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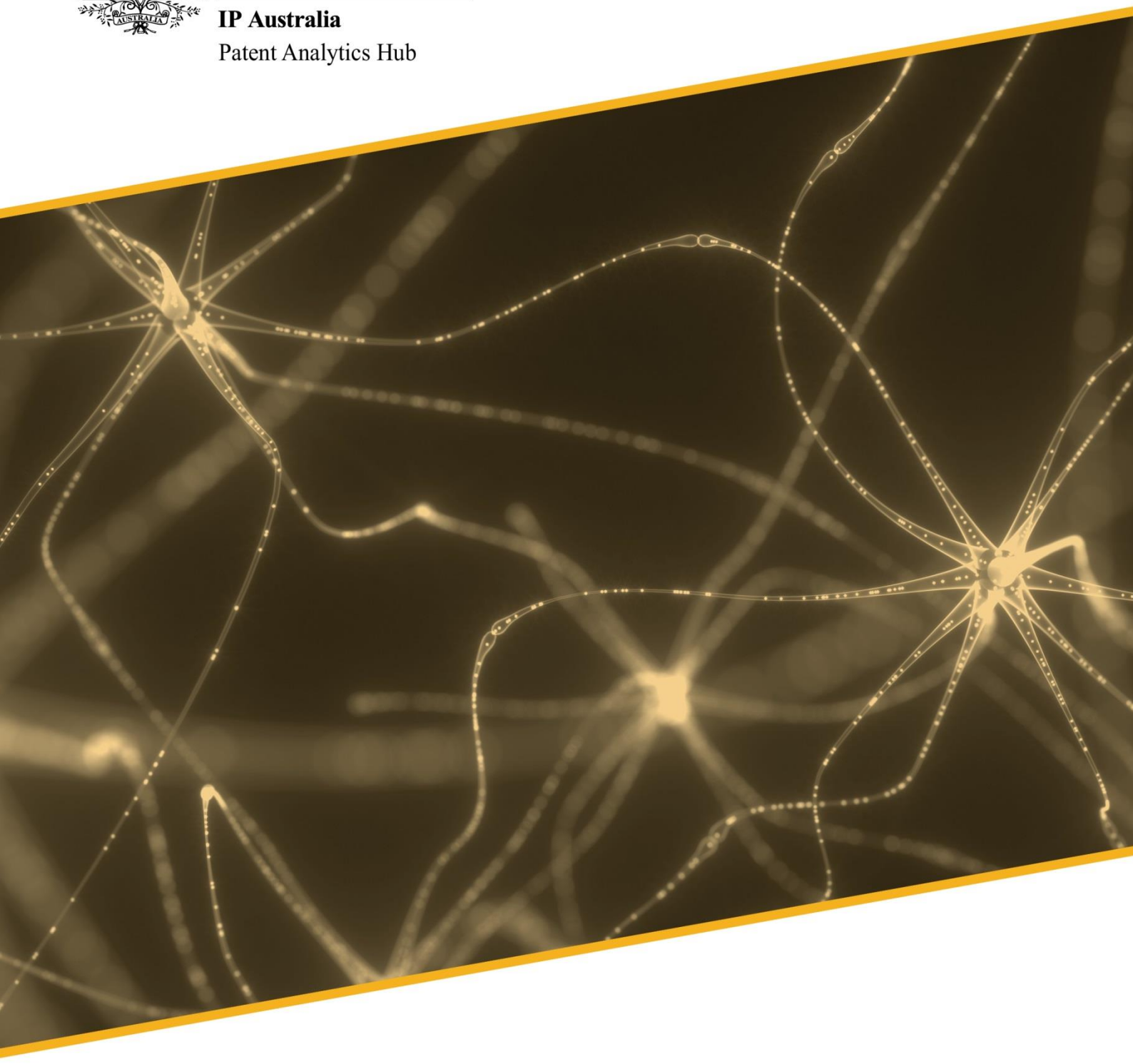

Patent Analytics Report: Recording Brainwaves

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Disclaimer

The information contained in this brief has been gathered from global intellectual property (IP) databases and represents a snapshot of IP rights at a particular point in time. It is provided for general information only and should not be relied upon for the purposes of any particular matter. It is not a report on patentability or freedom to operate and should not be relied upon for those purposes.

Foreword

Communities often access the benefits from biomedical research through innovations that include new medicines, vaccines, diagnostics and devices.

Advancing blue-sky research and discoveries to enable translation and the realisation of innovative products requires access to a diverse range of skills and capabilities. These skill sets include numerous scientific disciplines and associated expertise in business development, marketing, manufacturing, quality systems, policy, networking and intellectual property.

The National Foundation for Medical Research and Innovation (NFMRI) is pleased and thankful to have the support of IP Australia's patent analytics team who continue to provide expert services to a number of Australian research projects supported by our Foundation.

The patent analytics team have not only provided helpful information in this written report, but have worked with institutions and researchers to understand their needs whilst providing additional advice and assistance.

I encourage researchers and institutions to consider translational pathways and opportunities early in their research projects. Patent analytics can help researchers efficiently identify major teams and technologies working in similar areas. It can assist in understanding intellectual property opportunities and competing technologies. This information can be useful in market assessments including the identity of potential competitors, collaborators and commercial pathways.

Patent analytics can be a useful tool assisting researchers to make informed decisions that will benefit and advance their discoveries. I recommend researchers and their translation commercialisation teams to consider the Brainwaves Patent Analytics Report and how patent analytics could assist them with the strategic direction of their research.

NFMRI
National Foundation for Medical Research and Innovation

Dr Noel Chambers
Chief Executive Officer

National Foundation for Medical Research and Innovation
nfmri.org.au

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Summary

Brainwaves are the communication between neurons within our brains, forming the basis of thoughts, emotions and behaviours. Electroencephalograms, or EEGs, can be used to monitor and measure these patterns.

However, most brain function remains a scientific mystery. Here we show that innovation in technology to record brainwaves is an area of growth with strong commercial interest.

This report outlines findings from an investigation of patent families filed since 2000, analysing trends, markets and commercial players in this space.

We have also provided the content of this report in our new, world-leading interactive visualisation which allows the field of research to be more deeply understood. https://public.tableau.com/profile/patent.analytics.hub#!/

Key report findings

3770 patent families have been filed for technology to record brainwaves, with 1008 related specifically to positioning or attachment means for electrodes.

Saluda Medical is the largest Australian applicant with 10 patent families.

Of the patent families related specifically to positioning or attachment means for electrodes, 85 per cent are active.

Collaboration in this technology is dominated by the Belgian non-profit research entity IMEC and the university KU Leuven, who have collaborated on nine patent families together.

Medtronic is the top global innovator in this area, with 52 patent families.

The United States dominates as the largest target market with 833 of the 1008 patent families filed here.

Trends demonstrate brainwave-related technology is an area of growth, with strong commercial interest to patent holders and applicants.


HOLLY HOUSE HOSPITAL
Symphony
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STUDY 1
08/09/04
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HLP
AL
5cm
MF 1.09
TR 480.0
TE 14.0
TA 01:31
BW 90.0
M/ND
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HE
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FoV 230*230
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Introduction

IP Australia is dedicated to building prosperity for Australia, and ensuring that Australians benefit from great ideas. Using patent analytics to provide evidence of innovation trends, we leverage our unique access to IP data, knowledge and expertise to deliver value to the broader economy.

This patent analytics report was prepared in partnership with the NFMRI as part of IP Australia's commitment to support Australian research and innovation. The Foundation makes a social investment in biomedical research by partnering with researchers and donors to identify, evaluate and support innovative and high quality research projects.

To support the needs of the Foundation, IP Australia have analysed the development of technology relating to detecting and recording neural signals – or brainwaves – and in particular the placement of electrodes to record brainwaves.

We have also provided the content of this report in our new, world-leading interactive visualisation which allows the field of research to be more deeply understood. https://public.tableau.com/profile/patent.analytics.hub#!/

Why patent data?

Patents can be used as indicators of innovative activity. By extraction and analysis of data associated with patent documents, we can measure aspects of inventive activity such as scope, intensity, collaboration and impact. These metrics can be developed across technology sectors and by measures including individuals (inventors), institutions (applicants), countries and regions.

Patents are granted for devices, substances, methods or processes that are new, inventive and useful (Appendix A: Definitions), giving exclusive commercial rights in exchange for full public disclosure of the invention. This means that patents are a source of data on innovation trends in science and technology.

About brainwaves

Brainwaves are the communication between neurons within our brains, forming the basis of thoughts, emotions, and behaviours. In 1875, Richard Caton made the first recordings of brainwave activity – associated with behaviour – by attaching electrodes to the brain surfaces of living animals.[1] Brainwaves refer to changes in electrical action potential or current across nerve cells. Typical brainwave patterns are classified by frequency and amplitude into four brainwave states that range from the high amplitude, low frequency delta to the low amplitude, high-frequency beta. These brainwave states range from deep dreamless sleep to high arousal.[2]

The first EEG, using non-invasive scalp electrodes to measure brainwaves, was developed by psychiatrist Hans Berger in 1929,[3] in a form that is almost identical to modern technology. The first patent application for an EEG device was filed in 1941 by Lovett Garceau (US2409033). Currently, recording and analysis of brainwaves is used for medical diagnosis and for therapy of neurodegenerative disease. Technological advancements in brainwave recording and analysis continue in emerging areas such as machine-brain interfaces to restore mobility and independence to people with paralysis by enabling direct brain control of these devices.

[1] Frontiers in Integrative Neuroscience - https://www.frontiersin.org/articles/10.3389/fnint.2013.00058/full
[2] Herrmann, N., 1997, 'What is the function of the various brainwaves?', Scientific American [online]
[3] IMOTIONS - https://imotions.com/blog/history-of-eeg/

Inventions for recording brainwaves

As a basis for this analysis, we searched the worldwide patent databases for inventions for detecting or recording brainwaves. The search found 3770 unique patent families filed worldwide since 2000.

Detail on the search methodology is provided in Appendix B: Search strategy.

Timeline

Analysing patent families filed across time provides an understanding of growth, decline or periods of high action in this technology space.

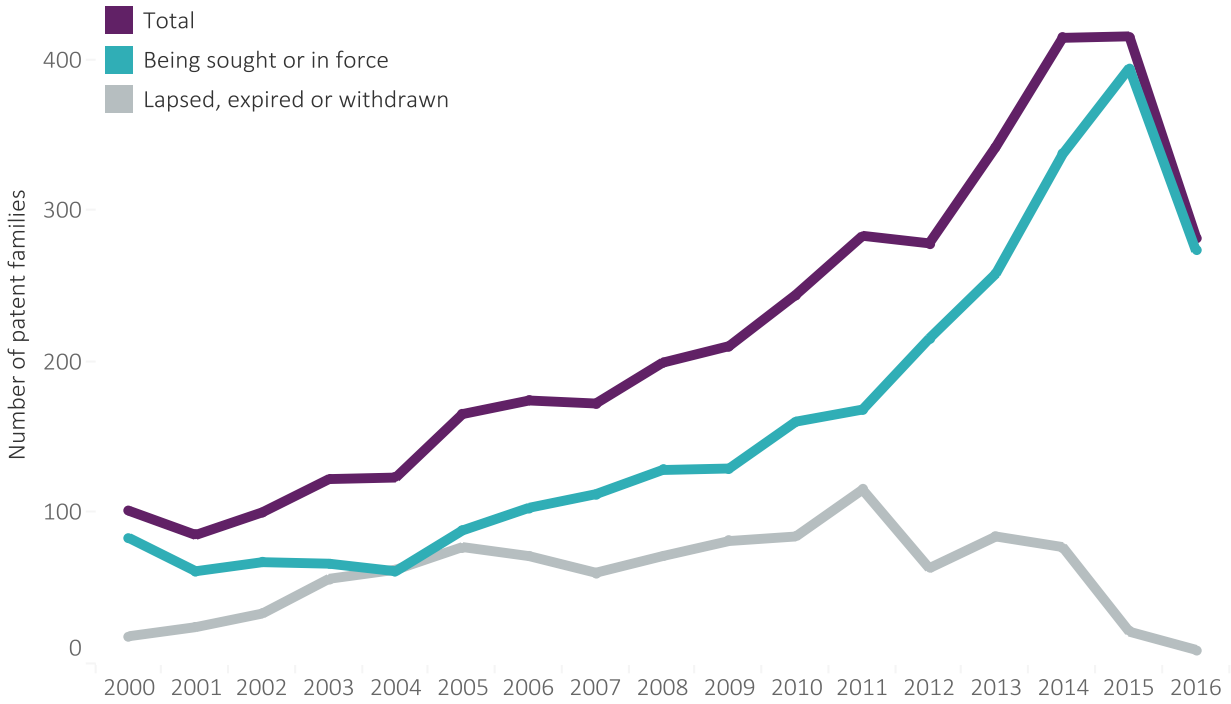
Figure 1 shows the number of patent families by their current legal status and earliest priority year. The legal status was divided into two categories: patent families with at least one family member with protection actively being sought or in force (patent families filed, accepted or granted), and patent families with all family members lapsed, expired or withdrawn.

The results demonstrate that patenting activity has continually grown over time, a three-fold increase in patenting activity over 12 years. Specifically, approximately 100 patent families were filed each year from 2000-02, rising to over 400 families per year in 2014 and 2015. The data is not complete from 2015 due to a lag in patent publication; the dip in 2016 reflects incomplete data rather than a trend decline.

This timeline analysis also shows us that this technology field is of ongoing commercial interest. Of the 3770 unique patent families captured in this report, 2763 are in an active state, with patent protection being sought or in force (73 per cent).

Figure 1: Patent families relating to detecting and recording brainwaves by priority year

Source: PATSTAT 2018 Spring Edition

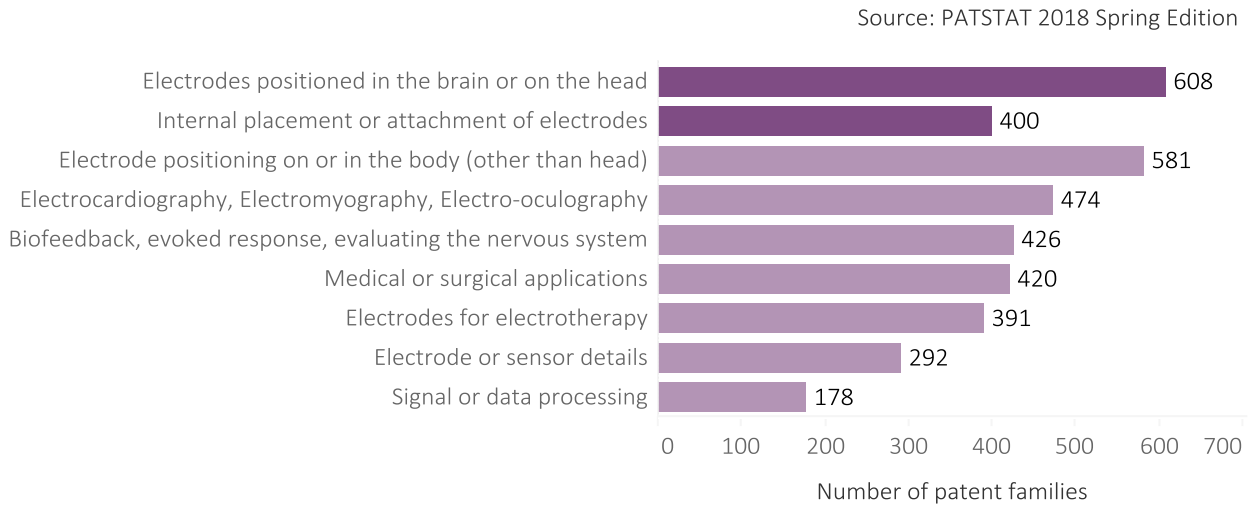


Technology analysis

Within the 3770 patent families are a range of technology categories contributing to overall brainwaves-related technology.

We divided the patent families into nine technology categories relating to physical aspects and uses of the technology (Figure 2). The technology category was based on Cooperative Patent Classification (CPC) and International Patent Classification (IPC) (detailed in Appendix C: Technology analysis). This report is directed to the detection and recording of brainwaves; it is not a comprehensive search of broader technologies such as electrotherapy in which EEG electrodes are used to deliver electrical stimulus, evoked response or electrode composition.

Figure 2: Technology analysis of patent families relating to detecting and recording brainwaves



Technology categories

Electrodes positioned in the brain or on the head (608 patent families) relates to inventions for recording brainwaves that further specify either the positioning of electrodes in the brain or on the head.

Internal placement or attachment of electrodes (400 patent families) relates to inventions for recording brainwaves that further specify the internal attachment or placement means for electrodes.

Electrode positioning on or in the body (other than the head) (581 patent families) relates to recording brainwaves, further specifying positioning of electrodes on or in the body, except in the brain or on the head.

Electrocardiography, Electromyography, Electrooculography (474 patent families) relates to recording Electrocardiography (ECG), Electromyography (EMG), Electrooculography (EOG) or EEG signals. ECG, EMG and EOG measure electrical activity of the heart, muscles and eyes respectively.

Biofeedback, evoked response, evaluating the nervous system (426 patent families), relates to brainwave recording to learn how to control response to stimuli.[4] Therapeutic applications include anxiety, pain and post-traumatic stress disorder. Evoked response is EEG signals detected in response to stimuli such as light, touch or vibration. Evaluating the nervous system includes evaluation of both the peripheral and central nervous systems. This comprises inventions for diagnosis and monitoring of disorders of the nervous system, including movement, cognitive and seizure diseases such as Parkinson's disease, anxiety and epilepsy.

Medical and surgical applications (420 patent families) includes inventions relating to electrodes attached to the body, devices for magnetic, radiation and ultrasound therapies, and other medical applications. It excludes electrotherapy, ECG, EMG, EOG, evoked response and evaluation of the brain and nervous system, which are included in other categories.

Electrodes for electrotherapy (391 patent families) relates to the use of electrical energy, including deep brain stimulation with regular electrical impulse, such as a 'brain pacemaker'[5] used in the treatment of disorders such as Parkinson's disease, Alzheimer's disease, major depression and pain.

Electrode or sensor details (292 patent families) relates to the composition, manufacture and testing of the electrodes and accessories, including materials, components and circuits.

Signal or data processing and transmission (178 patent families) includes computational systems, remote monitoring of patients using telemetry and imaging for diagnostic purposes.

[4] EEG Education and Research, www.eegspectrum.com/faq/

[5] Live Science, www.livescience.com/61573-alzheimers-brain-pacemaker.html

Electrode position for recording brainwaves

The remainder of this report will focus on the 1008 unique patent families identified as inventions relating to detecting or recording brainwaves, with the focus on electrode positioning, placement or attachment (the first two categories above).

Timeline

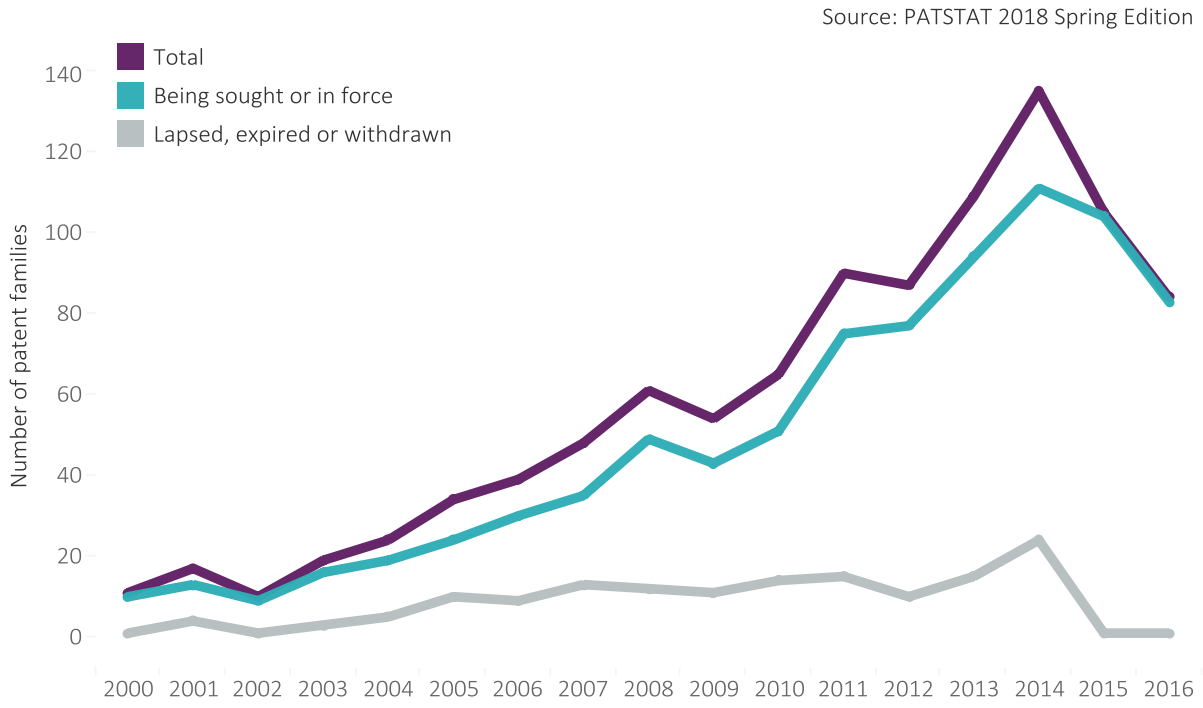
The number of patent families by earliest priority year is shown in Figure 3.

Of the 1008 patent families filed worldwide, 859 are in an active state (85 per cent), indicating a relatively high commercial interest within the broader field.

Patenting activity relating to electrode positioning, placement or attachment means for recording brainwaves has increased five-fold since 2003.

Between 2000 and 2003, 19 or less patent families were filed annually. Between 2013 and 2015, this increased to 100 or more patent families filed each year. Overall this trend follows that of the broader field shown in Figure 1. Notable increases were detected in 2011, 2013 and 2014, primarily driven by patent family filings relating to electrodes positioned in the brain or on the head by a number of different entities. Additionally, Medtronic filed nine patent families in both 2011 and in 2014, NeuroNexus Technology and Interuniversity MicroElectronics Center each filed five patent families in 2011 and Biosense Webster filed six patent families in 2014. These entities are discussed further in the Top Applicants section in this report.

Figure 3: Patent families relating to electrode positioning, placement or attachment means by priority year



Target markets

The target markets for inventions in any technology can be indicated by the jurisdictions in which patent families are filed. Applicants must file patent applications in each country or patent jurisdiction where they wish to have patent protection. Figure 4 shows the number of patent families filed by jurisdiction, where jurisdictions have at least 10 patent families relating to electrode positioning, placement or attachment means for detecting and recording brainwaves.

PCT applications have been excluded from this figure because they do not represent an enforceable right in any jurisdiction. European patents are enforceable in designated contracting states to the European Patent Convention at the date of filing of the application. They are therefore included in the target market analysis. Patent applications can also be filed directly in individual European countries, for example Germany (Figure 4). The United States is the largest target market, with 833 of the 1008 patent families filed here. This is considerably larger than the number of patent families filed in second largest target market, Europe. This highlights the importance of the United States in this technology. Europe is the second largest target market, with 482 patent families filed with the European Patent Office.

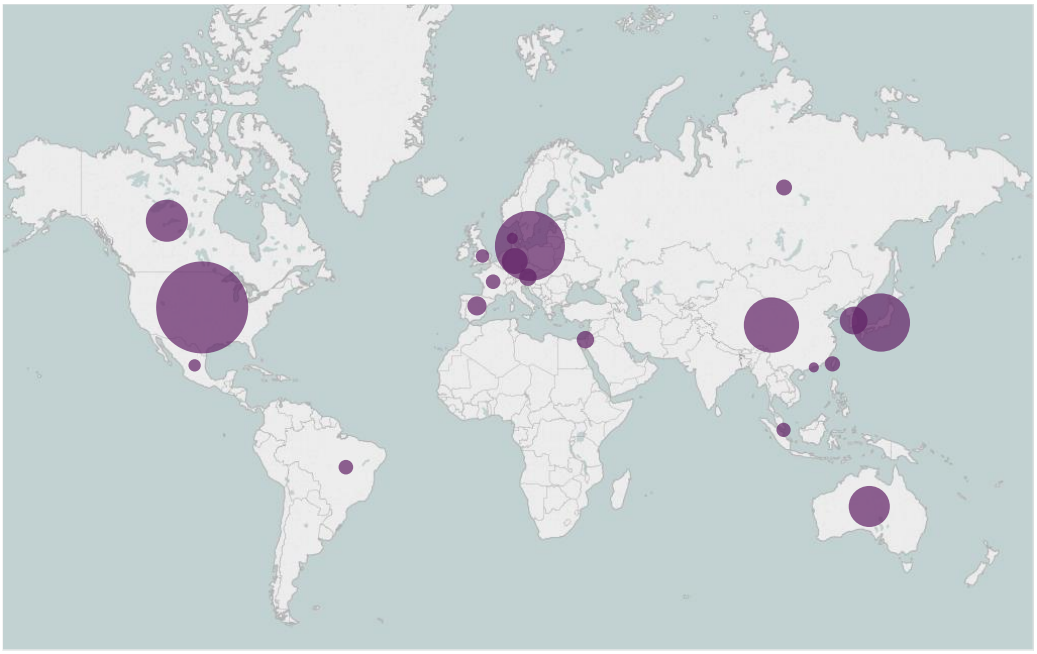
Japan is the third largest target market, with 334 patent families filed here. This is followed by China in fourth place with 300 patent families. It is evident from the data that the Japanese and Chinese markets are increasingly important, with filings into these countries growing rapidly in more recent years, and particularly since 2012.

Canada is in fifth place with 174 patent families. Australia is the sixth largest target market in the world, with 166 patent families filed.

Figure 4: Patent families relating to electrode positioning, placement or attachment means, by filing jurisdiction

Source: PATSTAT 2018 Spring Edition

United States	833
Europe	482
Japan	334
China	300
Canada	174
Australia	166
Korea	76
Germany	66
Spain	36
Austria	30
Israel	30
Russia	25
Taiwan	23
Brazil	21
France	21
Singapore	20
United Kingdom	18
Mexico	15
Denmark	12
Hong Kong	10



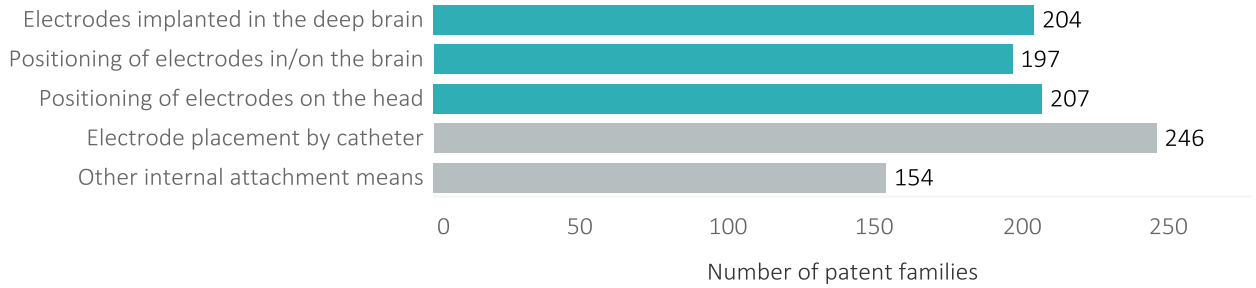
Sub-category technology analysis

This analysis provides insight on focus areas of innovation. We divided the 1008 patent families into five sub-categories (Figure 5) of electrode positioning on or in the brain, or placement or attachment means (Appendix C).

Electrodes implanted to detect or record brainwaves are used for brain-machine interfaces (also known as computer-brain interfaces), or for treatment of neurodegenerative disorders via implantable medical devices.

Figure 5: Technology analysis: electrode positioning, placement and attachment means

Source: PATSTAT 2018 Spring Edition



Electrodes implanted in the deep brain

This sub-category includes electrodes implanted in the deep brain or cortex, which record brainwaves (204 patent families). Examples include the following patent families.

Second Sight Medical Products[6] have developed Argus II®,[7] a bionic eye with an electrode array configurable as a subdural micro-ECoG (electrocorticography) array and/or intracortically as a LFP (local field potential) array (WO2012158834). The array is set on or in the motor strip, which sends and receives signals to drive a robotic limb or stimulate a muscle. Similarly, the University of Kansas[8] and Case Western Reserve University[9] have developed neural prosthetic devices to implant into the somatosensory cortex, or the cortical motor area, for neural recording, signal processing and microstimulation. These devices bridge brain areas with disrupted communication (WO2013052180).

AB Medica[10] have focused on a wireless implantable device positioned in the subdural or intraparenchymal areas. An arrangement of grid electrodes acquires and monitors brainwaves by EEG and ECoG (WO2012143850). The device is used to treat epilepsy and neurodegenerative disorders.

Cortec GmbH[11] have developed a planar electrode array implanted at the surface of the cortex to measure brainwaves by ECoG and LFP. The array may further comprise depth electrodes implanted at the cortical surface or in different layers of the cortex (WO2016075298).

[6] Second Sight, www.secondsight.com/history-en.html
[7] Second Sight, www.secondsight.com/g-the-argus-ii-prosthesis-system-pf-en.html
[8] The University of Kansas, www.ku.edu/about/
[9] Case Western Reserve University https://case.edu/about/

[10] AB Medica, www.abmedica.it/en/azienda/chi-siamo
[11] CorTec, http://cortec-neuro.com/company/about-us

Positioning of electrodes in or on the brain (excluding cortex or deep brain)

This sub-category includes electrodes implanted or attached to the brain for recording brainwaves (197 patent families). The positioning in the brain excludes the cortex and deep brain, included in the previous sub-category. Examples include the following patent families.

Neuropace[12] have an implantable brain electrode to measure EEG and ECoG changes before clinical symptoms occur. The system detects and predicts neurological events, such as epileptic seizures (WO2003001996).

Tohoku-MicroTec[13] and University Tohoku[14] have together developed a wireless system of electrodes placed in the cranium. Each electrode is a probe of a length specific for the measurement point, such as the brain surface or deep cerebral region. The system transmits a brainwave signal, detected by the electrodes, to a communication unit placed on the scalp (EP2937036) in the treatment of epilepsy.

Medtronic[15] have developed a system for treating Rapid Eye Movement (REM) Behaviour Disorder (WO2012027286). An electrode implanted in the midbrain nuclei measures LFP, EEG and/or ECoG. Upon REM sleep, a brain stimulus is delivered.

Kyushu Institute of Technology[16] have a brainwave measurement system to treat epilepsy. Electrodes are implanted between the dura mater and the arachnoid mater of the brain meninges (US20120302857).

Stanford University have developed an implantable coil, configured to sense electrical signals (EEG, ECG), or physical (body temperature) or chemical (glucose content in blood) parameters (WO2014071079).

Synchron,[17] formerly SmartStent, a spin-out from The University of Melbourne, filed a patent for an intravascular device implanted to sense or stimulate activity of neural tissue (AU2017276276). This patent was co-filed with Australian Thomas Oxley, CEO of Synchron.

Positioning of electrodes on the head

This sub-category relates to electrodes that record brainwaves through external attachment (207 patent families), including the surface of the head or scalp. Examples include the following patent families.

Bio-Signal Group[18] have developed a multichannel EEG headset. Electrodes, traces, and connection terminals are on one side of a flexible insulating layer, with a shield protecting against signal interference (WO2013126798).

Brainscope[19] have a headset for portable EEG (WO2014137549). Electrodes in a flexible layer fit the forehead. EEG signals are processed by various means including Fast Fourier Transform (FFT), wavelet, spectral and microstate analysis. Similar headsets have been developed by NeuroSky[20] (WO2008091323), Samsung Electronics[21] (WO2016080804) and NIBS Neuroscience Technologies[22] (WO2016009424).

[12] Neuropace, www.neuropace.com/about-us-corporate/
[13] Tohoku-MicroTec, www.t-microtec.com/category/1420389.html
[14] University Tohoku, www.tohoku.ac.jp/en/about/index.html
[15] Medtronic, www.medtronic.com/us-en/about.html
[16] Kyutech, About Kyutech

[17] Synchron, www.synchronmed.com/about/
[18] Bio-Signal Group. http://biosignalgroup.com/about-us/#our-story
[19] Brainscope, http://brainscope.com/
[20] NeuroSky, http://neurosky.com/about-neurosky/
[21] Samsung Electronics, www.samsung.com/au/aboutsamsung/home/
[22] NIBS Neuroscience Technologies, www.nibsneuroscience.com/about-1/

Electrode placement by catheter

Patent families in this sub-category describe a catheter or guidewire for placing an electrode or an electrode on a stent, or attaching an electrode to blood vessels (246 patent families). This includes methods to deliver electrodes for temporary or permanent use, such as stents, catheters, and guidewires. Patent families in this group are classified as detecting or recording brainwaves, but not specifically as being attached to the brain. Examples include the following patent families.

Ad-Tech Medical Instrument Corporation[23] have developed an intracranial catheter assembly (WO2004096314), with an outer catheter, or depth electrode, and an inner catheter that allows regular transfer of fluids to or from brain tissue without extended contact with the brain during insertion. The electrode monitors brain activity, and may provide stimulation.

Brainlab AG have investigated microneedles and developed a device for localising target areas in the brain using a multichannel microprobe with many microelectrodes, through which brainwave signals are obtained (US20030078485). The microprobe is precisely positioned using a neuronavigation system in which the required number of trajectories is minimised. This allows detection of specific functional areas of the brain for surgery or deep brain stimulation.

Terumo Corporation have developed a monitoring device attached to an expandable body delivered through blood vessels (WO2014162660). The monitoring device comprises an electrode to detect neural activity through the inner wall of a blood vessel.

Other internal attachment means

These patent families include mechanisms of internal attachment, or attachment to internal body parts such as bones or nerves (154 patent families), including delivery of electrodes via burr holes and needles. This includes detection or recording of brainwaves, but not specifically by being attached to the brain. Examples include the following patent families.

Assistance Publique De Paris[24] have an intracerebral probe mounted in a burr hole (US20100168826). The probe, temporarily implanted, comprises electrodes to identify brain dysfunction in the treatment of neurological or psychiatric symptoms.

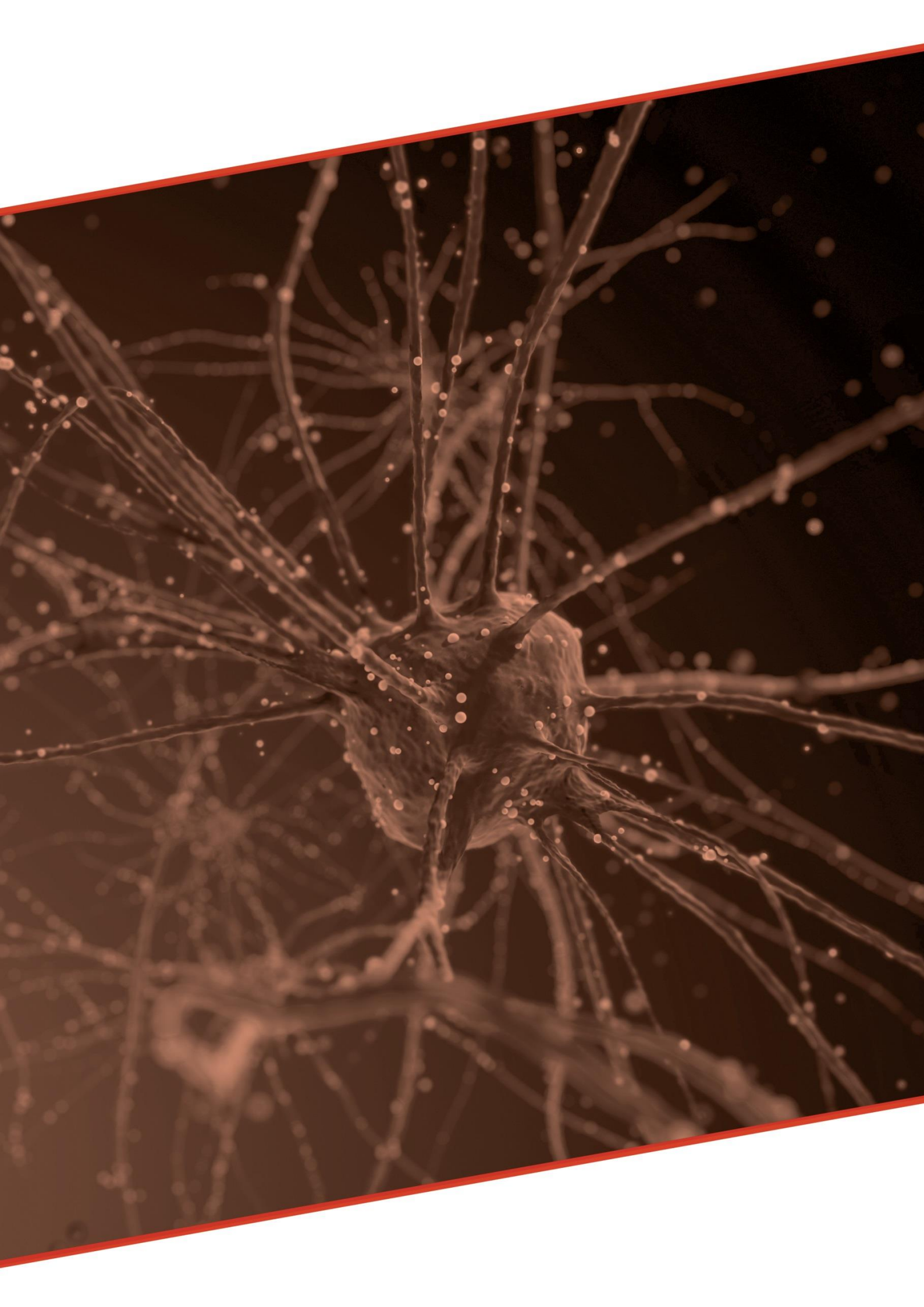
Luxembourg Institute of Science and Technology[25] and Luxembourg Institute of Health[26] have an implantable device with a surface chemical composition that enhances cell adhesion (WO2016038158).

The Case Western Reserve University[27] have developed an electrode for insertion between nerve fascicles (WO2012149039), with conductive fibres in a nonconductive sheath. A layer of polymer switches from a high strength/tensile modulus state to a low strength/tensile modulus state upon introduction of the fibres into the nerve.

Verily Life Sciences, formerly Google Life Sciences,[28] have a system for recording nerve activity. Electrodes on a flexible, nonconductive substrate can roll into a cuff to encircle a nerve bundle. The cuff can expand and contract without strain at the nerve-cuff interface (WO2017143189).

[23] Ad-Tech Medical Instrument Corp., https://adtechmedical.com/about-us

[24] Assistance Publique De Paris, www.aphp.fr/nous-connaitre
[25] Luxembourg Institute of Science and Technology, https://www.list.lu/
[26] Luxembourg Institute of Health, www.lih.lu/page/homepage
[27] CWRU, https://case.edu/
[28] X.company, https://x.company/projects/verily/



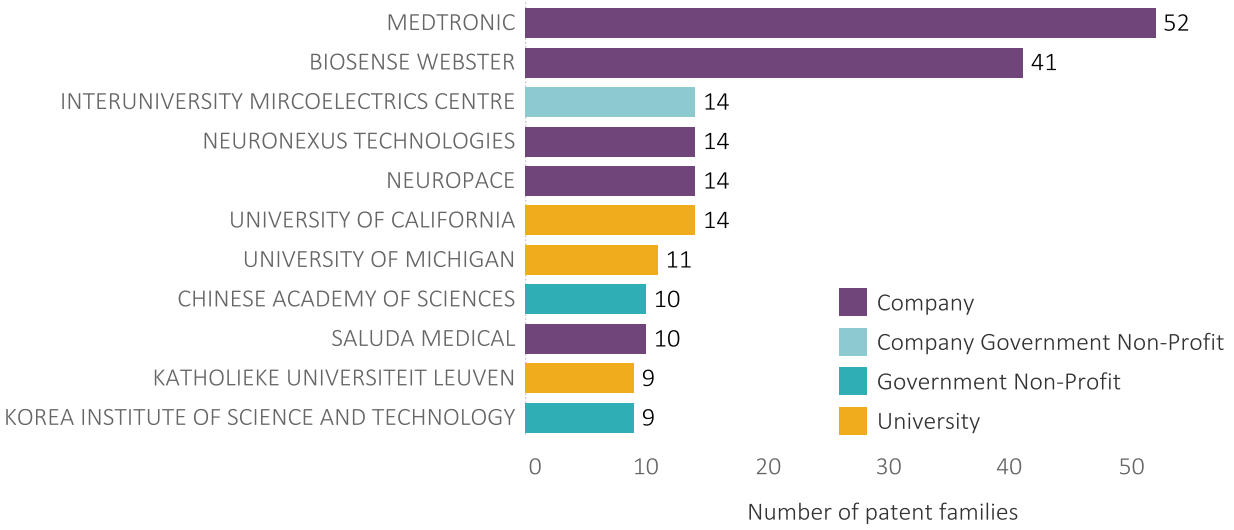
Top applicants

A patent provides an exclusive right to the patent owner for up to 20 years over their invention, to protect their ideas and products. The number of patent families filed by an applicant in a particular technology can be indicative of their interest and market presence or desire to build and maintain a market share. Figure 6 shows the top applicants for inventions relating to positioning, placement or attachment means for detecting and recording brainwaves.

The top 11 applicants contributed 188 patent family filings in total, of which 171 patent families are active (91 per cent). This indicates that these patents are commercially valuable to these applicants.

Figure 6: Patent families relating to electrode positioning, placement or attachment means by applicant

Source: PATSTAT 2018 Spring Edition



Medtronic

Medtronic[15] is the top applicant identified in this report, with 52 patent family filings since 2000. Medtronic is a global healthcare company, with headquarters in the United States and operating in 160 countries including Australia. Their portfolio includes a Minimally Invasive Therapies Group. Covidien, Ireland, was acquired in January 2015.[29, 30]

Six of the 52 Medtronic patent families were originally filed by Covidien. Sapiens Steering Brain Stimulation GmbH (Sapiens SBS), a developer of deep brain stimulation technologies, was acquired in 2014.[31] Ten of the 52 Medtronic patent families in this field were originally filed by Sapiens SBS.

[29] Bloomberg, www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=31232183

[30] Medtronic, www.medtronic.com/us-en/about/corporate-social-responsibility/suppliers/covidien-frequently-asked-questions.html

[31] Medtronic, http://newsroom.medtronic.com/phoenix.zhtml?c=251324&p=irol-newsArticle&id=1960861

Medtronic's products include the BIS™ Brain Monitoring System, which provides 'insight into the direct and patient-specific effects of anaesthesia on the brain' and 'helps clinicians determine and administer the precise amount of drug to meet theindividual patient needs'.[32]

Medtronic has been a regular and increasingly active patent filer since 2000 in this focused technology area. Their patent family filings have grown over time from two filings in 2000, to nine filings in both 2011 and 2014.

Biosense Webster

Biosense Webster was formed in 1998 when Biosense Inc. joined Webster Laboratories. Currently operating under the Johnson & Johnson family of companies, their offerings include a broad range of electrophysiology catheter designs.[33] They are the second top applicant with 41 patent families largely relating to catheters for placement of electrodes to record EEG signals.

Biosense Webster has been a regular, active patent filer since 2000 with increased activity since 2014. Their patent family filings spiked in 2015 with 18 filings in this year alone.

Interuniversity MicroElectronics Center

The Interuniversity MicroElectronics Center (IMEC) was founded in 1984 as part of a Flemish Government program to strengthen the microelectronics industry in Flanders – which included establishing the IMEC laboratory for advanced research in microelectronics (.

With headquarters in Leuven, Belgium, IMEC is a non-profit subsidiary of IMEC International,[34] a research and innovation hub for nanoelectronics and digital technology. They partner with other companies, start-ups, and academic researchers.[35] The Holst Centre,[36] established by IMEC and the Netherlands Organisation for Applied Scientific Research (Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek), has developed a prototype EEG headset that can measure emotions and cognitive processes.[37]

This report identified 14 patent families belonging to IMEC, all filed since 2005. Eleven of these patent families have been filed since 2011.

NeuroNexus Technologies

NeuroNexus Technologies, which is a United States subsidiary of Nuvectra, is a neurotechnology company involved in the development and commercialisation of neural interface devices. The company's commercialised technologies were originally developed at the University of Michigan.[38] Products from NeuroNexus include neural probes with high-density microelectrode arrays for recording brain activity.[39]

This study identified 14 patent families from NeuroNexus. Their first filing was a single patent family with priority in 2005 and they have been a consistent patent filer to date.

NeuroPace

NeuroPace, Inc., established in 1997, is a medical device company based in the United States.[12,40] NeuroPace are market leaders in the design, development and manufacture of implantable devices used to manage neurological disorders such as epilepsy. Their main product is the RNS® System, which is a small, implantable, neurostimulator device that monitors and responds to brain activity.[41]

We have identified 14 relevant patent families belonging to NeuroPace, all of which are active. NeuroPace has been a regular and consistent patent filer in this area since 2000.

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[32] Medtronic, www.medtronic.com/covidien/en-us/products/brain-monitoring.html
[33] Biosense Webster, www.biosensewebster.com/about/
[34] Bloomberg, www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=4181735
[35] IMEC, www.imec-int.com/en/about-us
[36] Holst Centre, www.holstcentre.com/about-holst-centre/holst-centre-in-a-nutshell/
[37] IMEC, www.imec-int.com/en/articles/imec-and-holst-centre-introduce-eeg-headset-for-emotion-detection
[38] NeuroNexus, https://neuronexus.com/about
[39] NeuroNexus, https://neuronexus.com/products/neural-probes
[40] Bloomberg, www.bloomberg.com/research/stocks/private/snapshot.asp?privcapid=125322,
[41] NeuroPace, www.neuropace.com/the-rns-system/

University of California

The University of California, established in 1869, is a public university with 10 campuses.[42] The University operates publicly-funded, multidisciplinary research centres.[43] Research fields include neuroscience (Helen Wills Neuroscience Institute at UC Berkeley)[44] and, more specifically, brain imaging (Henry H. Wheeler, Jr. Brain Imaging Center).[45]

We have identified 14 patent families by the University of California filed since 2003, with 11 filed since 2011.

University of Michigan

Founded in 1817, the University of Michigan is based in Ann Arbor in the United States.[46] Research is central to the University's mission, with expenditures in excess of a billion dollars.[47] The University's Direct Brain Interface Laboratory focuses on the development of EEG-based brain-computer interfaces into clinical tools for use by people with physical impairments.[48]

This study found 11 patent families filed by the University of Michigan since 2003. The University has been a regular and consistent filer since then.

Chinese Academy of Sciences

The Chinese Academy of Sciences was founded in 1949 from the Academia Sinica institution established in 1928.[49] They are now the world's largest research organisation, with 56 000 staff across 104 research institutes, 12 branch academies and three universities.

We identified 10 patent families belonging to the Chinese Academy of Sciences, filed since 2012, with eight filed in 2016 and predominantly relating to positioning electrodes in or on the brain.

Saluda Medical

Saluda Medical Pty Ltd, established in 2013 and based in Artarmon, Australia, has commercialised research from National ICT Australia (NICTA).[50] Their Evoke™ System is a closed loop control system that records the response of neurons to stimulation. The same array used for neurostimulation, is also used for deep brain stimulation.[51]

Saluda Medical has 10 patent families in this technology area, the first of which was originally filed by NICTA in 2011.

Katholieke Universiteit Leuven

The Katholieke Universiteit Leuven (KU Leuven) is a Belgian education and research university.[52] Research includes a number of neuroscience projects,[53] such as clinical application of cross-frequency coupling EEG neurofeedback (Research Group for Neuromotor Rehabilitation), and transcranial-focused ultrasound for non-invasive brain stimulation (Laboratory for Neuro- and Psychophysiology).

We identified nine patent families filed by KU Leuven, all filed since 2005.

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[42] University of California, www.Universityofcalifornia.edu/uc-system
[43] University of California, www.Universityofcalifornia.edu/uc-system/parts-of-uc
[44] Berkeley Neuroscience, Helen Wills Neuroscience Institute, http://neuroscience.berkeley.edu/about/
[45] Henry H. Wheeler Jr. Brain Imaging Centre, http://bic.berkeley.edu/
[46] Bloomberg, www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=3758920
[47] University of Michigan, www.umich.edu/research/
[48] University of Michigan, http://umich.edu/~umdbi/

[49] Chinese Academy of Sciences, http://english.cas.cn/about_us/introduction/201501/t20150114_135284.shtml
[50] Saluda Medical - www.saludamedical.com/company/
[51] Saluda Medical - www.saludamedical.com/technology/applications/
[52] KU Leuven, www.kuleuven.be/english/about-kuleuven/
[53] KU Leuven - www.kuleuven.be/english/research/

Korea Institute of Science and Technology

Established in 1966, the Korea Institute of Science and Technology was the first science and technology research institute of Korea, with its main campus in Seoul.[54] Research divisions include a Brain Science Institute, which further includes centres for Neuroscience, Functional Connectomics, Neuromedicine and BioMicrosystems.[55]

We found nine patent families belonging to the Korea Institute of Science and Technology, all filed since 2009.

[54] KIST, https://eng.kist.re.kr/kist_eng/?sub_num=628
[55] KIST, https://eng.kist.re.kr/kist_eng/?sub_num=439

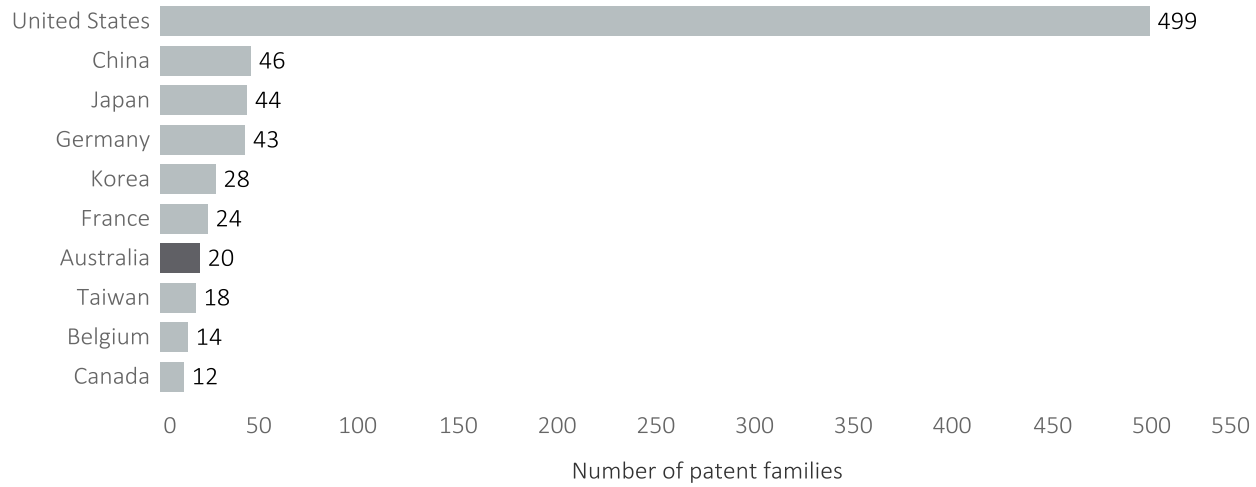
Applicant origin

Analysis of patent family applicant origin indicates countries with investment or interest in a specific area of innovation. Figure 7 shows patent families originating from each country. Country information is derived from applicant address data.

Australia ranks seventh globally for applications, with 20 patent families originating here, just behind France (24 patent families).

Figure 7: Patent families relating to electrode positioning, placement or attachment means, by applicant origin

Source: PATSTAT 2018 Spring Edition



Top patent filers

A total of 499 patent family filings originate from applicants in the United States, 10 times more than any other country. Five of the top seven applicants are from the United States: Medtronic; NeuroPace; NeuroNexus Technologies; The University of California; and The University of Michigan.

In second place is China. The Chinese Academy of Sciences is a top applicant.

Japan is in third place. The Japan Lifeline Company, a manufacturer of medical devices,[56] and the Sony Corporation hold the most patent families with seven and six families, respectively.

In fourth place is Germany. Thirty-two different applicants are responsible for these 43 patent families, with no single most prominent filers identified.

Korea is in fifth place. Korea Institute of Science and Technology is a top applicant.

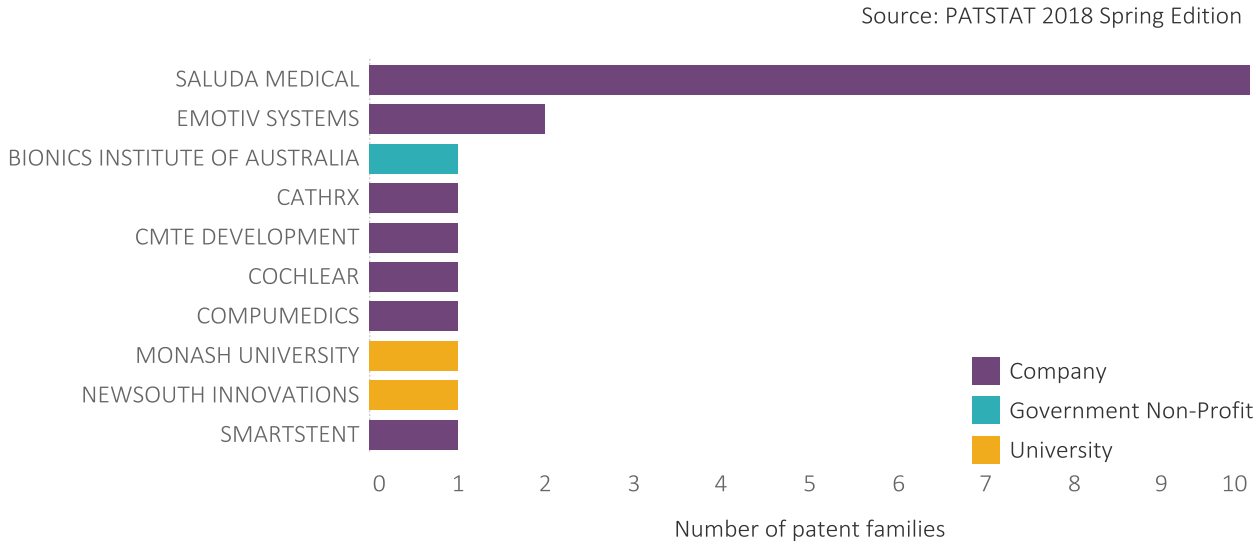
It is important to note that some data is missing for patent families originating in Japan and China. No person or country code information is available for about 112 families from Japan and six from China. These families only have filings in one country, and the applicant probably originates from the country of the filing. The inclusion of this data would elevate Japan, to 156 patent families and second largest originator of patent families.

[56] Japan Lifeline, https://www.japanlifeline.com/the/

Australian applicants

To better understand Australian patenting activity, we analysed data relating to Australian applicants. Australians filed 20 patent families, with 10 separate applicants. The top filer is Saluda Medical, also a top global applicant. In second place is Emotiv Systems. The other eight entities: Bionics Institute of Australia, Cathrx, CMTE Development, Cochlear, Compumedics, Monash University, Newsouth Innovations (the technology transfer office for the University of New South Wales) and SmartStent each have one patent family.

Figure 8: Patent families on electrode positioning, placement or attachment means by Australian applicants



Saluda Medical

Saluda Medical patent families include WO2016191808, an invention for monitoring neural responses to stimuli and assessing time-varying effects of local field potentials arising from a source other than electrical stimuli. WO2015070281 relates to monitoring brain neural activity. By applying a stimulus to a target area, it captures a measure of any late response arising in the target area, which can be a useful biomarker for identification of disease progression or medication efficiency. Both patent families are classified in the sub-category of electrodes implanted in the brain.

Emotiv Systems

Australian company Emotiv Systems, founded in 2003, specialises in brain-computer interaction (BCI).[57] They received an Australian government grant of $1.5 million in the financial year 2005-06. WO2009087486 discusses biosensor noise reduction with, non-invasive electrodes. WO2008109694 relates to positioning of electrodes with conductive hydrogel.

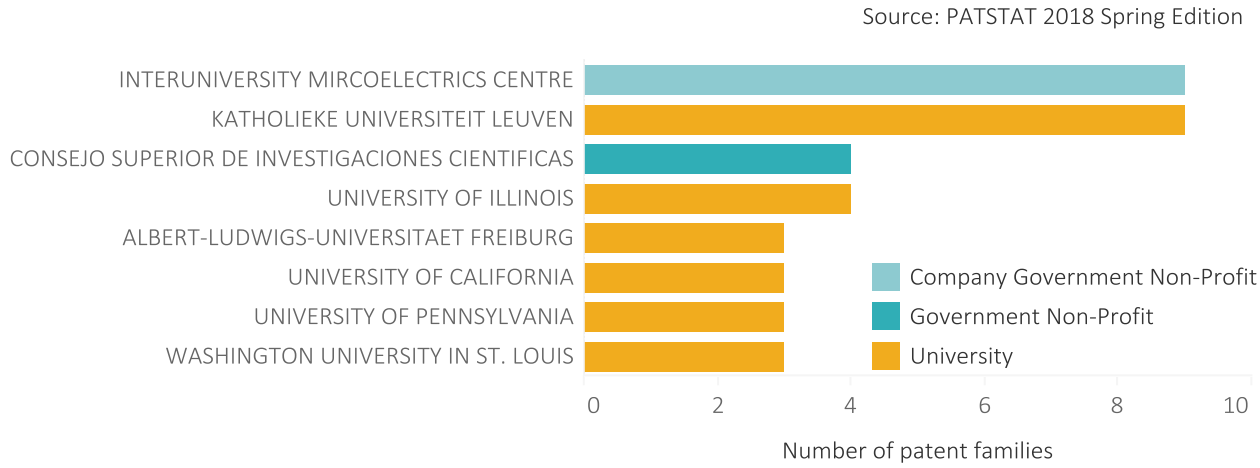
Emotiv Systems co-founder Tan Le subsequently, started Emotiv in 2011, based in San Francisco,[58] and producing EPOC+, a swireless EEG for advanced BCI.[59]

[57] ASIC Connect, https://connectonline.asic.gov.au/RegistrySearch/faces/landing/panelSearch.jspx?searchText=107441458&searchType=OrgAndBusNm&_adf.ctrl-state=15dhm7mb8y_15
[58] Visualcv, www.visualcv.com/tanttle
[59] Emotiv, www.emotiv.com/epoc/

Collaboration

One powerful advantage of analysing patent data is the ability to identify research partners collaborating on patent applications. Co-application on a patent gives a proxy indictor for collaboration. Figure 9 shows the top collaborating applicants for patent families relating to electrode positioning or attachment means for detecting or recording brainwaves. The top eight joint applicants are universities and non-profit research institutions.

Figure 9: Top collaborators in patent families relating to electrode positioning, placement or attachment means



KU Leuven and IMEC are the top collaborators, both based in Belgium. They have been co-applicants for nine patent families, such as WO2007003019, describing the functional restoration of a damaged nervous system by bridging with microelectrode elements for both stimulation and recording. They have collaborated with the Albert-Ludwigs-Universitaet Freiburg a German entity and also with two Belgian entities: Atlas Neuroengineering and Vlaams Interuniversitair Instituut voor Biotechnologie VZW with WO2014000806, for a probe device and a means of stimulation and recording located on a die.

Consejo Superior de Investigaciones Cientificas (the Spanish National Research Council) have collaborated with Spanish entities including La Institució Catalana de Recerca I Estudis Avançats (Catalan Institution for Research and Advanced Studies)[60] and L'Institut d'Investigacions Biomèdiques August Pi Isunyer (the August Pi i Sunyer Biomedical Research Institute),[61] with WO2015092109, describing a neuronal microelectrode between polymer layers.

The University of Illinois has collaborated with Washington University in St. Louis on three patent families, including WO2017173339, describing an implantable device for optogenetics and interfacing with target tissue. They have also collaborated with University of Pennsylvania on WO2012167096, for interfacing with brain tissue for monitoring and actuation of spatio-temporal electrical waveforms.

[60] ICREA, www.icrea.cat/en/who-we-are

[61] Universitat de Barcelona, www.ub.edu/web/ub/en/recerca_innovacio/recerca_a_la_UB/instituts/institutsparticipats/idibaps.html

Conclusion

This report set out to explore the patent landscape for innovations relating to positioning of electrodes for detecting or recording brainwaves. This analysis demonstrates strong and ongoing commercial interest.

In this space, Australia's role has been strong but small with 10 applicants filing 20 patent families. Saluda Medical is the leading player in this space. Australia is an important market, the sixth largest target market globally, with 166 patent families filed here.

The sector, however, is dominated by players from the United States – the predominant source of patent families. Playing the largest role is Medtronic, a global healthcare company based in the United States, which has filed 52 patent families since the start of this century.

Across time, interest in the technology has grown. This technology has seen a five-fold increase in patenting activity over 10 years. Among the top applicants, 91 per cent of patent families remain active, indicating the commercial value of patent families to their holders.

Based on available patent data, this is a sector with strong growth and potential.

Appendix A: Definitions

Patents, applications and publications

A patent is a right that is granted for any device, substance, method or process that is new, inventive and useful. Australian patent rights are legally enforceable and give the owner, or patentee, exclusive rights to commercially exploit the invention in Australia for a period of up to 20 years. In this report, an application refers to a single patent filing. A patent application is usually published within 18 months of its earliest filing date (also known as the priority date). We consider that the priority date is most relevant for our analysis as it is the closest date to that when the invention occurred.

There are two major routes for filing a patent application: international route and direct filing. The international route involves filing a Patent Cooperation Treaty (PCT) application, which establishes a filing date in all 152 contracting states.[62] Subsequent prosecution at national patent offices, referred to as national phase entry, is made at the discretion of the applicant. A patent can only be enforced once it has been granted and a PCT application must enter the national phase to proceed towards grant. Alternatively, applications can be filed directly in the countries of interest.

A patent application is considered to be in force when it has not lapsed (due to expiry or non-payment of renewal fees), been revoked or withdrawn. Data was taken from the most recent legal status action in the PATSTAT database. A family has been designated as being in force if it contains at least one in force application.

Patent families

Applications with the same priority, but filed in different jurisdictions are known as patent families. Patent families enable us to analyse inventive activity regardless of the number of countries in which protection is sought. Patent families are used in analytics to represent a single invention. We determine patent families based on INPADOC database definition, with a unique family ID for patents that share a common priority document.[63] The number of patent families is typically used as a metric. There are some exceptions when reporting individual applications, as each application represents a legal right in an individual country. When analysing applicants, related commercial entities are grouped by a single, harmonised name. When individual publication numbers are quoted, we have chosen a representative publication from the patent family, typically US or WO English language documents.

Classification

Patents are hierarchically classified by technology into the hierarchical IPC or CPC systems. The CPC began in 2013, and provides significantly more depth to the hierarchy of the IPC.[64] For more information on the coverage of the CPC, see the CPC Annual Report 2016.[65]

[62] WIPO, www.wipo.int/pct/en/pct_contracting_states.html

[63] Martinez, 'Insight into Different Type of Patent Families', OECD Science, Technology and Industry Working Papers, No. 2010/2, OECD Publishing, Paris; see section 3.2, 'Extended families'.

[64] European Patent Office and United States Patent and Trademark Office, www.cooperativepatentclassification.org/

[65] EPO and USPTO, www.cooperativepatentclassification.org/publications/AnnualReports/CPCAnnualReport2016.pdf

Appendix B: Search strategy

Searching patent information to identify relevant records for analysis requires a stepped approach to identify broad categories of relevance, and then specific records within them that meet the technology brief.

The following outlines the detail of the search and analysis process conducted.

Data extraction and analysis

We used five phases of data extraction and analysis.

- Phase 1: Development of a search strategy (below).
- Phase 2: Data mining using the database PATSTAT 2018 Spring edition. The unique INPADOC family members relating to detecting or recording brainwaves and EEG were identified and used as the basis of the analysis.
- Phase 3: Data cleaning, focusing on consolidating applicant names and ensuring the return of correct records.
- Phase 4: Data categorisation according to the technological focus of the patent families. The technological focus was determined by taking into account the CPC and IPC symbols for the patent families.
- Phase 5: Data analysis using Tableau 2018.1 for calculation and visual presentation of patent metrics.

Search strategy

The search was limited to patent families that had an earliest filing date between 2000 and 2018 and CPC symbols or IPC symbols as listed here.

1. Patent families with an application containing one or more of the following CPC symbols:

    - A61B5/04001 or A61B5/0478 or A61B5/6868; or

2. Patent families with an application containing the following IPC symbol:

    - A61B5/0478.

Appendix C: Technology analysis

The technology analysis categorises all search results based on their IPC or CPC classification. Multiple CPC and IPC symbols may be present for a single patent family. A patent family will only appear in one category, here based on our prioritisation of the CPC or IPC symbols in the tables below.

Technology category

All search results are categorised into one of nine categories. The table below provides the CPC or IPC subclasses captured in each technology area, the sub-technology it relates to and a description to further define it.

Electrodes for the detection and recording of brainwaves			
Technology category	Description	CPC Subclass	IPC Subclass
Electrode positioned in the brain or on the head	Means of attachment to the brain, defined as positioned in the cortex or deep brain; anchored to the brain; electrodes attached to head or scalp, including headsets or electrode caps	A61B5/6868, A61N1/0531, A61N1/0534, A61N1/0539, A61B5/6814, A61N1/0562	N/a
Internal placement or attachment of electrode	Means of attachment via internal placement, invasive device, needle, micro-needle, guidewire, catheter, stent, burr holes; permanently implantable devices; access port, extracorporeal blood circuits, patch electrodes attached to blood vessels, nerves, bone	A61B5/6846, A61B5/6847, A61B5/6848, A61B5/6849, A61B5/685, A61B5/6851, A61B5/6852, A61B5/6853, A61B5/6858, A61B5/686, A61B5/6862, A61B5/6864, A61B5/6865, A61B5/6866, A61B5/6876, A61B5/6877, A61B5/6878, A61N1/0504, A61M25/01%	A61B90/11
Electrode positioning on or in the body (other than the head)	Means of attachment to other body parts (excludes brain or head); skin piercing electrodes; external attachment	A61N1/0502, A61N1/0492, A61B5/680%, A61B5/681%, A61B5/682%, A61B5/683%, A61B5/684%, A61B5/686%, A61B5/687%,	N/a
Biofeedback, evoked response, evaluating the nervous system,	EEG using biofeedback, EEG using evoked response, Detecting the frequency distribution of signals, evaluating the peripheral and central nervous system and diagnosis or monitoring conditions thereof	A61B5/048, A61B5/0482, A61B5/0484, A61B5/40%	A61B5/048, A61B5/0482, A61B5/0484
Electrodes for electrotherapy	Electrodes for brain stimulation; Prevent neurodegenerative response; Electrodes for electrotherapy for external use, electrodes for implantation or insertion into the body, for high-frequency therapy	A61N1%	A61N1/04%, A61N1/05%, A61N1/06%

Electrodes for the detection and recording of brainwaves (continued)			
Technology category	Description	CPC Subclass	IPC Subclass
Electrode or sensor details	Details of materials, construction or manufacture of components or accessories; includes input circuits; Microstructural Technology; Measuring electric variables; Materials characteristics; Material and methods of coating medical devices; Investigating analysing materials; Basic electric elements; Amplifiers; Electrode manufacture;	A61B5/04004, A61B2562%, A61B2560%, A61K%, A61L31%, A61L2420%, A61L2400, A61P%, B81B%, C07F%, C08G%, C08L%, C25D%, G01R%, G01N%, H01%, H03F%, H01M%	A61K%, A61P%, B29C%, B81C%, C23C%, C25D%, H01%
Signal or data processing	Signal processing; Data processing; Recognising patterns in signals; Computer systems based on computational models; image data processing or generations; imaging/photography/electrography, recognition of data, presentation of data, medical imaging apparatus involving image processing or analysis, remote monitoring of patient using telemetry; Transmission; Coding	A61B5/000%, A61B5/001%, A61B5/002%, A61B5/0031, A61B5/72%, A61B2576, G06F%, G06K%, G06N%, G06Q%, G06T%, G03F%, H04B%, H03M%	G05B19%, G06K%, G06F%, G06Q%, H04B%
ECG, EMG, EOG	ECG and electrodes specially adapted therefore, connected by snap fastener electrodes, EMG and electrodes specially adapted therefore, EOG and electrodes specially adapted therefore,	A61B5/0402, A61B5/0404, A61B5/0408, A61B5/0416, A61B5/042, A61B5/043, A61B5/044, A61B5/045, A61B5/046, A61B5/0472, A61B5/0488, A61B5/0492, A61B5/0496	A61B5/0492
Medical or surgical applications	Detecting or measuring other body parts or functions; therapy magnetic and radiation and ultrasound; Diagnosis using ultrasonic, sonic or infrasonic waves; Measuring temperature; detecting or measuring pulse, heart rate, blood flow; detecting / evaluating respiratory organs, for testing the eyes, surgical instruments medical care (evaluating monitoring diagnosing, general characteristics of surgical instruments, details of surgical instruments, transferring non-mechanical energy to body; drug delivery; preparations for medical purposes; physical therapy apparatus; ICT for operation of medical equipment; medical devices, optics, sensors attached or worn on the body surface, other medical applications. Also includes EEG electrodes not defined by the other categories above	A61N%, A61B8%, A61B5/48%, A61B5/01%, A61B5/02%, A61B5/05%, A61B5/06%, A61B5/08%, A61B5/14%, A61B17%, A61B2017%, A61B18%, A61B2018%, A61B1%, A61B3%, A61B90%, A61B2505%, A61B2217%, A61B2218%, A61M%, A61H%, A61F%, G02B%, G16H%, A61B5/0478, A61B5/0476, A61B5/04001	A61B5/01, A61B5/02%, A61B5/05%, A61B5/16, A61N%, A61B5/145%, A61B5/0408, A61B5/0478

The symbol '%' denotes the use of a wildcard in categorising by CPC or IPC.

Technology sub-category

This technology breakdown further categorises the search results of electrode position for recording brainwaves into one of five categories: Electrodes implanted in the deep brain, Positioning of electrodes in or on the brain (excluding cortex or deep brain), Positioning of electrodes on the head, Electrode placement by catheter and other internal attachment means.

Positioning, placement or attachment means of electrodes for detection and recording of brainwaves			
Sub-category	Description	CPC Subclass	IPC Subclass
Electrodes implanted in the deep brain	Positioned in the cortex or deep brain	A61N1/0531, A61N1/0534	N/a
Positioning of electrodes in or on the brain	Attachment to the brain or anchored to the brain (excluding deep brain)	A61B5/6868, A61N1/0539	N/a
Positioning of electrodes on the head	Electrodes attached to head or scalp, including electrode caps, headsets or headgear	A61B5/6814, A61N1/0562	N/a
Electrode placement by catheter	Internal attachment or placement via guidewire, catheter, stent or attached to blood vessels	A61B5/685%, A61B5/6862, A61B5/6876, A61M25/01	N/a
Other internal attachment means	Internal attachment or placement via invasive device, needles, microneedles, burr holes; or permanently implantable or attached to nerves or bones	A61B5/6846, A61B5/6847, A61B5/6848, A61B5/6849, A61B5/6877, A61B5/6878, A61N1/0504, A61B5/686, A61B5/6864, A61B5/6865, A61B5/6866	A61B90/11

The symbol '%' denotes the use of a wildcard in categorising by CPC or IPC.