About IP Pragmatics Limited

www.ip-pragmatics.com

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.

IP Pragmatics is an official partner of IPRIS and Wellspring Worldwide.

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Consulting	**IP Renewals**	**Tech transfer software**

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.
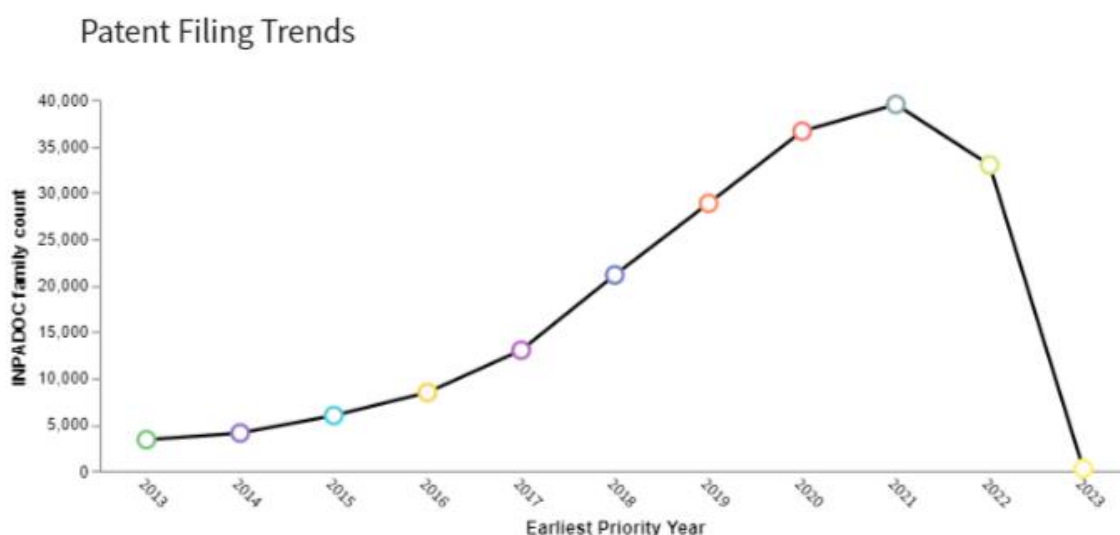

Source: Clarivate via Derwent Innovation (data for 2021-2023 is not complete given the 18-month delay from the priority filing date and the date of publication)

- 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.
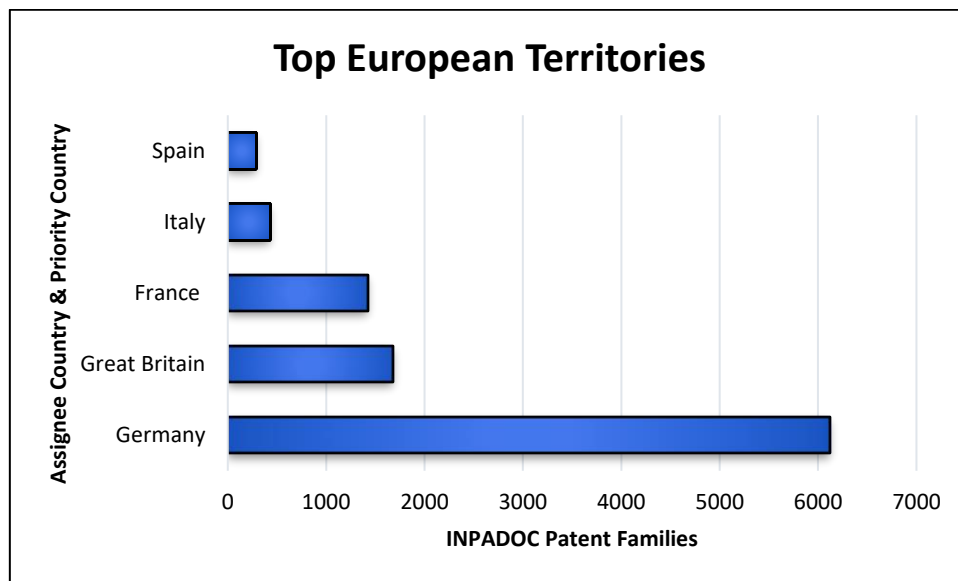
Defined by technology type, machine learning is the dominant AI sub-field of patenting activity, with neural networks forming the most prominent sub-category. Most innovation relating to training methods took place after 2016, wherein backpropagation is the leading neural network learning method, followed 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.
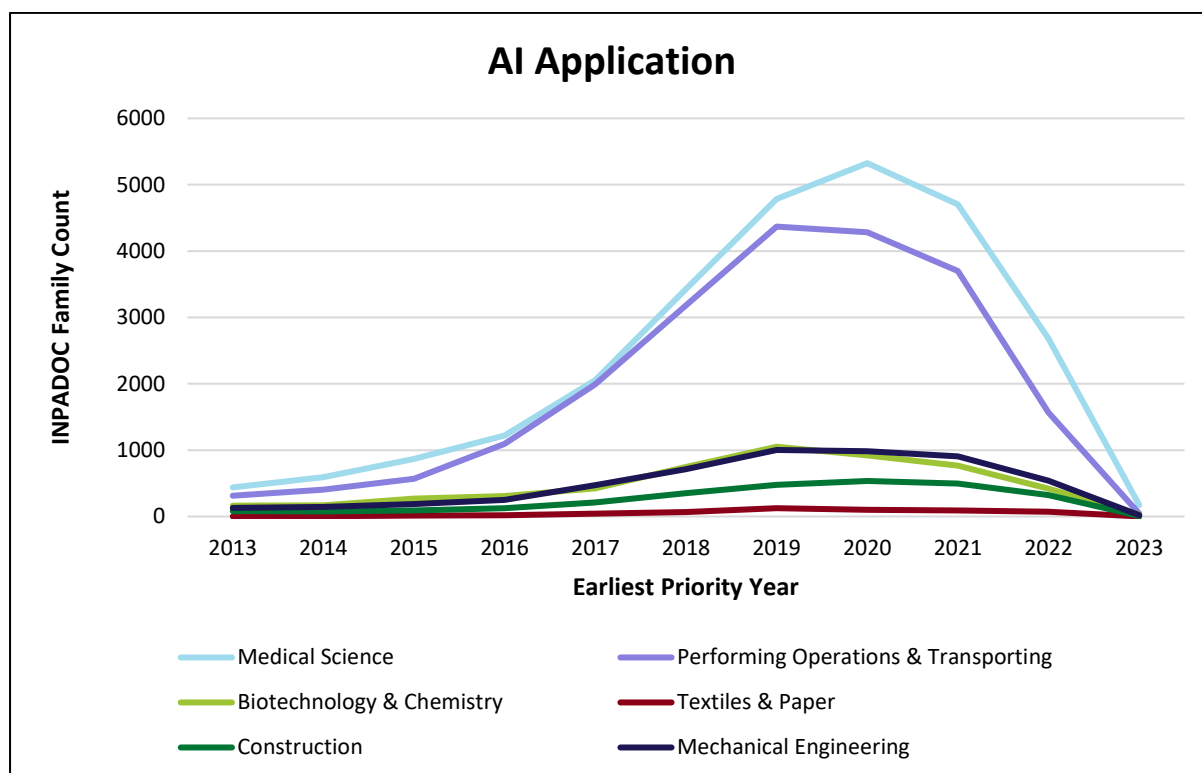
Note: data for 2021-2023 is not complete given the 18-month delay from the priority filing date and the date of publication

- 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.