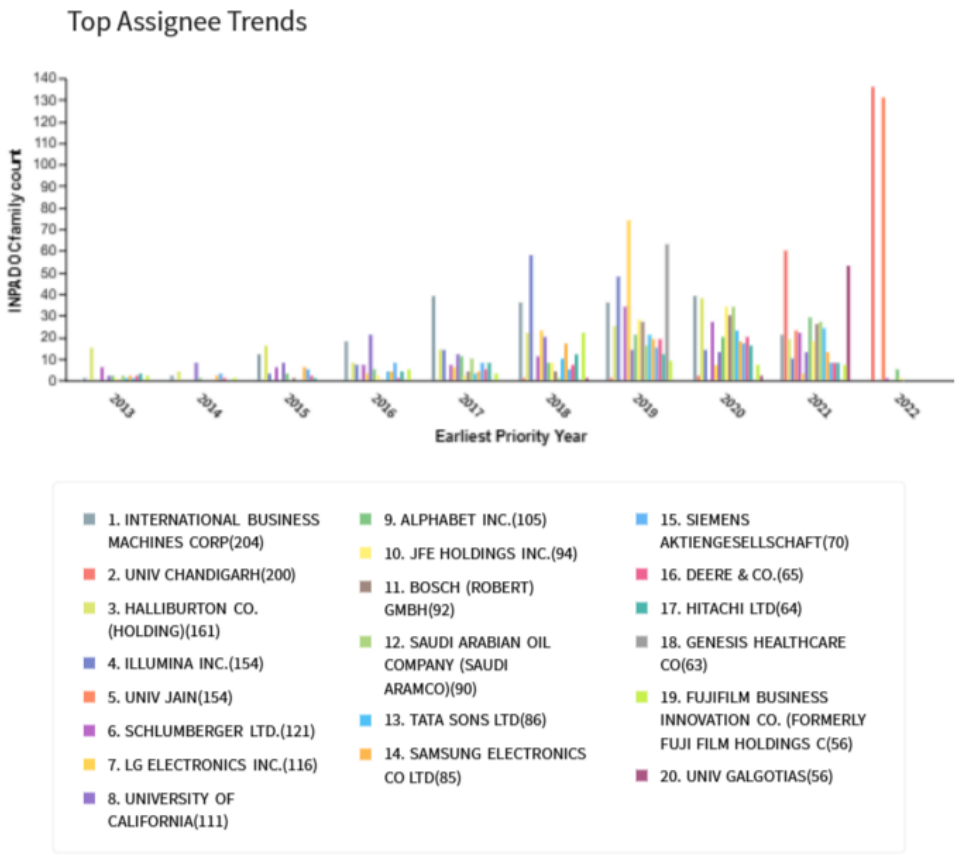
Source: Clarivate via Derwent Innovation

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
1	UNIVERSITY OF LONDON	10	Academic	GB
2	IMPERIAL COLLEGE	9	Academic	GB
3	UNIVERSITY OF OXFORD	5	Academic	GB
4	CAMBRIDGE UNIVERSITY	5	Academic	GB
5	BP P.L.C.	5	Commercial	GB
6	OXFORD NANOPORE TECHNOLOGIES LTD	5	Commercial	GB
7	RANDOX LABORATORIES LTD	4	Commercial	GB
8	CATAGEN LTD	4	Commercial	GB
9	CELL THERAPY CATAPULT LTD	4	Commercial	GB
10	ALPHABET INC. (DEEPMIND TECH LTD)	4	Commercial	GB
11	UNIV DUBLIN TECHNOLOGICAL	3	Academic	GB
12	GENOMICS PLC	3	Commercial	GB
13	PROTEINLOGIC LTD	2	Commercial	GB
14	EVONETIX LTD	2	Commercial	GB
15	BIOSTEALTH LTD	2	Commercial	GB

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
16	DXCOVER LTD	2	Commercial	GB
17	EXPERIMENT X LTD	2	Commercial	GB
18	OBSERVE TECHNOLOGIES LTD	1	Commercial	GB
19	ITI SCOTLAND LTD	1	Commercial	GB
20	UK MINISTRY OF DEFENCE	1	Commercial	GB

6.4.1 FILING TRENDS

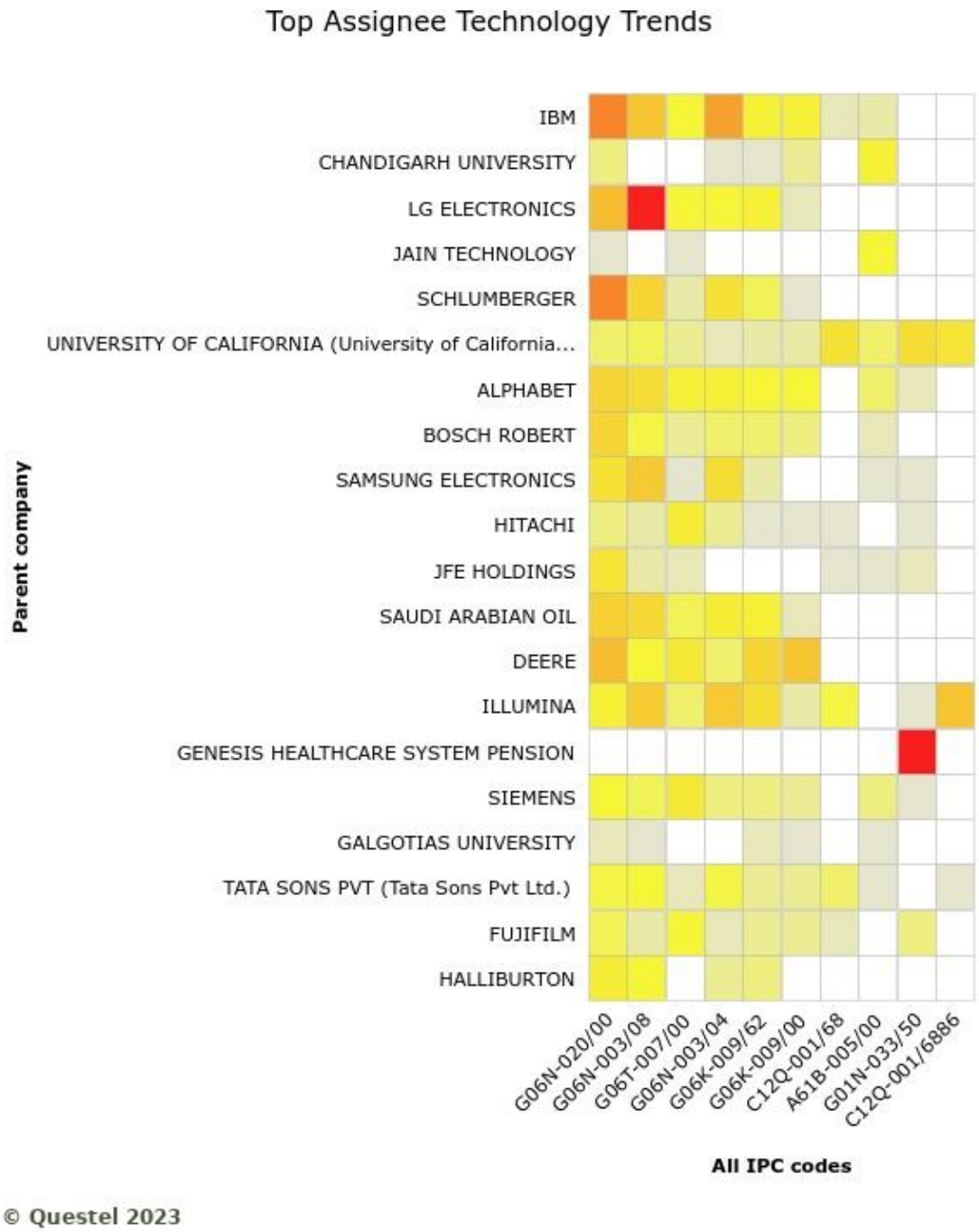
Leading assignees, such as IBM, have filed a significant number of patents over the last 10 years. IBM was the leading assignee within the patent landscape in 2017, before Illumina led the way in 2018, while Genesis Healthcare had the most significant increase in patent filings 2019. The rate of growth slowed down in 2020 with similar levels of patent activity by the top parent organisations. Interestingly, patent families filed (internationally) by Chinese academic organisations grew the most significantly in 2021 and 2022, however 2021-2023 data will not yet be complete, due to the 18-month delay between priority application and publication.



Source: Clarivate via Derwent Innovation

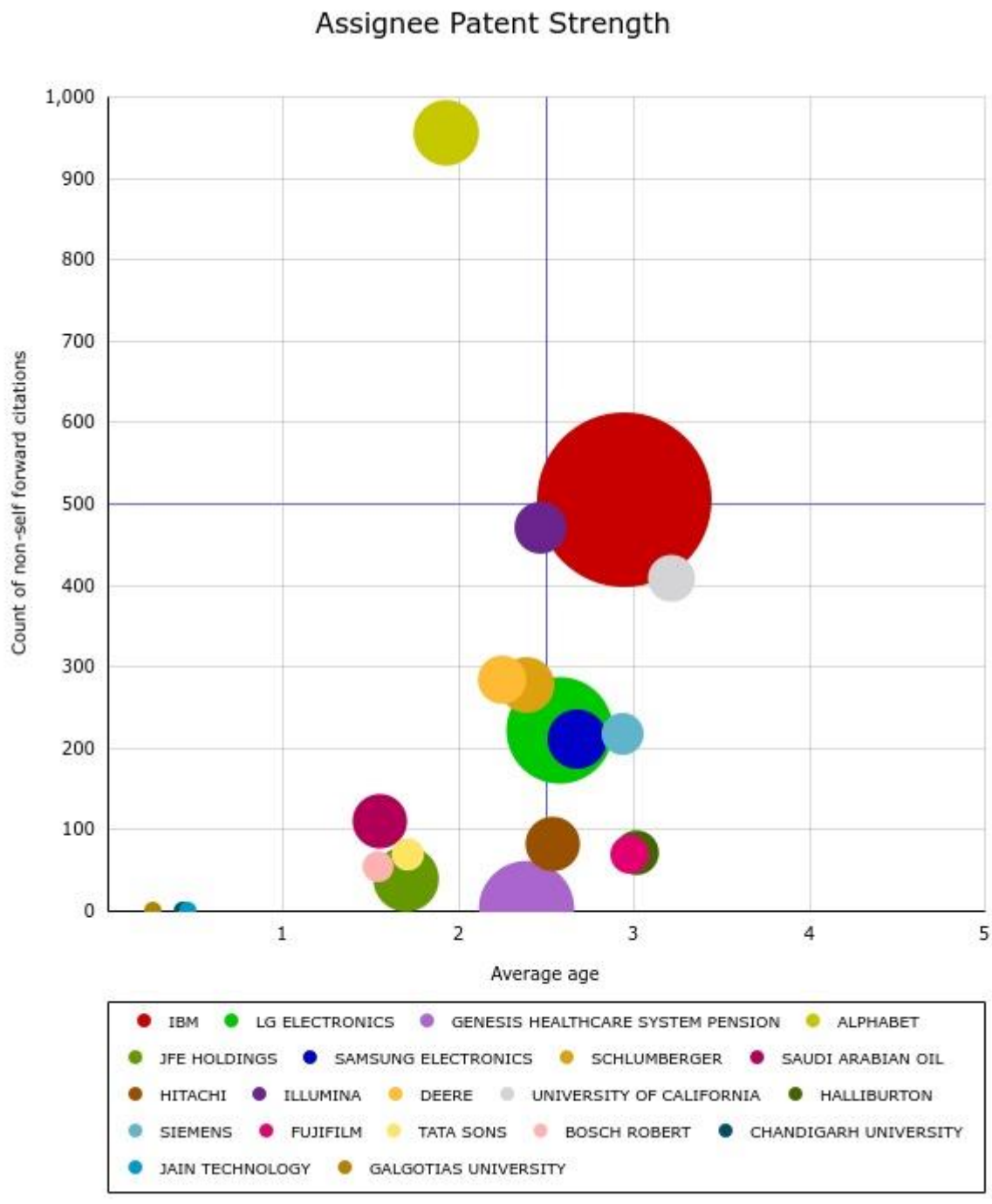
6.4.2 TECHNOLOGY FOCUS

There appears to be most competition in technology areas relating to machine learning (G06N20/00) and neural network learning methods (G06N3/08), with these areas being dominated by LG Electronics, IBM, Schlumberger, Alphabet, Illumina and Deere. Despite the high level of competition and patenting activity, a number of organisations have emerged as leading and dominant players in several key areas. For example, Genesis Healthcare leads AI-related innovation in the analysis of biological and chemical material (G01N33/50), while Illumina appears to be the most significant player in cancer genetic analysis (C12Q1/6886), and Deere is driving innovation in methods for recognising patterns (G06K9/00 and G06K9/62).



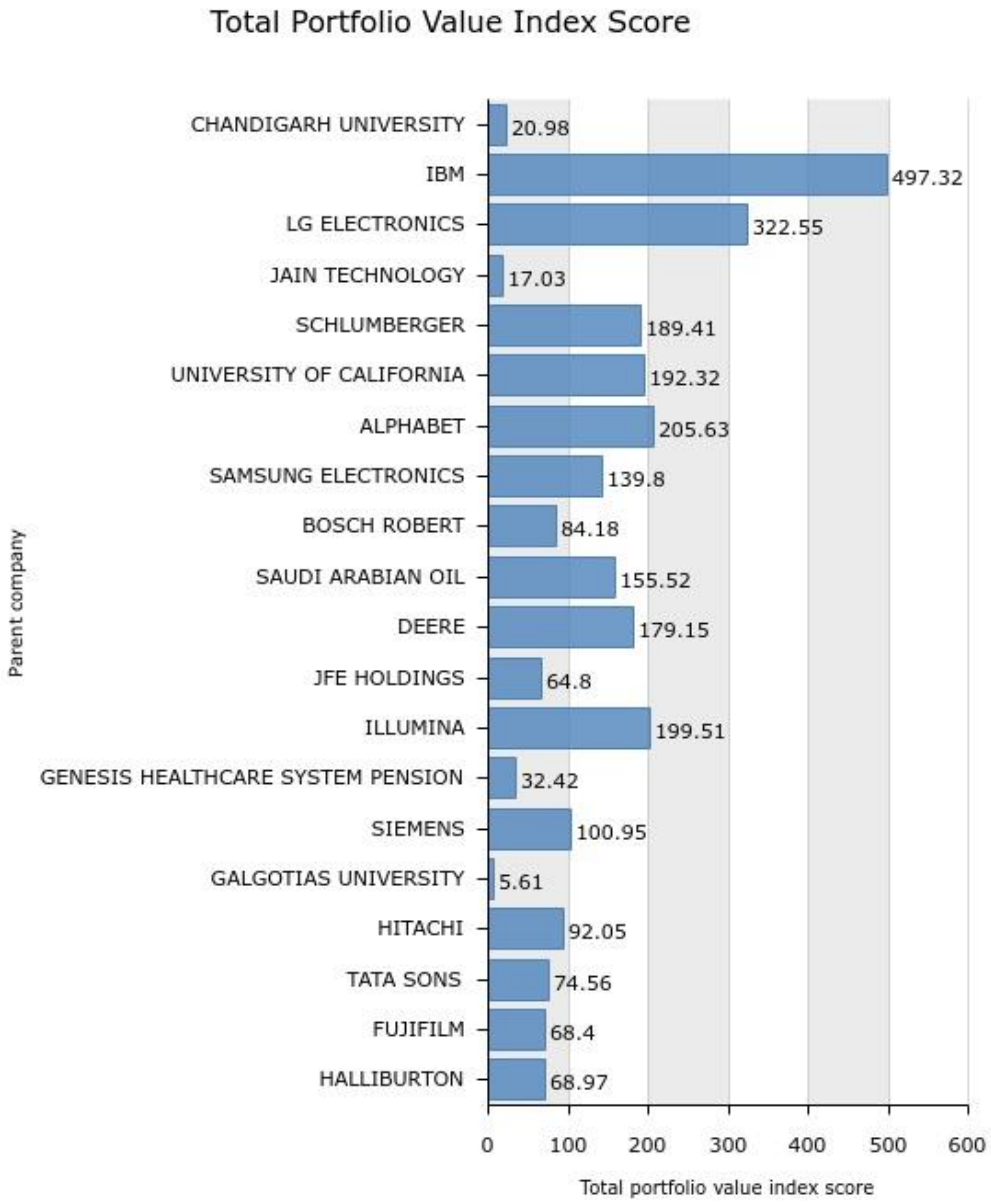
6.4.3 PATENT PORTFOLIO STRENGTH

Several of the top assignees established an early footing in the field of AI for biotechnology and chemistry fields, with IBM considered a pioneer. There are also a significant number of newcomers to the area, and Alphabet and Illumina appear to be having a most significant impact in this domain.



6.4.4 PATENT PORTFOLIO VALUE

The AI patent portfolios held by IBM appear to be the most valuable within the biotechnology and chemistry sectors. The patent portfolios held by LG Electronics, Alphabet and Illumina are also considered valuable for scientific research. As previously mentioned, the perceived value of a patent portfolio can be affected by a range of factors, such as portfolio size and legal status. The age and geographical distribution of patent filings will be similar for the top parent organisations, hence differentiation will be down to higher technological impact and portfolio size and status. For example, despite the patent portfolio held by Illumina having a higher technological impact than LG electronics, the LG electronics portfolio is considered more valuable due to having a much higher number of granted patent families.



6.5 LANDSCAPE MAP

We applied Derwent Innovation's proprietary ThemeScape™ mapping tool to generate a landscape map to visualise areas to identify areas of high patent coverage and areas of low patent coverage, as well as gain insight into the position of the patent portfolios of the top 10 assignees. **Concentrated areas of patent activity relate to cancer, genomic data, gaseous emissions, with significant activity also around microcontrollers.**

Figure 3 legend:

Company	Colour
International Business Machines Corp	
Univ Chandigarh	
Halliburton Co Holding	
Illumina Inc.	
Univ Jain	
Schlumberger Ltd.	
Lg Electronics Inc.	
University Of California	
Alphabet Inc.	
Jfe Holdings Inc.	

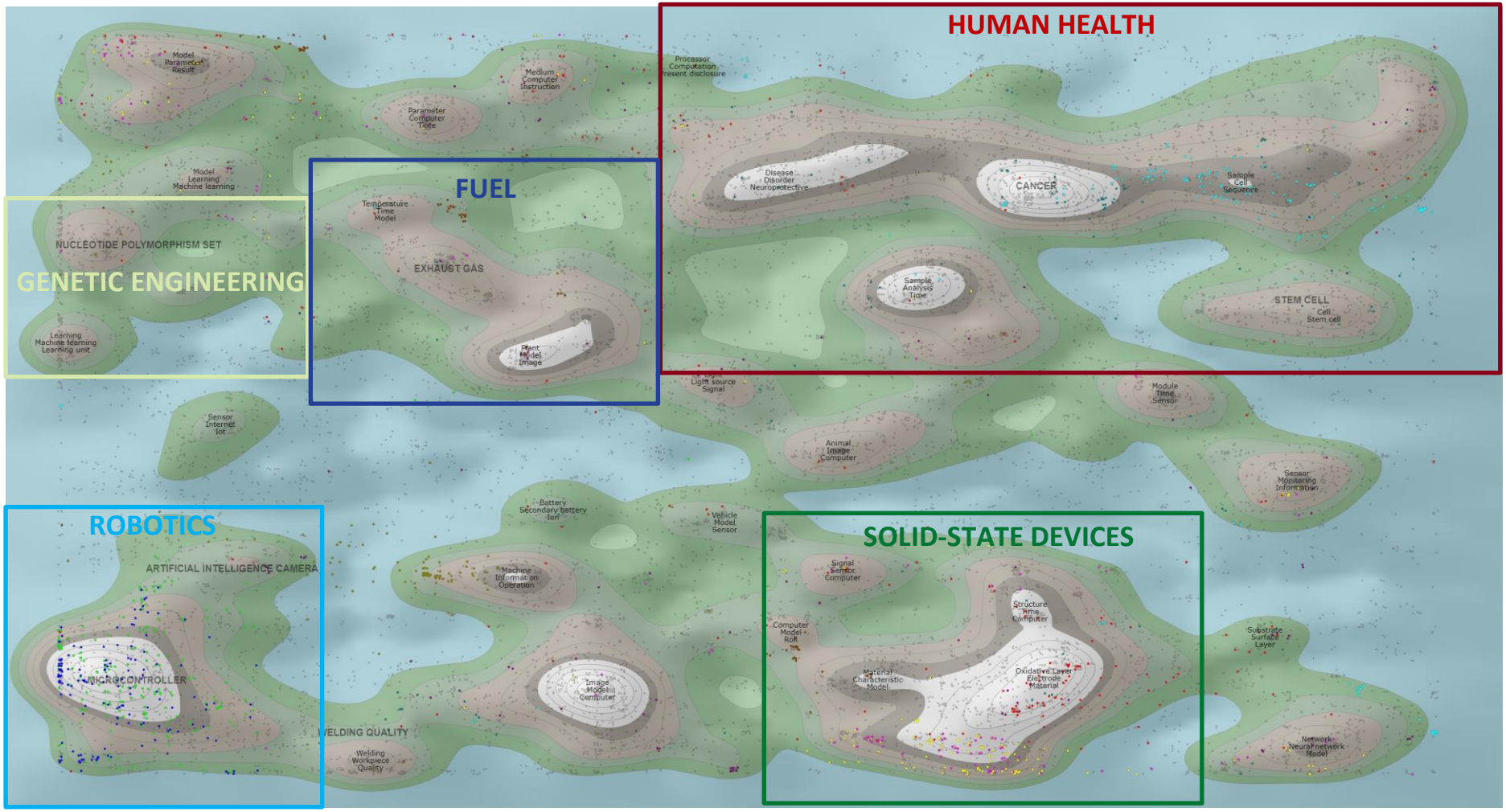


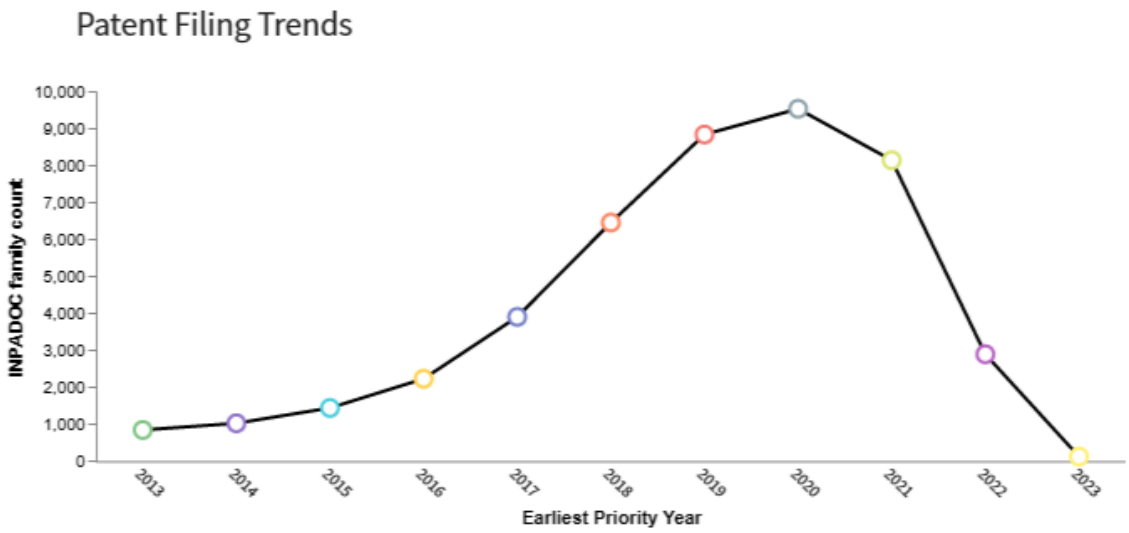
Figure 3. AI in biotechnology and chemistry sectors (Source: Clarivate via Derwent Innovation). Each dot indicates the location of an INPADOC patent family on the map. The map has been overlaid with the key areas in which the patents fall on the map.

7 ENGINEERING & TRANSPORT AI PATENT LANDSCAPE

The key search terms and classification codes outlined in Section 1.1 were used to understand how AI is facilitating research in the engineering sectors.

7.1 FILING RATE

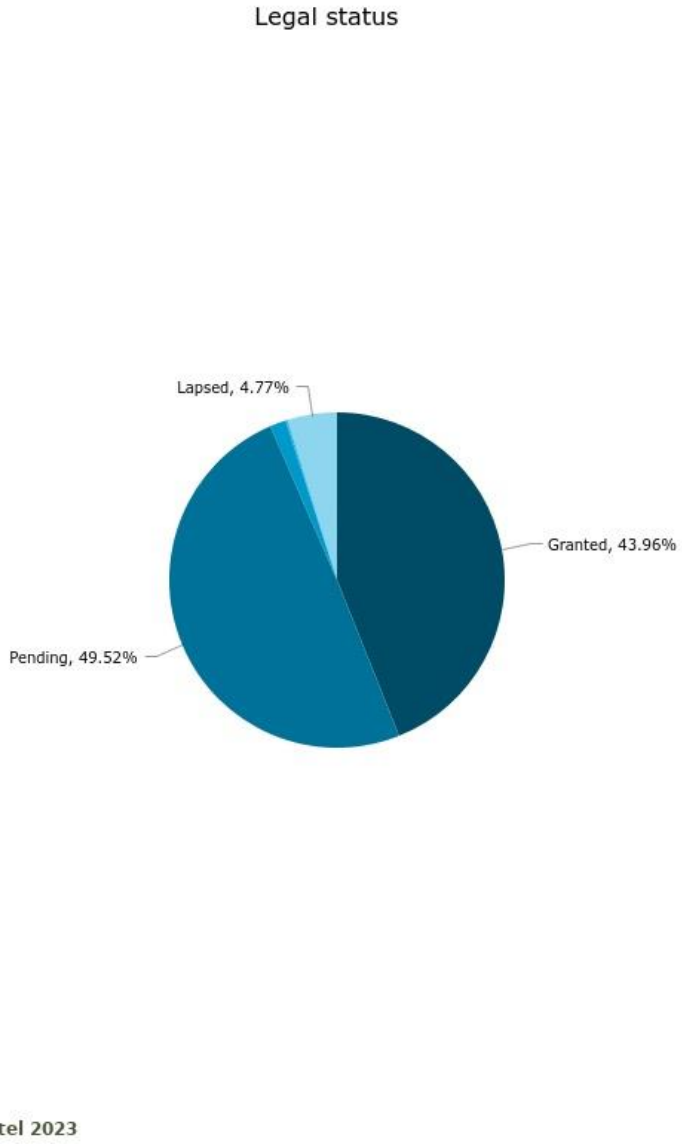
The last five years account for approximately 65% of the total patent landscape, once again highlighting the significant growth of AI patents within the engineering sector. Please note, 2021-2023 data given in the graph will not be complete, due to the 18-month delay between priority application and publication.



Source: Clarivate via Derwent Innovation

7.1.1 GLOBAL GRANT SUCCESS

As with the other scientific fields, the chart shows a low proportion of lapsed patent families and high number of granted patent families indicating that AI in engineering is both valuable and industrially important, and that this is a growth area for patenting with significant space for innovation given the high proportion of pending patent applications. Most notably, there is a much higher proportion of granted patents compared to the overall AI patent landscape, which indicates that this is a particularly important field.

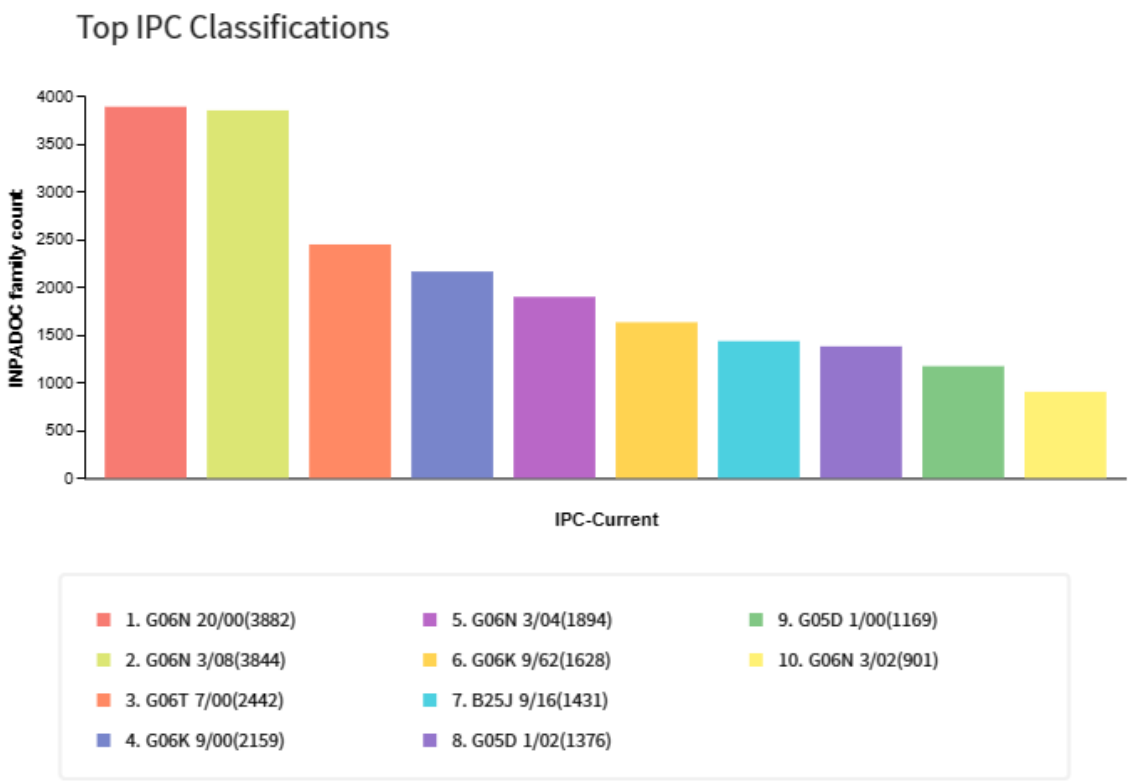


7.2 CLASSIFICATIONS

7.2.1 IPC CLASSIFICATIONS

The top AI IPCs for the engineering sector relate to patents that feature machine learning (G06N20/00), neural network learning methods (G06N3/08), image analysis (G06T7/00), and methods for recognising patterns (G06K9/00). A wide variety of AI technology was picked up by the top IPCs, which is to be expected, due to the range of AI applications and the complex nature of the data in engineering.

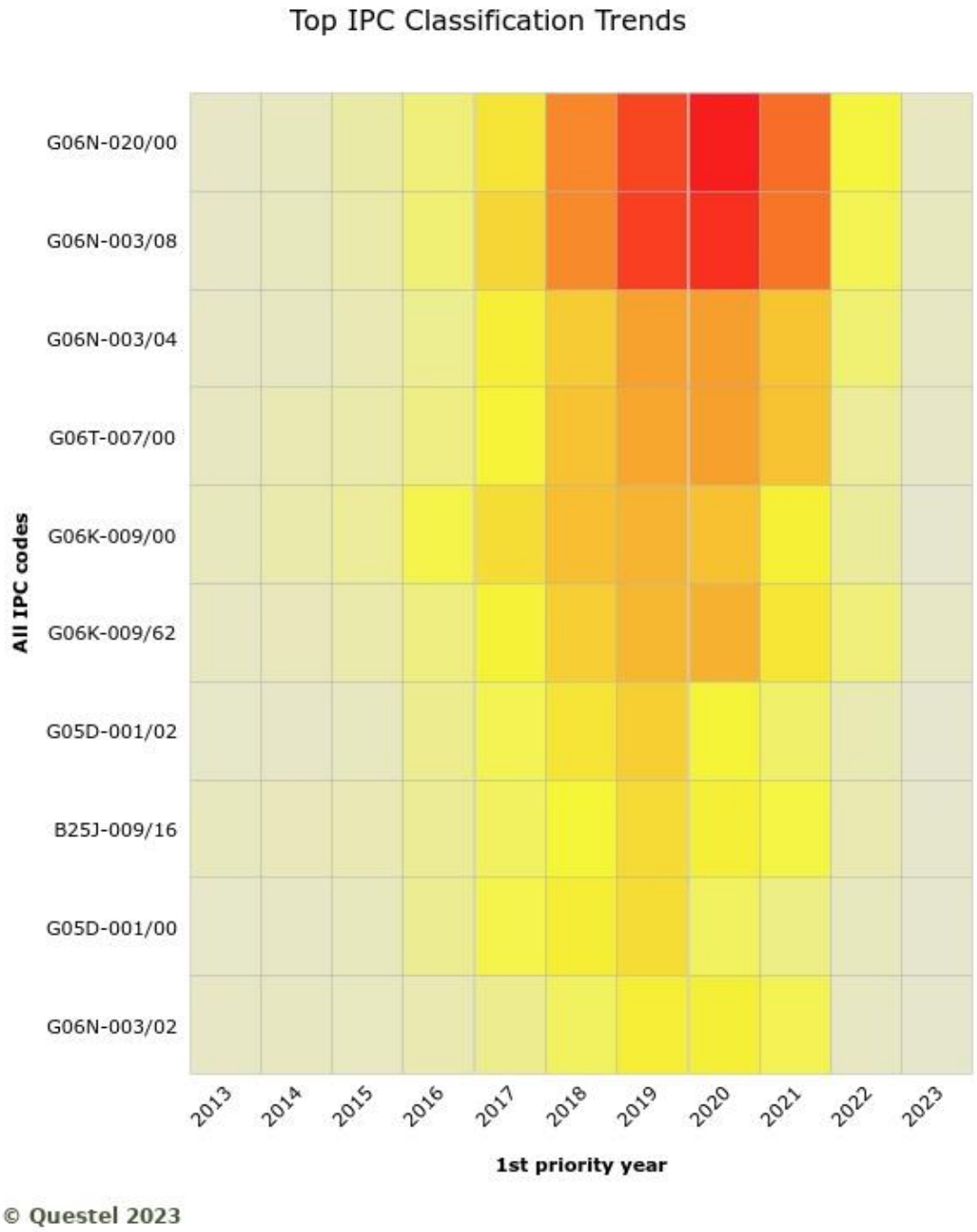
The top IPCs also indicate that AI is primarily used to control vehicles (G05D1/00) and manipulators (B25J9/00).



Source: Clarivate via Derwent Innovation

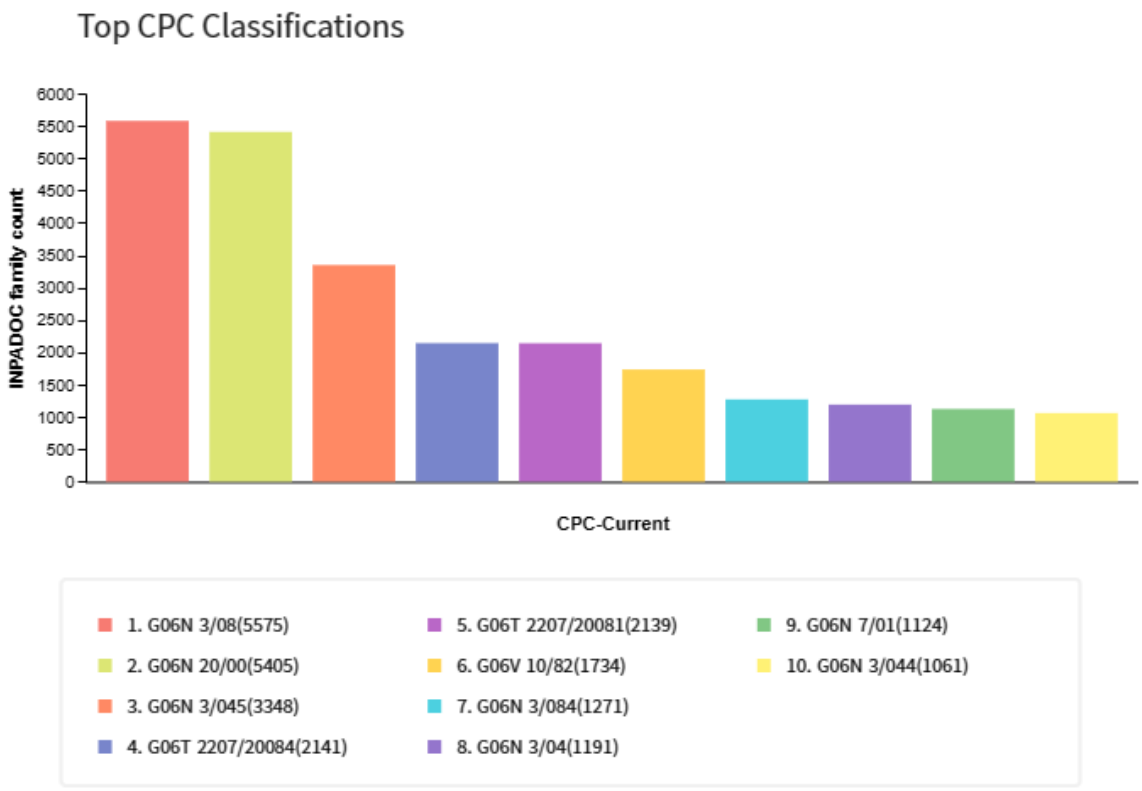
Rank	IPC	Number of Families	Definition	
1	G06N20/00	3882	G06N20/00	Machine learning
2	G06N3/08	3844	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/08	Learning methods
3	G06T7/00	2442	G06T7/00	Image analysis
4	G06K9/00	2159	G06K9/00	Methods or arrangements for recognising patterns
5	G06N3/04	1894	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/04	Architecture, e.g. interconnection topology
6	G06K9/62	1628	G06K9/00	Methods or arrangements for recognising patterns
			G06K9/62	Methods or arrangements for pattern recognition using electronic means
7	B25J9/16	1431	B25J9/00	Programme-controlled manipulators
			B25J9/16	Programme controls
8	G05D1/02	1376	G05D1/00	Control of position, course or altitude of land, water, air, or space vehicles, e.g. automatic pilot
			G05D1/02	Control of position or course in two dimensions
9	G05D1/00	1169	G05D1/00	Control of position, course or altitude of land, water, air, or space vehicles, e.g. automatic pilot
10	G06N3/02	901	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks

Again most patents were filed after 2018, with machine learning (G06N20/00) and neural network learning methods (G06N3/08) significant areas of patenting activity.



7.2.2 CPC CLASSIFICATIONS

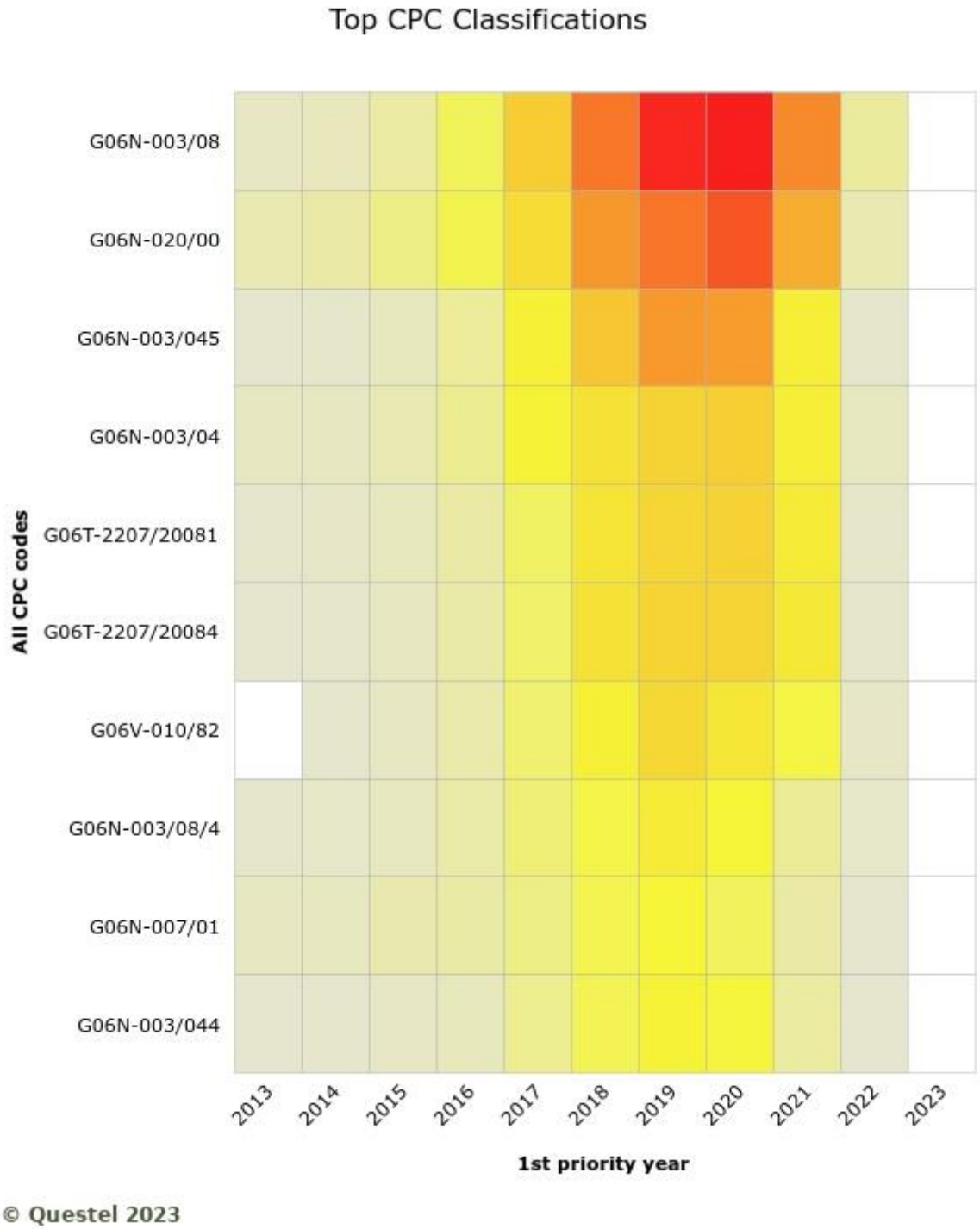
As with IPCs, the top CPC classifications also show patents to be mostly grouped around machine learning (G06N20/00) and neural network learning methods (G06N3/08). Combination of neural networks (G06N3/045) and recurrent networks (G06N3/044) are the most frequently applied types of neural network in engineering, with backpropagation being the leading neural network learning method (G06N3/084). There also appears to significant patent activity relating to probabilistic graphical models (G06N7/01) within the engineering industry. With respect to image analysis (IPC code G06T7/00), the top CPCs further indicate artificial neural networks (G06T2207/20084) and algorithmic training methods (G06T2207/20081) as the most common AI systems under development for image analysis within the engineering industry.



Source: Clarivate via Derwent Innovation

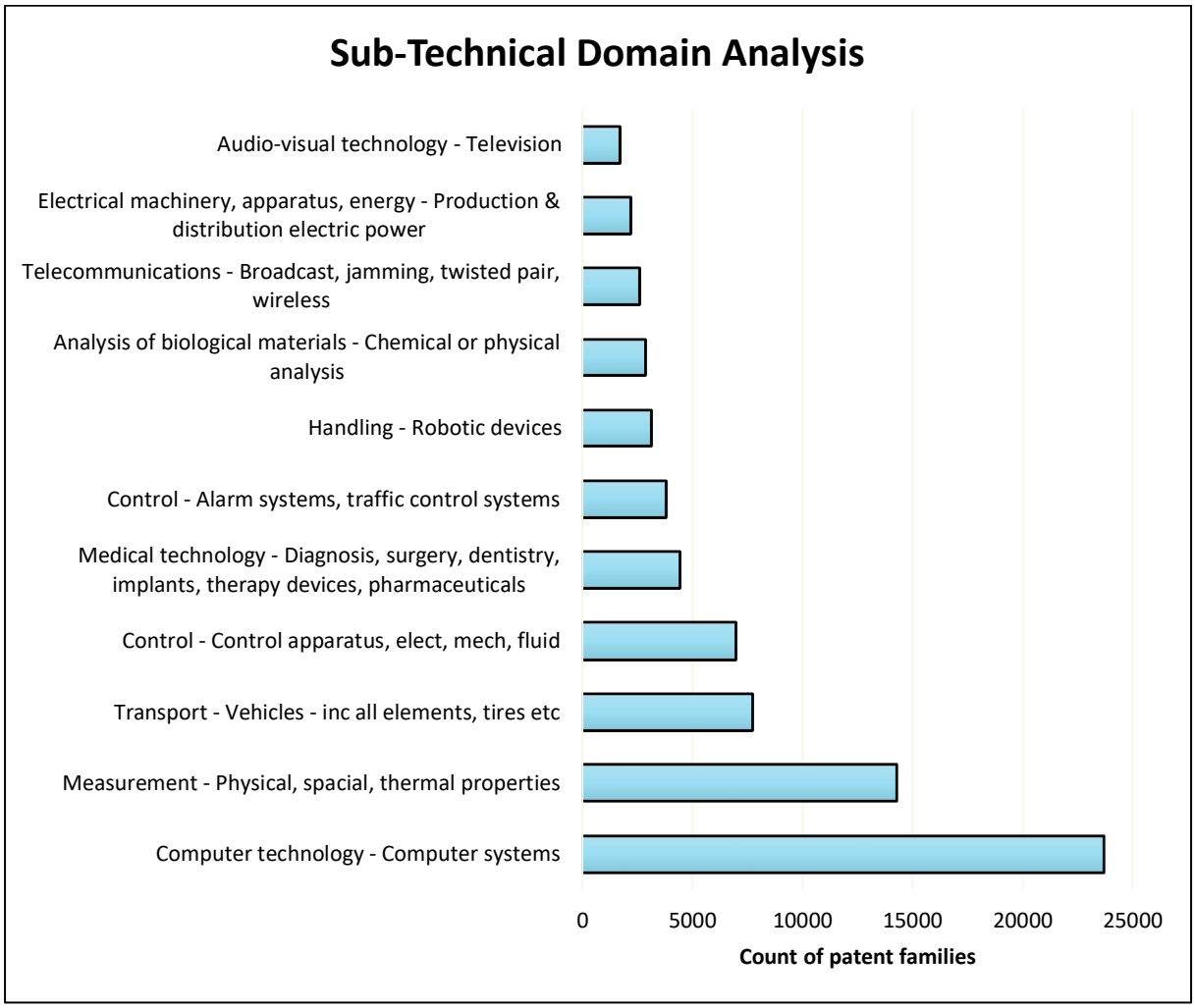
Rank	CPC	Number of Families	Definition	
1	G06N3/08	5575	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/08	Learning methods
2	G06N20/00	5405	G06N20/00	Machine learning
3	G06N3/045	3348	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/04	Architecture, e.g. interconnection topology
			G06N3/045	Combinations of networks
4	G06T2207/20084	2141	G06T2207/00	Indexing scheme for image analysis or image enhancement
			G06T2207/20	Special algorithmic details
			G06T2207/20084	Artificial neural networks [ANN]
5	G06T2207/20081	2139	G06T2207/00	Indexing scheme for image analysis or image enhancement
			G06T2207/20	Special algorithmic details
			G06T2207/20081	Training; Learning
6	G06V10/82	1734	G06V10/00	Arrangements for image or video recognition or understanding
			G06V10/70	using pattern recognition or machine learning
			G06V10/82	using neural networks
7	G06N3/084	1271	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/08	Learning methods
			G06N3/084	Backpropagation, e.g. using gradient descent
8	G06N3/04	1191	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/04	Architecture, e.g. interconnection topology
9	G06N7/01	1124	G06N7/00	Computing arrangements based on specific mathematical models
			G06N7/01	Probabilistic graphical models, e.g. probabilistic networks
10	G06N3/044	1061	G06N3/00	Computing arrangements based on biological models
			G06N3/02	Neural networks
			G06N3/04	Architecture, e.g. interconnection topology
			G06N3/044	Recurrent networks, e.g. Hopfield networks

Over the period, the CPC classification trends show a similar patent filing profile to the IPC classification trends. Patents classed as having combination of neural networks (G06N3/045) and recurrent networks (G06N3/044), have also followed suit with the number of patent filings increasing.



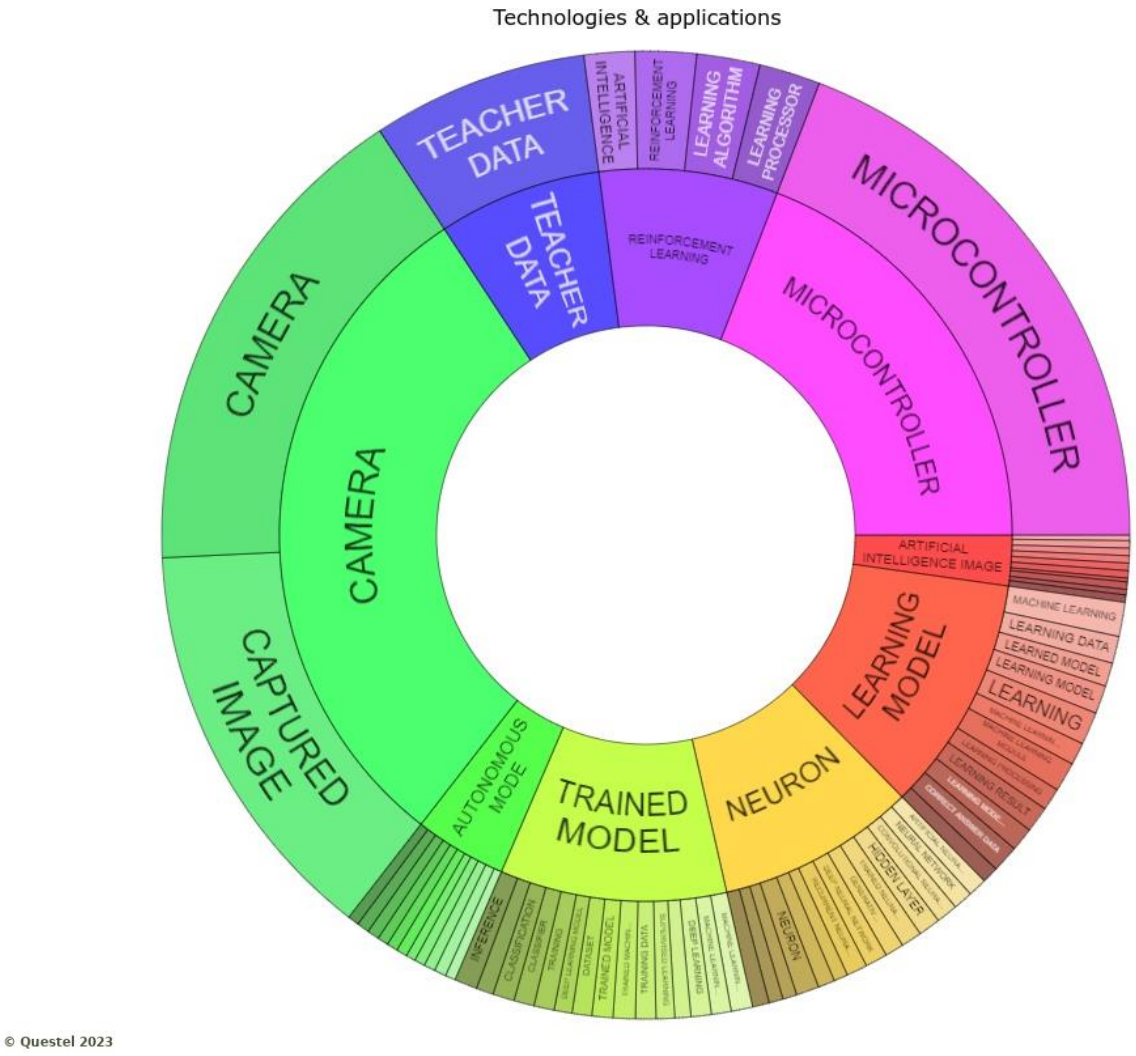
7.2.3 SUB-TECHNICAL DOMAINS

Diving into the technical domains, most innovation appears to relate to measurement and control systems, as well as AI technology for vehicles. There also appears to innovations in AI and robotic devices and electrical machinery, while there is some overlap with the medical technology patent landscape.



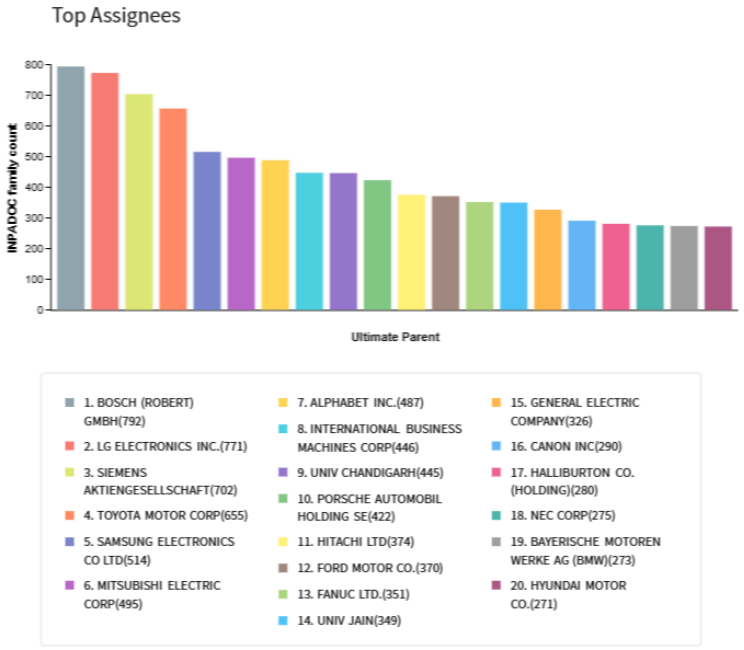
7.3 LANDSCAPE CONCEPTS

The following figure illustrates the distribution of the main concepts across the AI patent landscape in engineering research, which provides additional depth to key research areas identified from classification analysis. The main concepts focus on computer vision and microcontroller systems, as well as training models and reinforcement learning.



7.4 TOP ASSIGNEES

The top 20 assignees for the number of patents filed to AI technologies for engineering were in the main filed by commercial organisations.

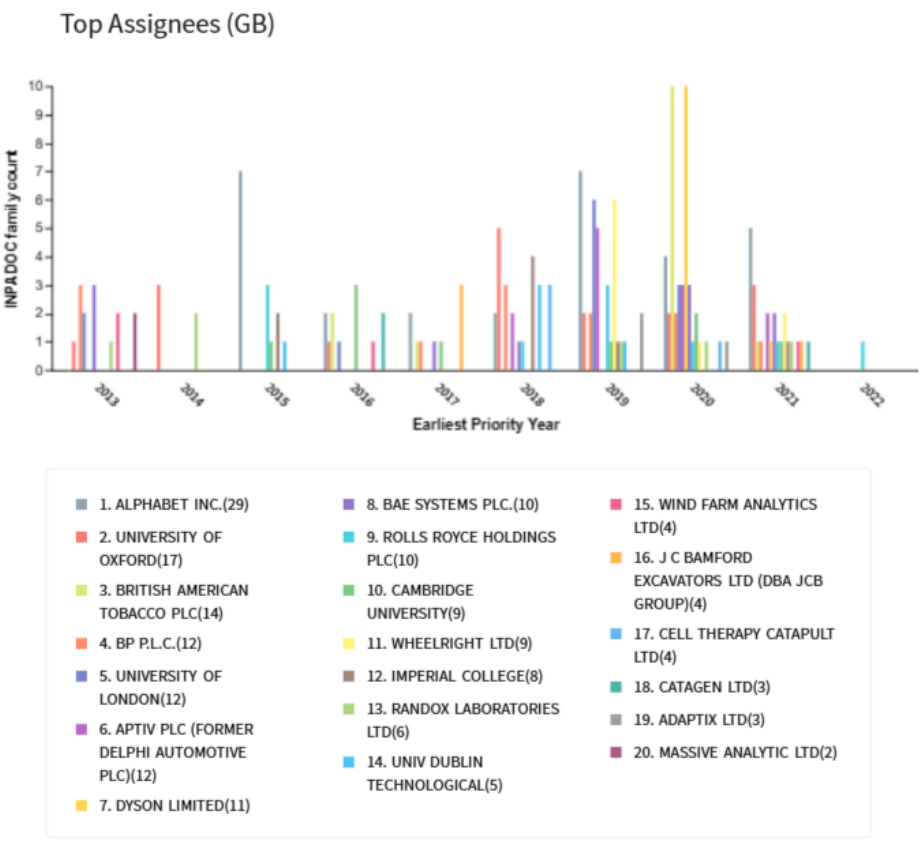


Source: Clarivate via Derwent Innovation

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
1	BOSCH ROBERT GMBH	792	Commercial	Germany
2	LG ELECTRONICS INC.	771	Commercial	Korea
3	SIEMENS AKTIENGESELLSCHAFT	702	Commercial	Germany
4	TOYOTA MOTOR CORP	655	Commercial	Japan
5	SAMSUNG ELECTRONICS CO LTD	514	Commercial	Korea
6	MITSUBISHI ELECTRIC CORP	495	Commercial	Japan
7	ALPHABET INC.	487	Commercial	US
8	INTERNATIONAL BUSINESS MACHINES CORP	446	Commercial	US
9	UNIV CHANDIGARH	445	Academic	India
10	PORSCHE AUTOMOBIL (VOLKSWAGEN)	422	Commercial	Germany
11	HITACHI LTD	374	Commercial	Japan
12	FORD MOTOR CO.	370	Commercial	US
13	FANUC LTD.	351	Commercial	Japan
14	UNIV JAIN	349	Academic	India
15	GENERAL ELECTRIC COMPANY	326	Commercial	US
16	CANON INC	290	Commercial	Japan
17	HALLIBURTON CO HOLDING	280	Commercial	US
18	NEC CORP	275	Commercial	Japan
19	BAYERISCHE MOTOREN WERKE AG (BMW)	273	Commercial	Germany
20	HYUNDAI MOTOR CO.	271	Commercial	Korea

GREAT BRITAIN

The top patent filing UK organisations include:



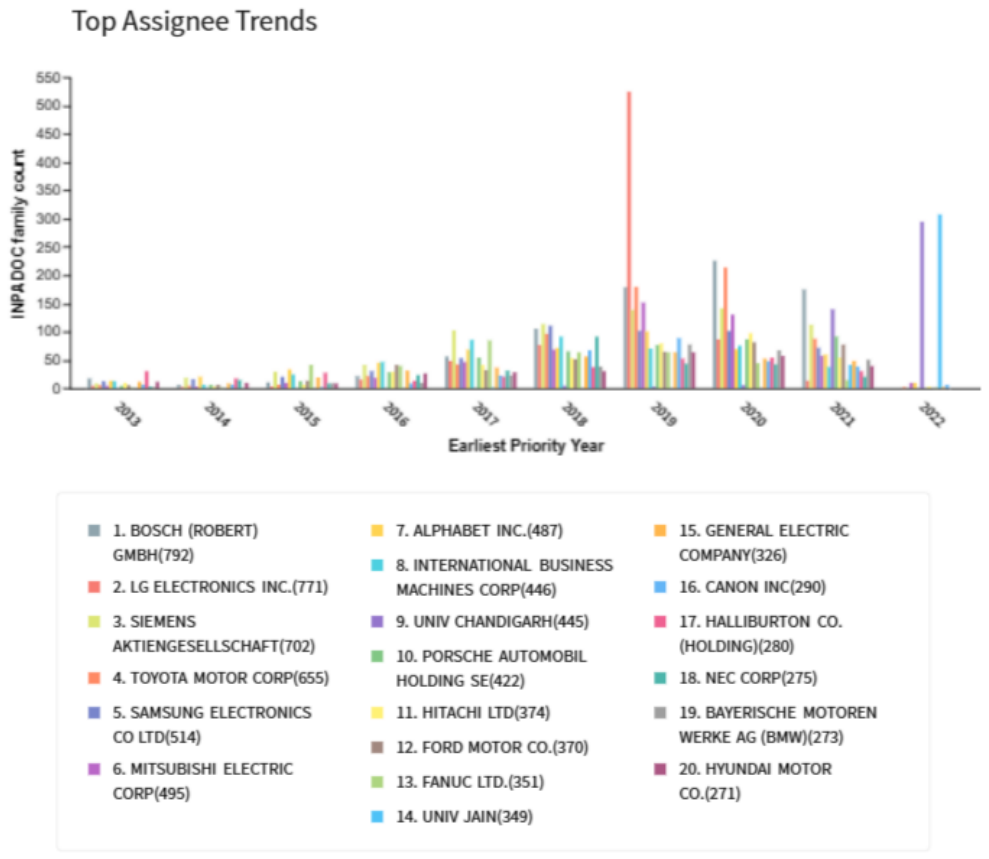
Source: Clarivate via Derwent Innovation

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
1	ALPHABET INC. (DEEPMIND TECH LTD)	29	Commercial	GB
2	UNIVERSITY OF OXFORD	17	Academic	GB
3	BRITISH AMERICAN TOBACCO PLC	14	Commercial	GB
4	BP P.L.C.	12	Commercial	GB
5	UNIVERSITY OF LONDON	12	Academic	GB
6	APTIV PLC	12	Commercial	GB
7	DYSON LIMITED	11	Commercial	GB
8	BAE SYSTEMS PLC.	10	Commercial	GB
9	ROLLS ROYCE HOLDINGS PLC	10	Commercial	GB
10	CAMBRIDGE UNIVERSITY	9	Academic	GB
11	WHEELRIGHT LTD	9	Commercial	GB
12	IMPERIAL COLLEGE	8	Commercial	GB
13	RANDOX LABORATORIES LTD	6	Commercial	GB
14	UNIV DUBLIN TECHNOLOGICAL	5	Academic	GB
15	WIND FARM ANALYTICS LTD	4	Commercial	GB

Rank	Assignee/Applicant	Document Count	Organisation Type	Country
16	J C BAMFORD EXCAVATORS LTD	4	Commercial	GB
17	CELL THERAPY CATAPULT LTD	4	Commercial	GB
18	CATAGEN LTD	3	Commercial	GB
19	ADAPTIX LTD	3	Commercial	GB
20	MASSIVE ANALYTIC LTD	2	Commercial	GB

7.4.1 FILING TRENDS

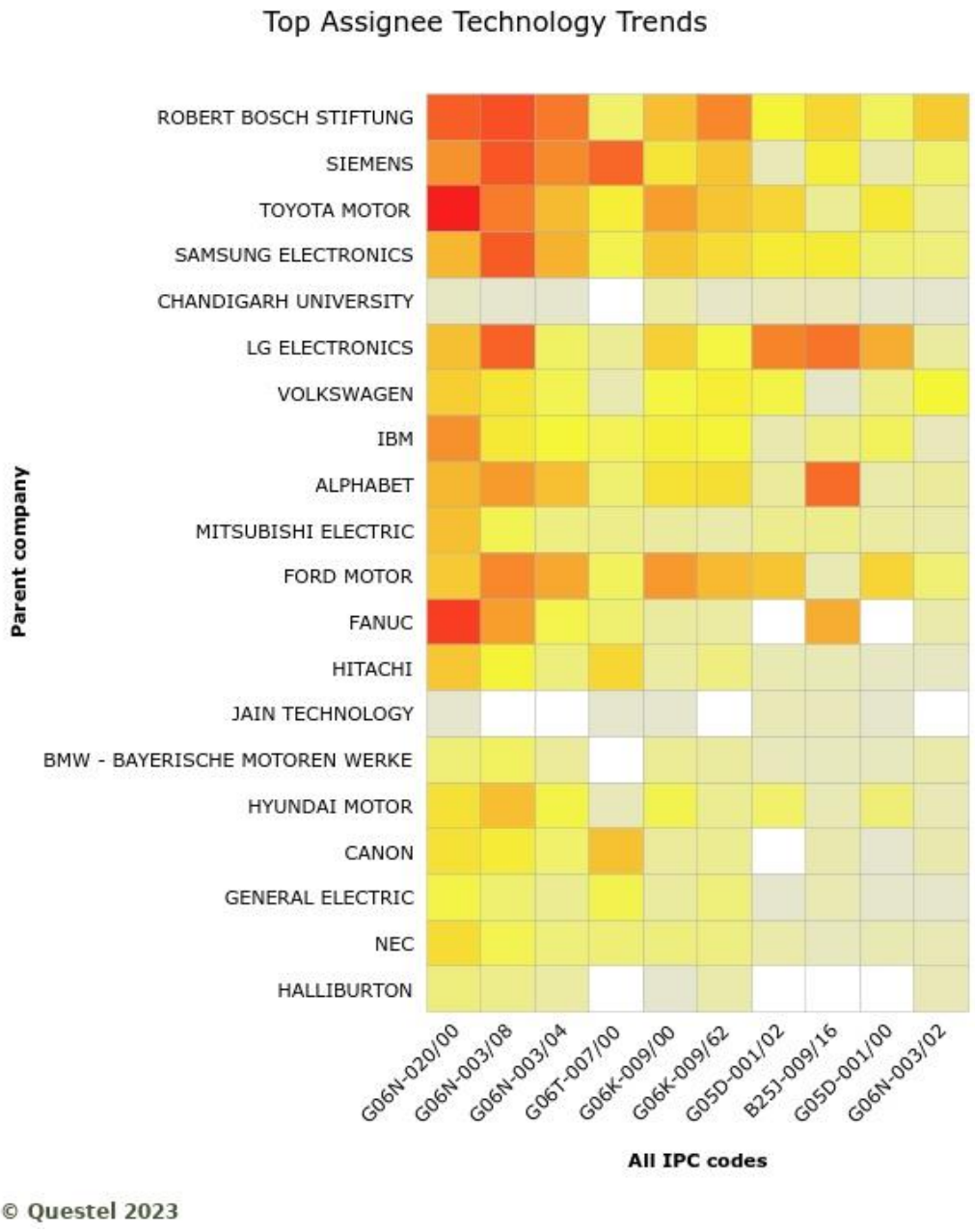
The top filing companies, such as Bosch and LG Electronics, have continued to increase the number of patents filed significantly. Interestingly, LG Electronics had a spike in patent filings in 2019. Bosch and Toyota emerged as the most active in 2020. The University of Chandigarh and JAIN have filed a significant number of patents in 2022, but the 2021-2023 data given in the graph will not be complete, due to the 18-month delay between priority application and publication.



Source: Clarivate via Derwent Innovation

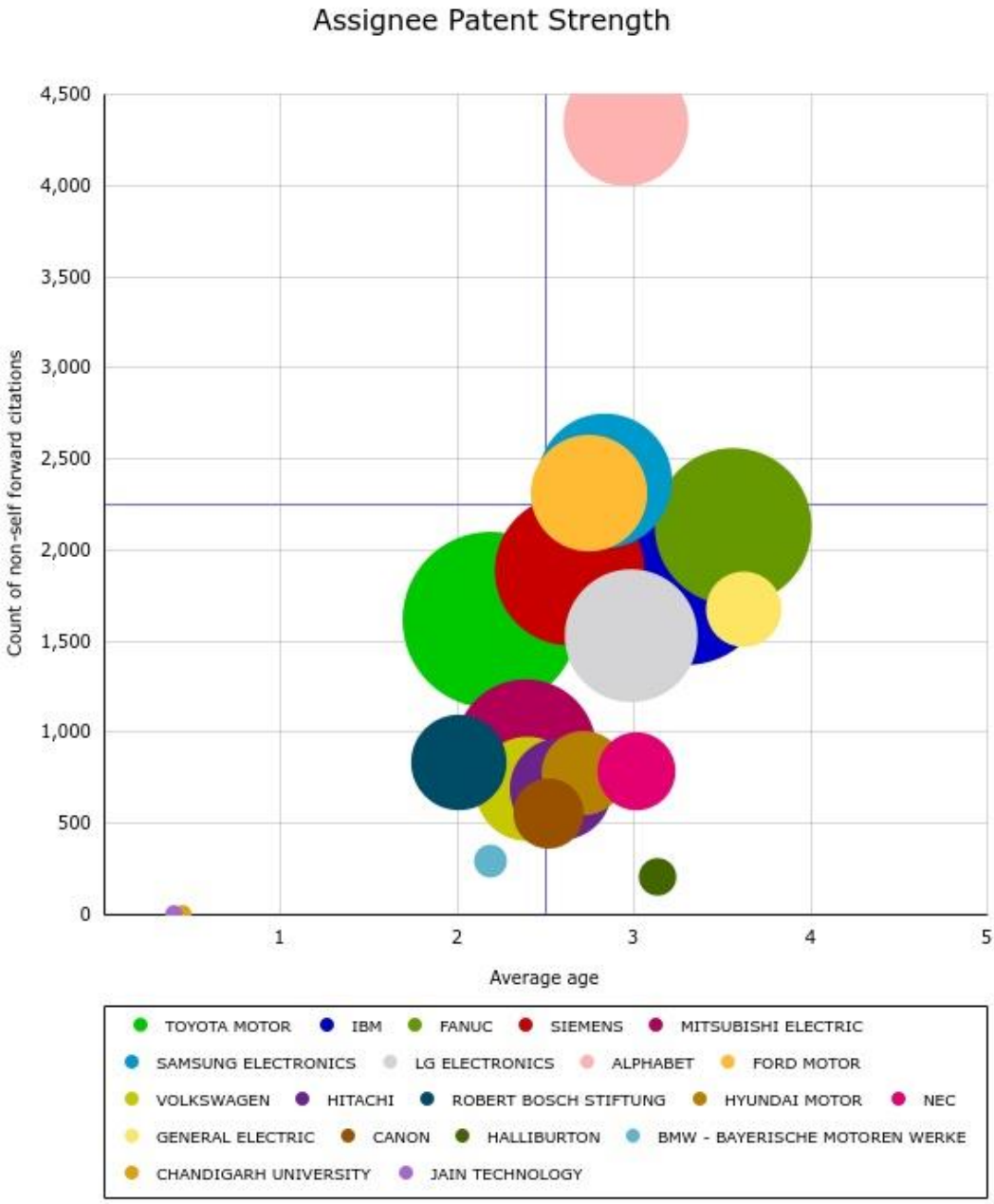
7.4.2 TECHNOLOGY FOCUS

Machine learning (G06N20/00) and neural network learning methods (G06N3/08) applied to engineering represent the most competitive areas, with a high number of these patents filed by major companies, such as FANUC and Toyota. Most of the automotive players have a higher proportion of patent filings in these methods, while Ford and Toyota have also invested significantly in methods for recognising patterns (G06K9/00). In contrast to other sectors, there appears to be less interest from the automotive industry in image analysis (G06T7/00), as this area is dominated by Siemens, Canon and Hitachi. There also appears to be significant activity around programme-controlled manipulators (B25J9/16), with substantial numbers of patents filed by Alphabet, FANUC and LG Electronics.



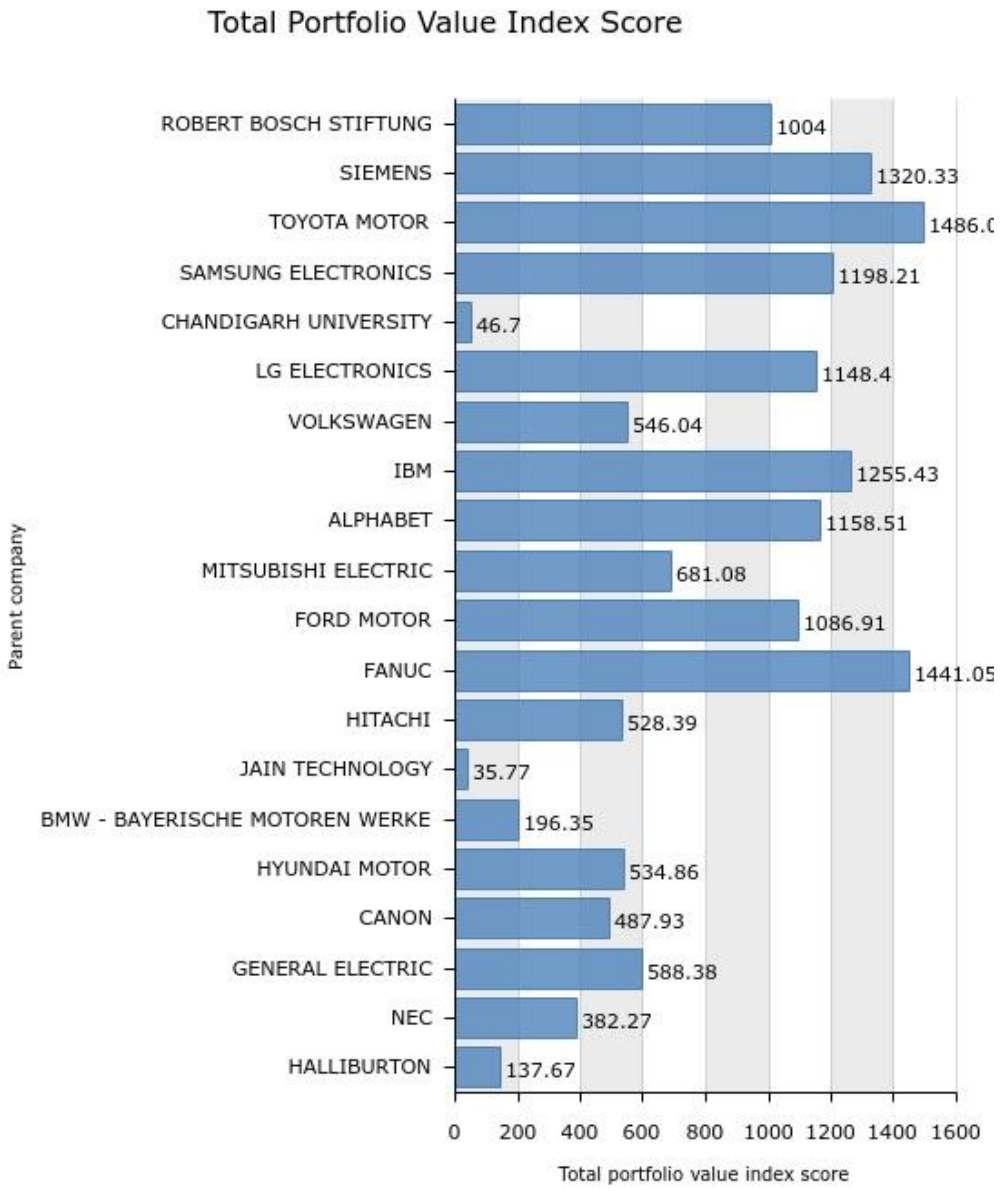
7.4.3 PATENT STRENGTH

Several players, such as FANUC, established an early footing in the engineering and AI space. The high number of assignees with patent portfolios of a similar age and technology impact illustrates how competitive the industry is, with Hyundai and JAIN being some of the latest newcomers. Most interestingly, despite significant patent filings from automotive players, such as Toyota and Mitsubishi, Alphabet is a pioneer in the field.



7.4.4 PATENT PORTFOLIO VALUE

Despite Alphabet being a pioneer in the area of AI and engineering, the greater proportion of granted patent families held by Toyota, FANUC, and Siemens mean that their patent portfolios are more valuable in the engineering field.



7.5 LANDSCAPE MAP

We applied Derwent Innovation's proprietary ThemeScape™ mapping tool to generate a landscape map to identify key areas of high patent coverage and areas of low patent coverage, as well as gain insight into the position of the patent portfolios of the top 10 assignees. This is illustrated in Figure 4 below. **The more heavily concentrated areas of the patent landscape relate to computer vision and vehicular environment, and robotics.**

Figure 4 legend:

Company	Colour
Bosch Robert Gmbh	
LG Electronics Inc.	
Siemens Aktiengesellschaft	
Toyota Motor Corp	
Samsung Electronics Co Ltd	
Mitsubishi Electric Corp	
Alphabet Inc.	
International Business Machines Corp	
Univ Chandigarh	
Porsche Automobil (Volkswagen)	

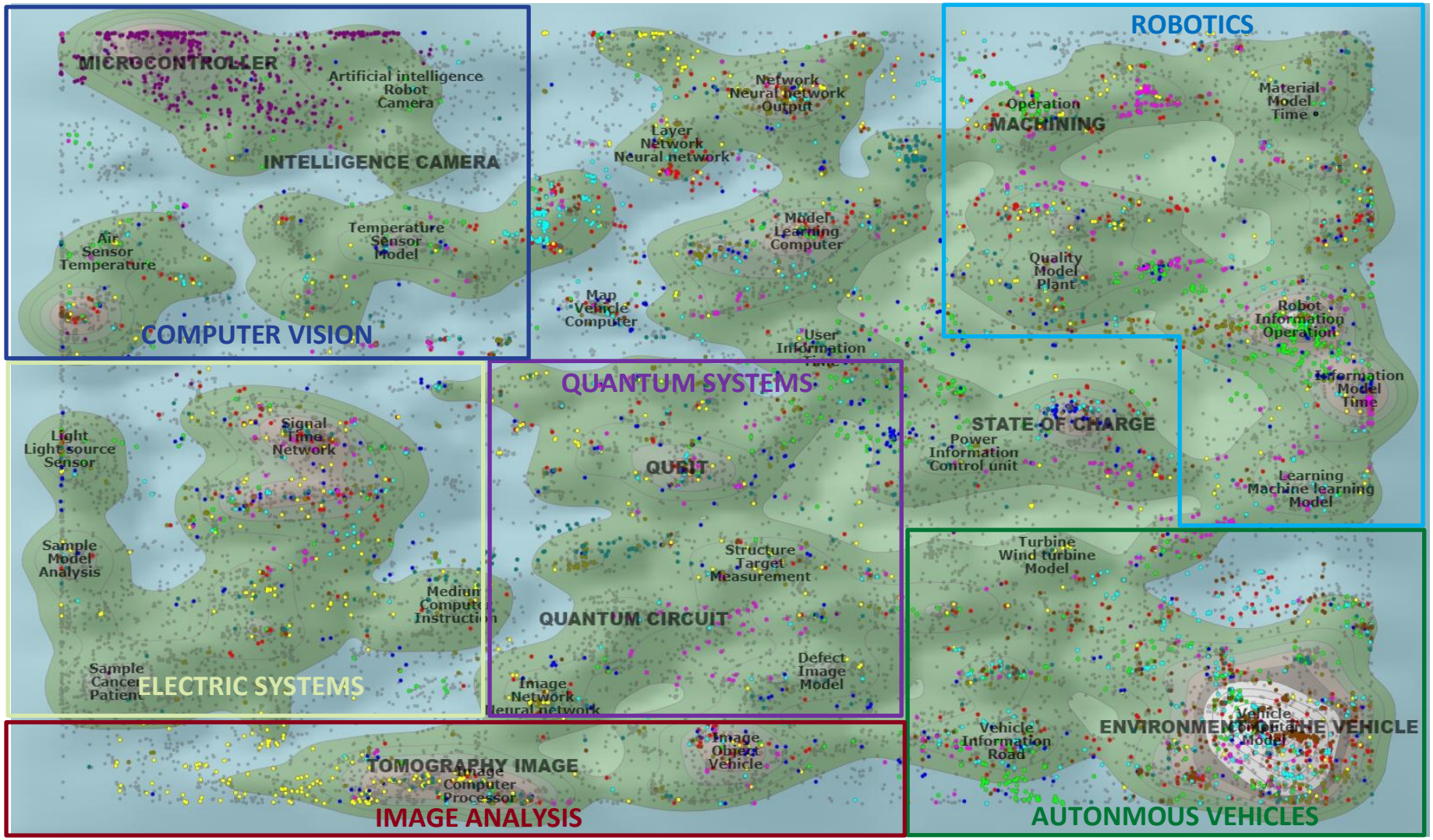


Figure 4. AI in the engineering and transport sectors (Source: Clarivate via Derwent Innovation). Each dot indicates the location of an INPADOC patent family on the map. The map has been overlaid with the key areas in which the patents fall on the map.

8 KEY PATENTS

The following section highlights exemplar patents which we consider as important AI related technologies within their respective scientific fields. A summary of the top 20 results is provided in the associated Excel documents (provided by Orbit by Questel) and tables, which also contains a link to the full document available in Espacenet. These patents are the earliest representative family members and were identified by manually reviewing the dataset picked up by the search strategy, taking into account technology impact and non-self forward citation metrics.

8.1 MEDICINE & PHARMACEUTICAL AI PATENTS

The following section of the report highlights exemplar AI-related patents which we consider to be key in the development of medical preparations and pharmaceuticals. It is evident that AI has been applied within the sector in a variety of ways, these primarily appear to be in the diagnosis, prognosis, and therapeutic response prediction, as well as systems for identifying effective treatments, AI-platforms for drug discovery and clinical trials.

Key Patent Results (Pharma)

Publication Number	Title (English)	Assignee	Publication Date
EP3622520A1	Deep learning-based techniques for training deep convolutional neural networks	ILLUMINA	18/03/2020
Summary/Abstract – The technology disclosed relates to constructing a convolutional neural network-based classifier for variant classification. In particular, it relates to training a convolutional neural network-based classifier on training data using a backpropagation-based gradient update technique that progressively match outputs of the convolutional network network-based classifier with corresponding ground truth labels. The convolutional neural network-based classifier comprises groups of residual blocks, each group of residual blocks is parameterized by a number of convolution filters in the residual blocks, a convolution window size of the residual blocks, and an atrous convolution rate of the residual blocks, the size of convolution window varies between groups of residual blocks, the atrous convolution rate varies between groups of residual blocks. The training data includes benign training examples and pathogenic training examples of translated sequence pairs generated from benign variants and pathogenic variants.			
US2022367053A1	Multimodal fusion for diagnosis, prognosis, and therapeutic response prediction	BRIGHAM & WOMENS HOSPITAL	17/11/2022

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – Systems and methods can quantify the tumor microenvironment for diagnosis, prognosis and therapeutic response prediction by fusing different data types (e.g., morphological information from histology and molecular information from omics) using an algorithm that harnesses deep learning. The algorithm employs tensor fusion to provide end-to-end multimodal fusion to model the pairwise interactions of features across multiple modalities (e.g., histology and molecular features) and deep learning. The systems and methods improve upon traditional methods for quantifying the tumor microenvironment that rely on concatenation of extracted features.			
WO2022/042510A1	Protein expression quantity prediction method and apparatus, computer device, and storage medium	SHENZHEN TAILI BIOTECHNOLOGY	03/03/2022
Summary/Abstract – A protein expression quantity prediction method and apparatus, a computer device, and a storage medium. The method comprises: acquiring test cell gray scale images respectively corresponding to multiple cells to be tested in a cell culture pool (101); inputting the multiple test cell gray scale images into a target generative network model, the target generative network model being obtained by training a generative adversarial network model by using multiple training cell gray scale images, and the multiple training cell gray scale images respectively having corresponding fluorescence image labels that are real fluorescence images corresponding to the training cell gray scale images (102); obtaining, according to the output of the target generative network model, prediction fluorescence images respectively corresponding to the multiple cells to be tested (103); and determining, according to the prediction fluorescence images, protein expression quantities respectively corresponding to the multiple cells to be tested (104). The method achieves fast determination of the protein expression quantities of cells in the culture pool according to gray scale images of the cells and avoids repeated culture and screening, thus effectively improving prediction efficiency of the protein expression quantities of the cells in a culture process.			
US2020184278A1	System and method for extremely efficient image and pattern recognition and artificial intelligence platform	Z ADVANCED COMPUTING	11/06/2020

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – Specification covers new algorithms, methods, and systems for: Artificial Intelligence; the first application of General-AI. (versus Specific, Vertical, or Narrow-AI) (as humans can do) (which also includes Explainable-AI or XAI); addition of reasoning, inference, and cognitive layers/engines to learning module/engine/layer; soft computing; Information Principle; Stratification; Incremental Enlargement Principle; deep-level/detailed recognition, e.g., image recognition (e.g., for action, gesture, emotion, expression, biometrics, fingerprint, tilted or partial-face, OCR, relationship, position, pattern, and object); Big Data analytics; machine learning; crowd-sourcing; classification; clustering; SVM; similarity measures; Enhanced Boltzmann Machines; Enhanced Convolutional Neural Networks; optimization; search engine; ranking; semantic web; context analysis; question-answering system; soft, fuzzy, or un-sharp boundaries/impreciseness/ambiguities/fuzziness in class or set, e.g., for language analysis; Natural Language Processing (NLP); Computing-with-Words (CWW); parsing; machine translation; music, sound, speech, or speaker recognition; video search and analysis (e.g., "intelligent tracking", with detailed recognition); image annotation; image or color correction; data reliability; Z-Number; Z-Web; Z-Factor; rules engine; playing games; control system; autonomous vehicles or drones; self-diagnosis and self-repair robots; system diagnosis; medical diagnosis/images; genetics; drug discovery; biomedicine; data mining; event prediction; financial forecasting (e.g., for stocks); economics; risk assessment; fraud detection (e.g., for cryptocurrency); e-mail management; database management; indexing and join operation; memory management; data compression; event-centric social network; social behavior; drone/satellite vision/navigation; smart city/home/appliances/IoT; and Image Ad and Referral Networks, for e-commerce, e.g., 3D shoe recognition, from any view angle.		
EP3991171A1	Determining biomarkers from histopathology slide images	TEMPUS LABS	04/05/2022
Summary/Abstract – A generalizable and interpretable deep learning model for predicting biomarker status and biomarker metrics from histopathology slide images is provided.			
EP3212061A1	Physiological monitoring system	IRHYTHM TECHNOLOGIES	06/09/2017
Summary/Abstract – The present disclosure relates to a cardiac monitoring system and methods for using such a system. Preferred embodiments detect and record cardiac information via a wearable device, then extract data features from the recorded cardiac information. The extracted data features may then be analyzed and used in clinical diagnosis.			
EP3043696A1	Systems and methods for improved brain monitoring during general anesthesia and sedation	MASSACHUSETTS GENERAL HOSPITAL	20/07/2016
Summary/Abstract – Systems and method for age-compensated monitoring of a patient experiencing administration of at least one drug having anesthetic properties are provided. In one embodiment, a system includes a plurality of sensors configured to acquire physiological data from the patient and at least one processor configured to receive the physiological data from the plurality of sensors, and determine, from the physiological data, signal markers indicative of an apparent or likely patient age. The at least one processor is also configured to at least one of scale and regulate the physiological data using at least the apparent patient age to create age-compensated data, and generate a report including the age-compensated data.			
WO2022/041729A1	Medication recommendation method, apparatus and device, and storage medium	KANG JIAN INFORMATION TECHNOLOGY SHENZHEN	03/03/2022

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – A medication recommendation method, apparatus and device, and a storage medium, which are applied to the field of smart medical care. The method comprises: inputting a diagnosis result into a drug recommendation model for drug matching, so as to obtain a candidate drug list; performing screening on the basis of the candidate drug list combined with inquiry data, so as to obtain recommended drugs; and finally selecting drugs, that meet conditions, on the basis of the actual condition of a patient, and storing the drugs in an inquiry form for subsequent use and consultation. The automatic drug recommendation is realized, and the phenomenon that a physician prescribes a useless drug due to the false memory of drug properties is also avoided. When issuing a prescription, the physician can quickly determine a corresponding treatment prescription according to recommended drugs in an inquiry form, thereby improving the diagnosis efficiency for physicians.			
WO2022/257344A1	Image registration fusion method and apparatus, model training method, and electronic device	BEIJING LONGWOOD VALLEY MEDICAL TECHNOLOGY	15/12/2022
Summary/Abstract – An image registration fusion method and apparatus, a model training method, and an electronic device. The fusion method comprises: obtaining two-dimensional medical images of at least two modalities of a patient (S110); respectively inputting the two-dimensional medical images of the at least two modalities into pre-trained corresponding image segmentation network models to respectively obtain an output of the two-dimensional medical image of each modal body position region (S120); and respectively performing three-dimensional reconstruction on the two-dimensional medical image of each modal body position region and then performing point cloud registration fusion to obtain a multi-modal fused three-dimensional medical image (S130). The method is high in image registration precision, low in time cost, and further capable of processing a complex multi-modal fusion condition, can further be applied to a non-rigid registration condition, and is accurate in registration result, and thus, an accurate treatment reference basis can be provided for medical staff.			
EP3622519A1	Deep learning-based aberrant splicing detection	ILLUMINA	18/03/2020
Summary/Abstract – The technology disclosed relates to constructing a convolutional neural network-based classifier for variant classification. In particular, it relates to training a convolutional neural network-based classifier on training data using a backpropagation-based gradient update technique that progressively match outputs of the convolutional network network-based classifier with corresponding ground truth labels. The convolutional neural network-based classifier comprises groups of residual blocks, each group of residual blocks is parameterized by a number of convolution filters in the residual blocks, a convolution window size of the residual blocks, and an atrous convolution rate of the residual blocks, the size of convolution window varies between groups of residual blocks, the atrous convolution rate varies between groups of residual blocks. The training data includes benign training examples and pathogenic training examples of translated sequence pairs generated from benign variants and pathogenic variants.			
EP3561075A1	Detecting mutations in tumour biopsies and cell-free samples	NATERA	30/10/2019

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – The invention provides a method for detecting one or more mutations or genetic variations in a blood, serum, or plasma sample of a subject having cancer or suspected of having cancer, the method comprising: identifying a plurality of mutations or genetic variations in a tumor sample of the subject by whole exome sequencing; collecting a blood, serum, or plasma sample from the subject, and isolating cell-free DNA from the blood, serum, plasma, or tumor sample; amplifying a plurality of loci corresponding to the mutations or genetic variations from the cell-free DNA to obtain amplicons; sequencing the amplicons to obtain sequence reads; and detecting one or more of the mutations or genetic variations present in the cell-free DNA from the sequence reads; optionally wherein the cell-free DNA comprises circulating tumor DNA.			
GB2577828A	Systems and methods for identifying cancer treatments from normalized biomarker scores	BOSTONGENE	08/04/2020
Summary/Abstract – Techniques for determining predicted response of a subject to multiple therapies using the subject's sequencing data. The techniques include accessing biomarker information indicating a distribution of values for each biomarker in at least a reference subset of a plurality of biomarkers across a respective group of people, each of the plurality of biomarkers being associated with at least one therapy in a plurality of therapies; determining, using the sequencing data and the biomarker information, a normalized score for each biomarker in at least a subject subset of the plurality of biomarkers to obtain a set of normalized biomarker scores for the subject; and determining, using the set of normalized biomarker scores for the subject, therapy scores for the plurality of therapies, each of the therapy scores indicative of predicted response of the subject to administration of a respective therapy in the plurality of therapies.			
US20200302297A1	Artificial intelligence-based base calling	ILLUMINA	24/09/2020
Summary/Abstract – The technology disclosed processes input data through a neural network and produces an alternative representation of the input data. The input data includes per-cycle image data for each of one or more sequencing cycles of a sequencing run. The per-cycle image data depicts intensity emissions of one or more analytes and their surrounding background captured at a respective sequencing cycle. The technology disclosed processes the alternative representation through an output layer and producing an output and base calls one or more of the analytes at one or more of the sequencing cycles based on the output.			
EP3451926A1	System and method for providing alerts optimized for a user	DEXCOM	13/03/2019
Summary/Abstract – Systems and methods are disclosed that provide smart alerts to users, e.g., alerts to users about diabetic states that are only provided when it makes sense to do so, e.g., when the system can predict or estimate that the user is not already cognitively aware of their current condition, e.g., particularly where the current condition is a diabetic state warranting attention. In this way, the alert or alarm is personalized and made particularly effective for that user. Such systems and methods still alert the user when action is necessary, e.g., a bolus or temporary basal rate change, or provide a response to a missed bolus or a need for correction, but do not alert when action is unnecessary, e.g., if the user is already estimated or predicted to be cognitively aware of the diabetic state warranting attention, or if corrective action was already taken.			
EP3338208A1	Data analytics and insight delivery for the management and control of diabetes	MEDTRONIC MINIMED	27/06/2018

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – Presented herein are various computer-implemented systems and related methods of providing guidance, recommendations, and insights to diabetic patients and/or caregivers of such patients. An embodiment of a method obtains input data for a user of a diabetes management device, compares the input data against historical event/outcome combinations maintained for the user, each of the event/outcome combinations including insight event data indicative of a glycemic event and a glycemic outcome corresponding to the insight event data, determines a correlation between the input data and a glycemic outcome, and generates a glycemic insight message for delivery to the user. The glycemic insight message has information regarding a relationship between at least some of the input data and the glycemic outcome. The timing of delivery of generated insight messages can be prioritized and optimized to increase the benefit to the recipient. Another embodiment identifies a glycemic response event based on an analysis of the obtained input data, generates a graphical representation of a glucose response to the glycemic response event, and delivers the graphical representation to a user device operated by the user.			
WO2022/268102A1	Deep learning-based cancer prognosis survival prediction method and device, and storage medium	ANKON TECHNOLOGY	29/12/2022
Summary/Abstract – Provided are a deep learning-based cancer prognosis survival prediction method and device, and a storage medium. The method comprises: data acquisition: acquiring sample data, the sample data comprising pathological image data and clinical data of a sample; data preprocessing; prediction model training: training and evaluating a prediction model to obtain an optimal prediction model; and risk prediction: performing risk prediction on a new sample on the basis of an optimal classifier model and the optimal prediction model.			
WO2022/188490A1	Survival time prediction method and system based on imaging genomics	SHENZHEN INSTITUTE OF ADVANCED TECHNOLOGY - CHINESE ACADEMY OF SIENCES	15/09/2022
Summary/Abstract – Disclosed in the present invention is a survival time prediction method and system based on imaging genomics. The method comprises: obtaining image data of tumor patients and survival time data and RNA data of the patients, to establish a data set; separating tumor regions of the patients from the image data; inputting the image data of the patients into a neural network to extract image features and cluster same to obtain a plurality of image modules; using the RNA data to obtain gene modules of the patients; performing screening according to correlations between the gene modules and the image modules to select a plurality of strongly correlated gene modules and image modules; performing pathway enrichment on genes in the selected gene modules to obtain gene pathways related to the image modules; calculating gene set variation analysis scores of the gene pathways, and retaining a gene pathway strongly correlated to the image modules; and using retained image features to perform survival time prediction. The present invention can improv the biological interpretability of survival time prediction, and also improves the generalization capability of deep learning.			
EP3622423A1	Individual and cohort pharmacological phenotype prediction platform	REGENTS OF THE UNIVERSITY OF MICHIGAN	18/03/2020

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – For patients who exhibit or may exhibit primary or comorbid disease, pharmacological phenotypes may be predicted through the collection of panomic, physiomic, environmental, sociomic, demographic, and outcome phenotype data over a period of time. A machine learning engine may generate a statistical model based on training data from training patients to predict pharmacological phenotypes, including drug response and dosing, drug adverse events, disease and comorbid disease risk, drug-gene, drug-drug, and polypharmacy interactions. Then the model may be applied to data for new patients to predict their pharmacological phenotypes, and enable decision making in clinical and research contexts, including drug selection and dosage, changes in drug regimens, polypharmacy optimization, monitoring, etc., to benefit from additional predictive power, resulting in adverse event and substance abuse avoidance, improved drug response, better patient outcomes, lower treatment costs, public health benefits, and increases in the effectiveness of research in pharmacology and other biomedical fields.			
EP3558422A1	Infusion systems and related personalized adjustment methods	MEDTRONIC MINIMED	30/10/2019
Summary/Abstract – Infusion systems, infusion devices, and related operating methods are provided. An exemplary method of operating an infusion device capable of delivering fluid to a patient involves obtaining, by a control system associated with the infusion device, an input meal indication, obtaining historical data for the patient associated with the input meal indication, determining an estimated carbohydrate amount corresponding to the input meal indication based at least in part on the historical data, determining a bolus dosage of the insulin based at least in part on the estimated carbohydrate amount, and operating an actuation arrangement of the infusion device to deliver the bolus dosage of the insulin to the patient.			
US20200411199A1	Platforms for conducting virtual trials	CANCER COMMONS	31/12/2020
Summary/Abstract – The present disclosure provides platforms, systems, media, and methods for capturing clinical cases and expert-derived treatment rationales to facilitate biomedical decision making, which can include virtual clinical trials that continuously learn from the experiences of all patients, on all treatments, and all the time. Algorithms such as Bayesian machine learning methods can be applied to coordinate such virtual trials.			

8.2 MEDICAL TECHNOLOGY AI PATENTS

The following section of the report highlights exemplar AI-related patents which we consider to be key in the medical technology industry. It is apparent that AI has had a very significant impact on medical image analysis, diagnostics and health management, as well as computer-assisted surgical systems.

Key Patent Results
(Medical Tech)

Publication Number	Title (English)	Assignee	Publication Date
US20210397966A1	Systems and methods for image segmentation	SHANGHAI UNITED IMAGING INTELLIGENCE	23/12/2021
Summary/Abstract – Described herein are neural network-based systems, methods and instrumentalities associated with image segmentation that may be implementing using an encoder neural network and a decoder neural network. The encoder network may be configured to receive a medical image comprising a visual representation of an anatomical structure and generate a latent representation of the medical image indicating a plurality of features of the medical image. The latent representation may be used by the decoder network to generate a mask for segmenting the anatomical structure from the medical image. The decoder network may be pre-trained to learn a shape prior associated with the anatomical structure and once trained, the decoder network may be used to constrain an output of the encoder network during training of the encoder network.			
US20210334974A1	Systems and methods for deep-learning-based segmentation of composite images	EXINI DIAGNOSTICS	28/10/2021
Summary/Abstract – Presented herein are systems and methods that provide for improved 3D segmentation of nuclear medicine images using an artificial intelligence-based deep learning approach. For example, in certain embodiments, the machine learning module receives both an anatomical image (e.g., a CT image) and a functional image (e.g., a PET or SPECT image) as input, and generates, as output, a segmentation mask that identifies one or more particular target tissue regions of interest. The two images are interpreted by the machine learning module as separate channels representative of the same volume. Following segmentation, additional analysis can be performed (e.g., hotspot detection/risk assessment within the identified region of interest).			
US20210007760A1	Surgical systems with sesnsing and machine learning capabilities and methods thereof	CAZE TECHNOLOGIES	14/01/2021
Summary/Abstract – Systems and methods for determining surgical system settings during a surgical procedure are disclosed. The surgical systems comprise of a control system, a means for tissue removal, sensing capabilities and machine learning application(s). The sensing capabilities and machine learning application(s) are configured to determine type and/or properties of the removed tissue and to predict preferred surgical settings for optimized removal and surgical outcomes. The learning machine application(s) communicates these preferred settings to a surgical control system.			

Publication Number	Title (English)	Assignee	Publication Date
US20220157468A1	Patient data visualization method and system for assisting decision making in chronic diseases	ZHEJIANG LAB	19/05/2022
Summary/Abstract – Provided is a patient data visualization method and system for assisting decision making in chronic diseases. According to the present application, a management data model diagram of a patient on a hyperplane is constructed by constructing a chronic disease knowledge graph, and combining static data and dynamic data of the patient, and then the management data model diagram is projected onto a two-dimensional plane. The difference of the Euclidean distance between features of a patient information model on a two-dimensional plane graph from the distance of standard features is compared, and a management plan is generated and recommended in combination with path node concepts and an attribute relationship between the concepts.			
WO2022/089221A1	Medical image segmentation method and apparatus, and device, system and computer storage medium	RAYCAN TECHNOLOGY	05/05/2022
Summary/Abstract – Disclosed are a medical image segmentation method and apparatus, and a device, a system and a computer storage medium. The method may comprise: calling a target detection model to detect, from a medical image to be segmented, a candidate area where a target organ is located; calling a target positioning model that is different from a neural network model to position, from the candidate area, a final area where the target organ is located; and calling a target segmentation model that is different from the neural network model to segment the final area, so as to obtain a segmentation result of the target organ. By utilizing the technical solution provided in the present application, fully automatic segmentation of a medical image can be realized, thereby helping assist doctors in making a diagnosis.			
US20190206565A1	Method for operating surgical instrument systems	CILAG INTERNATIONAL	04/07/2019
Summary/Abstract – A method for adjusting the operation of a surgical instrument using machine learning in a surgical suite is disclosed.			
EP3093821A1	Method and system for anatomical object pose detection using marginal space deep neural networks	SIEMENS HEALTHCARE	16/11/2016
Summary/Abstract – A method and system for anatomical object detection using marginal space deep neural networks is disclosed. The pose parameter space for an anatomical object is divided into a series of marginal search spaces with increasing dimensionality. A respective deep neural network is trained for each of the marginal search spaces, resulting in a series of trained deep neural networks. Each of the trained deep neural networks can evaluate hypotheses in a current parameter space using discriminative classification or a regression function. An anatomical object is detected in a medical image by sequentially applying the series of trained deep neural networks to the medical image.			
GB2594421A	Inlet instrumentation for ion analyser coupled to rapid evaporative ionisation mass spectrometry ("reims") device	MICROMASS	27/10/2021

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – An apparatus comprises: a user interface [1500, fig. 15A]; a robotic probe 1580 which generates an aerosol, smoke or vapour (e.g. for rapid evaporative ionisation mass spectrometry (REIMS); and a mass or ion mobility spectrometer for analysing the aerosol, smoke or vapour. Also disclosed in a laparoscopic tool comprising: an elongate portion; and a first device at the distal end of the elongate portion to generate an aerosol, smoke or vapour from tissue. Further disclosed is an apparatus comprising: a first device which emits a stream of electrically charged droplets at a target (i.e. a desorption electrospray ionisation (DESI) device); a transfer capillary to transfer generated ions from the target to an analyser; and a heating device which heats the first device, the stream of droplets, the target or the transfer capillary.			
WO2022/247296A1	Mark point-based image registration method	PERCEPTION VISION MEDICAL TECHNOLOGY	01/12/2022
Summary/Abstract – A mark point-based image registration method, comprising: inputting two medical images in any mode; extracting pyramid features of the two input images by using a pre-trained neural network, wherein the training process of the network comprises a plurality of different tasks and relates to a plurality of different input modes; extracting the pyramid features by using the neural network, and obtaining a plurality of matching point pairs representing certain semantics between the two images by means of the processes of searching, screening, matching and the like; fitting a transformation matrix and a displacement vector of rigid registration by minimizing the sum of point distances between all the matching point pairs, to obtain a medical image Warped image after the rigid registration; and on the basis of the rigid registration, obtaining a displacement field three-dimensional matrix of non-rigid registration by means of an interpolation method based on a radial basis, to obtain a medical image Warped image after the non-rigid registration. Therefore, the method can effectively improve the image registration effect.			
WO2021/259393A2	Image processing method and apparatus, and electronic device	BEIJING ANDE YIZHI TECHNOLOGY	30/12/2021
Summary/Abstract – The present disclosure relates to an image processing method and apparatus, and an electronic device. The method comprises: acquiring a medical image to be processed; inputting the medical image into a network module, and using the network module to acquire classification information of at least one type of preset lesions in the medical image, wherein the network module is trained and can detect the preset lesions, and the network module comprises at least two classifiers; and during the process of training the network module, adjusting the weight of an (i+1)th classifier for a training sample according to a classification result of an i-th classifier for the training sample, wherein i is an integer greater than 1 and less than or equal to n, and n represents the number of classifiers. According to the embodiments of the present disclosure, the prediction of a variety of diseases can be realized.			
WO2022/057078A1	Real-time colonoscopy image segmentation method and device based on ensemble and knowledge distillation	SHENZHEN UNIVERSITY	24/03/2022

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – Disclosed in the present invention are a real-time colonoscopy image segmentation method and device based on ensemble and knowledge distillation. The method comprises: acquiring a plurality of training images, the training images being classified into a plurality training image sets, and the training images in the same training image set being from the same data set; first training teacher models, different teacher models obtaining first segmented images respectively according to different training image sets; and then extracting a student model by using trained teacher models jointly. The training images are colonoscopy image screenshots, and a trained student model can generate a real-time colonoscopy image segmented image according to a real-time colonoscopy image. Therefore, the problem that data sets among different hospitals are discontinuous and cannot be collected together to train a colonoscopy automatic image segmentation model is solved.			
EP3246875A2	Method and system for image registration using an intelligent artificial agent	SIEMENS HEALTHCARE	22/11/2017
Summary/Abstract – Methods and systems for image registration using an intelligent artificial agent are disclosed. In an intelligent artificial agent based registration method, a current state observation of an artificial agent is determined based on the medical images to be registered and current transformation parameters. Action-values are calculated for a plurality of actions available to the artificial agent based on the current state observation using a machine learning based model, such as a trained deep neural network (DNN). The actions correspond to predetermined adjustments of the transformation parameters. An action having a highest action-value is selected from the plurality of actions and the transformation parameters are adjusted by the predetermined adjustment corresponding to the selected action. The determining, calculating, and selecting steps are repeated for a plurality of iterations, and the medical images are registered using final transformation parameters resulting from the plurality of iterations.			
EP3316808A1	Surgical system with user adaptable techniques employing simultaneous energy modalities based on tissue parameters	CILAG INTERNATIONAL	09/05/2018
Summary/Abstract – Various forms are directed to systems and methods for dissection and coagulation of tissue. A surgical instrument includes an end effector configured to dissect and seal tissue at a distal end thereof, and a generator that is electrically coupled to the surgical instrument and that is configured to deliver energy to the end effector. The surgical instrument includes an end effector configured to interact with a tissue at a distal end thereof, a generator electrically coupled to the surgical instrument and configured to deliver radio frequency (RF) energy and ultrasonic energy to the end effector to allow the end effector to interact with the tissue. The energy delivered to the end effector switches between RF energy and ultrasonic energy based on a determination of various factors such as tissue impedance.			
WO2022/222458A1	Artificial intelligence-assisted diagnosis model construction system for medical images	UNIVERSITY WENZHOU MEDICAL	27/10/2022

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – The present invention provides an artificial intelligence-assisted diagnosis model construction system for medical images, comprising a data center module, a data desensitization module, a data preprocessing module, and a model construction module which are connected in sequence. The data center module receives and stores image data and corresponding labels thereof; the data desensitization module performs desensitization processing on each piece of image data to remove privacy information; the data preprocessing module converts all image data formats without privacy information into image formats, and inputs the image formats into corresponding preprocessing pipelines for data processing; and the model construction module divides the preprocessed image data into training and verification samples, imports the training and verification samples into a pre-training model integrated on the basis of a federated machine learning method for training and verification, and obtains a final artificial intelligence-assisted diagnosis mode. By implementing the present invention, the problems that most existing models cannot be updated on the basis of latest clinical data after being constructed, and data discharge safety and non-universality are caused can be solved.			
WO2022/121160A1	Method for enhancing quality and resolution of ct images based on deep learning	SUBTLE INTELLIGENT TECHNOLOGY	16/06/2022
Summary/Abstract – Disclosed in the present invention is a method for enhancing the quality and resolution of CT images based on deep learning, comprising the following steps: S1: pre-processing collected clinical data to obtain a data set; S2: building a deep learning model comprising a generative network, a decider network, and a cognitive network; S3: building a loss function; S4: using the data set and the loss function to update the parameters of the iterative generative network in order to obtain a trained deep learning model; and S5: inputting a low-quality low-resolution image into the trained deep learning model to obtain a high-quality high-resolution image. The present invention builds a deep learning model based on deep learning and pre-processes clinical data to obtain a data set, reducing the impact of spatial misalignment of data collected at different times due to movement of the patient or other reasons; by means of the deep learning model combined with the loss function, end-to-end processing of the two tasks of enhancing CT image quality and super-resolution can be implemented to directly obtain final results.			
WO2022/100417A1	Interpretation method and apparatus for medical auxiliary decision-making model, and storage medium and electronic device	YIDU CLOUD BEIJING TECHNOLOGY	19/05/2022
Summary/Abstract – Provided are an interpretation method and apparatus for a medical auxiliary decision-making model, and a storage medium and an electronic device, which relate to the technical field of big data processing. The method comprises: acquiring input data of a medical auxiliary decision-making model and a data prediction result corresponding to the input data, and generating a feature subset according to sub-features comprised in the input data (S110); combining target features comprised in the feature subset to obtain feature pairs, and mining value ranges of feature values of the target features comprised in the feature pairs, so as to obtain a candidate value range of each target feature (S120); fusing a value range to be fused to the current value range, which corresponds to the target features, in a preset initial rule library, so as to obtain a target rule library; and matching, in the target rule library, a decision-making path from the input data to a prediction result, and interpreting the medical auxiliary decision-making model according to a target rule comprised in the decision-making path (S140). Thus, the interpretability of the medical auxiliary decision-making model is enhanced.			

Publication Number	Title (English)	Assignee	Publication Date
WO2022/083124A1	Personalized diabetes health management system and device, and storage medium	PING AN TECHNOLOGY SHENZHEN	28/04/2022
Summary/Abstract – Provided are a personalized diabetes health management system and device, and a storage medium. The system comprises: a data collection unit used for acquiring the mode in which a patient is in and collecting blood glucose data of time-series changes of the patient in said mode, the mode comprising sleep, diet, exercise and leisure modes; a blood glucose prediction unit used for inputting the blood glucose data into a blood glucose prediction model to predict and output a predicted blood glucose value in a future period of time, wherein the blood glucose prediction model is obtained by training by means of using the patient's own data in the mode; and a comparison unit used for comparing the predicted blood glucose value with a preset abnormal blood glucose threshold, wherein if the predicted blood glucose value exceeds the abnormal blood glucose threshold, an early warning reminder is issued. Personalized diabetes health management can be achieved, the management is more comprehensive, and blood glucose warning information is more accurate.			
WO2022/041727A1	Question and answer management method, apparatus, and device for medical inquiry system, and storage medium	KANG JIAN INFORMATION TECHNOLOGY SHENZHEN	03/03/2022
Summary/Abstract – A question and answer management method, apparatus, and device for a medical inquiry system, and a storage medium, applied to the field of wisdom medical treatment and capable of reducing the online misdiagnosis rate. The method comprises: obtaining target feature data from a target terminal; calling a preset neural network pre-classification model to pre-classify the target feature data; if the target feature data is a first type of data, calling a preset knowledge graph model and the first type of data to perform medical graph reasoning to generate first diagnosis suggestion data and send same to the target terminal; if the target feature data is a second type of data, performing medical graph query according to a preset knowledge graph decision tree model and the second type of data to generate multiple supplemental problems and send same to the target terminal; generating electronic medical record data; and calling the neural network pre-classification model to reperform pre-classification processing on the electronic medical record data until second diagnosis suggestion data is generated and sent to the target terminal.			
WO2022/057306A1	Medical image data amplification method, apparatus, computer device, and medium	PINGAN INTERNATIONAL SMART CITY TECHNOLOGY	24/03/2022
Summary/Abstract – The present application relates to the field of artificial intelligence, is applied to the field of smart medical care, and discloses a medical image data amplification method, apparatus, medium, and electronic device. The method comprises: using normal medical-image sample data and abnormal medical-image sample data from a sample data set to train a base model to obtain a first model; selecting a data amplification strategy from a data amplification strategy set as a candidate data amplification strategy, and using the candidate data amplification strategy to amplify at least the sample data set to generate a set of sample data; using sets of sample data to train the first model to obtain each trained recognition model; determining performance indicators of each trained recognition model; according to the performance indicators, determining a target data amplification strategy among the candidate data amplification strategies; using the target data amplification strategy to amplify the sample data set. The method enables the amplification of medical image data and improves the quality of the amplified medical image data.			

Publication Number	Title (English)	Assignee	Publication Date
EP3240475A1	Efficiently encoding and compressing ecg data optimized for use in an ambulatory ecg monitor	BARDY DIAGNOSTICS	08/11/2017

Summary/Abstract – A method (200) for efficiently encoding and compressing ECG data optimized for use in an ambulatory electrocardiography monitor is provided. ECG data is first encoded and compressed (202) in a lossy process and further encoded and compressed (203) in a lossless process. A compression ratio significantly higher than other Holter-type monitors is achieved. Requirements for storage space and power cell consumption are reduced, contributing to the long-term availability of the monitor.

8.3 BIOTECHNOLOGY & CHEMISTRY AI PATENTS

The following section of the report highlights exemplar AI-related patents which we consider to be key in the biotechnology and chemistry sectors. Key patents relate to machine learning for environmentally controlled vertical farming system, and crop health monitoring, assessment and prediction. AI has also had a profound impact on the monitoring of bioreactors, genomic engineering, hydraulic fracturing and natural resource exploration using microbial/genetic information.

Key Patent Results
(Biotech & Chemistry)

Publication Number	Title (English)	Assignee	Publication Date
US20220121884A1	System and method for extremely efficient image and pattern recognition and artificial intelligence platform	Z ADVANCED COMPUTING	21/04/2022
Summary/Abstract – Specification covers new algorithms, methods, and systems for: Artificial Intelligence; the first application of General-AI (versus Specific, Vertical, or Narrow-AI) (as humans can do) (which also includes Explainable-AI or XAI); addition of reasoning, inference, and cognitive layers/engines to learning module/engine/layer; soft computing; Information Principle; Stratification; Incremental Enlargement Principle; deep-level/detailed recognition, e.g., image recognition (e.g., for action, gesture, emotion, expression, biometrics, fingerprint, tilted or partial-face, OCR, relationship, position, pattern, and object); Big Data analytics; machine learning; crowd-sourcing; classification; clustering; SVM; similarity measures; Enhanced Boltzmann Machines; Enhanced Convolutional Neural Networks; optimization; search engine; ranking; semantic web; context analysis; question-answering system; soft, fuzzy, or un-sharp boundaries/impreciseness/ambiguities/fuzziness in class or set, e.g., for language analysis; Natural Language Processing (NLP); Computing-with-Words (CWW); parsing; machine translation; music, sound, speech, or speaker recognition; video search and analysis (e.g. “intelligent tracking”, with detailed recognition); image annotation; image or color correction; data reliability; Z-Number; Z-Web; Z-Factor; rules engine; playing games; control system; autonomous vehicles or drones; self-diagnosis and self-repair robots; system diagnosis; medical diagnosis/images; genetics; drug discovery; biomedicine; data mining; event prediction; financial forecasting (e.g., for stocks); economics; risk assessment; fraud detection (e.g., for cryptocurrency); e-mail management; database management; indexing and join operation; memory management; data compression; event-centric social network; social behavior; drone/satellite vision/navigation; smart city/home/appliances/IoT; and Image Ad and Referral Networks, for e-commerce, e.g., 3D shoe recognition, from any view angle.		
EP4046159A1	Methods for automated chromosome analysis	METASYSTEMS HARD & SOFTWARE	24/08/2022
Summary/Abstract – An automated or semi-automated process to prepare karyotypes from metaphase cell images with improved accuracy involves the use of deep convoluted neural networks for both chomosome segmentation and chromosone classification.			

Publication Number	Title (English)	Assignee	Publication Date
US20220027706A1	Membrane fouling warning method based on knowledge-fuzzy learning algorithm	BEIJING UNIVERSITY OF TECHNOLOGY	27/01/2022
Summary/Abstract – An intelligent warning method based on knowledge-fuzzy learning algorithm is designed for membrane fouling with high accuracy. A multi-step prediction strategy, using the least-squares linear regression model, is developed to predict the characteristic variables of membrane fouling Meanwhile, the knowledge of membrane fouling category, which is extracted from the real wastewater treatment process, can be expressed as the form of fuzzy rules. Moreover, a knowledge-based fuzzy neural network is designed to establish the membrane fouling warning model, thus deal with the problem of difficult warning of membrane fouling. The results reveal that the intelligent warning method can improve the ability to solve the membrane fouling, mitigate the deleterious effect on the process performance and ensure the safety operation of the wastewater treatment process.			
US20200333295A1	Enhanced non-destructive testing in directed energy material processing	RESEARCH FOUNDATION OF SUNY	22/10/2020
Summary/Abstract – A system and method for measuring characteristics, comprising: a directed energy source having an energy output which changes over time, incident on an object undergoing additive manufacturing; a sensor configured to measure a dynamic thermal response of at least a portion of the object undergoing additive manufacturing proximate to a directed location of the directed energy source over time with respect distance from the directed location; and at least one processor, configured to analyze the measured dynamic thermal response to determine presence of a manufacturing defect in the object undergoing additive manufacturing, before completion of manufacturing.			
EP3755139A1	Controlled agricultural system and method for agriculture	FLUENCE BIOENGINEERING	30/12/2020
Summary/Abstract – The present disclosure relates to the control of an agricultural system, for example, control of a growth area (350) having a plurality of growth locations (404) for growing a plants, wherein a distance between the growth locations (404) is adjustable. Furthermore, the disclosure relates to a method for agriculture.			
US20190145251A1	Hydraulic fracturing	SHEAR FRAC GROUP	16/05/2019
Summary/Abstract – A system and method of hydraulic fracturing a geological formation in Earth's crust, including injecting fracing fluid through a wellbore into the geological formation, measuring pressure associated with the hydraulic fracturing, determining net stress of the geological formation from the hydraulic fracturing, and determining presence of complex shear fracturing or complex shear fractures correlative with the net stress.			
EP3622519A1	Deep learning-based aberrant splicing detection	ILLUMINA	18/03/2020

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – The technology disclosed relates to constructing a convolutional neural network-based classifier for variant classification. In particular, it relates to training a convolutional neural network-based classifier on training data using a backpropagation-based gradient update technique that progressively match outputs of the convolutional network network-based classifier with corresponding ground truth labels. The convolutional neural network-based classifier comprises groups of residual blocks, each group of residual blocks is parameterized by a number of convolution filters in the residual blocks, a convolution window size of the residual blocks, and an atrous convolution rate of the residual blocks, the size of convolution window varies between groups of residual blocks, the atrous convolution rate varies between groups of residual blocks. The training data includes benign training examples and pathogenic training examples of translated sequence pairs generated from benign variants and pathogenic variants.			
US10255670B1	Image sensor and module for agricultural crop improvement	DOLLY & WU	09/04/2019
Summary/Abstract – An example machinery includes a crop management motorized vehicle having an intelligent, modularized image sensor (e.g. camera or video) system that is portable to other crop management vehicles such as a combine, planter or a tillage machine. The image sensor system includes a framework having a bank of procedures for monitoring and control of navigation, spray application, weeding, seeding, machine configuration, and so on, in real time as the machines go through a crop field throughout a crop cycle. One example implementation includes electronic circuits, with more than one set mounted on a platform that facilitates moving the setup to other agricultural machines. The framework captures, preserves and corrects the captured images for real time analysis and response, and for crop yield analysis that is correlated with the machine settings and crop management practices.			
EP3669377A1	Disease-associated microbiome characterization process	PSOMAGEN	24/06/2020
Summary/Abstract – Embodiments of a method and/or system for characterizing one or more microorganism-related conditions can include: determining a microorganism dataset associated with a set of subjects; and with a set of microbiome characterization modules, applying analytical techniques to perform a characterization process for the one or more microorganism-related conditions based on the microorganism dataset.			
EP3635640A1	Real-time adaptive control of additive manufacturing processes using machine learning	RELATIVITY SPACE	15/04/2020
Summary/Abstract – Disclosed herein are machine learning-based methods and systems for automated object defect classification and adaptive, real-time control of additive manufacturing and/or welding processes.			
US20170159045A1	Microbial strain improvement by a htp genomic engineering platform	ZYMERGEN	08/06/2017
Summary/Abstract – The present disclosure provides a HTP microbial genomic engineering platform that is computationally driven and integrates molecular biology, automation, and advanced machine learning protocols. This integrative platform utilizes a suite of HTP molecular tool sets to create HTP genetic design libraries, which are derived from, inter alia, scientific insight and iterative pattern recognition. The HTP genomic engineering platform described herein is microbial strain host agnostic and therefore can be implemented across taxa. Furthermore, the disclosed platform can be implemented to modulate or improve any microbial host parameter of interest.			

Publication Number	Title (English)	Assignee	Publication Date
US20180093418A1	Three-dimensional objects and their formation	VELO3D	05/04/2018
Summary/Abstract – The present disclosure provides three-dimensional (3D) methods, apparatuses, software (e.g., non-transitory computer readable medium), and systems for the formation of at least one desired 3D object; comprising use of a geometric model, a physics based model, one or more markers, one or more modes, or any combination thereof. The disclosure provides reduction of deformation that may be caused by the forming process of the 3D object.			
US20180014471A1	Vertical growth tower and module for an environmentally controlled vertical farming system	MJNN	18/01/2018
Summary/Abstract – A multi-stage, plant growing system is configured for high density growth and crop yields and includes among other things, towers or vertical growth columns, an enclosed controlled environmental growth chamber, interchangeable growth modules, and control systems capable of machine learning wherein the crops are optimally spaced and continually staged in their planting cycles utilizing special growth modules to provide an accelerated and continuous annual production yield. A vertical growth tower for vertical farming comprising a plurality of growth modules, each growth module comprising an enclosure configured to securely hold at least one plant; a drain aperture in the enclosure; and at least one lateral growth opening in the enclosure configured to permit and to encourage lateral growth of the at least one plant away from the enclosure; wherein one or more of the growth modules is configured to stackably support one or more of the other growth modules above and/or below itself within the vertical growth tower.			
US20180310828A1	Reflective mode multi-spectral time-resolved optical imaging methods and apparatuses for tissue classification	SPECTRAL	01/11/2018
Summary/Abstract – Certain aspects relate to apparatuses and techniques for non-invasive optical imaging that acquires a plurality of images corresponding to both different times and different frequencies. Additionally, alternatives described herein are used with a variety of tissue classification applications, including assessing the presence and severity of tissue conditions, such as burns and other wounds.			
US20220107298A1	Systems and methods for crop health monitoring, assessment and prediction	ECOATION INNOVATIVE SOLUTIONS	07/04/2022
Summary/Abstract – Systems and methods for monitoring and assessing crop health and performance can provide rapid screening of individual plants. The systems and methods have an automated component, and rely primarily on the detection and interpretation of plant-based signals to provide information about crop health. In some cases knowledge from human experts is captured and integrated into the automated crop monitoring systems and methods. Predictive models can also be developed and used to predict future health of plants in a crop.			
EP3278115A2	Instrument and system for rapid microorganism identification and antimicrobial agent susceptibility testing	ACCELERATE DIAGNOSTICS	07/02/2018

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – A system for automated microorganism identification and antibiotic susceptibility testing comprising a reagent cartridge, a reagent stage, a cassette, a cassette, stage, a pipettor assembly, an optical detection system, and a controller is disclosed. The system is designed to dynamically adjust motor idle torque to control heat load and employs a fast focus process for determining the true focus position of an individual microorganism. The system also may quantify the relative abundance of viable microorganisms in a sample using dynamic dilution, and facilitate growth of microorganisms in customized media for rapid, accurate antimicrobial susceptibility testing.			
EP3090029A2	Microbiome based systems, apparatus and methods for the exploration and production of hydrocarbons	BIOTA TECHNOLOGY	09/11/2016
Summary/Abstract – There are provided methods, systems and processes for the utilization of microbial and related genetic information for use in the exploration, determination, production and recovery of natural resources, including energy sources, and the monitoring, control and analysis of processes and activities.			
WO2015/065964A1	Functional genomics using crispr-cas systems, compositions, methods, screens and applications thereof	BROAD INSTITUTE OF MIT & HARVARD	07/05/2015
Summary/Abstract – The present invention generally relates to libraries, kits, methods, applications and screens used in functional genomics that focus on gene function in a cell and that may use vector systems and other aspects related to Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)-Cas systems and components thereof. The present invention also relates to rules for making potent single guide RNAs (sgRNAs) for use in CRISPR-Cas systems. Provided are genomic libraries and genome wide libraries, kits, methods of knocking out in parallel every gene in the genome, methods of selecting individual cell knock outs that survive under a selective pressure, methods of identifying the genetic basis of one or more medical symptoms exhibited by a patient, and methods for designing a genome-scale sgRNA library.			
EP3030400A1	Automatic process control of additive manufacturing device	MIT - MASSACHUSETTS INSTITUTE OF TECHNOLOGY	15/06/2016
Summary/Abstract – Automatic process control of additive manufacturing. The system includes an additive manufacturing device for making an object (16) and a local network computer controlling the device. At least one camera (10) is provided with a view of a manufacturing volume of the device to generate network accessible images of the object (16). The computer is programmed to stop the manufacturing process when the object (16) is defective based on the images of the object (16).			
EP4022281A1	Methods and systems for droplet manipulation	VOLTA LABS	06/07/2022
Summary/Abstract – Described herein are systems and methods for processing at least one biological sample. The systems and methods may process the biological sample, or plurality thereof, using at least one droplet. The droplet, or plurality thereof, may be manipulated using the systems and methods described herein.			

8.4 ENGINEERING & TRANSPORT AI PATENTS

The following section of the report highlights exemplar AI-related patents which we consider to be key in the engineering industries. AI innovation is having a most significant impact on intelligent diagnosis systems for structural defects, autonomous vehicle control and machine learning systems for controlling robots.

Key Patent Results
(Engineering)

Publication Number	Title (English)	Assignee	Publication Date
US20210396842A1	Multi-scale inspection and intelligent diagnosis system and method for tunnel structural defects	SHANDONG UNIVERSITY	23/12/2021
Summary/Abstract –A multi-scale inspection and intelligent diagnosis system and method for tunnel structural defects includes: a traveling section; a supporting section, disposed on the traveling section, and including a rotatable telescopic platform, where two mechanical arms working in parallel are disposed on the rotatable telescopic platform; an inspection section, mounted on the supporting section, and configured to perform multi-scale inspection on surface defects and internal defects in different depth ranges of a same position of a tunnel structure, and transmit inspected defect information to a control section; and the control section, configured to: construct a deep neural network-based defect diagnosis model; construct a data set by using historical surface defect and internal defect information, and train the deep neural network-based defect diagnosis model; and receive multi-scale inspection information in real time, and automatically recognize types, positions, contours, and dielectric attributes of the internal and surface defects.			
WO2022/141669A1	Bearing fault diagnosis method for dynamic joint distribution alignment network under variable working conditions	SOOCHOW UNIVERSITY	07/07/2022

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract –A bearing fault diagnosis method for a dynamic joint distribution alignment network under variable working conditions, comprising the following steps: collecting bearing vibration data under different working conditions to obtain a source domain sample and a target domain sample (S1); constructing a deep convolutional neural network model for dynamic joint distribution alignment (S2); simultaneously feeding the source domain sample and the target domain sample into a parameter-initialized deep convolutional neural network model, so that a feature extractor extracts high-level features of the source domain sample and the target domain sample, and calculates a marginal distribution distance and a conditional distribution distance (S3); obtaining a joint distribution distance according to the marginal distribution distance and the conditional distribution distance, and combining the joint distribution distance with label loss to obtain an objective function (S4); optimizing the objective function by using a stochastic gradient descent method, and training the deep convolutional neural network model to obtain an optimized deep convolutional neural network model (S5); and inputting the target domain sample into the optimized deep convolutional neural network model to obtain a predicted label of a target domain, and comparing the predicted label of the target domain with a true label of the target domain to obtain diagnosis accuracy (S6). The method can reduce the influence of domain drift, so that a deep learning model can well complete a fault diagnosis task under variable working conditions; moreover, the speed is high, and the calculation amount is small.			
US20180032082A1	Machine learning navigational engine with imposed constraints	MOBILEYE VISION TECHNOLOGIES	01/02/2018
Summary/Abstract –Systems and methods are provided for navigating an autonomous vehicle using reinforcement learning techniques. In one implementation, a navigation system for a host vehicle may include at least one processing device programmed to: receive, from a camera, a plurality of images representative of an environment of the host vehicle; analyze the plurality of images to identify a navigational state associated with the host vehicle; provide the navigational state to a trained navigational system; receive, from the trained navigational system, a desired navigational action for execution by the host vehicle in response to the identified navigational state; analyze the desired navigational action relative to one or more predefined navigational constraints; determine an actual navigational action for the host vehicle, wherein the actual navigational action includes at least one modification of the desired navigational action determined based on the one or more predefined navigational constraints; and cause at least one adjustment of a navigational actuator of the host vehicle in response to the determined actual navigational action for the host vehicle.			
EP4087518A1	Patient-specific medical procedures and devices, and associated systems and methods	CARLSMED	16/11/2022
Summary/Abstract –Systems and methods for designing and implementing patient-specific surgical procedures and/or medical devices are disclosed. In some embodiments, a method includes receiving a patient data set of a patient. The patient data set is compared to a plurality of reference patient data sets, wherein each of the plurality of reference patient data sets is associated with a corresponding reference patient. A subset of the plurality of reference patient data sets is selected based, at least partly, on similarity to the patient data set and treatment outcome of the corresponding reference patient. Based on the selected subset, at least one surgical procedure or medical device design for treating the patient is generated.			
WO2022/053001A1	Weld seam internal defect intelligent detection device and method, and medium	SHANGHAI SPACEFLIGHT PREC MACHINERY INSTITUTE	17/03/2022

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract –A weld seam internal defect intelligent detection device and method, and a detection medium. An X-ray is emitted by an X-ray tube to perform radiographic inspection, an optical image is achieved by means of an optical path simulation and control unit, and a digital image containing weld seam internal quality information is obtained on an imaging plate. The generated image is automatically uploaded to a cloud platform server, undergoes intelligent pre-processing using digital image processing technologies and deep leaning neural network algorithms, and is analyzed to determine defect existence, defect position, defect type and defect rating. Thus the quality detection of the image presented is achieved. The weld seam detection of a complex structure is accurately controlled during the detection process. Manual assessment is replaced by intelligent defect recognition during the image evaluation process, the length of manual detection is effectively shortened, and the efficiency of weld seam quality detection is improved, while the accuracy of defect recognition is guaranteed.			
US20200371509A1	Manufacturing optimization using a multi-tenant machine learning platform	MARKFORGED	26/11/2020
Summary/Abstract –Techniques for manufacturing optimization using a multi-tenant machine learning platform are disclosed. A method for manufacturing optimization includes: obtaining physical sensor data, by a manufacturing device associated with a tenant of a multi-tenant machine learning platform; determining, by a machine learning spoke system associated with the tenant, a machine learning parameter based on at least the physical sensor data; preventing exposure of the first physical sensor data of the first manufacturing device to any other tenant of the multi-tenant machine learning platform; transmitting the machine learning parameter from the machine learning spoke system to a machine learning hub system of the multi-tenant machine learning platform; and updating, by the machine learning hub system, a multi-tenant machine learning model based at least on the machine learning parameter.			
EP3947080A1	Autonomous vehicle system	INTEL	09/02/2022
Summary/Abstract –An apparatus comprising at least one interface to receive a signal identifying a second vehicle in proximity of a first vehicle; and processing circuitry to obtain a behavioral model associated with the second vehicle, wherein the behavioral model defines driving behavior of the second vehicle; use the behavioral model to predict actions of the second vehicle; and determine a path plan for the first vehicle based on the predicted actions of the second vehicle.			
US20200225673A1	Obstacle recognition method for autonomous robots	AI	16/07/2020
Summary/Abstract –Provided is a method including capturing, by an image sensor disposed on a robot, images of a workspace; obtaining, by a processor of the robot or via the cloud, the captured images; comparing, by the processor of the robot or via the cloud, at least one object from the captured images to objects in an object dictionary; identifying, by the processor of the robot or via the cloud, a class to which the at least one object belongs using an object classification unit; and instructing, by the processor of the robot, the robot to execute at least one action based on the object class identified.			
US20190384303A1	Behavior-guided path planning in autonomous machine applications	NVIDIA	19/12/2019

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract –In various examples, a machine learning model—such as a deep neural network (DNN)—may be trained to use image data and/or other sensor data as inputs to generate two-dimensional or three-dimensional trajectory points in world space, a vehicle orientation, and/or a vehicle state. For example, sensor data that represents orientation, steering information, and/or speed of a vehicle may be collected and used to automatically generate a trajectory for use as ground truth data for training the DNN. Once deployed, the trajectory points, the vehicle orientation, and/or the vehicle state may be used by a control component (e.g., a vehicle controller) for controlling the vehicle through a physical environment. For example, the control component may use these outputs of the DNN to determine a control profile (e.g., steering, decelerating, and/or accelerating) specific to the vehicle for controlling the vehicle through the physical environment.			
EP3636507A1	Comfort responsibility sensitivity safety model	MOBILEYE VISION TECHNOLOGIES	15/04/2020
Summary/Abstract –An autonomous system may selectively displace human driver control of a host vehicle. The system may receive an image representative of an environment of the host vehicle and detect an obstacle in the environment of the host vehicle based on analysis of the image. The system may monitor a driver input to a throttle, brake, and/or steering control associated with the host vehicle. The system may determine whether the driver input would result in the host vehicle navigating within a proximity buffer relative to the obstacle. If the driver input would not result in the host vehicle navigating within the proximity buffer, the system may allow the driver input to cause a corresponding change in one or more host vehicle motion control systems. If the driver input would result in the host vehicle navigating within the proximity buffer, the system may prevent the driver input from causing the corresponding change.			
US20210224556A1	Real-time detection of lanes and boundaries by autonomous vehicles	NVIDIA	22/07/2021
Summary/Abstract –In various examples, sensor data representative of an image of a field of view of a vehicle sensor may be received and the sensor data may be applied to a machine learning model. The machine learning model may compute a segmentation mask representative of portions of the image corresponding to lane markings of the driving surface of the vehicle. Analysis of the segmentation mask may be performed to determine lane marking types, and lane boundaries may be generated by performing curve fitting on the lane markings corresponding to each of the lane marking types. The data representative of the lane boundaries may then be sent to a component of the vehicle for use in navigating the vehicle through the driving surface.			
US20220101635A1	Object detection and detection confidence suitable for autonomous driving	NVIDIA	31/03/2022
Summary/Abstract –In various examples, detected object data representative of locations of detected objects in a field of view may be determined. One or more clusters of the detected objects may be generated based at least in part on the locations and features of the cluster may be determined for use as inputs to a machine learning model(s). A confidence score, computed by the machine learning model(s) based at least in part on the inputs, may be received, where the confidence score may be representative of a probability that the cluster corresponds to an object depicted at least partially in the field of view. Further examples provide approaches for determining ground truth data for training object detectors, such as for determining coverage values for ground truth objects using associated shapes, and for determining soft coverage values for ground truth objects.			
US20190179317A1	Controlling vehicle sensors using an attention model	LAZR	13/06/2019

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – A non-transitory computer-readable medium stores instructions executable by one or more processors to implement a sensor control architecture for controlling at least a first sensor of a vehicle. The sensor control architecture is configured to receive sensor data generated by one or more sensors of the vehicle. The one or more sensors are configured to sense an environment through which the vehicle is moving. The sensor control architecture is also configured to determine, based on the received sensor data and using an attention model that is trained using a machine learning technique, one or more sensor settings, and to cause one or more sensor parameters of the first sensor to be adjusted in accordance with the determined sensor settings. The one or more sensor parameters include at least one sensor parameter that defines an area of focus for the first sensor.			
EP3707572A1	Systems and methods for safe and reliable autonomous vehicles	NVIDIA	16/09/2020
Summary/Abstract – Autonomous driving is one of the world's most challenging computational problems. Very large amounts of data from cameras, RADARs, LIDARs, and HD-Maps must be processed to generate commands to control the car safely and comfortably in real-time. This challenging task requires a dedicated supercomputer that is energy-efficient and low-power, complex high-performance software, and breakthroughs in deep learning Al algorithms. To meet this task, the present technology provides advanced systems and methods that facilitate autonomous driving functionality, including a platform for autonomous driving Levels 3, 4, and/or 5. In preferred embodiments, the technology provides an end-to-end platform with a flexible architecture, including an architecture for autonomous vehicles that leverages computer vision and known ADAS techniques, providing diversity and redundancy, and meeting functional safety standards. The technology provides for a faster, more reliable, safer, energy-efficient and space-efficient System-on-a-Chip, which may be integrated into a flexible, expandable platform that enables a wide-range of autonomous vehicles, including cars, taxis, trucks, and buses, as well as watercraft and aircraft.			
US20190329421A1	Wireless tag detection and localization by a mobile robot	COBALT ROBOTICS	31/10/2019
Summary/Abstract – A mobile robot is configured for operation in a commercial or industrial setting, such as an office building or retail store. The robot can patrol one or more routes within a building, and can detect violations of security policies by objects, building infrastructure and security systems, or individuals. In response to the detected violations, the robot can perform one or more security operations. The robot can include a removable fabric panel, enabling sensors within the robot body to capture signals that propagate through the fabric. In addition, the robot can scan RFID tags of objects within an area, for instance coupled to store inventory. Likewise, the robot can generate or update one or more semantic maps for use by the robot in navigating an area and for measuring compliance with security policies.			
EP3442320A1	Systems and methods for hazard mitigation	AUTONOMOUS ROADWAY INTELLIGENCE	20/02/2019

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – A system and method to avoid collisions on highways, and to minimize the fatalities, injury, and damage when a collision is unavoidable. The system includes sensor means to detect other vehicles, and computing means to evaluate when a collision is imminent and to determine whether the collision is avoidable. If the collision is avoidable by a sequence of controlled accelerations and decelerations and steering, the system implements that sequence of actions automatically. If the collision is unavoidable, a different sequence is implemented to minimize the overall harm of the unavoidable collision. The system further includes indirect mitigation steps such as flashing the brake lights automatically. An optional post-collision strategy is implemented to prevent secondary collisions, particularly if the driver is incapacitated. Adjustment means enable the driver to set the type and timing of automatic interventions.			
US20200254622A1	Machine learning device, robot system, and machine learning method for learning workpiece picking operation	FANUC	13/08/2020
Summary/Abstract – A machine learning device that learns an operation of a robot for picking up, by a hand unit, any of a plurality of workpieces placed in a random fashion, including a bulk-loaded state, includes a state variable observation unit that observes a state variable representing a state of the robot, including data output from a three-dimensional measuring device that obtains a three-dimensional map for each workpiece, an operation result obtaining unit that obtains a result of a picking operation of the robot for picking up the workpiece by the hand unit, and a learning unit that learns a manipulated variable including command data for commanding the robot to perform the picking operation of the workpiece, in association with the state variable of the robot and the result of the picking operation, upon receiving output from the state variable observation unit and output from the operation result obtaining unit.			
US20170291301A1	Feature detection apparatus and methods for training of robotic navigation	BRAIN	12/10/2017
Summary/Abstract – A robotic device may be operated by a learning controller comprising a feature learning configured to determine control signal based on sensory input. An input may be analyzed in order to determine occurrence of one or more features. Features in the input may be associated with the control signal during online supervised training. During training, learning process may be adapted based on training input and the predicted output. A combination of the predicted and the target output may be provided to a robotic device to execute a task. Feature determination may comprise online adaptation of input, sparse encoding transformations. Computations related to learning process adaptation and feature detection may be performed on board by the robotic device in real time thereby enabling autonomous navigation by trained robots.			
GB2514644A	Supervisor engine for process control	FISHER ROSEMOUNT SYSTEMS	03/12/2014
Summary/Abstract – A first user interface device records the state of its user interface on a server. A second user interface requests the state and replicates the user interface. The user interface devices may be mobile devices or one may be a work station and the other a mobile device. The state information may help user collaboration, a single user with multiple devices or device location. The state information may also be transferred directly from one user device to another. The user interface devices may access process data related to operating a process control plant. The user interface devices may respond to location information by displaying information relevant to their location.			
US20210148987A1	Battery adaptive charging	QNOVO	20/05/2021

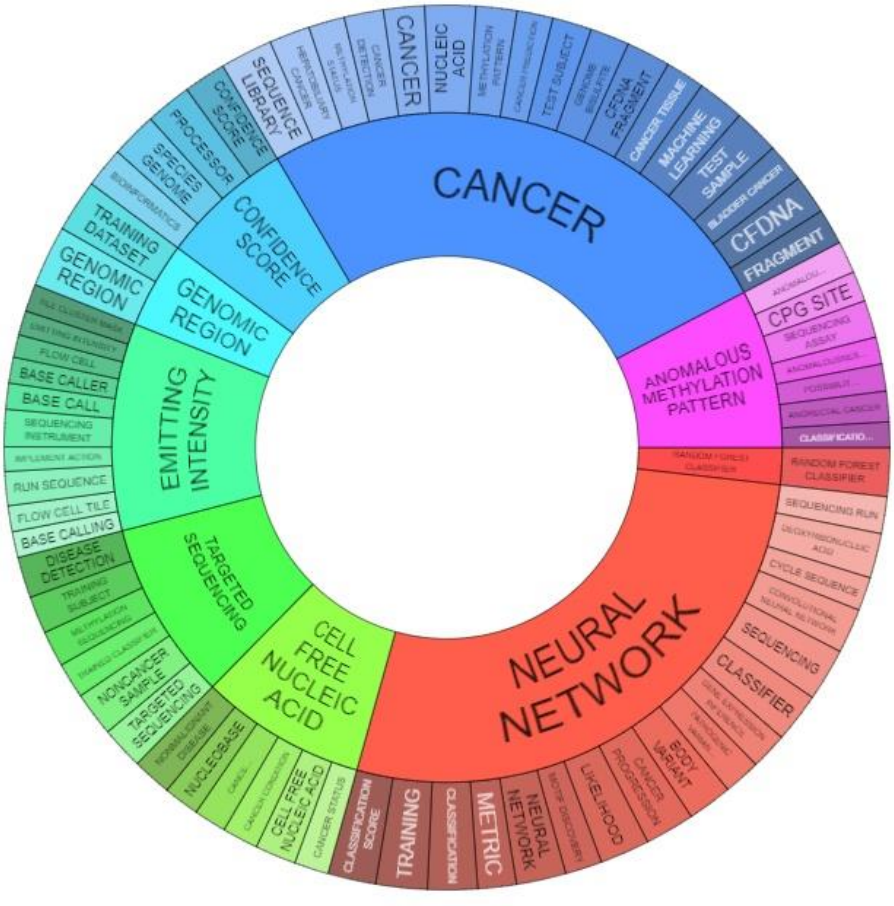
Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – Systems and apparatus may carry out analysis of battery physical phenomena, and characterize batteries based on phenomena occurring in particular time and/or frequency domains. These systems may be additionally responsible for charging and/or monitoring a rechargeable battery. Examples of battery physical phenomena include mass transport (e.g., diffusion and/or migration) in battery electrolytes, mass transport in battery electrodes, and reactions on battery electrodes.			

9 CASE STUDIES

9.1 ILLUMINA

The patent landscape has highlighted Illumina as one of the most influential players in the application of AI in life science. Illumina is a leader in the development of systems for the analysis of genetic variation and biological function. The company's patent portfolio has recently concentrated on applying neural network systems to help decipher the vast amounts of genomic data created by the advancements in sequencing technology, as illustrated by the distribution of the main concepts across the patent portfolio. There appears to be a significant focus on improving our understanding of the genetic causes of disease, such as cancer.

Technologies & applications



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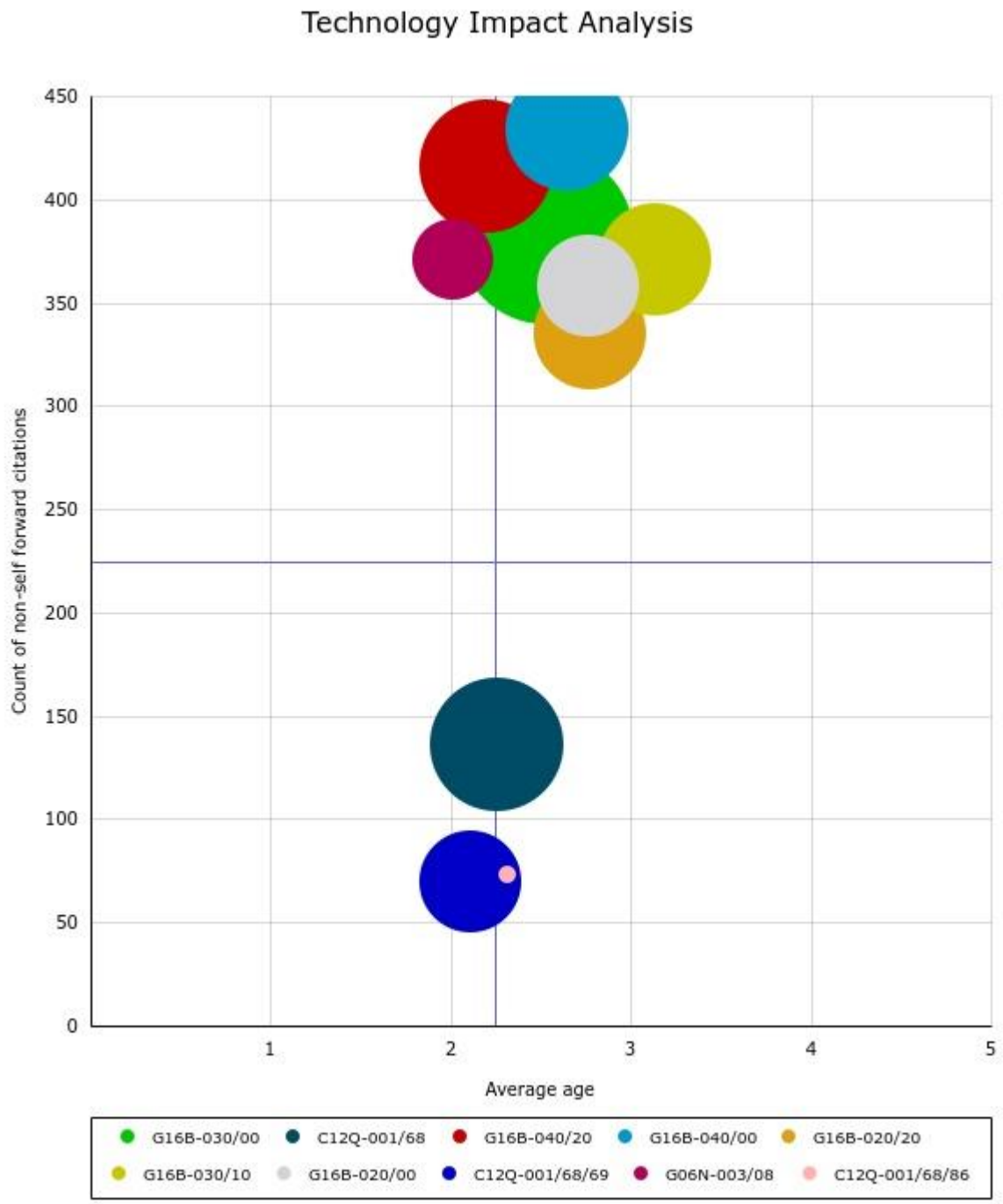
Recently the company developed two key AI platforms, PrimateAI and SpliceAI, wherein PrimateAI is a deep neural network designed to predict mutations that are key in disease pathogenesis, while SpliceAI is an open-source deep learning system that aims to identify previously undetected and noncoding mutations that relate to rare genetic conditions and other diseases. The impact that these

AI tools have had on the medicine and pharmaceuticals patent landscape is demonstrated by the recent collaboration announced with AstraZeneca in 2022, which is aimed at leveraging the capabilities provided by PrimateAI and SpliceAI to help the drug discovery process by identifying key genetic variants in human disease.

The portion of Illumina's patent portfolio relating to ICT specially adapted for bioinformatics-related machine learning or data mining (G16B40/00) and sequence analysis (G16B30/00) has the most significant impact on the patent landscape.



The patents filed by Illumina, which appear to have the most significant impact are listed in the following table. Most notably, within the portfolio the patents that relate to PrimateAI and SpliceAI appear within this list (US20190114544A1 & US20190114391A1). It is also important to note that the company was one of the first to engineer a sequencing-based COVID-19 diagnostic test for the detection of SARS-Cov-2[13], and the company owns patents for methods of diagnosing respiratory pathogens and predicting covid-19 related outcomes (WO2021/262894A1). The strategically significant Illumina patent filings also relate to multi-assay prediction models for cancer detection (US20190316209A1), which led to the release of a pan-cancer companion diagnostic to match patients with rare genetic mutations to targeted therapy, such as Bayer's VITRAKVI® (larotrectinib) for patients with NTRK fusion cancer[14].

Publication Number	Title (English)	Assignee	Publication Date
US20230108241A1	Predicting variant pathogenicity from evolutionary conservation using three-dimensional (3d) protein structure voxels	ILLUMINA	06/04/2023
Summary/Abstract –The technology disclosed relates to determining pathogenicity of nucleotide variants. In particular, the technology disclosed relates to specifying a particular amino acid at a particular position in a protein as a gap amino acid, and specifying remaining amino acids at remaining positions in the protein as non-gap amino acids, generating a gapped spatial representation of the protein that includes spatial configurations of the non-gap amino acids, and excludes a spatial configuration of the gap amino acid, determining an evolutionary conservation at the particular position of respective amino acids of respective amino acid classes based at least in part on the gapped spatial representation, and based at least in part on the evolutionary conservation of the respective amino acids, determining a pathogenicity of respective nucleotide variants that respectively substitute the particular amino acid with the respective amino acids in alternate representations of the protein.			
WO2021/262894A1	Methods for diagnosing respiratory pathogens and predicting covid-19 related outcomes	ILLUMINA SOFTWARE	30/12/2021
Summary/Abstract – Provided by the inventive concept is a DNA methylation-based platform, and machine learning algorithms, for diagnosing respiratory pathogens including SARS-CoV-2 and predicting COVID-19 related outcomes, and methods of using the same, such as in identifying the presence of a viral infection, such as a SARS-CoV-2 infection, determining whether a subject has COVID-19, and/or whether a subject with COVID-19 is likely to develop acute respiratory distress syndrome or multisystem inflammatory syndrome in children.			
US20200365229A1	Model-based featurization and classification	GRAIL (owned by Illumina)	19/11/2020

[13] https://www.illumina.com/company/news-center/blog/first-fda-eua-sequencing-covid-19-test.html

[14] https://investor.illumina.com/news/press-release-details/2022/Illumina-Introduces-New-Pan-Cancer-Companion-Diagnostic-to-Match-Patients-with-Rare-Genetic-Mutations-to-Targeted-Therapy/default.aspx#:~:text=The%20CDx%20pan%2Dcancer%20indication,in%20accordance%20with%20the%20approved

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – In various embodiments, an analytics system uses models to determine features and classification of disease states. A disease state can indicate presence or absence of cancer, a cancer type, or a cancer tissue of origin. The models can include a binary classifier and a tissue of origin classifier. The analytics system can process sequence reads from test biological samples to generate data for training the classifiers. The analytics system can also use combinations of machine learning techniques to train the models, which can include a multilayer perceptron. In some embodiments, the analytics system uses methylation information to train the models to determine predictions regarding disease state.			
US20190316209A1	Multi-assay prediction model for cancer detection	GRAIL (owned by Illumina)	17/10/2019
Summary/Abstract – A predictive cancer model generates a cancer prediction for an individual of interest by analyzing values of one or more types of features that are derived from cfDNA obtained from the individual. Specifically, cfDNA from the individual is sequenced to generate sequence reads using one or more physical assays, examples of which include a small variant sequencing assay, whole genome sequencing assay, and methylation sequencing assay. The sequence reads of the physical assays are processed through corresponding computational analyses to generate each of small variant features, whole genome features, and methylation features. The values of features can be provided to a predictive cancer model that generates a cancer prediction. In some embodiments, the values of different types of features can be separately provided into different predictive models. Each separate predictive model can output a score that can serve as input into an overall model that outputs the cancer prediction.			
US20190114544A1	Semi-supervised learning for training an ensemble of deep convolutional neural networks	ILLUMINA	18/04/2019
Summary/Abstract – The technology disclosed relates to constructing a convolutional neural network-based classifier for variant classification. In particular, it relates to training a convolutional neural network-based classifier on training data using a backpropagation-based gradient update technique that progressively match outputs of the convolutional network network-based classifier with corresponding ground truth labels. The convolutional neural network-based classifier comprises groups of residual blocks, each group of residual blocks is parameterized by a number of convolution filters in the residual blocks, a convolution window size of the residual blocks, and an atrous convolution rate of the residual blocks, the size of convolution window varies between groups of residual blocks, the atrous convolution rate varies between groups of residual blocks. The training data includes benign training examples and pathogenic training examples of translated sequence pairs generated from benign variants and pathogenic variants.			
US20190114391A1	Deep learning-based aberrant splicing detection	ILLUMINA	18/04/2019
Summary/Abstract – The technology disclosed relates to constructing a convolutional neural network-based classifier for variant classification. In particular, it relates to training a convolutional neural network-based classifier on training data using a backpropagation-based gradient update technique that progressively match outputs of the convolutional network network-based classifier with corresponding ground truth labels. The convolutional neural network-based classifier comprises groups of residual blocks, each group of residual blocks is parameterized by a number of convolution filters in the residual blocks, a convolution window size of the residual blocks, and an atrous convolution rate of the residual blocks, the size of convolution window varies between groups of residual blocks, the atrous convolution rate varies between groups of residual blocks. The training data includes benign training examples and pathogenic training examples of translated sequence pairs generated from benign variants and pathogenic variants.			

The impact of the company's research can be observed from later patents citing Illumina's patent portfolio in the drug discovery space. For instance, Synkrino Biotherapeutics has developed an artificial intelligence analysis system of the RNA transcriptome for drug discovery, following on from Illumina patent filings. Similarly, Illumina filings were also cited in a patent held by Genomic Expression (WO2022/240867A1), which relates to the identification and design of cancer therapies based on RNA sequencing. The technology also appears to have played an important role in understanding disease pathology and predicting treatment outcomes, as exemplified by a citation by Hoffmann La Roche (US20210350930A1).

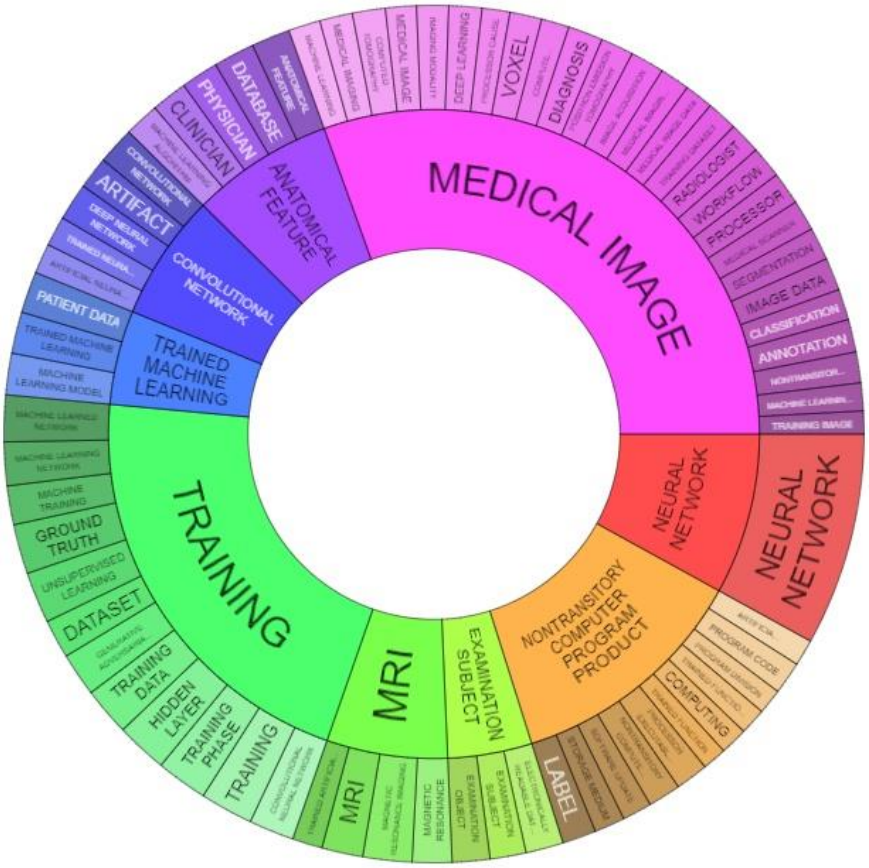
Publication Number	Title (English)	Assignee	Publication Date
WO2022/240867A1	Identification and design of cancer therapies based on rna sequencing	GENOMIC EXPRESSION	17/11/2022
Summary/Abstract – Provided herein are compositions and methods for quantifying the RNA transcription level of one or more genes in biological samples. Such methods can be useful for detecting aberrantly expressed genes, and diagnosing various diseases and conditions, such as a cancer. The methods can also include providing a wellness recommendations, including, for example, a treatment recommendation, suitable therapeutic agent, combination therapy, or clinical trial.			
US20210350930A1	Clinical predictor based on multiple machine learning models	HOFFMANN LA ROCHE	11/11/2021
Summary/Abstract – A method comprises: receiving data corresponding to a plurality of data categories of a patient; selecting, from a plurality of trained machine learning models and based on the plurality of data categories, a first machine learning model and a second machine learning model, the first machine learning model being trained using first data of a first subset of the plurality of data categories and having a first weight indicative of a first performance metric value, the second machine learning model being trained using second data of a second subset of the plurality of data categories and having a second weight indicative of a second performance metric value; generating a first prediction result and a second prediction result using, respectively, the first model and the second model; and generating a combined prediction result based on the first prediction result, the second prediction result, the first weight and the second weight.			
US20230071113A1	Identification of clonal neoantigens and uses thereof	ACHILLES THERAPEUTICS	09/03/2023
Summary/Abstract – A method of treating a subject having been diagnosed as having cancer with an immunotherapy is described. The method comprises targeting one or more clonal neoantigens selected using a method comprising determining whether a tumour-specific mutation is likely to be clonal in a subject. The method comprises providing sequence data from one or more samples from the subject comprising tumour genetic material, the sequence data comprising for each of the one or more samples, and determining the likelihood that the tumour-specific mutation is clonal as a posterior probability depending on: a prior probability of the mutation being clonal, and the probabilities of observing the sequence data if the tumour-specific mutation is (i) clonal and (ii) non-clonal, in view of a tumour fraction for each of the one or more samples and one or more candidate joint genotypes.			
US20210277487A1	Detection of colorectal cancer	UNIVERSAL DIAGNOSTICS (owned by Roche Holding)	09/09/2021

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – The present disclosure provides, among other things, methods for colorectal cancer screening and compositions related thereto. In various embodiments, the present disclosure provides methods for colorectal cancer screening that include analysis of methylation status of one or more methylation biomarkers, and compositions related thereto. In various embodiments, the present disclosure provides methods for colorectal cancer screening that include screening methylation status of one or more methylation biomarkers in cfDNA, e.g., in ctDNA. In various embodiments, the present disclosure provides methods for colorectal cancer screening that include screening methylation status of one or more methylation biomarkers in cfDNA, e.g., in ctDNA, using MSRE-qPCR.			
US20200098017A1	System and method for assessing valuation of document	INNOPLEXUS	26/03/2020
Summary/Abstract – A system and method for assessing valuation of a document. The system includes a server arrangement communicably coupled to a client device. The server arrangement is configured to obtain information pertaining to document and ontologically map to identify relevant entities and semantic inter-relationships between identified entities for the current research work in the document; access information about entities and semantic inter-relationships related to existing research work in technical field from publicly accessible knowledge; compare the entities and the semantic inter-relationships related to the current research work in the document with the entities and the semantic inter-relationships related to existing research work determine a novelty of the document; and determine an assessment value of the document, based on the determined novelty of the document with respect to the publicly accessible knowledge, utilizing an expectation maximization algorithm.			
US20210183472A1	Artificial intelligence analysis of rna transcriptome for drug discovery	SYNKRINO BIOTHERAPEUTICS	17/06/2021
Summary/Abstract – A system and method may be provided to receive sample RNA reads from patients and generate lists of genes and their associated RNA expression levels in each patient. Some of the RNA reads may be matched to an RNA transcript or gene or gene family in terms of their match likelihood and other RNA reads may be matched to an RNA transcript or gene or gene family through the use of one or more machine learning classifiers. A machine learning classifier may be trained based on the plurality of the lists and a plurality of corresponding patients' clinical status data to identify gene patterns that recur with a high degree of frequency in the plurality of the lists. Those gene patterns can be capable of modifying a disease or treatment response and can be targeted for drug/treatment development.			

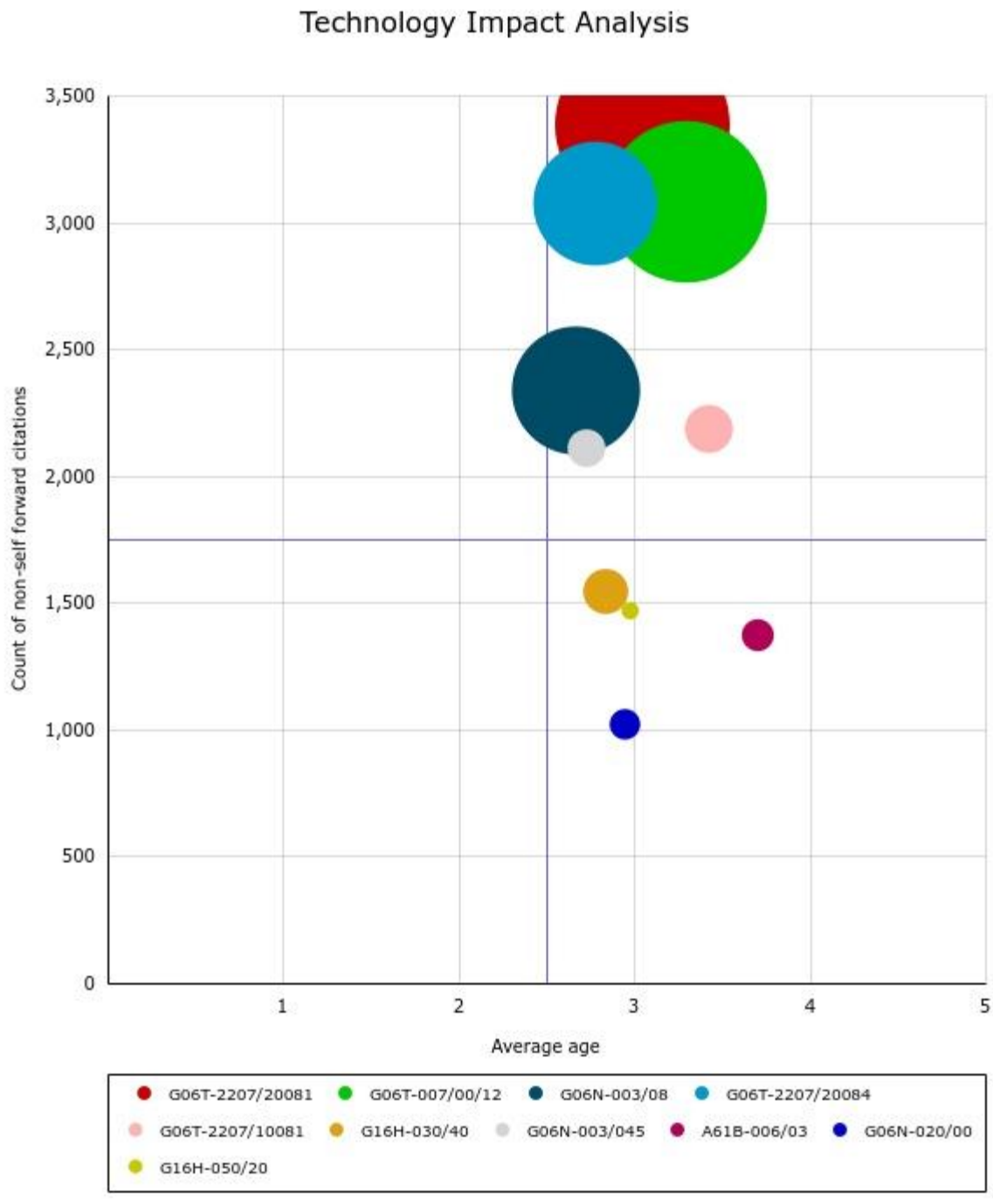
9.2 SIEMENS

The growth in available healthcare data, such as electronic health records, has been the key driver of AI in the healthcare market. This has played an important role in improving patient outcomes, as the demand for diagnostic services is reported to be outpacing the supply of experts in the workforce[3]. Innovation is therefore imperative for sustained growth in the area; Siemens has been highlighted as a key player shaping the medical technology patent landscape. The patent portfolio held by the company primarily relates to the application of AI to medical images, such as magnetic resonance imaging, with significant focus on neural networks and convolutional networks, as illustrated by the distribution of the main concepts across the patent portfolio.

Technologies & applications



The portion of Siemens' patent portfolio relating to biomedical image inspection (G06T7/0012), image analysis learning methods (G06T2207/20081) and artificial neural networks (G06T2207/20084) appears to be having the most significant impact on the patent landscape.



The impact of these areas of research is illustrated through the collaborations between Siemens and numerous hospitals to advance the development of personalised medicine and improve healthcare by developing the capabilities of AI for imaging technologies, as illustrated by the collaboration with Ohio State University Wexner Medical Center[15]. The patents which appear to have the most significant impact are listed in the following table. In particular the company has developed AI capabilities for facilitating the assessment of abnormality patterns associated with covid-19 from x-ray images (US20220022818A1), wherein the portfolio appears to have made a particular impact on the patent landscape by developing intelligent multi-scale medical image landmark detection (US20170116497A1) and systems for approximating deep neural networks for anatomical object detection (US20160328643A1).

Publication Number	Title (English)	Assignee	Publication Date
US20190205606A1	Method and system for artificial intelligence based medical image segmentation	SIEMENS HEALTHCARE	04/07/2019
Summary/Abstract – Methods and systems for artificial intelligence based medical image segmentation are disclosed. In a method for autonomous artificial intelligence based medical image segmentation, a medical image of a patient is received. A current segmentation context is automatically determined based on the medical image and at least one segmentation algorithm is automatically selected from a plurality of segmentation algorithms based on the current segmentation context. A target anatomical structure is segmented in the medical image using the selected at least one segmentation algorithm.			
US20170372193A1	Image correction using a deep generative machine-learning model	SIEMENS HEALTHCARE	28/12/2017
Summary/Abstract – For correction of an image from an imaging system, a deep-learnt generative model is used as a regularlizer in an inverse solution with a physics model of the degradation behavior of the imaging system. The prior model is based on the generative model, allowing for correction of an image without application specific balancing. The generative model is trained from good images, so difficulty gathering problem-specific training data may be avoided or reduced.			
US20170337682A1	Method and system for image registration using an intelligent artificial agent	SIEMENS HEALTHCARE	23/11/2017
Summary/Abstract – Methods and systems for image registration using an intelligent artificial agent are disclosed. In an intelligent artificial agent based registration method, a current state observation of an artificial agent is determined based on the medical images to be registered and current transformation parameters. Action-values are calculated for a plurality of actions available to the artificial agent based on the current state observation using a machine learning based model, such as a trained deep neural network (DNN). The actions correspond to predetermined adjustments of the transformation parameters. An action having a highest action-value is selected from the plurality of actions and the transformation parameters are adjusted by the predetermined adjustment corresponding to the selected action. The determining, calculating, and selecting steps are repeated for a plurality of iterations, and the medical images are registered using final transformation parameters resulting from the plurality of iterations.			

[15] https://healthitanalytics.com/news/oh-medical-center-siemens-strike-personalized-medicine-partnership

Publication Number	Title (English)	Assignee	Publication Date
US20170116497A1	Intelligent multi-scale medical image landmark detection	SIEMENS HEALTHCARE	27/04/2017
Summary/Abstract – Intelligent multi-scale image parsing determines the optimal size of each observation by an artificial agent at a given point in time while searching for the anatomical landmark. The artificial agent begins searching image data with a coarse field-of-view and iteratively decreases the field-of-view to locate the anatomical landmark. After searching at a coarse field-of view, the artificial agent increases resolution to a finer field-of-view to analyze context and appearance factors to converge on the anatomical landmark. The artificial agent determines applicable context and appearance factors at each effective scale.			
US20170200067A1	Deep image-to-image network learning for medical image analysis	SIEMENS	13/07/2017
Summary/Abstract – A method and apparatus for automatically performing medical image analysis tasks using deep image-to-image network (DI2IN) learning. An input medical image of a patient is received. An output image that provides a result of a target medical image analysis task on the input medical image is automatically generated using a trained deep image-to-image network (DI2IN). The trained DI2IN uses a conditional random field (CRF) energy function to estimate the output image based on the input medical image and uses a trained deep learning network to model unary and pairwise terms of the CRF energy function. The DI2IN may be trained on an image with multiple resolutions. The input image may be split into multiple parts and a separate DI2IN may be trained for each part. Furthermore, the multi-scale and multi-part schemes can be combined to train a multi-scale multi-part DI2IN.			
US20160328643A1	Method and system for approximating deep neural networks for anatomical object detection	SIEMENS	10/11/2016
Summary/Abstract – A method and system for approximating a deep neural network for anatomical object detection is discloses. A deep neural network is trained to detect an anatomical object in medical images. An approximation of the trained deep neural network is calculated that reduces the computational complexity of the trained deep neural network. The anatomical object is detected in an input medical image of a patient using the approximation of the trained deep neural network.			
US20210219935A1	Data-driven plaque determination in medical imaging	SIEMENS HEALTHCARE	22/07/2021
Summary/Abstract – In hemodynamic determination in medical imaging, the classifier is trained from synthetic data rather than relying on training data from other patients. A computer model (in silico) may be perturbed in many different ways to generate many different examples. The flow is calculated for each resulting example. A bench model (in vitro) may similarly be altered in many different ways. The flow is measured for each resulting example. The machine-learnt classifier uses features from medical scan data for a particular patient to estimate the blood flow based on mapping of features to flow learned from the synthetic data. Perturbations or alterations may account for therapy so that the machine-trained classifier may estimate the results of therapeutically altering a patient-specific input feature. Uncertainty may be handled by training the classifier to predict a distribution of possibilities given uncertain input distribution. Combinations of one or more of uncertainty, use of synthetic training data, and therapy prediction may be provided.			
US20150238148A1	Method and system for anatomical object detection using marginal space deep neural networks	SIEMENS	27/08/2015

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – A method and system for anatomical object detection using marginal space deep neural networks is disclosed. The pose parameter space for an anatomical object is divided into a series of marginal search spaces with increasing dimensionality. A respective deep neural network is trained for each of the marginal search spaces, resulting in a series of trained deep neural networks. Each of the trained deep neural networks can evaluate hypotheses in a current parameter space using discriminative classification or a regression function. An anatomical object is detected in a medical image by sequentially applying the series of trained deep neural networks to the medical image.			
US20150112182A1	Method and system for machine learning based assessment of fractional flow reserve	SIEMENS	23/04/2015
Summary/Abstract – A method and system for determining fractional flow reserve (FFR) for a coronary artery stenosis of a patient is disclosed. In one embodiment, medical image data of the patient including the stenosis is received, a set of features for the stenosis is extracted from the medical image data of the patient, and an FFR value for the stenosis is determined based on the extracted set of features using a trained machine-learning based mapping. In another embodiment, a medical image of the patient including the stenosis of interest is received, image patches corresponding to the stenosis of interest and a coronary tree of the patient are detected, an FFR value for the stenosis of interest is determined using a trained deep neural network regressor applied directly to the detected image patches.			
US20220022818A1	Assessment of abnormality patterns associated with covid-19 from x-ray images	SIEMENS	27/01/2022
Summary/Abstract – Systems and methods for assessing a disease are provided. An input medical image in a first modality is received. Lungs are segmented from the input medical image using a trained lung segmentation network and abnormality patterns associated with the disease are segmented from the input medical image using a trained abnormality pattern segmentation network. The trained lung segmentation network and the trained abnormality pattern segmentation network are trained based on 1) synthesized images in the first modality generated from training images in a second modality and 2) target segmentation masks for the synthesized images generated from training segmentation masks for the training images. An assessment of the disease is determined based on the segmented lungs and the segmented abnormality patterns.			

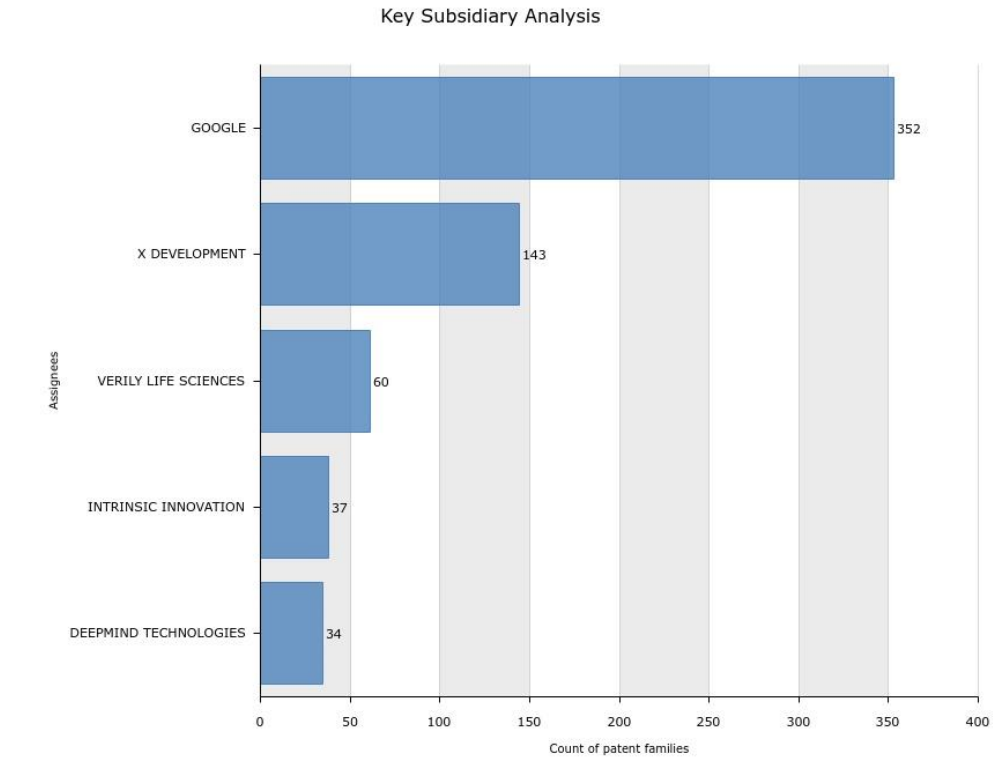
The technology being developed by Siemens is heavily cited by other key players such as Phillips, as illustrated by a recent patent filing relating to medical imaging (EP4159138A1) and object visualisation in x-ray imaging (EP4144298A1). The technology also appears to be very relevant in recent developments in computer vision platforms for coronary artery narrowing detection based on patient imaging and 3D deep learning (EP4131154A1), and prediction and prevention of medical events using machine-learning algorithms (US11610679B1). It is clear to see how Siemens has helped to positively influence growth in medical technology.

Publication Number	Title (English)	Assignee	Publication Date
EP4162879A1	Determining vessel parameters	PHILIPS	12/04/2023
Summary/Abstract – A system (100) for providing value of a transit velocity of an injected contrast agent bolus in a lumen, is provided. The system comprises one or more processors (120) configured to: receive X-ray angiographic image data comprising a temporal sequence of images representing a flow of the injected contrast agent bolus through a vessel tree comprising the lumen; generate a time-intensity curve for the vessel tree from the temporal sequence of images; calculate a transit time (TT) from the time-intensity curve; determine an estimate of the transit length (dT) of the lumen based on an analysis of an earlier X-ray image and a later X-ray image; and calculate the value of the transit velocity of the injected contrast agent bolus in the lumen based on a ratio of the estimated transit length (dT) to the calculated transit time (TT).			
WO2023/051907A1	Autofocus	BRAINLAB	06/04/2023
Summary/Abstract – The invention proposes a computer implemented method for assessing a medical image of an object imaged with an X-ray system. The method proposes to generate one or more positioning data sets, which differ in at least on positioning parameter. The X-ray system images medical images of the object with the one or more positioning data sets. The obtained medical images were assessed by measuring a quality measure in the medical images and comparing the measured quality measures with an evaluation criterion. A positive assessed medical image with the corresponding positioning data is then provided for further processing.			
EP4159138A1	Prospective quality assessment for imaging examination prior to acquisition	PHILIPS	05/04/2023
Summary/Abstract – The present invention relates to medical imaging. In order to reduce repeat images, it is proposed to enable automated prediction of quality metrics prior to image formation by exploiting data from sensors. This may greatly improve the quality of medical image data acquired in the actual imaging examination, thereby leading to fewer retakes, less delayed treatment to patients, shortened workflow, and higher patient rate. In X-ray and CT exams, fewer retakes may also reduce radiation doses for patients.			
US11610679B1	Prediction and prevention of medical events using machine-learning algorithms	HEALTH AT SCALE	21/03/2023
Summary/Abstract – The present disclosure relates to providing personalized prediction and prevention of various types of medical events (e.g., emergency department visits, hospital admissions, complications) using machine-learning algorithms. An exemplary method comprises: obtaining a plurality of feature values of the patient; providing the plurality of feature values to a set of one or more trained machine-learning models to obtain: a first probabilistic value indicating a likelihood of a future medical event, a second probabilistic value indicating a likelihood of a reason for the future medical event, a third probabilistic value indicating a likelihood that the future medical event can be prevented, displaying, on the display, a risk value of the future medical event based on the first probabilistic value, a reason of the future medical event based on the second probabilistic value, an interceptability value of the future medical event based on the third probabilistic value.			

Publication Number	Title (English)	Assignee	Publication Date
EP4144298A1	Object visualisation in x-ray imaging	PHILIPS	08/03/2023
Summary/Abstract – An X-ray imaging system (100) includes an X-ray source (110) and an X-ray detector (120) that are separated by an examination region (150) for performing an X-ray imaging operation on an object (160). A processor (140) is configured to identify (S120) one or more internal structures (180) within the object (160), based on a comparison of depth sensor data representing a three-dimensional surface (170) of the object (160), with an anatomical model comprising the one or more internal structures (180). The processor (140) is also configured to compute (S130), using the depth sensor data and the identified one or more internal structures (180), a surface projection (190) of the one or more internal structures, on the surface (170) of the object (160), from a perspective of the X-ray source (110); and to output (S140) an image representation of the surface projection (190) for displaying as an overlay on the surface (170) of the object (160).			
US2023051749A1	Generating synthesized digital images utilizing class-specific machine-learning models	ADOBE SYSTEMS	16/02/2023
Summary/Abstract – This disclosure describes methods, non-transitory computer readable storage media, and systems that generate synthetized digital images using class-specific generators for objects of different classes. The disclosed system modifies a synthesized digital image by utilizing a plurality of class-specific generator neural networks to generate a plurality of synthesized objects according to object classes identified in the synthesized digital image. The disclosed system determines object classes in the synthesized digital image such as via a semantic label map corresponding to the synthesized digital image. The disclosed system selects class-specific generator neural networks corresponding to the classes of objects in the synthesized digital image. The disclosed system also generates a plurality of synthesized objects utilizing the class-specific generator neural networks based on contextual data associated with the identified objects. The disclosed system generates a modified synthesized digital image by replacing the identified objects in the synthesized digital images with the synthesized objects.			
EP4131154A1	Coronary artery narrowing detection based on patient imaging and 3d deep learning	ROBOVISION	08/02/2023
Summary/Abstract – The invention relates, amongst others, to a method for determining an FFR-related parameter value, comprising: providing a CT image comprising coronary arteries obtained from coronary CT angiography, CCTA; extracting, from said CT image and for each of said coronary arteries, a respective centerline; extracting, from said CT image and for each of said coronary arteries, a respective artery contour; and determining, based at least on a coronary artery model comprising said respective centerlines and said respective artery contours, said FFR-related parameter value; wherein said CT image is a 3D CT image comprising voxels, each voxel being associated with a radiodensity value, preferably a Hounsfield unit value; wherein said extracting of said respective centerlines comprises applying, on said 3D CT image comprising voxels, a first NN being a 3D NN trained with respect to the centerline; wherein said extracting of said respective artery contours comprises applying, on said CT image, a second NN trained with respect to a radius from the centerline; and wherein said determining of said FFR-related parameter value comprises applying, on said coronary artery model, a third NN trained with respect to FFR-related training data.			

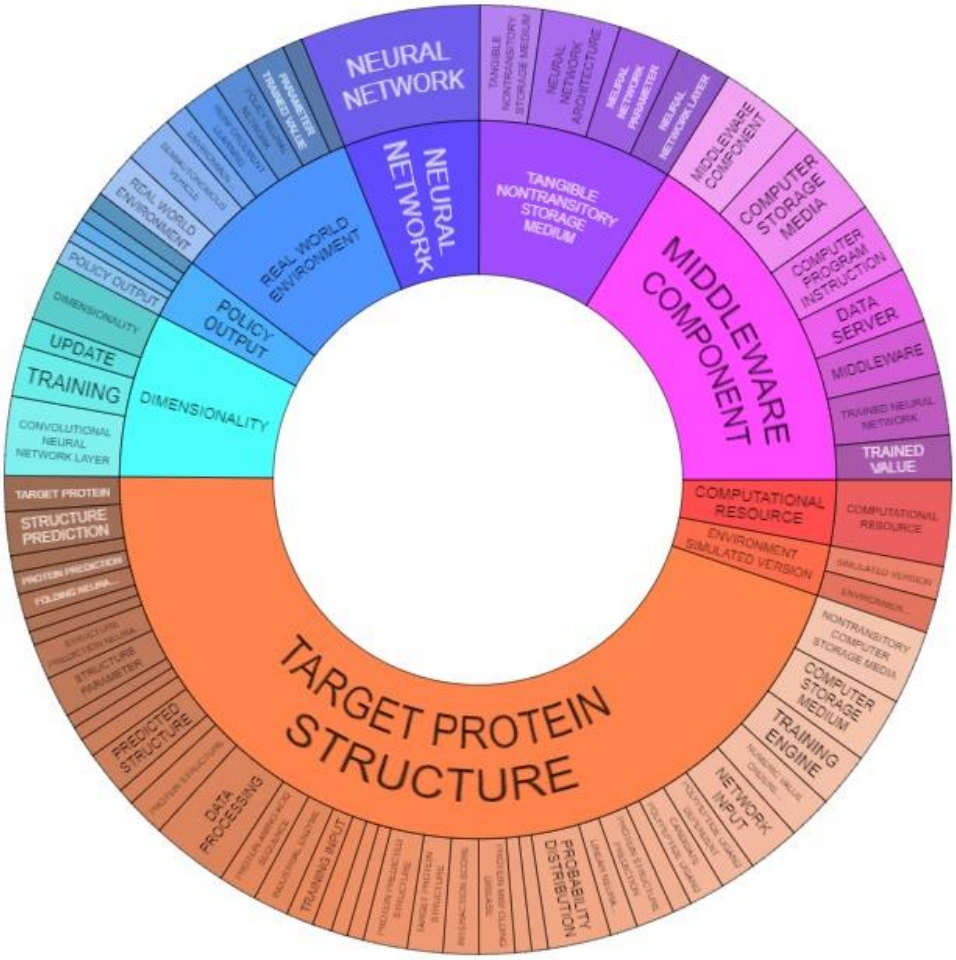
9.3 ALPHABET

AI has transformed the biotechnology and pharmaceutical patent landscape. Alphabet is highlighted as one of the most influential players in applying AI systems within the field, and the company owns multiple subsidiaries that have been actively filing patents to AI technologies, which will have an impact on the patent landscape and market, as shown in the following figure.

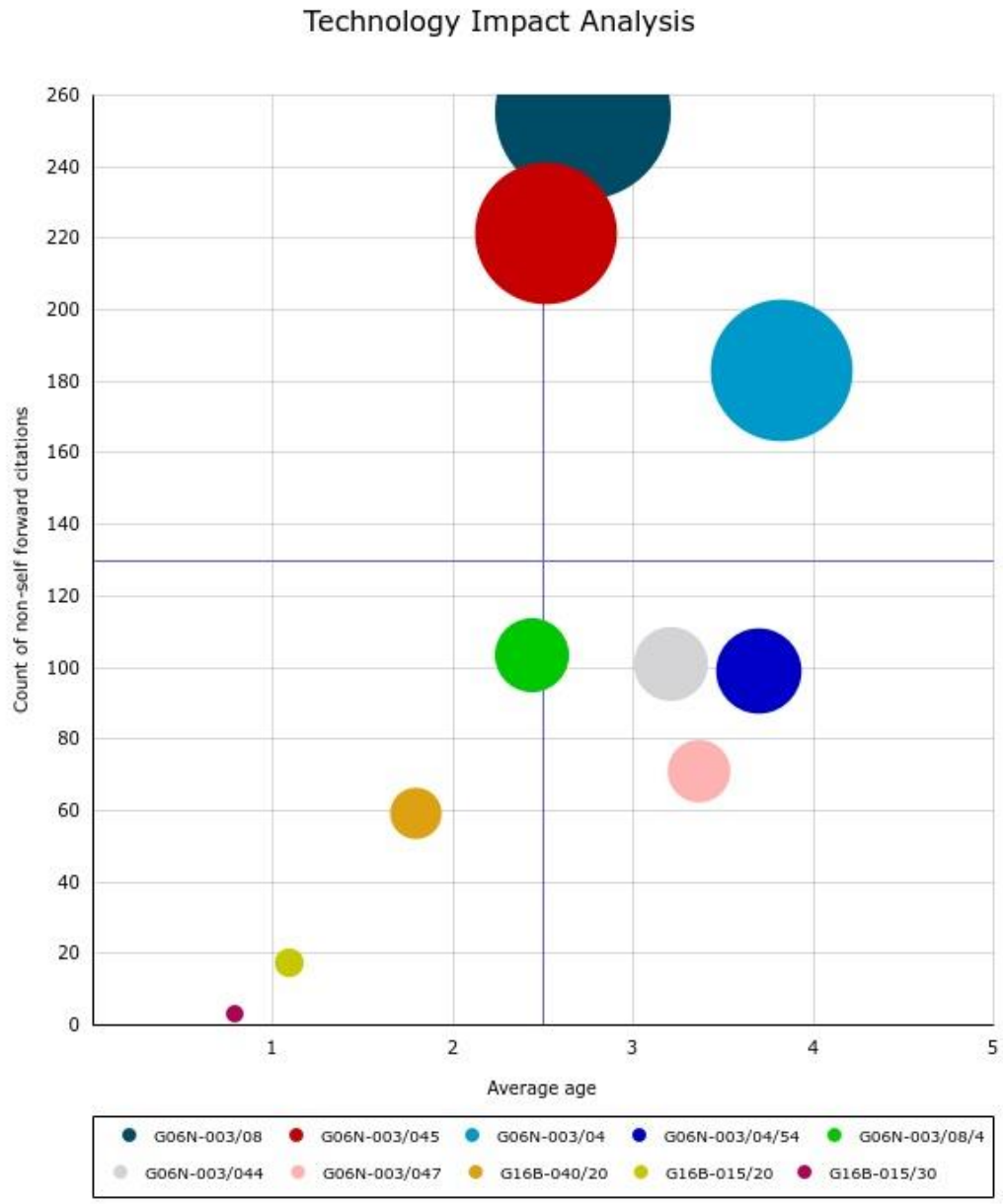


While Google and Verily Life Sciences have numerous patent filings related to medical imaging machine learning techniques, X development and Intrinsic Innovation are more focused on robotic systems. Interestingly, Deepmind Technologies holds a patent portfolio with significant patent activity relating to neural networks for predicting protein structures, such as US20210304847A1, which is having a profound effect in the medicine and pharmaceutical patent landscape. The following concept map provides some insights on the focus of the patent portfolio.

Technologies & applications



The patent portfolio relating to combinations of networks (G06N3/045), neural network learning methods and architectures (G06N3/08 & G06N3/04), are the most established and have most significant impact on the patent landscape. It appears that only recently has Alphabet's patent portfolio has entered the analysis protein and domain folding space (G16B15/20), as well as drug targeting using structural data/docking or binding prediction (G16B15/30).



Deepmind Technologies has engineered AlphaFold, an AI program that performs predictions of protein structures[16]. The patent portfolio relating to AlphaFold is illustrated in the following table, wherein the majority of patent filings leading up to and following the launch of AlphaFold appear to comprise combinations of neural networks, supervised data analysis, and backpropagation machine learning techniques, as well as pattern recognition systems. Interestingly, the company has filed a cluster of patents that are technologically similar, considered a patent ring-fencing strategy aimed at blocking new market entrants, which provides a mechanism for further enhancing value and appropriation from intellectual property.

Publication Number	Title (English)	Assignee	Publication Date
WO2022/194434A1	Predicting complete protein representations from masked protein representations	DEEPMIND TECHNOLOGIES	22/09/2022
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for unmasking a masked representation of a protein using a protein reconstruction neural network. In one aspect, a method comprises: receiving the masked representation of the protein; and processing the masked representation of the protein using the protein reconstruction neural network to generate a respective predicted embedding corresponding to one or more masked embeddings that are included in the masked representation of the protein, wherein a predicted embedding corresponding to a masked embedding in a representation of the amino acid sequence of the protein defines a prediction for an identity of an amino acid at a corresponding position in the amino acid sequence, wherein a predicted embedding corresponding to a masked embedding in a representation of the structure of the protein defines a prediction for a corresponding structural feature of the protein.			
WO2022/167325A1	Predicting protein amino acid sequences using generative models conditioned on protein structure embeddings	DEEPMIND TECHNOLOGIES	11/08/2022
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for performing protein design. In one aspect, a method comprises: processing an input characterizing a target protein structure of a target protein using an embedding neural network having a plurality of embedding neural network parameters to generate an embedding of the target protein structure of the target protein; determining a predicted amino acid sequence of the target protein based on the embedding of the target protein structure, comprising: conditioning a generative neural network having a plurality of generative neural network parameters on the embedding of the target protein structure; and generating, by the generative neural network conditioned on the embedding of the target protein structure, a representation of the predicted amino acid sequence of the target protein.			
WO2022/089805A1	Training protein structure prediction neural networks using reduced multiple sequence alignments	DEEPMIND TECHNOLOGIES	05/05/2022

[16] https://www.nature.com/articles/s41586-021-03819-2

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for training neural networks to predict the structure of a protein. In one aspect, a method comprises: obtaining, for each of a plurality of proteins, a full multiple sequence alignment for the protein; generating, for each of the plurality of proteins, target structure parameters characterizing a structure of the protein from the full multiple sequence alignment for the protein, comprising processing a representation of the full multiple sequence alignment for the protein using the structure prediction neural network to generate output structure parameters characterizing a structure of the protein, and determining the target structure parameters for the protein based on the output structure parameters for the protein; determining, for each of the plurality of proteins, a reduced multiple sequence alignment for the protein, comprising removing or masking data from the full multiple sequence alignment for the protein.			
US20210304847A1	Machine learning for determining protein structures	DEEPMIND TECHNOLOGIES	30/09/2021
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for performing protein structure prediction. In one aspect, a method comprises, at each of one or more iterations: determining an alternative predicted structure of a given protein defined by alternative values of structure parameters; processing, using a geometry neural network, a network input comprising: (i) a representation of a sequence of amino acid residues in the given protein, and (ii) the alternative values of the structure parameters, to generate an output characterizing an alternative geometry score that is an estimate of a similarity measure between the alternative predicted structure and the actual structure of the given protein.			
WO2023/057455A1	Training a neural network to predict multi-chain protein structures	DEEPMIND TECHNOLOGIES	13/04/2023
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for predicting a structure of a protein that comprises a plurality of amino acid chains using a protein structure prediction neural network, where each chain comprises a respective sequence of amino acids. In one aspect, a method comprises: receiving a network input for the protein structure prediction neural network, wherein the network input characterizes the protein; processing the network input characterizing the protein using the protein structure prediction neural network to generate a network output that characterizes a predicted structure of the protein; and determining the predicted structure of the protein based on the network output.			
WO2022/112255A1	Predicting protein structures using protein graphs	DEEPMIND TECHNOLOGIES	02/06/2022
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for determining a predicted structure of a protein. According to one aspect, there is provided a method comprising: maintaining graph data representing a graph of the protein; obtaining a respective pair embedding for each edge in the graph; processing the pair embeddings using a sequence of update blocks, wherein each update block performs operations comprising, for each edge in the graph: generating a respective representation of each of a plurality of cycles in the graph that include the edge by, for each cycle, processing embeddings for edges in the cycle in accordance with the values of the update block parameters of the update block to generate the representation of the cycle; and updating the pair embedding for the edge using the representations of the cycles in the graph that include the edge.			
WO2022/112248A1	Predicting protein structures by sharing information between multiple sequence alignments and pair embeddings	DEEPMIND TECHNOLOGIES	02/06/2022

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for predicting a structure of a protein comprising one or more chains. In one aspect, a method comprises: obtaining an initial multiple sequence alignment (MSA) representation; obtaining a respective initial pair embedding for each pair of amino acids in the protein; processing an input comprising the initial MSA representation and the initial pair embeddings using an embedding neural network to generate an output that comprises a final MSA representation and a respective final pair embedding for each pair of amino acids in the protein; and determining a predicted structure of the protein using the final MSA representation, the final pair embeddings, or both.			
WO2022/112260A1	Predicting protein structures over multiple iterations using recycling	DEEPMIND TECHNOLOGIES	02/06/2022
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for predicting a structure of a protein comprising one or more chains. In one aspect, a method comprises, at each subsequent iteration after a first iteration in a sequence of iterations: obtaining a network input for the subsequent iteration that characterizes the protein; generating, from (i) structure parameters generated at a preceding iteration that precedes the subsequent iteration in the sequence, (ii) one or intermediate outputs generated by the protein structure prediction neural network while generating the structure parameters at the last iteration, or (iii) both, features for the subsequent iteration; and processing the features and the network input for the subsequent iteration using the protein structure prediction neural network to generate structure parameters for the subsequent iteration that define another predicted structure for the protein.			
WO2022/112220A1	Predicting symmetrical protein structures using symmetrical expansion transformations	DEEPMIND TECHNOLOGIES	02/06/2022
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for predicting a structure of a protein that comprises a plurality of amino acid chains. According to one aspect, a method comprises: obtaining initial structure parameters for a first amino acid chain in the protein; obtaining data identifying a symmetry group; processing the initial structure parameters for the first amino acid chain and the data identifying the symmetry group using a folding neural network that comprises a sequence of update blocks, wherein each update block performs operations comprising: applying a symmetrical expansion transformation to the current structure parameters for the first amino acid chain; and processing the current structure parameters for the amino acid chains in the protein, in accordance with values of the update block parameters of the update block, to update the current structure parameters for the first amino acid chain.			
US20210166779A1	Protein structure prediction from amino acid sequences using self-attention neural networks	DEEPMIND TECHNOLOGIES	03/06/2021
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for determining a predicted structure of a protein that is specified by an amino acid sequence. In one aspect, a method comprises: obtaining a multiple sequence alignment for the protein; determining, from the multiple sequence alignment and for each pair of amino acids in the amino acid sequence of the protein, a respective initial embedding of the pair of amino acids; processing the initial embeddings of the pairs of amino acids using a pair embedding neural network comprising a plurality of self-attention neural network layers to generate a final embedding of each pair of amino acids; and determining the predicted structure of the protein based on the final embedding of each pair of amino acids.			

Publication Number	Title (English)	Assignee	Publication Date
WO2022/112257A1	Predicting protein structures using auxiliary folding networks	DEEPMIND TECHNOLOGIES	02/06/2022
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for training a structure prediction neural network that comprises an embedding neural network and a main folding neural network. According to one aspect, a method comprises: obtaining a training network input characterizing a training protein; processing the training network input using the embedding neural network and the main folding neural network to generate a main structure prediction; for each auxiliary folding neural network in a set of one or more auxiliary folding neural networks, processing at least a corresponding intermediate output of the embedding neural network to generate an auxiliary structure prediction; determining a gradient of an objective function that includes a respective auxiliary structure loss term for each of the auxiliary folding neural networks; and updating the current values of the embedding network parameters and the main folding parameters based on the gradient.			
US20210398606A1	Protein structure prediction using geometric attention neural networks	DEEPMIND TECHNOLOGIES	23/12/2021
Summary/Abstract – Methods, systems, and apparatus, including computer programs encoded on a computer storage medium, for determining a predicted structure of a protein that is specified by an amino acid sequence. In one aspect, a method comprises: obtaining an initial embedding and initial values of structure parameters for each amino acid in the amino acid sequence, wherein the structure parameters for each amino acid comprise location parameters that specify a predicted three-dimensional spatial location of the amino acid in the structure of the protein; and processing a network input comprising the initial embedding and the initial values of the structure parameters for each amino acid in the amino acid sequence using a folding neural network to generate a network output comprising final values of the structure parameters for each amino acid in the amino acid sequence.			
US20180032863A1	Training a policy neural network and a value neural network	DEEPMIND TECHNOLOGIES	01/02/2018
Summary/Abstract – Methods, systems and apparatus, including computer programs encoded on computer storage media, for training a value neural network that is configured to receive an observation characterizing a state of an environment being interacted with by an agent and to process the observation in accordance with parameters of the value neural network to generate a value score. One of the systems performs operations that include training a supervised learning policy neural network; initializing initial values of parameters of a reinforcement learning policy neural network having a same architecture as the supervised learning policy network to the trained values of the parameters of the supervised learning policy neural network; training the reinforcement learning policy neural network on second training data; and training the value neural network to generate a value score for the state of the environment that represents a predicted long-term reward resulting from the environment being in the state.			
US10867242B2	Selecting actions to be performed by a reinforcement learning agent using tree search	DEEPMIND TECHNOLOGIES	15/12/2020

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – Methods, systems and apparatus, including computer programs encoded on computer storage media, for training a value neural network that is configured to receive an observation characterizing a state of an environment being interacted with by an agent and to process the observation in accordance with parameters of the value neural network to generate a value score. One of the systems performs operations that include training a supervised learning policy neural network; initializing initial values of parameters of a reinforcement learning policy neural network having a same architecture as the supervised learning policy network to the trained values of the parameters of the supervised learning policy neural network; training the reinforcement learning policy neural network on second training data; and training the value neural network to generate a value score for the state of the environment that represents a predicted long-term reward resulting from the environment being in the state.			
EP4165562A2	Generating neural network outputs by enriching latent embeddings using self-attention and cross-attention operations	DEEPMIND TECHNOLOGIES	19/04/2023
Summary/Abstract – This specification describes a method for using a neural network to generate a network output that characterizes an entity. The method includes: obtaining a representation of the entity as a set of data element embeddings, obtaining a set of latent embeddings, and processing: (i) the set of data element embeddings, and (ii) the set of latent embeddings, using the neural network to generate the network output characterizing the entity. The neural network includes: (i) one or more cross-attention blocks, (ii) one or more self-attention blocks, and (iii) an output block. Each cross-attention block updates each latent embedding using attention over some or all of the data element embeddings. Each self-attention block updates each latent embedding using attention over the set of latent embeddings. The output block processes one or more latent embeddings to generate the network output that characterizes the entity.			
US20220415453A1	Determining a distribution of atom coordinates of a macromolecule from images using auto-encoders	DEEPMIND TECHNOLOGIES	29/12/2022
Summary/Abstract – Methods, systems and apparatus, including computer programs encoded on computer storage media. One of the methods includes obtaining a plurality of images of a macromolecule having a plurality of atoms, training a decoder neural network on the plurality of images, and after the training, generating a plurality of conformations for at least a portion of the macromolecule that each include respective three-dimensional coordinates of each of the plurality of atoms, wherein generating each conformation includes sampling a conformation latent representation from a prior distribution over conformation latent representations, processing a respective input including the sampled conformation latent representation using the decoder neural network to generate a conformation output that specifies three-dimensional coordinates of each of the plurality of atoms for the conformation, and generating the conformation from the conformation output.			

Forward citation analysis can be a very useful tool for measuring the impact of innovation on the patent landscape and the wider market, as it helps to identify other patents that have cited a given patent document; it appears that US20210166779A1and US20210304847A1 filed by Deepmind Technologies have had the most profound effect on the patent landscape. However, since AlphaFold is a fairly recent development, there are limitations to the insights gathered from such analysis since the time window for any other patent documents to cite Deepmind Technologies patent filings will be shorter, and not forgetting the 18-month lag time between the filing of a priority application and subsequent patent publication. Nevertheless, it appears that patent filings related to AlphaFold have been cited by other major industry players, which suggests that the development of Alphafold is having an important impact on the industry. In particular, AlphaFold has helped the pharmaceutical and biotechnology sector accelerate drug design and discovery[17], as illustrated by the following table of citations, wherein the following patents cite the patent portfolio held by Deepmind Technologies: Shuimu BioSciences (CN115035947B, CN114613427B), Structura Biotechnology (WO2022/221956A1), and Pythia Labs (US11450407B1). These recent patent filings highlight how software tools can cut the cost and time for in silico design and testing of new drug candidates in preclinical pipelines.

AlphaFold has also attracted interest from other major AI players. For example, Microsoft has traditionally developed AI for a range of applications in the life sciences, such as association-based predictions of pathogen characteristics (US8000900B2), however more recently following the launch of AlphaFold, it appears that the company has entered the space in predicting protein structure (WO2022/146631A1 & WO2022/146632A1). The technology being developed is directly related to AlphaFold, as the patent filings were cited by the patent examining search report. The technology also appears to have applications in atomic structure computation technology being developed by Samsung Electronics (US11586982B2). As a result, we can be expect to see more major players enter the protein prediction space, given the potential commercial benefits.

[17] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7614146/

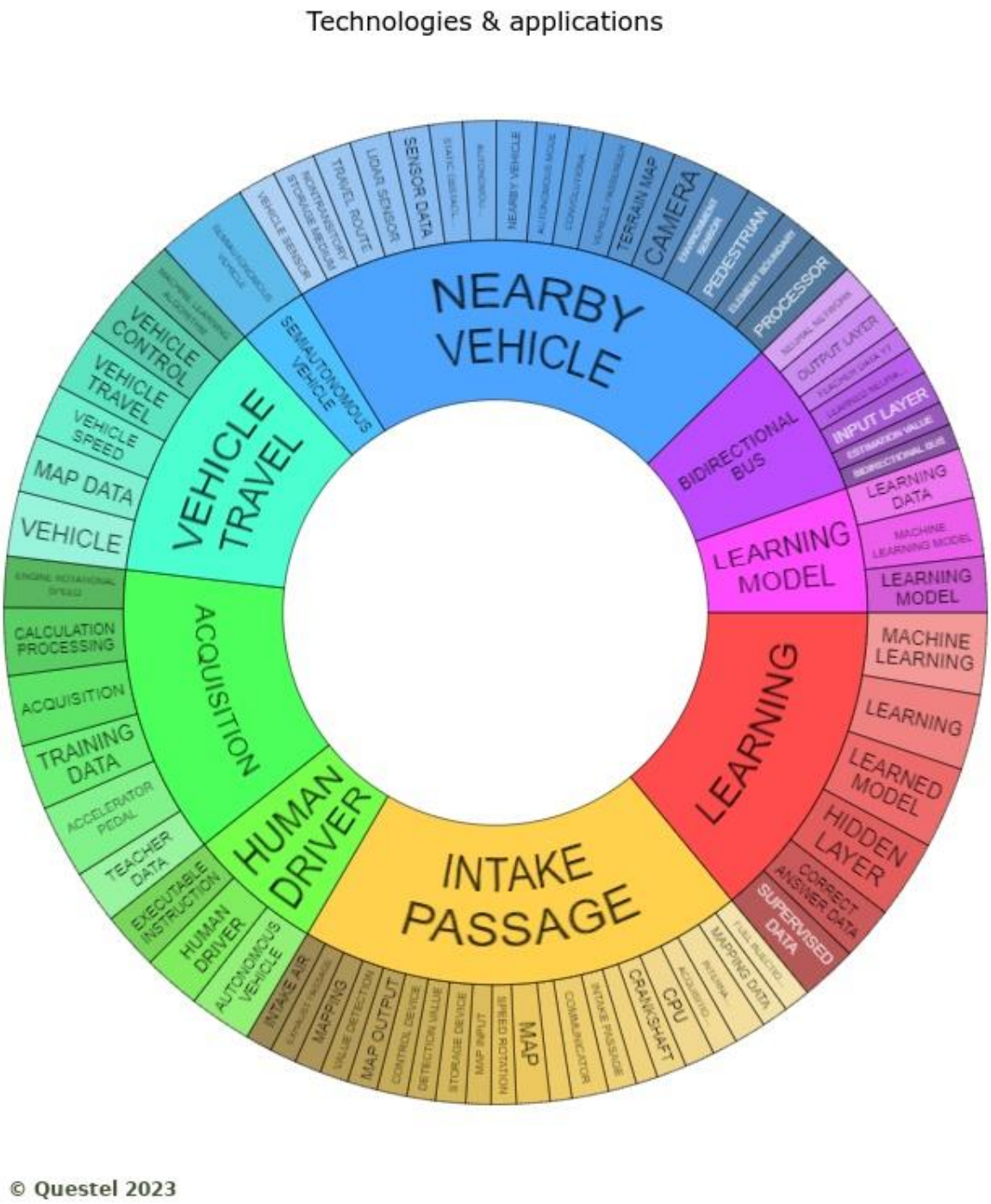
Publication Number	Title (English)	Assignee	Publication Date
WO2022/221956A1	Methods and systems for reconstruction of three-dimensional structure and three-dimensional motion of a protein molecule	STRUCTURA BIOTECHNOLOGY	27/10/2022
Summary/Abstract – Provided are systems and methods for determining 3D structure and 3D motion of a protein molecule from 2D or 3D particle observation images. The method including: initializing pose parameters and unknown model parameters; the parameters of the one or more flow generators; image formation including: generating one or more 3D deformation fields by inputting the latent coordinate vector into the one or more flow generators; performing a convection and projection operation; and performing CTF corruption; fitting the unknown model parameters to the experimental images by gradient-based optimization of an objective function; latent variable search for a given experimental image including: performing the image formation one or more times to generate simulated images; selecting one or more latent coordinate vectors based on similarity; updating the at least one of the unknown model parameters including: generating simulated images; evaluating the objective function; computing the gradient of the objective function.			
US11450407B1	Systems and methods for artificial intelligence-guided biomolecule design and assessment	PYTHIA LABS	20/09/2022
Summary/Abstract – Described herein are systems and methods for designing and testing custom biologic molecules in silico which are useful, for example, for the treatment, prevention, and diagnosis of disease. In particular, in certain embodiments, the biomolecule engineering technologies described herein employ artificial intelligence (AI) software modules to accurately predict performance of candidate biomolecules and/or portions thereof with respect to particular design criteria. In certain embodiments, the AI-powered modules described herein determine performance scores with respect to design criteria such as binding to a particular target. AI-computed performance scores may, for example, be used as objective functions for computer implemented optimization routines that efficiently search a landscape of potential protein backbone orientations and binding interface amino-acid sequences. By virtue of their modular design, AI-powered scoring modules can be used separately, or in combination, such as in a pipeline approach where different structural features of a custom biologic are optimized in succession.			
CN115035947B	Protein structure modeling method and device, electronic equipment and storage medium	SHUIMU BIOSCIENCE	10/03/2023

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – The invention relates to a protein structure modeling method and device, electronic equipment and a storage medium. The method comprises the following steps: performing structure prediction on a protein sequence to obtain first protein structure information and a Ca atom pair distance error of the protein sequence; determining a structural domain according to the Ca atom pair distance error; obtaining a protein sequence fragment according to the electron cloud density map; screening the structural domains according to the electron cloud density map and the protein sequence fragments to obtain a target structural domain; and obtaining a protein structure model according to the target structural domain and the electron cloud density map. According to the protein structure modeling method disclosed by the embodiment of the invention, the structural domain can be determined on the basis of the protein sequence, the structural domain is screened on the basis of the electron cloud density map, and then docking is performed on the basis of the target structural domain and the electron cloud density map to obtain the protein structure model; a good modeling effect can be obtained under the condition that the resolution of the electron cloud density map is low, and the modeling efficiency is improved.			
WO2022/146632A1	Protein structure prediction	MICROSOFT TECHNOLOGY LICENSING	07/07/2022
Summary/Abstract – According to implementations of the present disclosure, a solution is proposed for protein structure prediction. In this solution, from a fragment library for a target protein, a plurality of fragments is determined for each of a plurality of residue positions of the target protein. Each fragment comprises a plurality of amino acid residues. Then, a feature representation of structures of the plurality of fragments is generated for the each residue position. Next, a prediction of at least one of a structure and a structural property of the target protein is determined based on the respective feature representations generated for the plurality of residue positions. In this way, the solution can leverage structural information of fragment libraries to complement and complete information used in protein structure prediction, and the accuracy of protein structure prediction is thus improved.			
WO2022/146631A1	Protein structure prediction	MICROSOFT TECHNOLOGY LICENSING	07/07/2022
Summary/Abstract – According to implementations of the subject matter described herein, there is provided a solution for protein structure prediction. In this solution, a constraint set for a target protein is obtained, the constraint set comprising constraints for structural properties of the target protein. Feature information is extracted from the constraints respectively, and weights corresponding to the constraints are determined respectively based on the feature information of the constraints. Each weight indicates a degree of influence of the corresponding constraint in prediction of a structure of the target protein. The structure of the target protein is predicted based on the constraints in the constraint set and the weights. According to the solution, through the pre-processing on the constraints for use, it is possible to solve potential conflicts in the constraint set and eliminate constraint redundancy. This enables accurate prediction of the structure of the target protein.			
CN114613427B	Protein three-dimensional structure prediction method and device, electronic equipment and storage medium	SHUIMU BIOSCIENCE	31/01/2023

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – The invention relates to a protein three-dimensional structure prediction method and device, electronic equipment and a storage medium, and the method comprises the steps: inputting a to-be-processed protein sequence into a protein language model, and obtaining protein representation information and residue attention information; coding the to-be-processed protein sequence to obtain an outer product matrix; obtaining residue pair representation information according to the residue pair attention information and the outer product matrix; and determining three-dimensional structure information of the to-be-processed protein sequence according to the protein representation information, the residue pair representation information, the initialized protein skeleton information and the structure prediction model. According to the protein three-dimensional structure prediction method provided by the embodiment of the invention, the three-dimensional structure of the protein sequence can be predicted based on the residue pair attention model and the structure prediction model, the three-dimensional structure of the protein can be accurately predicted under the condition that a single protein sequence is input, and the prediction efficiency is improved.			
US11586982B2	Electronic and atomic structure computation utilizing machine learning	SAMSUNG ELECTRONICS	21/02/2023
Summary/Abstract – A method for obtaining learned self-consistent electron density and/or derived physical quantities includes: conducting non-self-consistent (NSC) calculation to generate a first NSC dataset X1 from a first plurality of configurations of atoms; conducting self-consistent (SC) calculation to generate a first SC dataset Y1 from the first plurality of configurations of atoms; mapping the first NSC dataset X1 to the first SC dataset Y1 utilizing machine learning algorithm to generate a mapping function F; and generating a learned self-consistent data Y2 from a new NSC data X2 utilizing the mapping function F.			

9.4 TOYOTA

AI within the engineering and transport sectors of the patent landscape is very competitive, with the presence of many major automotive players, such as Toyota. It is well known that the automotive industry is under increasing scrutiny to lower gaseous emissions, in light of climate change. It is interesting to see that a significant portion of the AI patent portfolio held by Toyota is focused on intake passages for optimal combustion to help reduce emissions, as shown in the following graphic illustrating the main areas of focus.



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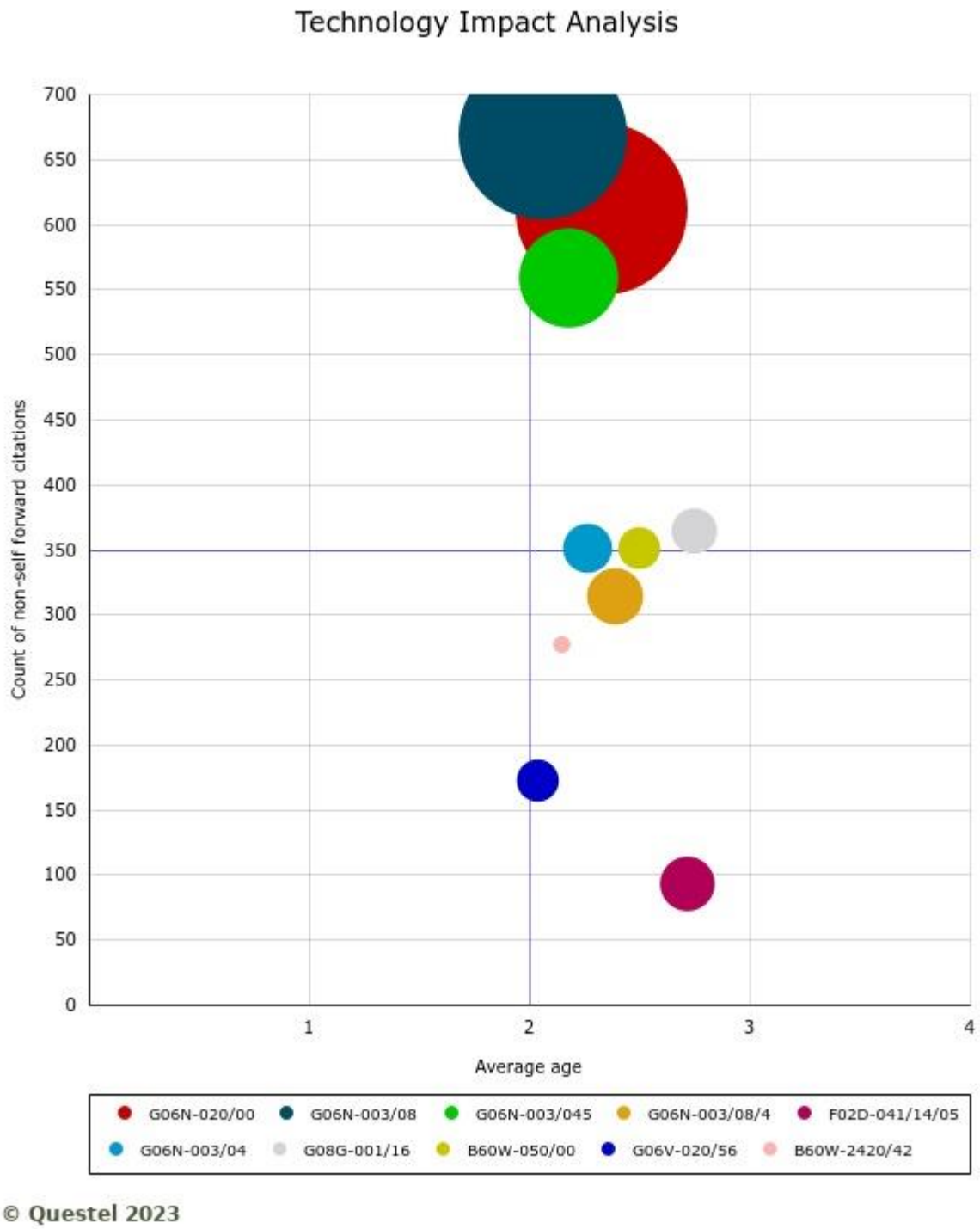
The patent portfolio relating to neural network learning methods (G06N3/08), machine learning (G06N20/00) and combination of neural networks (G06N3/045) appear to be having the most significant impact on the patent landscape. Interestingly, traffic-control systems for road vehicles (G08G1/16) have also had a significant impact.



The impact of these patents is evident through the collaboration between the Alan Turing Institute and Toyota Mobility Foundation to focus on leveraging AI to help improve city planning and traffic management[18]. The development of the Toyota real-time traffic information service (Toyota Touch 2) has also helped to lower gaseous emissions by helping to avoid traffic congestion. The company has also filed a number of recent patents that broadly relate to the accurate measurement of gaseous emissions of gasoline powered-vehicles, in order to increase engine efficiency and effectively limit said emissions, as shown by the following table. The company has also begun to focus on AI systems to manage vehicular batteries, likely to be linked to the global drive to lower gaseous emissions, which has translated in the more popular adoption of electric vehicles.

Publication Number	Title (English)	Assignee	Publication Date
EP3819489A1	System and method for emissions determination	TOYOTA MOTOR	12/05/2021
Summary/Abstract – A method for determining particulate emissions (PE) at an outlet of a gasoline engine (16) is proposed. The method comprises determining a logarithmic particulate emission value (LPE) at the engine outlet by means of a dynamic machine-learning-based model (110), using parameters (RS,AMF,AFR) associated with an engine operating state as an input; and applying an exponential function to the determined logarithmic particulate emission value (LPE) to yield the particulate emissions (PE) at the engine outlet (16).An engine control unit configured to implement such method is also proposed, as well as a system for determining particulate emissions (PE) at an outlet of a gasoline engine, the system comprising processing means configured to implement the above method.			
US20210095610A1	Internal combustion engine, state determination system for internal combustion engine, data analysis device, and control device for internal combustion engine	TOYOTA MOTOR	01/04/2021
Summary/Abstract – An internal combustion engine includes a state determination device. The state determination device includes a storage device and an execution device. The execution device executes an acquisition process, and a determination process. The execution device executes a guard process of bringing an internal combustion engine state variable closer to an allowable range or a value within the allowable range when the internal combustion engine state variable acquired in the acquisition process is out of the predetermined allowable range. The execution device determines the state of the internal combustion engine based on the internal combustion engine state variable after the guard process in the subsequent determination process when the guard process is executed.			
JP2020133620A	Catalyst deterioration detection device, catalyst deterioration detection system, data analysis device, control device of internal combustion engine, and method for providing state information of used vehicle	TOYOTA MOTOR	31/08/2020

[18] https://media.toyota.co.uk/alan-turing-institute-and-the-toyota-mobility-foundation-collaborate-on-improving-city-planning-and-traffic-management-with-artificial-intelligence/

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – PROBLEM TO BE SOLVED: To provide a catalyst deterioration detection device which can reduce an accumulated amount of deviation of components of a fluid flowing into the catalyst with respect to components appropriate to purification of the catalyst. SOLUTION: Map data 76a stored in a storage device 76 is data specifying a neural network which uses, as inputs, time series data of variables corresponding to an upstream air-fuel ratio Afu and a downstream air-fuel ratio Afd so as to output a deterioration level variable, which is a variable indicating a deterioration level of an upstream catalyst 32. A CPU 72 calculates the deterioration level variable of the upstream catalyst 32 by input of the time series data of the variables corresponding to the upstream air-fuel ratio Afu and the downstream air-fuel ratio Afd into a mapping defined by the map data 76a.			
US20200263618A1	Pm amount estimation device, pm amount estimation system, pm amount estimating method, data analysis device, control device for internal combustion engine, and receiver	TOYOTA MOTOR	20/08/2020
Summary/Abstract – A PM amount estimation device is applied to a filter that collects PM in the exhaust gas discharged to an exhaust passage of an internal combustion engine. A storage device stores mapping data which is data defining a mapping that outputs the PM amount collected by the filter. The mapping has at least one of an intake air temperature variable and a wall surface variable, and a flow rate variable as inputs. The intake air temperature variable relates to the temperature of air drawn into the engine. The wall surface variable relates to a cylinder wall surface temperature of the engine. The flow rate variable indicates the flow rate of the fluid entering the filter. The execution device calculates the PM amount based on the output of the mapping having the acquired data as an input.			
US20200332731A1	Oxygen storage amount estimation device, oxygen storage amount estimation system, controller for internal combustion engine, data analysis device, and method for estimating oxygen storage amount	TOYOTA MOTOR	22/10/2020
Summary/Abstract – An oxygen storage amount estimation device estimates an oxygen storage amount of a catalyst disposed in an exhaust passage of an internal combustion engine. The oxygen storage amount estimation device includes a storage device and processing circuitry. The storage device stores mapping data, which is data specifying a mapping that uses multiple variables including at least an excess-deficient amount variable and a previous value of a storage amount variable as an input to output a value of the storage amount variable. The processing circuitry executes a storage amount variable calculation process that repeatedly calculates a value of the storage amount variable based on an output of the mapping using the multiple variables and an operation process that operates predetermined hardware based on a calculation result of the storage amount variable calculation process. The mapping data includes data learned by machine learning.			
US20200263581A1	Catalyst temperature estimation device, catalyst temperature estimation system, data analysis device, and control device of internal combustion engine	TOYOTA MOTOR	20/08/2020

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – A catalyst temperature estimation device that estimates a temperature of a catalyst provided in an exhaust passage of an internal combustion engine includes a storage device and processing circuitry. The storage device stores mapping data that specifies a mapping that uses multiple input variables to output an estimation value of the temperature of the catalyst. The multiple input variables include at least one variable of an ambient temperature variable or an excess amount variable. The multiple input variables further include a fluid energy variable, which is a state variable related to energy of fluid flowing into the catalyst, and a previous cycle value of the estimation value of the temperature of the catalyst. The processing circuitry is configured to execute an acquisition process, a temperature calculation process, and an operation process. The mapping data includes data that is learned through machine learning.			
US20200175369A1	Machine learning device, machine learning method, electronic control unit and method of production of same, learned model, and machine learning system	TOYOTA MOTOR	04/06/2020
Summary/Abstract – A learning use data set showing relationships among an engine speed, an engine load rate, an air-fuel ratio of the engine, an ignition timing of the engine, an HC or CO concentration of exhaust gas flowing into an exhaust purification catalyst and a temperature of the exhaust purification catalyst is acquired. The acquired engine speed, engine load rate, air-fuel ratio of the engine, ignition timing of the engine, and HC or CO concentration of the exhaust gas flowing into the exhaust purification catalyst are used as input parameters of a neural network and the acquired temperature of the exhaust purification catalyst is used as training data to learn a weight of the neural network. The learned neural network is used to estimate the temperature of the exhaust purification catalyst.			
JP2022044943A	Battery degradation diagnosing system	TOYOTA MOTOR	18/03/2022
Summary/Abstract – PROBLEM TO BE SOLVED: To estimate battery capacities with high accuracy. SOLUTION: A battery system 40 diagnoses the degradation of a battery 41. The battery system 40 comprises a memory 432 in which is stored a capacity estimation model having undergone machine learning; and a processor 431 for estimating the capacity retention rate of the battery 41 using the capacity estimation model. The capacity estimation model is a trained model having been trained using battery currents, use patterns pertaining to SOC and temperature and the measured values of capacity degradation rate per unit hour of the battery as training data. The processor 431 acquires the capacity degradation rate per unit hour of the battery 41 by inputting the use pattern of the battery 41 to the capacity estimation model, and integrates the acquired capacity degradation rates per unit hour so as to estimate the capacity retention rate of the battery 41.			
US20200271725A1	Systems, methods, and storage media for predicting a discharge profile of a battery pack	TOYOTA MOTOR	27/08/2020

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – Systems, methods, and storage media for generating a predicted discharge profile of a vehicle battery pack are disclosed. A method includes receiving, by a processing device, data pertaining to cells within a battery pack installed in each vehicle of a fleet of vehicles operating under a plurality of conditions, the data received from at least one of each vehicle in the fleet of vehicles, providing, by the processing device, the data to a machine learning server, directing, by the processing device, the machine learning server to generate a predictive model, the predictive model based on machine learning of the data, generating, by the processing device, the predicted discharge profile of the vehicle battery pack from the predictive model, and providing the discharge profile to an external device.			
JP2017224522A	Battery system	TOYOTA MOTOR	21/12/2017
Summary/Abstract – PROBLEM TO BE SOLVED: To exercise performance of nickel metal hydride battery, in a battery system including a nickel metal hydride battery containing a hydrogen-storing alloy as a negative electrode active material. SOLUTION: A battery system 2 includes a battery 100 (nickel metal hydride battery) containing a hydrogen-storing alloy as a negative electrode active material 5, and an ECU300 for controlling a PCU200 so that charge power to the battery 100 is less than a charge power upper limit Win, and discharge power from the battery 100 is less than a discharge power upper limit Wout. The ECU300 calculates a crack index value X related to a crack amount occurring in the negative electrode active material 5 from OCV, a current Ib and a temperature Tb, and increases the charge power upper limit Win and discharge power upper limit Wout as the crack amount indicated by the crack index value X increases.			

These patent filings appear to have had an effect on the developments of other key players, such as BASF (WO2022/191905A1) and PSA Automobiles (WO2022/167736A1), which show how Toyota's innovations are helping to lower emissions. The following table shows exemplary patents citing the Toyota patent portfolio.

Publication Number	Title (English)	Assignee	Publication Date
JP7250205B1	Learning model generating method, learning model generating device, combustion prediction method, combustion prediction device, and program	TOKYO GAS	31/03/2023
Summary/Abstract – [Problem] To increase the prediction accuracy of an objective variable related to combustion of a furnace. Resolution Means: a learning model generation method is provided in which a computer acquires, as a control variable, furnace state information, and a measurement value of an objective variable corresponding to the input amount and the state information as teacher data, and the computer uses the teacher data to generate a learning model in which the input amount and the state information are input and a prediction value of the objective variable is output. Selected Drawing: FIG.1			
WO2022/191905A1	Systems, methods, and computer-readable media for providing a maintenance recommendation for a catalyst	BASF	15/09/2022

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – Methods, systems, and computer readable media are disclosed for providing a maintenance recommendation for a catalyst based on a trained machine learning model. The method includes: extract training data comprising one or more parameters from each catalyst of a plurality of catalysts: classify the training data in accordance with at least one catalyst feature at least one of the contaminations of the catalyst: determine a feature vector from the classified training data based on the one or more parameters extracted from catalyst of the plurality of catalysts, generate a performance baseline curve from the training data in accordance with the destruction removal efficiency (DRE) of a gas; and provide based on the trained machine learning model a maintenance recommendation for the catalyst.			
WO2022/167736A1	Method for controlling the operation of a catalytic converter for exhaust gases produced by a motor vehicle combustion engine	PSA AUTOMOBILES	11/08/2022
Summary/Abstract – Intake of aair (C1) and/or fuel (C2) in a combustion engine (1) is controlled on the basis of an order (5a) to activate a controller (7). The activation order (5a) is issued by an analysis system (5) in real time operation of the catalytic converter (4) on the basis of measurements (M1, M2) provided by photovoltaic oxygen sensors (8a, 8b) positioned upstream and downstream of the catalytic converter (4). An integrator (10) performs an integral proportional correction of the measurements (M1) provided by the upstream sensor (8a). The activation of the integrator (10) is dependent on validation of an error convergence of the oxygen richness of the exhaust gases (G1) measured by the upstream sensor (8b) relative to an error threshold, and on validation of detection of a stable operating state of the catalytic converter (4) over a predefined period.			
CN114483271A	Vehicle tail gas waste heat recovery system based on artificial intelligence	TERMINUS TECHNOLOGY	13/05/2022
Summary/Abstract – The invention relates to a vehicle tail gas waste heat recovery system based on artificial intelligence, and the system comprises a first analysis device which is used for taking each piece of reserve data corresponding to each motion period before a to-be-predicted motion period of a certain type of vehicles as each input signal of a recurrent neural network model, namely an artificial intelligence model, taking the reserve data of the automobile of the type in the to-be-predicted motion period as a single output signal of the recurrent neural network model; the second analysis equipment is used for completing multiple times of learning of the recurrent neural network model; and the prediction execution equipment is used for executing the recurrent neural network model after multiple times of learning so as to obtain reserve data of the current automobile type in the next motion period. According to the invention, the artificial intelligence can be adopted to complete the prediction processing of the subsequent emission data based on the historical emission data of different types of automobiles, so that key reference information is provided for formulating a tail gas waste heat recovery strategy and a tail gas filtering strategy.			
WO2022/037987A1	Method and device for monitoring and controlling an oxygen load of an exhaust gas catalytic converter of an exhaust gas tract of an internal combustion engine	VITESCO TECHNOLOGY	24/02/2022

Publication Number	Title (English)	Assignee	Publication Date
Summary/Abstract – The invention relates to a method for monitoring and controlling an oxygen load of an exhaust gas catalytic converter (120) of an exhaust gas tract (110) of an internal combustion engine (100), wherein the exhaust gas tract (110) has a first lambda sensor (130) arranged upstream of the exhaust gas catalytic convertor (120) in the exhaust gas flow direction, the method having the following steps: operating the internal combustion engine (100) and sensing a first lambda signal (240) of the first lambda sensor (130) which is characteristic for the oxygen content of the exhaust gas upstream of the exhaust gas catalytic converter (120); determining an oxygen supply flow into the exhaust gas catalytic converter (120) by means of the determined first lambda signal (240) and an exhaust gas mass flow upstream of the exhaust gas catalytic converter (120); providing an oxygen load model (300) of the exhaust gas catalytic converter (120) and determining the oxygen load of the exhaust gas catalytic converter (120) by means of the oxygen supply flow and the oxygen load model (300); controlling operating parameters (290) of the internal combustion engine (100) to control the oxygen load of the exhaust gas catalytic converter (120) by means of the determined oxygen load.			
JP07250205B1	Compound device and its operation control method	PANASONIC	26/09/1995
Summary/Abstract – PURPOSE: To provide a simple and clear operating method for the compound device. CONSTITUTION: Concerning the operation control method for controlling the operations of the compound device provided with plural functions 2, 4, 5, 6 and 8, operation control parameter information for designating operation contents is supplied to the compound device and the compound device, that reads this operation control parameter information, automatically conducts the plural functions according to the operation control parameter information. Only by reading the operation control parameter information described in storage media 11, 13 and 15 into the compound device or transferring the data of operation control parameter information from an external input/output terminal or the like to the compound device, the compound device automatically and successively conducts operations concerning the plural functions designated by the operation control parameter information.			

10 PATENTING AI TECHNOLOGIES – OTHER CONSIDERATIONS

10.1 PATENTABILITY OF SOFTWARE & AI INVENTIONS

While patents are the strongest form of IP right available, they are also the most difficult form of protection to obtain. Patented inventions allow the owner the right to take legal action against anyone who makes, uses, sells or imports it without permission for a defined period of time. To be granted a patent, inventions must meet 3 essential qualities:

1. Novelty: the invention must be new
2. Inventive: the invention is not just a simple modification to something that already exists
3. Industrial applicability: the invention is something that can be made or used

Software patents have always been a sensitive topic of discussion. Because documentation is more typically found in source code rather than in journals and electronically published articles, it can be difficult for patent offices to assess the novelty of inventions, which has often resulted in patents being granted for inventions considered to be obvious by experts in the field. There are jurisdictions that are viewed as taking a more "friendly" approach towards software subject matter. These include the US, Japan, Australia, and Canada.

European patent law explicitly excludes computer programs and methods of doing business from patent protection: "computer programs as such", but it has been left to case law to provide a definition of what "as such" means. Therefore, it is still possible, in certain circumstances, to obtain European patent protection for inventions devised in a software and/or business context. The EPO (European Patent Office) believes that in order for a claimed invention devised in a software to be patentable, the claimed invention must define "technical" features which solve a "technical problem" in a non-obvious manner. In addition, the technical effect must go beyond the "normal" physical effects produced when an ordinary piece of software is executed on computer hardware (e.g. the graphical display of data on a monitor or the movement of data from one location to another would be considered normal physical interactions). If an effect of this type can be identified, the program is not excluded and patentable.

Statutory law in the UK regarding the patentability of software and business method inventions is essentially the same as it is in Europe. In theory, the approach of the UKIPO concerning the patentability of software and business method inventions should produce the same result as the approach of the EPO, and the UK courts have indicated that both approaches ought to produce the same result. However, in practice, the UKIPO appears to take a much narrower view of what can be considered as "technical" compared with the EPO. The unfortunate effect of this is that the prospects of getting granted patents for software inventions at the UKIPO appear to be considerably less than at the EPO.

Mathematical methods per se, which include AI and machine learning algorithms and computational models, are excluded from patentability in the major patent offices. However, this exclusion is interpreted narrowly, and the EPO has published guidelines to help assess whether or not inventions

would be considered patentable subject matter[19]. Similarly to software inventions, if mathematical methods can be claimed in such a way that they can be considered to have "technical character" such that the AI method is applied to a technical field, or the AI method is adapted for implementation to a specific system, inventions are more likely to be considered patentable. Thus, claiming the use of a neural network on its own may not itself establish technical character for a claimed invention. However, its specific technical use to solve a technical problem may be viewed favourably. For example, the use of a neural network in a heart-monitoring apparatus for the purpose of identifying irregular heartbeats makes a technical contribution. The classification of digital images, videos, audio or speech signals based on low-level features (e.g. edges or pixel attributes for images) are further typical technical applications of classification algorithms[3].

This guidance aligns well with how software-based inventions are considered before the EPO. No comparable guidance available in the US yet, but the USPTO considers AI inventions largely in line with the EPO.

Patents can be highly valuable assets, but the significant time and investment required to obtain a patent means that for software and AI based approaches, they are often not considered essential, as the benefits have to significantly outweigh the costs (time and financial). When deciding if patent protection should be sought, consider the risks of not patenting it against the benefits/costs of doing so.

10.1.1 EUROPE

For an invention to be patentable, it must be novel and inventive over what is currently in the public domain. Over the years, the EPO and the UKIPO have developed the way in which the allowability of patent applications for computer software and business methods is assessed. The European Patent Office does not grant patents for computer programs ("software patents") or computer implemented business methods that make no technical contribution. In theory the EPO has settled on an approach that gives greater certainty to applicants in comparison to other patent offices, such as the US patent office, where the law in this area is in a state of flux.

The EPO updated its guidance[20] in 2018 to discuss computer implemented inventions. The Guidelines explain that claims in a patent application concerning a computer-implemented invention may comprise:

- A method claim;
- A computer program product claim;
- A corresponding data carrier signal carrying the computer program product;
- A computer readable (storage) medium or data carrier.

[19] https://www.epo.org/law-practice/legal-texts/html/guidelines2018/e/g_ii_3_3_1.htm

[20] https://www.epo.org/law-practice/legal-texts/guidelines.html

The guidelines have been updated since to include for the first-time patentability in relation to Artificial Intelligence and Machine Learning, and on Simulation, design or modelling and inventions realized in a distributed computing environment.

It can be seen that software and AI/ML related inventions can be patentable in Europe, but the invention needs to provide a technical solution to a technical problem that does not fall foul of the various patentability exclusions set out in the EPC.

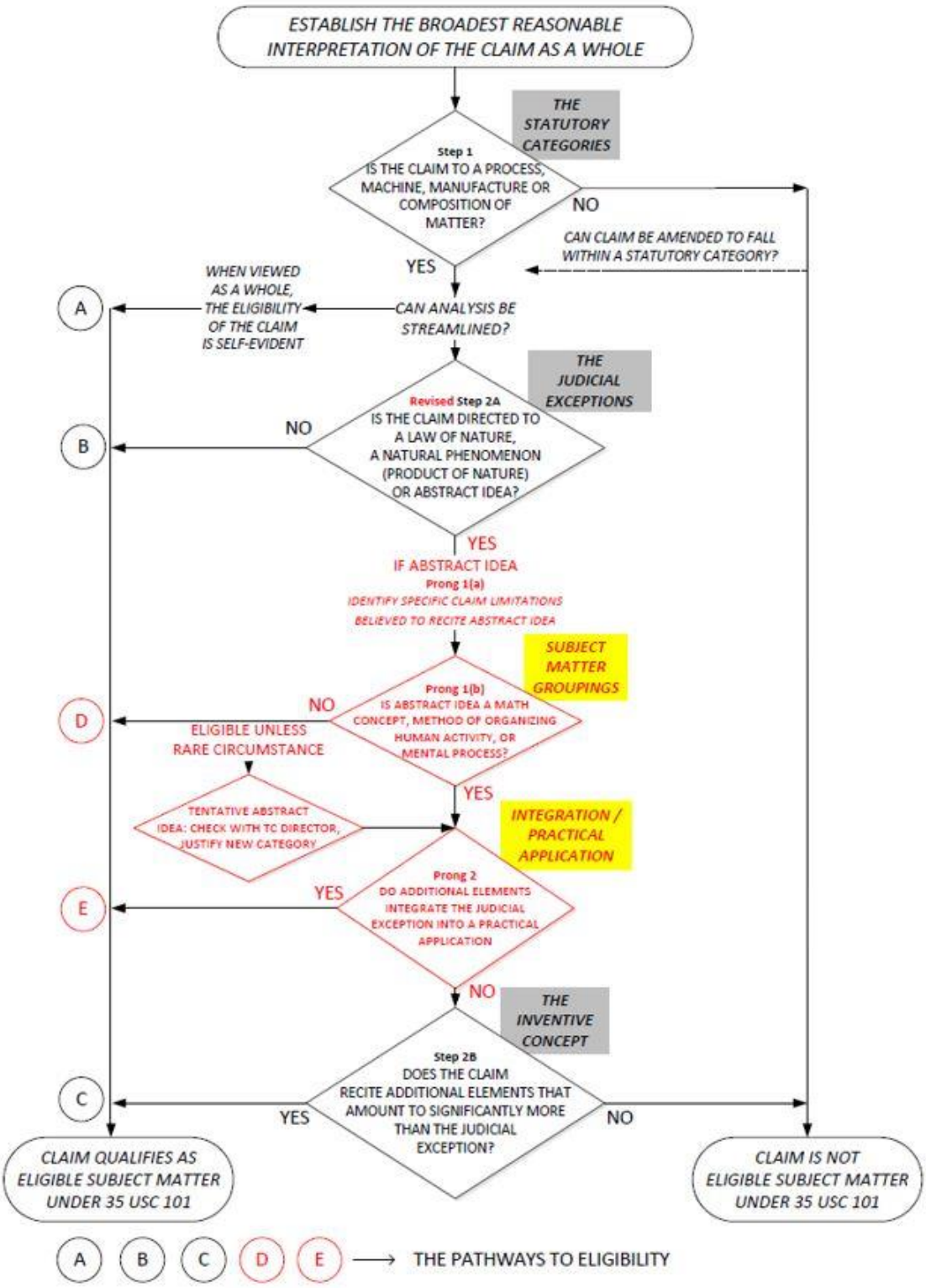
These relatively recent revisions of the guidance means that due to the unclear nature of "software patents" before the EPO there are a high number of Boards of Appeal cases covering computer-implemented inventions. A recent decision by the Board of Appeal[21] provides further guidance on how features of an invention should be assessed to determine whether they contribute to providing a patentable "technical effect". The key conclusion is that features which are specifically chosen with the intention of overcoming a technical problem in the prior art are more likely to be considered relevant for patentability than features chosen based on business-related motivations.

10.1.2 UNITED STATES

Historically, it was the case that it was much easier to get a patent granted for a software invention in the US, which was regarded as one of the leading jurisdictions in terms of allowing patents for digital inventions. However, the scope of allowable claims in the US is in flux as court decisions appear, and the USPTO is much more restrictive than it once was and is now more similar to the European approach. That being said the courts have not exactly been crystal clear about the line between a patentable software invention and an unpatentable abstract idea. The USPTO has issue guidance in 2019 in the Manual of Patent Examining Procedure[22] gives a short list of what may be deemed abstract and therefore it can be assumed that if it's not on the list, it's not abstract. Pure math is included as abstract, as is methods of organizing human activity or a mental process.

[21] T 697/17- SQL extensions/Microsoft Technology Licensing

[22] https://www.uspto.gov/web/offices/pac/mpep/index.html


ESTABLISH THE BROADEST REASONABLE INTERPRETATION OF THE CLAIM AS A WHOLE
THE STATUTORY CATEGORIES
Step 1
IS THE CLAIM TO A PROCESS, MACHINE, MANUFACTURE OR COMPOSITION OF MATTER?
NO
CAN CLAIM BE AMENDED TO FALL WITHIN A STATUTORY CATEGORY?
YES
WHEN VIEWED AS A WHOLE, THE ELIGIBILITY OF THE CLAIM IS SELF-EVIDENT
A
CAN ANALYSIS BE STREAMLINED?
THE JUDICIAL EXCEPTIONS
Revised Step 2A
IS THE CLAIM DIRECTED TO A LAW OF NATURE, A NATURAL PHENOMENON (PRODUCT OF NATURE) OR ABSTRACT IDEA?
NO
B
YES
IF ABSTRACT IDEA
Prong 1(a)
IDENTIFY SPECIFIC CLAIM LIMITATIONS BELIEVED TO RECITE ABSTRACT IDEA
SUBJECT MATTER GROUPINGS
Prong 1(b)
IS ABSTRACT IDEA A MATH CONCEPT, METHOD OF ORGANIZING HUMAN ACTIVITY, OR MENTAL PROCESS?
NO
D
ELIGIBLE UNLESS RARE CIRCUMSTANCE
TENTATIVE ABSTRACT IDEA: CHECK WITH TC DIRECTOR, JUSTIFY NEW CATEGORY
YES
INTEGRATION / PRACTICAL APPLICATION
Prong 2
DO ADDITIONAL ELEMENTS INTEGRATE THE JUDICIAL EXCEPTION INTO A PRACTICAL APPLICATION
YES
E
NO
THE INVENTIVE CONCEPT
Step 2B
DOES THE CLAIM RECITE ADDITIONAL ELEMENTS THAT AMOUNT TO SIGNIFICANTLY MORE THAN THE JUDICIAL EXCEPTION?
YES
C
NO
CLAIM QUALIFIES AS ELIGIBLE SUBJECT MATTER UNDER 35 USC 101
CLAIM IS NOT ELIGIBLE SUBJECT MATTER UNDER 35 USC 101
A B C D E ⟶ THE PATHWAYS TO ELIGIBILITY

IAM[23] summarise the similarities and difference between the USPTO and EPO as being:

- Differences:
    - The EPO requires a further technical effect for software-related inventions.
    - If an abstract idea (e.g., a mathematical concept) is claimed in the United States, it must be tied to a practical application of the concept.
    - Improvements in the functioning of a computer or other technology and/or one or more elements that are not well understood, routine or conventional in the field may evidence that a claim is patent eligible in the United States.
- Similarities:
    - Case law defines what a further technical effect is in Europe and, similarly, what may constitute a practical application in the United States.
    - Software related to user interfaces, business methods, mathematical methods and simulations require extra care in Europe and, similarly, may be patent eligible in the United States provided that the technical aspect of the invention is sufficiently described.
    - Software related to image processing and cryptography is usually considered to have technical character by the EPO and is likely to be patent eligible in the United States if the technical aspects are sufficiently described beyond a high level of generality in the field.

10.2 ENFORCEMENT OF AI PATENTS

AI technology has developed rapidly over the last 10 years, which has raised many legal challenges given how fast the technology has advanced and patentability obstacles. It is particularly difficult to prove infringement, as AI processes often takes place within a "black box", as well as difficulty in determining the location that a patented process takes place, for instance when AI is spread across the cloud or servers in multiple territories[24]. Also, since AI is a relatively new technology, many AI products have recently entered the market, hence AI patents are reported to have not yet had the opportunity to be extensively tested in litigation[25].

Despite the notable challenges in infringement of AI patents, the case between Alice Corp. v CLS Bank International provides an example of a case that has had a profound impact on the litigation of software patents in the US. The outcome of the case has improved the methodology for the assessment whether patent claims relate to an ineligible concept, such as an abstract idea[26]. This has contributed to an increase in the number of litigations in the US, which is also reflected in the science

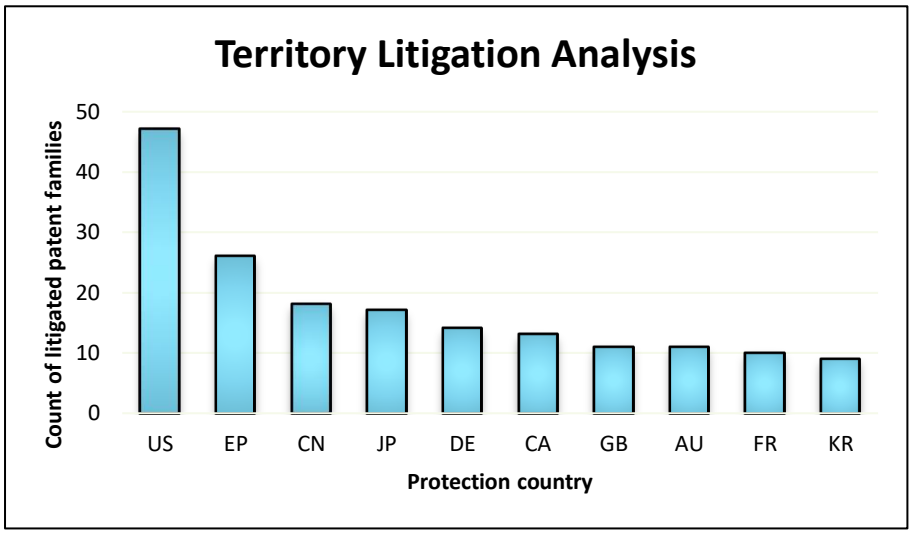
[23] https://www.iam-media.com/law-policy/six-big-ways-us-and-europe-differ-software-patents

[24] https://www.marks-clerk.com/insights/articles/the-impact-of-artificial-intelligence-on-patent-infringement-claims/

[25] https://www.kilburnstrode.com/knowledge/ai/ai-musings/infringing-ai-patents

[26] https://www.wipo.int/wipo_magazine/en/2019/04/article_0006.html

and engineering patent landscape, as can be seen in the following figure (data provided by Questel Orbit). The top litigated players include Siemens, Samsung Electronics, Alphabet, Canon, and Toshiba; the litigated patent documents tend to come under scrutiny using the aforementioned Alice eligibility test.



11 APPENDIX

11.1 SEARCH STRINGS

Search Strategy	Patent Families
1. Patent Landscape – General AI Patent Landscape (Derwent Innovation)	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep ADJ3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301)) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A01* or A61* or A62* or A99* OR B OR C OR D OR E OR F or Y) OR (MC=((A??) OR (B??) OR (C??) OR (D??) OR (E??) OR (F??) OR (G??) OR (H??) OR (J??) OR (K??) OR (L??) OR (M??) OR (N??) OR (P??) OR (Q??) OR (S??) OR (X??))))	194463
1A. Sub-Search – Medicine & Pharmaceutical Patent Landscape (Derwent Innovation)	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND (PRC=(GB) OR PAOC=(GB))) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A61K* or A61P* OR A61Q*) OR (MC=((B??))))	217
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301)) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A61K* or A61P* OR A61Q*) OR (MC=((B??))));	14220
1B. Sub-Search – Medical Technology Patent Landscape (Derwent Innovation)	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND (PRC=(GB) OR PAOC=(GB))) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A61B* OR A61C* OR A61D* OR A61F* OR A61G* OR	604

A61H* OR A61J* OR A61L* OR A61M* OR A61N* OR A62B*) OR (MC=((S05) OR (P31) OR (P32) OR (P33) OR (P34))));	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301)) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A61B* OR A61C* OR A61D* OR A61F* OR A61G* OR A61H* OR A61J* OR A61L* OR A61M* OR A61N* OR A62B*) OR (MC=((S05) OR (P31) OR (P32) OR (P33) OR (P34))));	54902
1C. Sub-Search – Biotechnology & Chemical Patent Landscape (Derwent Innovation)	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND (PRC=(GB) OR PAOC=(GB))) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A01* or A99* OR C* OR D*) OR (MC=((A??) OR (C??) OR (D??) OR (E??) OR (F??) OR (H??) OR (J??) OR (L??) OR (M??) OR (N??) OR (P1?))));	384
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301)) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A01* or A99* OR C* OR D*) OR (MC=((A??) OR (C??) OR (D??) OR (E??) OR (F??) OR (H??) OR (J??) OR (L??) OR (M??) OR (N??) OR (P1?))));	31606
1D. Sub-Search – Engineering & Transport Patent Landscape (Derwent Innovation)	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND (PRC=(GB) OR PAOC=(GB))) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(B OR E OR F) OR (MC=((G??) OR (Q??) OR (P7?) OR (S01) OR (S02) OR (S03) or (S06) OR (X??))));	926
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2	121438

languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301)) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(B OR E OR F) OR (MC=((G??) OR (Q??) OR (P7?) OR (S01) OR (S02) OR (S03) or (S06) OR (X??))));	
2. European Patent Landscape – European Patent Landscape (Derwent Innovation)	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND (PRC=(GB) OR PAOC=(GB))) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A01* or A61* or A62* or A99* OR B OR C OR D OR E OR F or Y) OR (MC=((A??) OR (B??) OR (C??) OR (D??) OR (E??) OR (F??) OR (G??) OR (H??) OR (J??) OR (K??) OR (L??) OR (M??) OR (N??) OR (P??) OR (Q??) OR (S??) OR (X??))))	1676
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND (PRC=(DE) OR PAOC=(DE))) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A01* or A61* or A62* or A99* OR B OR C OR D OR E OR F or Y) OR (MC=((A??) OR (B??) OR (C??) OR (D??) OR (E??) OR (F??) OR (G??) OR (H??) OR (J??) OR (K??) OR (L??) OR (M??) OR (N??) OR (P??) OR (Q??) OR (S??) OR (X??))))	6118
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND (PRC=(FR) OR PAOC=(FR))) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A01* or A61* or A62* or A99* OR B OR C OR D OR E OR F or Y) OR (MC=((A??) OR (B??) OR (C??) OR (D??) OR (E??) OR (F??) OR (G??) OR (H??) OR (J??) OR (K??) OR (L??) OR (M??) OR (N??) OR (P??) OR (Q??) OR (S??) OR (X??))))	1421
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR	286

predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND (PRC=(ES) OR PAOC=(ES))) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A01* or A61* or A62* or A99* OR B OR C OR D OR E OR F or Y) OR (MC=((A??) OR (B??) OR (C??) OR (D??) OR (E??) OR (F??) OR (G??) OR (H??) OR (J??) OR (K??) OR (L??) OR (M??) OR (N??) OR (P??) OR (Q??) OR (S??) OR (X??))))	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND (PRC=(IT) OR PAOC=(IT))) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A01* or A61* or A62* or A99* OR B OR C OR D OR E OR F or Y) OR (MC=((A??) OR (B??) OR (C??) OR (D??) OR (E??) OR (F??) OR (G??) OR (H??) OR (J??) OR (K??) OR (L??) OR (M??) OR (N??) OR (P??) OR (Q??) OR (S??) OR (X??))))	427
2. Patent Landscape (China only excluded) – General AI Patent Landscape (Derwent Innovation)	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND CC=(AM OR AP OR AR OR AT OR AU OR BA OR BE OR BG OR BR OR BY OR CA OR CH OR CL OR CO OR CR OR CS OR CU OR CY OR CZ OR DD OR DE OR DK OR DO OR DZ OR EA OR EC OR EE OR EG OR EM OR EP OR ES OR FI OR FR OR GB OR GC OR GE OR GR OR GT OR HK OR HN OR HR OR HU OR ID OR IE OR IL OR IN OR IS OR IT OR JO OR JP OR KE OR KG OR KR OR KZ OR LT OR LU OR LV OR MA OR MC OR MD OR ME OR MN OR MO OR MT OR MW OR MX OR MY OR NI OR NL OR NO OR NZ OR OA OR PA OR PE OR PH OR PL OR PT OR RO OR RS OR RU OR SA OR SE OR SG OR SI OR SK OR SM OR SU OR SV OR TH OR TJ OR TN OR TR OR TT OR TW OR UA OR US OR UY OR UZ OR VN OR WO OR YU OR ZA OR ZM OR ZW)) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A01* or A61* or A62* or A99* OR B OR C OR D OR E OR F or Y) OR (MC=((A??) OR (B??) OR (C??) OR (D??) OR (E??) OR (F??) OR (G??) OR (H??) OR (J??) OR (K??) OR (L??) OR (M??) OR (N??) OR (P??) OR (Q??) OR (S??) OR (X??))))	78028
3A. Patent Landscape Sub-Search (China only excluded) – AI Sub-Types Patent Landscape (Derwent Innovation)	
"String 2"AND (CTB=((logic ADJ2 program*) OR (expert ADJ2 system) OR (knowledge ADJ2 system*)) or MC=(T01-J16A) or AIC=(G05B13/028 or G06F11/2257 or G10K2210/3024 or G16H50/20))	10521
"String 2"AND (CTB=(fuzzy ADJ2 logic*) or AIC=(G06N7/02* or G05B13/0275 or G10H2250/151 or B60G2600/1879 or F05B2270/707 or F16H2061/0081) or MC=(T01-J16B))	2131

"String 2"AND (CTB=(neural ADJ2 net*) or AIC=(G06N3/02* OR G06N7/046 OR G06N3/082 OR G06N3/084 OR G06T3/4046 OR G06T9/002 OR G06T2207/20084 OR G05B13/027 OR G10L15/16 OR G01N2201/1296 OR G01N29/4481 OR G01S7/417 OR G06F11/1476 OR G06F11/2263 OR G06F2207/4824 OR G11B20/10518 OR G10H2250/311 OR G10K2210/3038 OR H02P21/0014 OR H02P23/0018 OR H03H2017/0208 OR H03H2222/04 OR B60G2600/1878 OR B23K31/006 OR B29C2945/76979 OR B29C66/965 OR F02D41/1405 OR F05B2270/709 OR F16H2061/0084) OR MC=(T01-J16C1))	32894
"String 2"AND (CTB=(machine ADJ2 learn*) OR AIC=(G06N0020* OR G06N000308*) OR MC=(T01-J16C2));	47074
"String 2"AND (ALL=(Ontolog* NEAR5 engineer*))	14
"String 2"AND (CTB=(Probab* ADJ3 (reason* or logic*))	76
"String 2"AND (CTB=(natural* ADJ2 (language OR picture*) ADJ2 process*) OR AIC=(G06F17/2282 or G06F17/27 or G06F17/30401 or G06F17/3043 or G06F17/30654 or G06F17/30663 or G06F17/30666) OR MC=(T01-J16C3)	2702
"String 2"AND (CTB=((genetic* OR evolv* OR evolution*) ADJ2 (algorithm* OR program*)) OR AIC=(G06N3/086 OR G06N3/004) OR MC=(T01-J16C4))	1235
3B. Patent Landscape Sub-Search (China only excluded) – Machine Learning Methods (Derwent Innovation)	
"String 2"AND (CTB=(neural ADJ2 net*) or AIC=(G06N3/02* OR G06N7/046 OR G06N3/082 OR G06N3/084 OR G06T3/4046 OR G06T9/002 OR G06T2207/20084 OR G05B13/027 OR G10L15/16 OR G01N2201/1296 OR G01N29/4481 OR G01S7/417 OR G06F11/1476 OR G06F11/2263 OR G06F2207/4824 OR G11B20/10518 OR G10H2250/311 OR G10K2210/3038 OR H02P21/0014 OR H02P23/0018 OR H03H2017/0208 OR H03H2222/04 OR B60G2600/1878 OR B23K31/006 OR B29C2945/76979 OR B29C66/965 OR F02D41/1405 OR F05B2270/709 OR F16H2061/0084) OR MC=(T01-J16C1))	33211
"String 2"AND CTB=(probab* ADJ2 graph* ADJ2 model*) OR AIC=(G06N7/01 OR G06N7/005)	2546
"String 2"AND CTB=((support* ADJ2 vector* ADJ2 machine*) OR SVM) OR AIC=(G06N20/10)	4623
CTB=((branch* ADJ2 bound*) and ((decision* OR regress*) ADJ2 tree*)) OR AIC=(G06N5/01*)	1427
"String 2"AND (CTB=(ensemble*) OR AIC=(G06N20/20))	7107
"String 2"AND CTB=((rule* ADJ2 learn*) OR (knowledge* ADJ2 represent*)) OR AIC=(G06N5/02*)	1699
"String 2"AND CTB=(((instanc* or memor*) ADJ2 base*) ADJ3 learn*)	38
"String 2"AND CTB=(laten* ADJ2 (represent* OR variable*))	262
"String 2"AND CTB=((multitask* OR (multi* ADJ2 task*)) ADJ3 learn*)	101
"String 2"AND CTB=(relation* ADJ2 learn*)	60
"String 2"AND CTB=(logic* ADJ2 learn*)	16
3C. Patent Landscape Sub-Search (China only excluded) – Neural Network Learning Methods (Derwent Innovation)	
"String 2"AND (CTB=((unsupervi* OR (("no" OR "not" OR "non" OR none* OR without*) ADJ2 supervi*)) NEAR3 learn*) OR AIC=(G06N3/088))	1975
"String 2"AND (CTB=(((weak* OR semi* OR self*) ADJ2 supervi*) NEAR3 learn*) OR AIC=(G06N3/0895))	275
"String 2"AND (CTB=(reinforc* ADJ2 learn*) OR AIC=(G06N3/092))	1503
"String 2"AND (CTB=(active ADJ2 learn*) OR AIC=(G06N3/091))	94

“String 2”AND (CTB=(backpropagat* OR (back ADJ2 propagat*)) OR AIC=(G06N3/084))	3260
“String 2”AND (CTB=(advers* ADJ3 learn*) OR AIC=(G06N3/094))	85
“String 2”AND (CTB=(transfer* ADJ3 learn*) OR AIC=(G06N3/096))	522
“String 2”AND (CTB=((distribut* OR federat*) ADJ3 learn*) OR AIC=(G06N3/098))	262
“String 2”AND (CTB=((bio* ADJ2 inspir*) OR ((genetic* OR evolution*) NEAR5 (algorithm* or program*))) OR AIC=(G06N3/086 OR G06N3/004* or G06N3/126))	1327
3D. Patent Landscape Sub-Search (China only excluded) – Neural Network Architecture (Derwent Innovation)	
“String 2”AND (CTB=(combin* NEAR3 network*) OR AIC=(G06N3/045*))	7947
“String 2”AND (CTB=(((convolut* or conv) ADJ3 net*) or ConvNet) OR AIC=(G06N3/0464))	7836
“String 2”AND (CTB=((recurrent* or hopfield*) ADJ3 network*) OR AIC=(G06N3/044*))	3526
“String 2”AND (CTB=(activat* ADJ3 function*) OR AIC=(G06N3/048))	1858
“String 2”AND (CTB=(fuzzy*) OR AIC=(G06N3/043))	1264
“String 2”AND (CTB=((probab* or stochastic*) ADJ3 net*) OR AIC=(G06N3/047))	1150
“String 2”AND (CTB=(generativ* ADJ3 net*) OR AIC=(G06N3/0475))	907
“String 2”AND (CTB=((Knowledge* OR logic*) NEAR5 (neur* ADJ3 net*)) OR AIC=(G06N3/042))	732
“String 2”AND (CTB=((tempor* ADJ3 net*) OR (delay* ADJ3 element*) OR (oscillat* ADJ3 neuro*) or (puls* ADJ3 input*)) OR AIC=(G06N3/049))	516
“String 2”AND (CTB=((Feedforward* OR (Feed ADJ2 forward*)) ADJ3 net*) OR AIC=(G06N3/0499))	395
“String 2”AND (CTB=(chaos* or fractal*) OR AIC=(G06N3/0418))	192
“String 2”AND (CTB=((Quanti* OR Spars* OR Compress*) ADJ3 net*) OR AIC=(G06N3/0495))	137
“String 2”AND (CTB=(Adapt* ADJ2 resonanc* ADJ2 theor*) OR AIC=(G06N3/0409))	25
“String 2”AND (CTB=(neocognitron*) OR AIC=(G06N3/0463))	7
4A. Patent Landscape Sub-Search (China only excluded) – AI Applications (Derwent Innovation)	
“String 2”AND AIC=(A*)	26333
“String 2”AND AIC=(B*)	21581
“String 2”AND AIC=(C*)	5274
“String 2”AND AIC=(D*)	531
“String 2”AND AIC=(E*)	2778
“String 2”AND AIC=(F*)	5366
5A. Patent Landscape Sub-Search (China only excluded) – Pharmaceutical Patent Landscape (Derwent Innovation)	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND CC=(AM OR AP OR AR OR AT OR AU OR BA OR BE OR BG OR BR OR BY OR CA OR CH OR CL OR CO OR CR OR CS OR CU OR CY OR CZ OR DD OR DE OR DK OR DO OR DZ OR EA OR EC OR EE OR EG OR EM OR EP OR ES OR FI OR FR OR GB OR GC OR GE OR GR OR GT OR HK OR HN OR HR OR HU OR ID OR IE	7745

OR IL OR IN OR IS OR IT OR JO OR JP OR KE OR KG OR KR OR KZ OR LT OR LU OR LV OR MA OR MC OR MD OR ME OR MN OR MO OR MT OR MW OR MX OR MY OR NI OR NL OR NO OR NZ OR OA OR PA OR PE OR PH OR PL OR PT OR RO OR RS OR RU OR SA OR SE OR SG OR SI OR SK OR SM OR SU OR SV OR TH OR TJ OR TN OR TR OR TT OR TW OR UA OR US OR UY OR UZ OR VN OR WO OR YU OR ZA OR ZM OR ZW)) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A61K* or A61P* OR A61Q*) OR (MC=((B??))))	
5B. Patent Landscape Sub-Search (China only excluded) – Medical Technology Patent Landscape (Derwent Innovation)	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND CC=(AM OR AP OR AR OR AT OR AU OR BA OR BE OR BG OR BR OR BY OR CA OR CH OR CL OR CO OR CR OR CS OR CU OR CY OR CZ OR DD OR DE OR DK OR DO OR DZ OR EA OR EC OR EE OR EG OR EM OR EP OR ES OR FI OR FR OR GB OR GC OR GE OR GR OR GT OR HK OR HN OR HR OR HU OR ID OR IE OR IL OR IN OR IS OR IT OR JO OR JP OR KE OR KG OR KR OR KZ OR LT OR LU OR LV OR MA OR MC OR MD OR ME OR MN OR MO OR MT OR MW OR MX OR MY OR NI OR NL OR NO OR NZ OR OA OR PA OR PE OR PH OR PL OR PT OR RO OR RS OR RU OR SA OR SE OR SG OR SI OR SK OR SM OR SU OR SV OR TH OR TJ OR TN OR TR OR TT OR TW OR UA OR US OR UY OR UZ OR VN OR WO OR YU OR ZA OR ZM OR ZW)) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A61B* OR A61C* OR A61D* OR A61F* OR A61G* OR A61H* OR A61J* OR A61L* OR A61M* OR A61N* OR A62B*) OR (MC=((S05) OR (P31) OR (P32) OR (P33) OR (P34))));	28733
5C. Patent Landscape Sub-Search (China only excluded) – Biotechnology & Chemistry Patent Landscape (Derwent Innovation)	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND CC=(AM OR AP OR AR OR AT OR AU OR BA OR BE OR BG OR BR OR BY OR CA OR CH OR CL OR CO OR CR OR CS OR CU OR CY OR CZ OR DD OR DE OR DK OR DO OR DZ OR EA OR EC OR EE OR EG OR EM OR EP OR ES OR FI OR FR OR GB OR GC OR GE OR GR OR GT OR HK OR HN OR HR OR HU OR ID OR IE OR IL OR IN OR IS OR IT OR JO OR JP OR KE OR KG OR KR OR KZ OR LT OR LU OR LV OR MA OR MC OR MD OR ME OR MN OR MO OR MT OR MW OR MX OR MY OR NI OR NL OR NO OR NZ OR OA OR PA OR PE OR PH OR PL OR PT OR RO OR RS OR RU OR SA OR SE OR SG OR SI OR SK OR SM OR SU OR SV OR TH OR TJ OR TN OR TR OR TT OR TW OR UA OR US OR UY OR UZ OR VN OR WO OR YU OR ZA OR ZM OR ZW)) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(A01* or A99* OR C* OR D*) OR (MC=((A??) OR (C??) OR (D??) OR (E??) OR (F??) OR (H??) OR (J??) OR (L??) OR (M??) OR (N??) OR (P1?))));	15012

5D. Patent Landscape Sub-Search (China only excluded) – Engineering & Transport Patent Landscape (Derwent Innovation)	
(((CTB=((artificial ADJ2 intel*) OR artificialintel* OR (machine ADJ2 learn*) OR machinelearn* OR (deep adj3 learn*) OR deeplearn* OR (neural ADJ2 net*) OR neuralnet* OR (machine ADJ2 intel*) OR machineintel* OR (natural* ADJ2 languag*) OR naturallanguag* OR (comput* ADJ2 intel*) OR computerintel* OR (comput* ADJ2 vision*) OR computervision* OR (predict* ADJ2 analys*) OR predictiveanalys*) OR MC=(T01-J16*) or AIC=(G06N0003* OR G06N0005* OR G06N0007* OR G06N0020* OR G06N0099* OR Y10S0706*)) AND PRD>=(20130301) AND CC=(AM OR AP OR AR OR AT OR AU OR BA OR BE OR BG OR BR OR BY OR CA OR CH OR CL OR CO OR CR OR CS OR CU OR CY OR CZ OR DD OR DE OR DK OR DO OR DZ OR EA OR EC OR EE OR EG OR EM OR EP OR ES OR FI OR FR OR GB OR GC OR GE OR GR OR GT OR HK OR HN OR HR OR HU OR ID OR IE OR IL OR IN OR IS OR IT OR JO OR JP OR KE OR KG OR KR OR KZ OR LT OR LU OR LV OR MA OR MC OR MD OR ME OR MN OR MO OR MT OR MW OR MX OR MY OR NI OR NL OR NO OR NZ OR OA OR PA OR PE OR PH OR PL OR PT OR RO OR RS OR RU OR SA OR SE OR SG OR SI OR SK OR SM OR SU OR SV OR TH OR TJ OR TN OR TR OR TT OR TW OR UA OR US OR UY OR UZ OR VN OR WO OR YU OR ZA OR ZM OR ZW)) NOT AIC=(G06Q* OR G09* OR Y10S0705*)) AND (AIC=(B OR E OR F) OR (MC=((G??) OR (Q??) OR (P7?) OR (S01) OR (S02) OR (S03) or (S06) OR (X??))));	45454

11.2 SEARCH CLASSIFICATION CODES

11.2.1 IPC/CPC CLASSIFICATIONS

IPC/CPC Code	Definition
A01	AGRICULTURE; FORESTRY; ANIMAL HUSBANDRY; HUNTING; TRAPPING; FISHING
A61	MEDICAL OR VETERINARY SCIENCE; HYGIENE
A61B	DIAGNOSIS; SURGERY; IDENTIFICATION
A61C	DENTISTRY; APPARATUS OR METHODS FOR ORAL OR DENTAL HYGIENE
A61D	VETERINARY INSTRUMENTS, IMPLEMENTS, TOOLS, OR METHODS
A61F	FILTERS IMPLANTABLE INTO BLOOD VESSELS; PROSTHESES; DEVICES PROVIDING PATENCY TO, OR PREVENTING COLLAPSING OF, TUBULAR STRUCTURES OF THE BODY, e.g. STENTS; ORTHOPAEDIC, NURSING OR CONTRACEPTIVE DEVICES; FOMENTATION; TREATMENT OR PROTECTION OF EYES OR EARS; BANDAGES, DRESSINGS OR ABSORBENT PADS; FIRST-AID KITS
A61G	TRANSPORT, PERSONAL CONVEYANCES, OR ACCOMMODATION SPECIALLY ADAPTED FOR PATIENTS OR DISABLED PERSONS
A61H	PHYSICAL THERAPY APPARATUS, e.g. DEVICES FOR LOCATING OR STIMULATING REFLEX POINTS IN THE BODY; ARTIFICIAL RESPIRATION; MASSAGE; BATHING DEVICES FOR SPECIAL THERAPEUTIC OR HYGIENIC PURPOSES OR SPECIFIC PARTS OF THE BODY
A61J	CONTAINERS SPECIALLY ADAPTED FOR MEDICAL OR PHARMACEUTICAL PURPOSES; DEVICES OR METHODS SPECIALLY ADAPTED FOR BRINGING PHARMACEUTICAL PRODUCTS INTO PARTICULAR PHYSICAL OR ADMINISTERING FORMS; DEVICES FOR ADMINISTERING FOOD OR MEDICINES ORALLY; BABY COMFORTERS; DEVICES FOR RECEIVING SPITTLE
A61K	PREPARATIONS FOR MEDICAL, DENTAL OR TOILETRY PURPOSES
A61L	METHODS OR APPARATUS FOR STERILISING MATERIALS OR OBJECTS IN GENERAL; DISINFECTION, STERILISATION OR DEODORISATION OF AIR; CHEMICAL ASPECTS OF BANDAGES, DRESSINGS, ABSORBENT PADS OR SURGICAL ARTICLES; MATERIALS FOR BANDAGES, DRESSINGS, ABSORBENT PADS OR SURGICAL ARTICLES
A61M	DEVICES FOR INTRODUCING MEDIA INTO, OR ONTO, THE BODY; DEVICES FOR TRANSDUCING BODY MEDIA OR FOR TAKING MEDIA FROM THE BODY; DEVICES FOR PRODUCING OR ENDING SLEEP OR STUPOR
A61N	ELECTROTHERAPY; MAGNETOTHERAPY; RADIATION THERAPY; ULTRASOUND THERAPY
A61P	SPECIFIC THERAPEUTIC ACTIVITY OF CHEMICAL COMPOUNDS OR MEDICINAL PREPARATIONSA62B
A61Q	SPECIFIC USE OF COSMETICS OR SIMILAR TOILETRY PREPARATIONS
A62	LIFE-SAVING; FIRE-FIGHTING
A62B	DEVICES, APPARATUS OR METHODS FOR LIFE-SAVING
A99	SUBJECT MATTER NOT OTHERWISE PROVIDED FOR IN THIS SECTION
B	PERFORMING OPERATIONS; TRANSPORTING
B23K31/006	relating to using of neural networks
B29C2945/76979	Using a neural network
B29C66/965	using artificial neural networks
B60G2600/1878	Neural Networks
B60G2600/1879	Fuzzy Logic Control

C	CHEMISTRY; METALLURGY
D	TEXTILES; PAPER
E	FIXED CONSTRUCTIONS
F	MECHANICAL ENGINEERING; LIGHTING; HEATING
F02D41/1405	Neural network control
F05B2270/707	fuzzy logic
F05B2270/709	with neural networks
F16H2061/0081	Fuzzy logic
F16H2061/0084	Neural networks
G01N2201/1296	using neural networks
G01N29/4481	Neural networks
G01S7/417	involving the use of neural networks
G05B13/027	using neural networks only
G05B13/0275	using fuzzy logic only
G05B13/028	using expert systems only
G06F11/1476	in neural networks
G06F11/2257	using expert systems
G06F11/2263	using neural networks
G06F17/2282	Automatic learning of transformation rules, e.g. by example
G06F17/27	Automatic analysis, e.g. parsing
G06F17/30401	Natural language query formulation
G06F17/3043	Translation of natural language queries to structured queries
G06F17/30654	Natural language query formulation or dialogue systems
G06F17/30663	Selection or weighting of terms from queries, including natural language queries
G06F17/30666	Syntactic pre-processing steps, e.g. stopword elimination, stemming
G06F2207/4824	Neural networks
G06N20/00	Machine learning
G06N20/10	using kernel methods, e.g. support vector machines [SVM]
G06N20/20	Ensemble learning
G06N3/00	Computing arrangements based on biological models
G06N3/004	Artificial life, i.e. computing arrangements simulating life
G06N3/02	Neural networks
G06N3/0409	Adaptive resonance theory [ART] networks
G06N3/0418	using chaos or fractal principles
G06N3/042	Knowledge-based neural networks; Logical representations of neural networks
G06N3/043	based on fuzzy logic, fuzzy membership or fuzzy inference, e.g. adaptive neuro-fuzzy inference systems [ANFIS]
G06N3/044	Recurrent networks, e.g. Hopfield networks
G06N3/045	Combinations of networks
G06N3/0463	Neocognitrons
G06N3/0464	Convolutional networks [CNN, ConvNet]
G06N3/047	Probabilistic or stochastic networks
G06N3/0475	Generative networks
G06N3/048	Activation functions
G06N3/049	Temporal neural networks, e.g. delay elements, oscillating neurons or pulsed inputs
G06N3/0495	Quantised networks; Sparse networks; Compressed networks
G06N3/0499	Feedforward networks

G06N3/08	Learning methods
G06N3/082	modifying the architecture, e.g. adding, deleting or silencing nodes or connections
G06N3/084	Backpropagation, e.g. using gradient descent
G06N3/086	using evolutionary algorithms, e.g. genetic algorithms or genetic programming
G06N3/088	Non-supervised learning, e.g. competitive learning
G06N3/0895	Weakly supervised learning, e.g. semi-supervised or self-supervised learning
G06N3/091	Active learning
G06N3/092	Reinforcement learning
G06N3/094	Adversarial learning
G06N3/096	Transfer learning
G06N3/098	Distributed learning, e.g. federated learning
G06N3/126	Evolutionary algorithms, e.g. genetic algorithms or genetic programming
G06N5/00	Computing arrangements using knowledge-based models
G06N5/01	Dynamic search techniques; Heuristics; Dynamic trees; Branch-and-bound
G06N5/02	Knowledge representation; Symbolic representation
G06N7/00	Computing arrangements based on specific mathematical models
G06N7/005	{Probabilistic networks}
G06N7/01	Probabilistic graphical models, e.g. probabilistic networks
G06N7/02	using fuzzy logic (
G06N7/046	Implementation by means of a neural network
G06N99/00	Subject matter not provided for in other groups of this subclass
G06Q	INFORMATION AND COMMUNICATION TECHNOLOGY [ICT] SPECIALLY ADAPTED FOR ADMINISTRATIVE, COMMERCIAL, FINANCIAL, MANAGERIAL OR SUPERVISORY PURPOSES; SYSTEMS OR METHODS SPECIALLY ADAPTED FOR ADMINISTRATIVE, COMMERCIAL, FINANCIAL, MANAGERIAL OR SUPERVISORY PURPOSES, NOT OTHERWISE PROVIDED FOR
G06T2207/20084	Artificial neural networks [ANN]
G06T3/4046	using neural networks
G06T9/002	using neural networks
G09	EDUCATION; CRYPTOGRAPHY; DISPLAY; ADVERTISING; SEALS
G10H2250/151	Fuzzy logic
G10H2250/311	Neural networks for electrophonic musical instruments or musical processing, e.g. for musical recognition or control, automatic composition or improvisation
G10K2210/3024	Expert systems, e.g. artificial intelligence
G10K2210/3038	Neural networks
G10L15/16	using artificial neural networks
G11B20/10518	using neural networks
G16H50/20	for computer-aided diagnosis, e.g. based on medical expert systems
H02P21/0014	using neural networks
H02P23/0018	using neural networks
H03H2017/0208	using neural networks
H03H2222/04	using neural networks
Y10S705/00	Data processing: financial, business practice, management, or cost/price determination
Y10S706/00	Data processing: artificial intelligence

11.2.2 DWPI MANUAL CLASSIFICATIONS

DWPI™ Manual Code	Definition
A	POLYMERS AND PLASTICS
B	PHARMACEUTICALS
C	AGRICULTURAL CHEMICALS
D	FOOD, FERMENTATION, DISINFECTANTS, DETERGENTS
E	GENERAL CHEMICALS
F	TEXTILES, PAPER, CELLULOSE
G	PRINTING, COATING, PHOTOGRAPHIC
H	PETROLEUM
J	CHEMICAL ENGINEERING
K	NUCLEONICS, EXPLOSIVES, PROTECTION
L	GLASS, CERAMICS, ELECTRO(IN)ORGANICS
M	METALLURGY
N	CATALYSTS
P	GENERAL
P1	AGRICULTURE, FOOD, TOBACCO
P7	PRESSING, PRINTING
P31	DIAGNOSIS, SURGERY
P32	DENTISTRY, BANDAGES, VETERINARY, PROSTHESIS
P33	MEDICAL AIDS, ORAL ADMINISTRATION
P34	STERILIZING, SYRINGES
Q	MECHANICAL
S	INSTRUMENTATION, MEASURING AND TESTING
S01	ELECTRICAL INSTRUMENTATION
S02	ENGINEERING INSTRUMENTATION
S03	SCIENTIFIC INSTRUMENTATION
S05	ELECTRICAL MEDICAL EQUIPMENT
S06	ELECTROPHOTOGRAPHY AND PHOTOGRAPHY
T01-J16	ARTIFICIAL INTELLIGENCE (AI)
T01-J16A	EXPERT SYSTEMS
T01-J16B	FUZZY LOGIC SYSTEMS
T01-J16C1	NEURAL NETWORKS
T01-J16C2	LEARNING
T01-J16C3	NATURAL AND PICTORIAL LANGUAGE PROCESSING
T01-J16C4	GENETIC ALGORITHMS
X	ELECTRIC POWER ENGINEERING

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