Global hot-spots of Advanced Technology

Background paper for Workshop on IFD's International engagement within Advanced Technologies,
Copenhagen 12 June 2018

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1. Executive Summary

Advanced Technology is considered a hyper growth area embedding present high powered but yet infant technology in future society. This is the case with big data, Industry 4.0, advanced material, photonics and quantum technology etc. In many cases, the new technological solutions will result in shifts of paradigm of present day life.

Traditionally the first wave of indicators on such shifts can be traced in an increase of academic papers. The second wave is in industrial patents. The third wave is in high growth rates among industrial leaders. Like tsunamis such growth areas attach investments in R&D in the initial phase before the technology becomes visible on the shores of the global market, where others “downstream” the technology.

In particular, within Advanced Technologies, global industrial leaders are the strongest drivers and investors in R&I. This is very prominent in a few regions in Asia and on the East and West Coast of USA where the global leaders have their headquarters.

However, even global leading companies are not islands. They thrive in competition, they provoke entrepreneurs to start and they generate spinouts. Not least, they cooperate closely with academia. In short, they generate and sustain technological clusters. Using data mining to identify the global hot spots of patent holders, hence leads to geographic centres of gravity for new technology.

The basis for the key stakeholder meeting on advanced technologies held the 12 June 2018 was technical topics selected by Research 2025 as particular positions of strength in Denmark.

To encourage discussion a datamining analysis on hot spots of patents families was conducted by The Danish Technological Institute for Innovation Fund Denmark.

The analyses and the comments from the workshop showed beyond any reasonable doubt that the centre of gravity within Advanced Technologies – with a few exceptions - is in mega centres in Asia and on the East and West Coast of USA. It should however be acknowledged that there are strong industrial clusters in Europe too:

- In Europe, UK (London & Oxbridge), The Netherlands, Germany (Bavaria), France (Paris), Switzerland, Northern Italy and Israel are the centres of gravity within a number of Advanced Technologies.
- In Asia, South Korea, Japan, China (Shanghai, Beijing, Hong Kong and Taiwan) are in the absolute lead.
- In USA, California and a zone from Boston to Washington DC are in the lead

2. Introduction

As an integrated part of Innovation Fund Denmark's (IFD) international strategy, IFD conducts regular workshops for key stakeholders on international technological trends and priorities. IFD uses the input from the meetings to prioritise its international engagement.

On 12 June 2018, IFD hosted a workshop on "Advanced Technologies". The topic included ICT, materials, smart production, nanotech and optical technologies. The national Danish report on strategic priorities "Research2025"[1] constitutes the basis for selecting the topics within Advanced Technologies.

The workshop was facilitated by Anna Laybourn, Brain2Business.

To inspire the discussion IFD invited Dr Andreas Gut, Federal Department of Economic affairs, Education and Research from Switzerland to introduce the Swiss considerations when selecting topics, countries and programmes for international collaboration. The Swiss approach is to match leading Swiss scientific and industrial clusters with world leading clusters – regardless of programme and geographic location. He also underlined the importance of maintaining stability in the international engagement.

In addition, IFD had invited the Stig Yding Sørensen, Danish Technological Institute to introduce datamining of global "hot spots" and leading companies based on patent families. The datamining concept is explained in chapter 5. The full power-point presentation is availed on IFD's homepage "innovationsfonden.dk/en/about-ifd" under Investment Strategies and Publications.

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The focus on patent families is of particular interest within Advanced Technologies, because private investments are driving this area. However, it is assumed that a national industrial cluster always includes three drives for development: academics, industry and a strong demand for the output[2]. Within some industrial clusters, national positions of strength develops because all three drivers are top class including a fierce competition among key players.

[1] Published by the Danish Ministry of Higher Education and Science 2017. Read here.
[2] Michael Porter: Clusters and the New Economics of Competition. Harvard Business Review, 1998

3. Key findings of the Data Mining Analysis

3.1. Information and Communication Technologies (ICT)

ICT is a pervasive technology integrated in all fields of technology. ICT has, to a large extent, been the driver of growth for the last 20-30 years, making global collaboration and production possible. The new wave of ICT is big data, which can be utilised in public sector, the health sector and in production. IFD has not had a high engagement in any international programmes within this field. Considering the pervasive nature of this technology, it is recommended to engage in interdisciplinary calls combining ICT with societal solutions (public services) as well as in production.

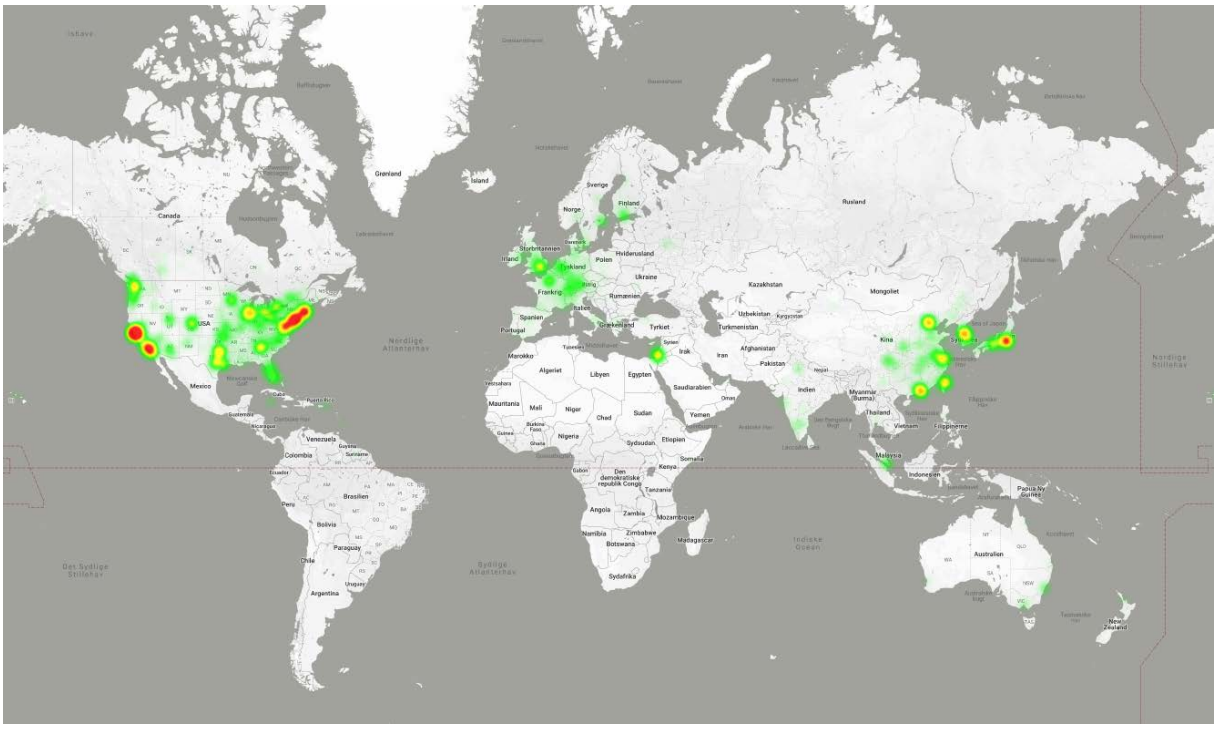
Although *Cyber Security* is not a "hotspot" for patents in Denmark, it is high on the agenda in the other Nordic countries. In public sectors, it makes good sense to collaborate with comparable countries with similar structures. *AI and Argumented Reality* are both supporting Industry 4.0 and smart solutions. A number of European countries have strong clusters within these fields. USA, Japan and Korea have, however, even stronger industrial (and academic) clusters.

Tabel 2.1 Key figures on ICT patents

	Global/EU/DK Patent families 1990-2018	**Global "hotspots"***	**Nationality of top 10 Global patent holders****	**Nationality of top 10 European patent holders*****
Artificial Intelligence (AI)	Global: 53.776 EU: 2.438 DK: 38 DK/EU 1,6%	China (Hong Kong & Taiwan), USA, South Korea, Japan	Japan (6), USA (3), South Korea (1)	DE (3), NL (1), UK (1),
Virtual & Argumented Reality	Global: 36.892 EU: 3.826 DK: 73 DK/EU 1,9%	USA, Japan, South Korea, Israel, China (Taiwan)	USA (5), Japan (2), South Korea (3),	DE (2), NL (1), UK (1), FR (1), FI (1)
Cyber Security	Global: 83.109 EU: 13.800 DK: 12 DK/EU 0,009%	USA, Japan, Israel	USA (5), South Korea (3), SE (1), Japan (1)	NL (2), DE (2), FI (1), FI (1), SE (1)
Wireless Communication	Global: 333.334 EU: 32.502 DK: 521 DK/EU 1,6%	USA, Japan. Israel UK	Korea (4), USA (2), Japan (2), SE (1), Canada (1)	DE (2), SW (1), NL (1), FR (1), FI (1), UK (1)

* Nationality of the biggest patent holders of the 10.000 most resent patents.
**Top 10 global number of organisations by country (Headquarter) who holds most patents.
***Some non-European companies are registered in Europe, and some with different names. The numbers hence don't add up to 10 cases.

Map 3.1 Global hotspots of 10.000 most recent patents within each of the four ICT topics combined



Ref.: Tech-mining Advanced Technologies, Danish Technological Institute, 2018

3.2. Materials, Production and Nanotechnologies

Europe has a number of strong clusters including industry and academia within this field. The strongest European clusters are located in Germany, UK, The Netherlands and France. Germany is the absolute leader in terms of patents within these five topics. In particular, Germany is the only big European player within Additive manufacturing & 3D printing.

In terms of being the top 10 global patent holders Japan is the leading country, followed by Korea and the East and West Coast of USA. South Korea is by far the most active within Drones, but there are also strong drone clusters in China (Hong Kong) and in San Francisco are leading within drone technology.

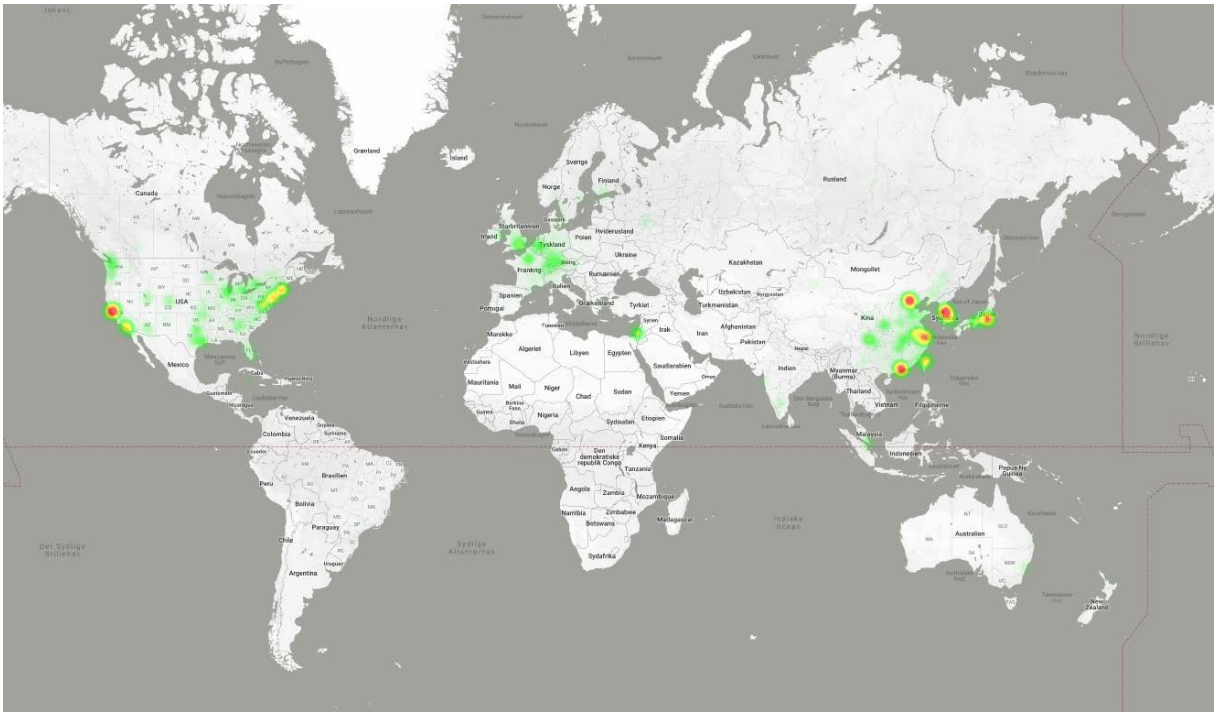
In regards to "hotspots" Korea, Japan, China (Beijing, Shanghai, Hong Kong and Taiwan), USA are in the lead. However, within satellites and robots, Israel are also amongst the world leaders.

Tabel 2.2 Key figures on Materials, Production and Nanotechnology

	Global/EU/DK Patent families 1990-2018	**Global "hotspots"***	**Nationality of top 10 Global patent holders****	**Nationality of top 10 European patent holders*****
Automation & Robotics	Global: 120.375 EU: 19.328 DK: 214 DK/EU 1,1%	China, USA, South Korea, Japan, DE, FR, UK, Israel	Japan (9), South Korea (1)	DE (7), SE (1), FR (1)
Nanotechnology	Global: 78.050 EU: 9.732 DK: 233 DK/EU 2,4%	Korea, China (Taiwan), USA, Japan	South Korea (6)	DE (6), FR (2), IT (1), NL (1)
Additive manufacturing & 3D printing	Global: 29.510 EU: 1.951 DK: 41 DK/EU 2,1%	Japan, Korea, China (Hong Kong, Taiwan), USA, DE, NL, Israel	USA (6), Japan (3), Taiwan (1)	DE (8)
Drones	Global: 11.766 EU: 669 DK: 3 DK/EU 0,5%	Korea, USA, China (Hong Kong)	China (5), USA (4), South Korea (1)	DE (5), UK (1), FR (1), IT (1)
Satellites	Global: 72.750 EU: 8.420 DK: 46 DK/EU 0,5%	China (Hong Kong), USA, Korea, Japan, Israel	Japan (6), Korea (3), USA (1)	FR (5), DE (4)

*Nationality of the biggest patent holders of the 10.000 most recent patents.
**Top 10 global number of organisations by country (Headquarter) who holds most patents.
***Some non-European companies are registered in Europe, and some with different names. The numbers hence don't add up to 10 cases

Map 3.2 Global Hotspots of 10.000 most recent patents within each of the five Materials, Production and Nanotechnology topics combined



Ref.: Tech-mining Advanced Technologies, Danish Technological Institute, 2018

3.3. Optical Technologies

In Denmark, the industrial implementation of advanced photonic solution is still young. But we have a strong academic environment conducting research in state of art photonics solutions. Compared to the 11 topics selected within Advanced Technologies, photonics has the highest rate of DK/EU patents: 2.5%

Both within photonics and sensor technology Germany has a very strong European position. The driving force behind Germany's lead position within sensor technology is the automobile industry.

The Netherlands and France both have strong research environment in academia and industry within photonics.

A number of world leading research institutes are engaged in photonic research and patenting: MIT and University of California, Fraunhofer and Max Plack in Germany and Commissariat a l´Energi in France. In Denmark DTU is the lead university.

Globally South Korea, Japan, Taiwan, Hong Kong and California are in the lead.

Table 2.3 Key figures on Optical Technologies

	Global/EU/DK Patent families 1990-2018	**Global "hotspots"***	**Nationality of top 10 Global patent holders****	**Nationality of top 10 European patent holders*****
Sensors	Global: 1.576.528 EU: 243.681 DK: 3.570 DK-EU 1,5%	South Korea, Japan, DE, Taiwan, USA, Israel, UK	Japan (7), South Korea (2), DE (1)	DE (8), NL (1), SE (1)
Photonics	Global: 43.214 EU: 8.076 DK: 198 DK-EU 2,5%	South Korea, Japan, USA, FR, DE, NL, UK, DK, SE, FI, China (Hong Kong & Taiwan)	USA (4), Japan (3), NL (1), South Korea (1), FR (1)	DE (4), FR (3), Swiss (1), NL (1)

*Nationality of the biggest patent holders of the 10.000 most recent patents.
**Top 10 global number of organisations by country (HQ) who have holds most patents.
***Some non-European companies are registered in Europe, and some with different names. The numbers hence don't add up to 10 cases.

Map 3.3 Global hotspots of 10.000 most recent patents within each of the two optical topics combined

Ref.: Tech-mining Advanced Technologies, Danish Technological Institute, 2018

4. R&D investments and hotspots patents

The patent hotspots of all thematic areas within Advanced Technologies are extremely concentrated geographically, as well as on very few very big companies. The global geographical areas are in Asia, in South Korea, Japan, China (Beijing, Singapore, Hong Kong and Taiwan) and in USA in California and the Boston-New York area.

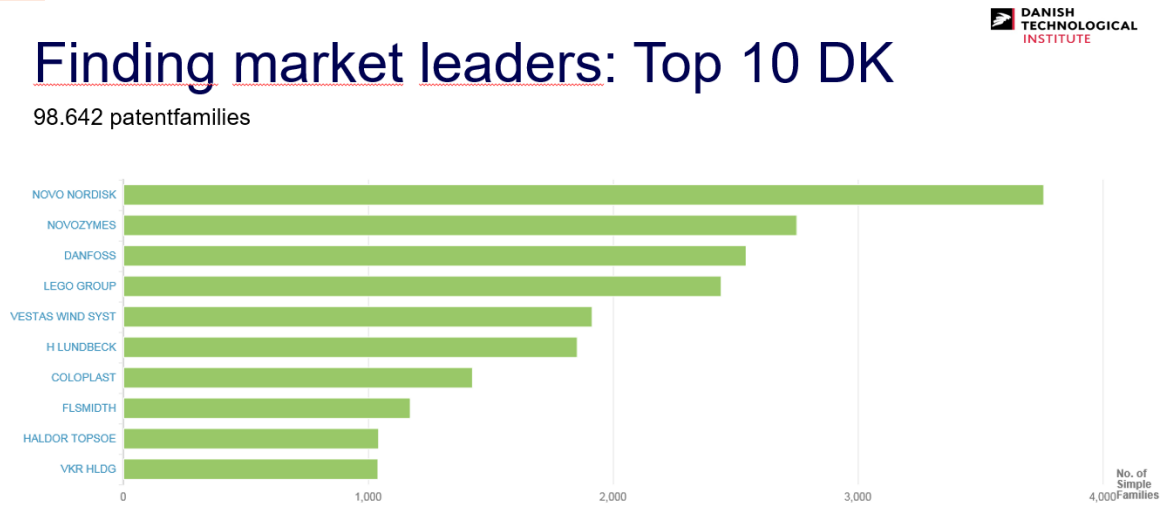
In many sectors in Europe there is a tradition of having a high focus on university research and to a lesser extent on industrial research. Often the private research is co-founded by national or EU funds. This is very prominent within bioresources and green technology.

Within Advanced Technologies or biomed this is, however, not the case. Here private investments are the drivers of technology.

Denmark has a few leading industries within Advanced Technologies investing heavily in R&D. The private research is strongly supported by academic research. Globally Denmark is a little country, but this symbiosis on R&D has in certain areas lifted Denmark up in an international class. Apart from the biomed companies all the other companies on the top 10 list of Danish patent holders are investing in Advanced Materials. This engagement has created a vibrant environment for SME's and entrepreneurs coming directly from universities or spin-out from large industrial partners.

Figure 4.1 Top 10 Danish patent holders

Example



Leading tech-companies in Denmark

Ref.: Tech-mining Advanced Technologies, Danish Technological Institute, 2018

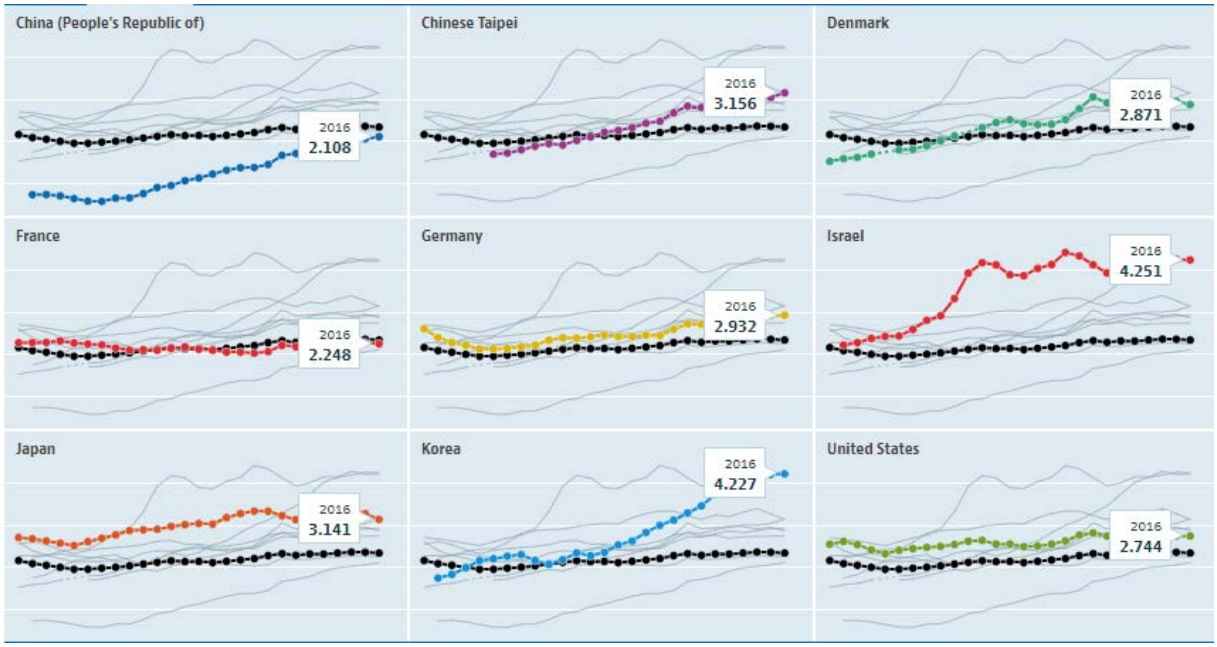
The EU target for R&D spending has since the Barcelona declaration in 2003 been 3% of GDP – 1% of public investment and 2% private investment. This target should be seen in a context where the average OECD spending was 2% of GDP and the Danish spending was 2.5%. The growth economies of Asia all invested more than 3%. South Korea being in the lead with around 4%. The only country matching this rate is Israel with an investment on around 4.4%.

In 2009, Denmark finally reached the 3% target, but this was partly due to a fixed national budget and the slowdown of the growth coursed by the global financial crises. Since 2009 the Danish R&D investment been around 2.9% of GDP.

In big economies like USA, Japan, Germany, France and China, R&D investments tend to concentrate in specific growth regions. R&D investments rates on around 2-3% of GDP will, hence, result in huge R&D investments in national innovation centres, typically around the capital or in regional capitals. Smaller economies cannot focus to the same extent. They must instead invest a higher percentage of GDP in R&D in order to reach the same critical levels. This is what is happening in the fast growing economies like South Korea, Switzerland and Israel.

The data mining of patents shows that there is a direct correlation between high national R&D investments and the ability to become a hotspot for patents. Since hotspots for patents are measured in relations to the latest 10.000 patents, it is yet to be seen whether high R&D investments and a high number of patents will generate a proportionally higher economic growth. Chances are that it will.

Figure 4.2 Gross domestic spending on R&D, % of GDP 1990-2016



Ref.: OECD: https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm

5. Tech mining as a tool to find the hotspots of advanced technology

By Stig Yding Sørensen, Danish Technological Institute

Patent information is information about intellectual property rights. With a patent, a sovereign state or intergovernmental organisation grants exclusive rights to the owner of an invention in form of a specific solution, product or process for a limited period. In exchange for the patent, there is a detailed public disclosure of the invention.

5.1. What is tech mining? – a brief introduction

The information is stored in national and international patent databases. Each national authority stores the information on the invention, the inventors, reference to other patents and technical classifications such as CPC (Cooperative Patent Classification) codes. The technical code systems are very detailed and were developed in a cooperation between the European Patent Office (EPO) and the patent office of the United States (USPTO)[3].

The same patent can be registered with patent authorities in several countries. In 2016, the number of new patent applications registered in a year passed 3 million patents according to WIPO[4]. Almost two out of three patents in 2016 were filed in Asia – in 2006 about half of the patents in the world were filed in Asia. In 2016, almost 21 percent of the patents were filed in North America and 11 percent in Europe.

The information is kept in publicly accessible databases and can be used for news searches to make sure that a "new" invention is in fact new. The attraction of the patent databases from an analytical point of view is that the databases are updated constantly with detailed information of new technologies and their assignees. Using big data techniques the wealth of patent data can be analysed for strategic information on technological development over time and place. This type of analysis is referred to as tech mining. The data source for tech mining can be patent databases, or it may be global publication databases or business related databases. In this instance, we are looking at patent data.

Tech mining is a relatively new analytical tool that has been developed over the past 10-15 years. Patent information has always been publicly available, but tech mining the big data in the databases is only possible thanks to the internet, powerful computers and analytical software. The analysis that we do now in matters of seconds were virtually impossible and almost unthinkable a decade ago.

The leader in tech mining is Georgia Tech, USA and over the years, Danish Technological Institute has worked with Georgia Tech and their analytical software package, Vantage Point, and with Thomson Innovation to understand tech mining. The tools have been applied in studies for the Danish government and for private companies. Tech mining is a fast evolving discipline and new tools for tech mining emerges such as PatSnap.

[3] http://www.cooperativepatentclassification.org/
[4] http://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2017-chapter2.pdf

5.2. Insights from tech-mining – with a few examples

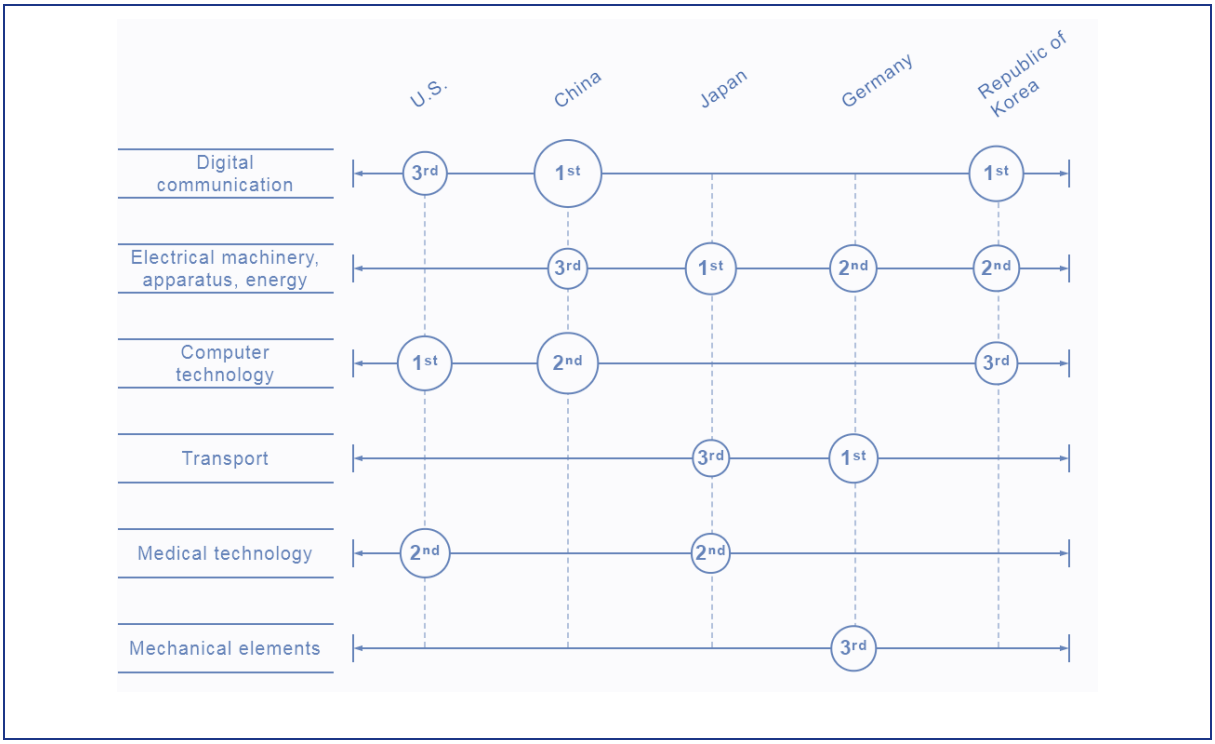
Tech mining provides insights that can be found nowhere else, but tech mining patent data is not an exact methodology. The advantage of tech mining is to identify trends and patterns in the data, but it is not sufficient for a full analysis or a complete understanding of technological developments and markets. The purpose of tech mining is to extract strategic insights on technologies, actors and markets from the data.

Tech mining patent data is useful for gaining insights into trends, insight into how one technology develops and relates to other technologies. Tech mining patent data is useful for identifying technological leaders and knowledge clusters, a growth in the number of patents might indicate a strategic interest or a market interest in a specific technological area. Tech mining also give insights to where the stakeholders (universities, research institutions, companies, inventors) are clustering.

Below a few examples of the use of tech mining.

For a policy maker it might be of value to identify national priorities in technological development. As an example, the organisation WIPO has generated a map of "Strategic information on technological priorities" that shows China as having digital communication as a top priority – both in comparison with other technological areas and in comparison with the US and Korea.

Figure 4.1: Strategic information on technological priorities



Source: WIPO Statistics Database, March 2018. Calculating the share of tech-patents for each country

For a company this may be strategic information in finding the best partners among world leaders or the worst competitors, for policy makers' tech mining of patent information gives insights into hot-spots of technological development and a way to identify national advantages in technology.

A patent overview of one company gives insights into technological priorities. One example is the patents of the IT-giant, Apple, where the technologies behind an iPhone is clearly visible in a map of their patents. Apple owns 26.210 patent families and the pool of patents are used to visualise the technologies in a landscape format.

Figure 4.2: Example patents from Apple

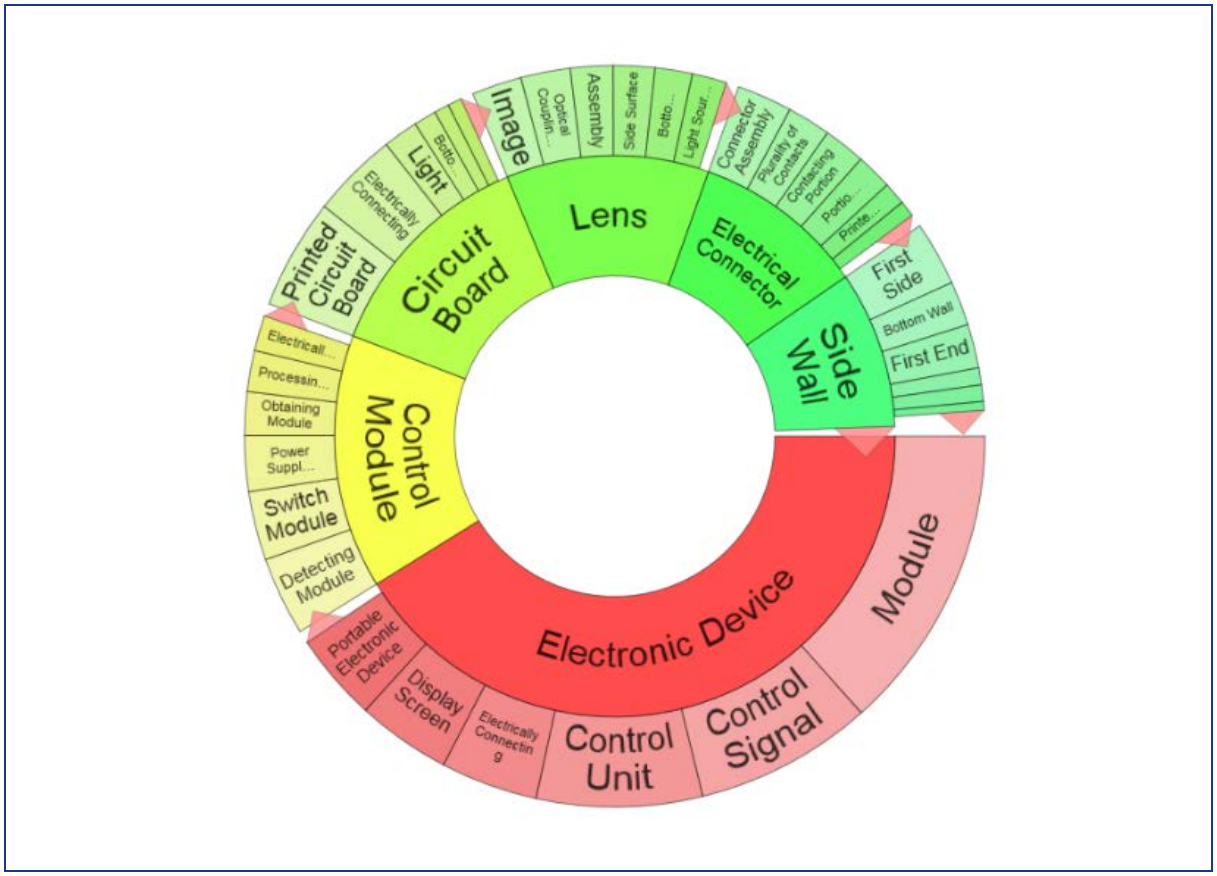
Source: Danish Technological Institute - based on Patsnap. Apple owns 26.120 patent families. Patsnap renders the landscape based on patent information. The "Mountains" are areas with related patents. The words on the top of the "mountains" are key words behind the technologies: portable, image, synchronization, input, touch, screen, memory, network, handheld all strongly relates to well-known Apple products: Iphone, Ipad etc.

Another company example is Foxconn, the world's largest contract electronics manufacturer with reportedly 1,3 million employees, also known as Hon Hai Precision Industry. Hon Hai Precision Industry owns more than 50.000 patent families.

The analytical software can generate a "wheel of invention" for the selected patents that categorises the most frequent keywords in the patent. The patents from Hon Hai Precision

Industry reveals that the world's largest contract electronics manufacturer is defending its position as contract manufacturer by patenting a wide range of related technologies – or perhaps is planning to introduce its own range of advanced electronic products?

Figure 4.3: Example patents from Hon Hai Precision Industries



Source: Danish Technological Institute - based on Patsnap's Wheel of Innovation. The Circle Chart categorizes the most frequent keywords into a 2-tier hierarchy of within the most recent 10,000 Simple Families in the technology field. The Wheel of Innovation above is based on patents owned by Hon Hai Industries.

Based on search: Hon Hai Precision Industry AND PATSNAPFILTER=(AN_FACET:("HON HAI PRECISION INDUSTRY CO., LTD." OR "HON HAI PRECISION INDUSTRY CO. LTD." OR "FOXCONN (KUNSHAN) COMPUTER INTERFACES CO. LTD." OR "FOXCONN (KUNSHAN) COMPUTER CONNECTOR CO. LTD.") AND AN_ST_FACET:("FOXCONN"))

5.3. The blind-spots of tech mining

The examples above also illustrates that tech mining in patents do not answer every relevant question. There are several blind-spots in tech mining to be aware of:

- **First**, for several reasons not all technologies are patented, for example: Some companies wants secrecy around their innovations, in some areas the technological innovation is moving so fast that technologies are obsolete before the patent process is done or some companies thinks that patenting is to expensive.

- **Secondly**, national authorities and local offices are located all over the world and this lead to inconsistencies in the written information manage the databases, for example: Danish Technological Institute is one of the leading patenting companies in Denmark, but the recorded name of the company may also be “DTI”, “technological institute” and other variations. So poor data consistency means that data may be overlooked and misinterpreted. Smart software helps to alleviate this problem to some degree.
- **Third**, patenting cultures may differ for country to country, for example: Chinese patents may be over-rated since there are personal rewards for taking out patents, and in the US fights over technology rights in the judicial system might also inflate the number of patents as compared with patents taking in Europe.[5,6]
- **Fourth**, there is no market information connected to the patent data, there is no data on licensing, on value of patents and often there is no links to business databases and the data cannot be readily summed into measures or indicators of strength. Tech mining should not stand as the only source for an analysis, but it provides a useful supplement to any technology analysis with data and insights there are impossible to gain through other types of sources.

[5] Chinapower: “Are patents indicative of Chinese innovation?” See https://chinapower.csis.org/patents/ and Markovich, “U.S. Patents and Innovation”, Council on foreign relations, 2012 see https://www.cfr.org/backgrounder/us-patents-and-innovation

[6][6] Europe has a loser pays cost juridical system, where often in the US it is each party is responsible for paying its own attorney's fees. That has led to some inflation in the patent system in the US, where “patent troll”s are companies with patents attempts to enforce patent rights against accused infringers far beyond the patent's actual value using hardball legal tactics. See Strowel & Utko,”The trends and current practices in the area of patentability of computer implemented inventions within the EU and the U.S.”, EU Commission, 2016. https://ec.europa.eu/digital-single-market/en/news/report-trends-and-current-practices-area-patentability-computer-implemented-inventions-within

An overview of the insights and blind-spots of tech mining discussed above is provided in the table below.

Figure 4.4: Insights and blind-spots in tech mining patents

Insights	Blind-spots
Trend overview Insight into related technologies Identification of leaders Identification of knowledge clusters Insight to new technologies Geographic information Indication of market interest	Not all technologies are patented - To keep innovation secret - Innovation is to fast - Patenting to expensive Poor data stringency / consistency Different patent registrering cultures Data to dream of: - Data on licensing - Value of patents - Links to business databases - Strength point indicators / measures

Source: Danish Technological Institute

5.4. Hot-spots of advanced technologies – an example

The Innovation Fund Denmark and the Danish Technological Institute has used tech mining of patents as a tool to provide a first identification of hot-spots of selected advanced technologies around the globe. The findings of the tech mining analysis were discussed by key stakeholders in a workshop held by The Innovation Fund Denmark. The analysis might be further qualified with a supplementary bibliometric study of literature databases, standard economic indicators or information from business-databases.

The technologies studies were selected among the advanced technologies in "Forsk2025"[7]. ICT technologies included artificial intelligence, machine learning and neural networks, wireless communication, virtual / augmented reality and cyber security. Materials, production and nano-tech technologies included automation and robotics, additive manufacturing / 3D-print, drones and Satellites, Nano-tech. Finally, Optical technologies included sensors and photonics.

The results for all the selected technologies are found here [Hyperlink]. Here is a short introduction on how to read the results of the analysis. All the graphics are generated through PatSnap.com and the maps through BatchGeo.com As an example is used the results for artificial intelligence.

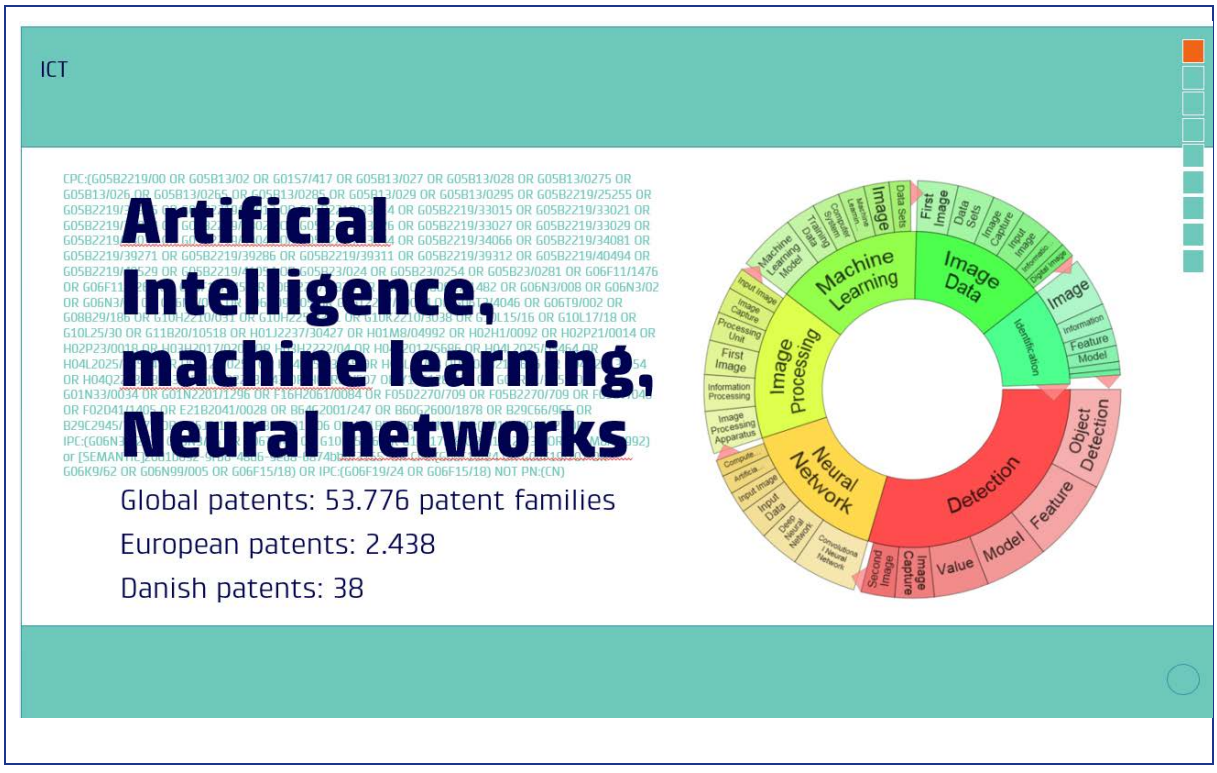
[7] https://ufm.dk/forskning-og-innovation/indsatsomrader/forsk2025

5.5. Overview slide

The first slide gives an overview of the search. In total 53.776 publicated patent families about artificial intelligence (and machine learning and neural networks). Among these 2.438 patents where found in European patent offices and 38 in Denmark. The wheel of fortune illustrates the most common key words of the patents identified. The wheel of fortune is useful for an inspection of the result: Is it the right population of patents we have identified with the query?

The search query for the PatSnap databases is also shown, but is mostly relevant for a follow query. The analysis on the following pages are made on this population.

Figure 4.5: Result of query for artificial intelligence, machine learning and neural networks

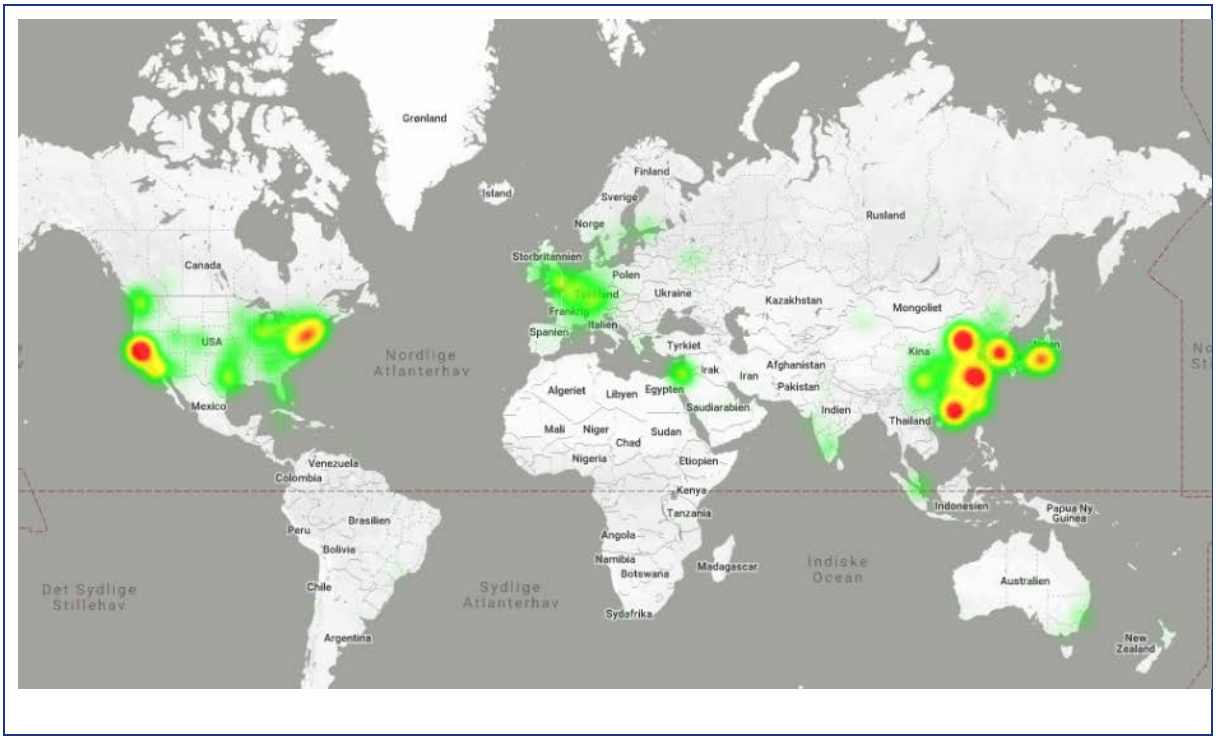


Source: Danish Technological Institute - based on Patsnap.

5.6. The heat map of assignees

In patents, the name and address of an assignee is noted. Plotting the assignees behind the most recent 10.000 patents generates a heat map that illustrates hot spots of technology invention. For artificial intelligence, it is clear that in the USA the primary hot spots are on the west coast and on the east coast. Other significant hotspots are found in East Asia: Eastern China, Taiwan, South Korea and Japan. The map also illustrates a huge interest in artificial intelligence in western USA, in Israel, in spots in India, Singapore and Australia. In Europe, the tech development seems to be concentrated in a line from London and south along the Rein River to Bavaria. In the Nordic Countries, a less significant "haze" of green color illustrates some activity in Denmark, Sweden and Finland.

Figure 4.6: Heat map of artificial intelligence assignees.

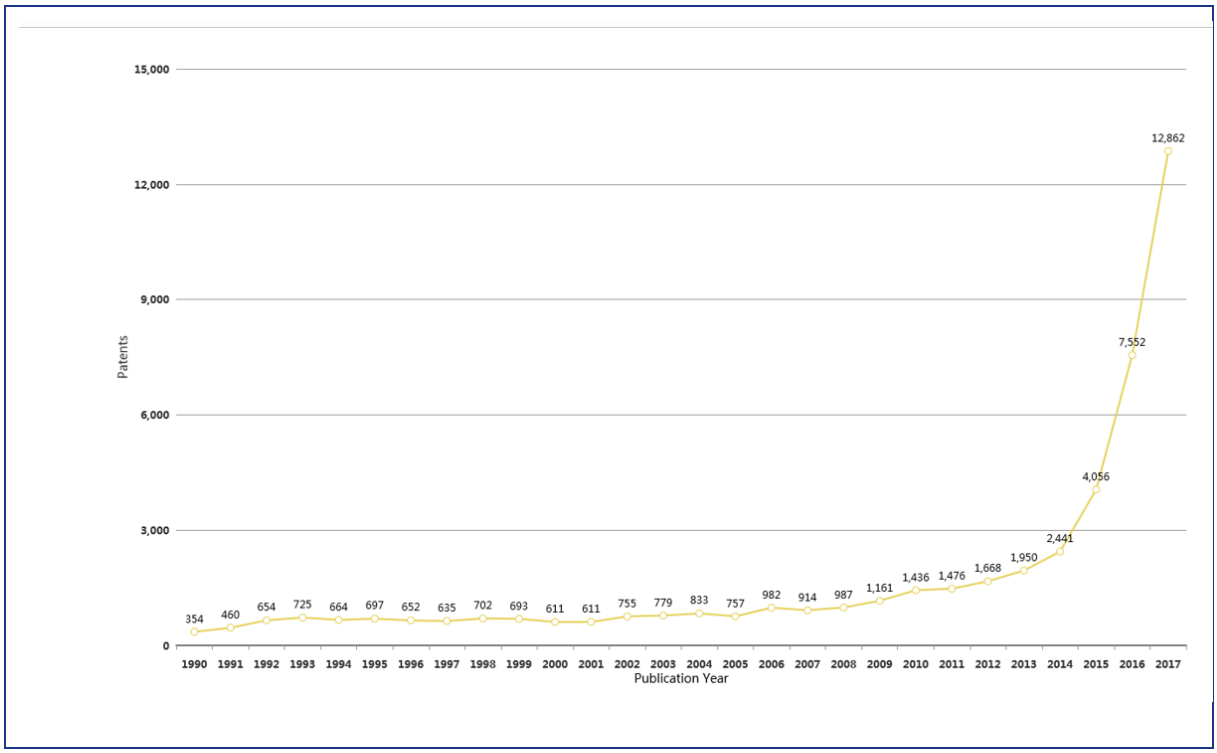


Source: Danish Technological Institute - based on Patsnap and GeoBatch. Made by plotting the address assignees behind the 10.000 most recent publicised patents on artificial intelligence.

5.7. Intensity of innovation

In patents, the date of publication is noted. This means that we year by year can count the number of publicised patents. Until about 2010, the patenting activity was slowly increasing, but after that, the number of yearly patents has been increasing exponentially. In 2017, more than 10x the number of new patents published as compared to 2010. A possible interpretation is that the number of patents reflects that artificial intelligence or machine learning is attracting government attention and market attention. The consequence might be a flood of products and services with integrated artificial intelligence. The attention is drawn to the change in attention in development of artificial intelligence.

Figure 4.7: Intensity of innovation for artificial intelligence

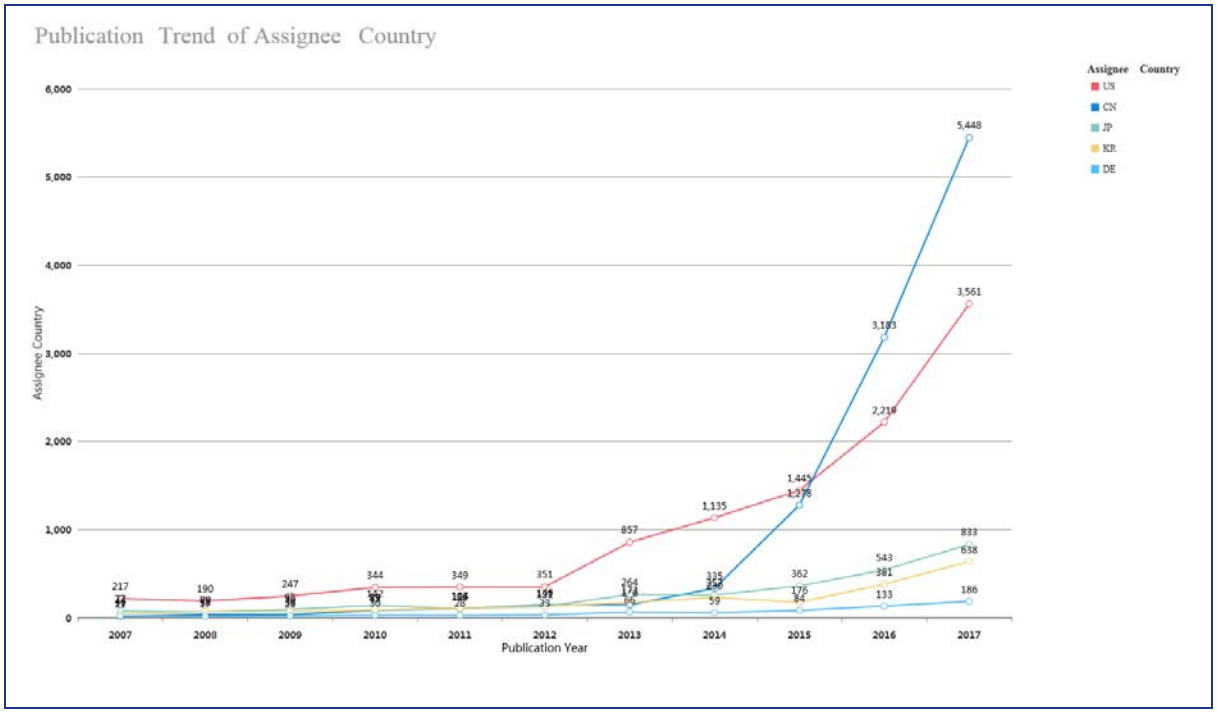


Source: Danish Technological Institute - based on Patsnap and GeoBatch. Made by plotting the yearly count of publicised patents per year

5.8. Intensity of innovation by country

In patents, the date of publication is noted as well as the patent office. The information is combined in the following slide. This reveals that the increased interest in artificial intelligence is primarily in the USA and China, whereas the attention in Germany is – according to the information in the patent databases – almost unaltered.

Figure 4.8: Intensity of innovation for artificial intelligence – by country

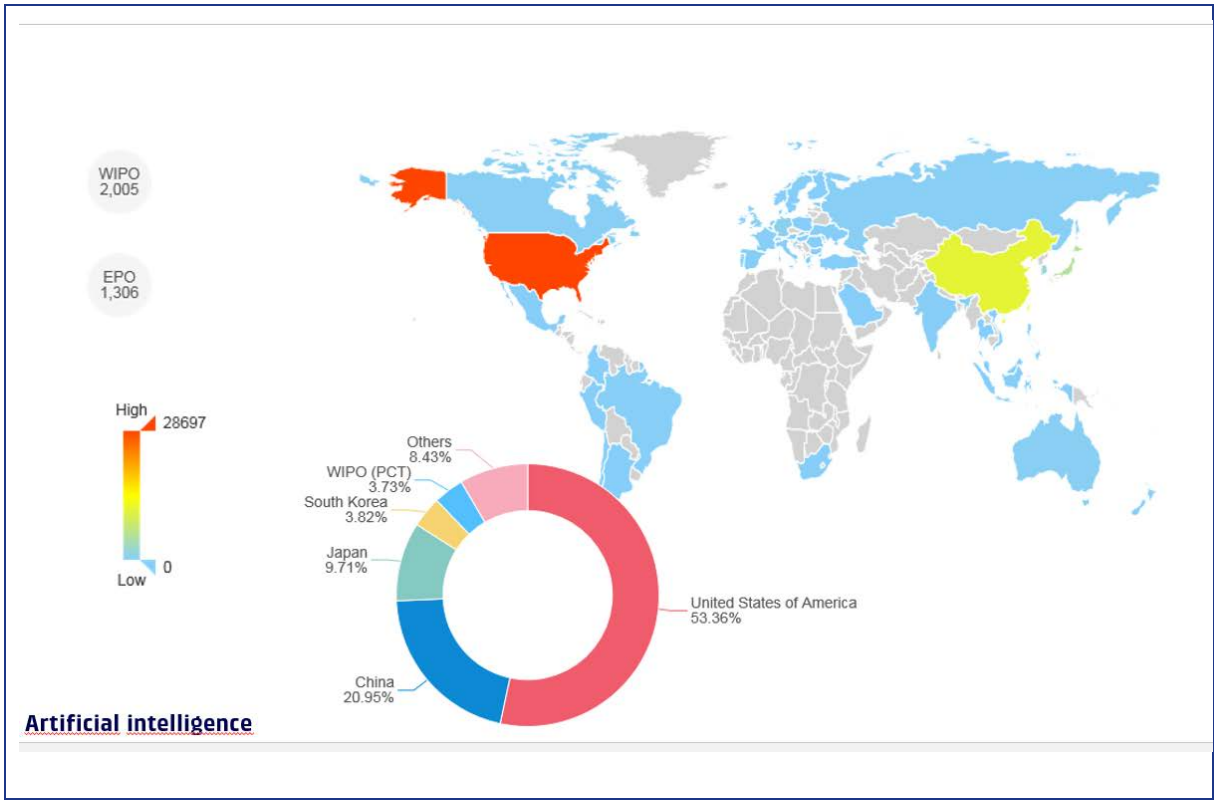


Source: Danish Technological Institute - based on Patsnap and GeoBatch. Made by plotting the yearly count of publicised patents per year – for the leading countries.

5.9. Geographical overview by patents by patent offices

A simple overview of the geographical spread can be made by counting the artificial intelligence patents by patent authority. The distribution of patents shows, that even if China is taking the lead per year then the USA still has the lead for while. 21 percent of all artificial patents has been published in China, while 54 percent is from USPTO.

Figure 4.9: Intensity of innovation for artificial intelligence – by patent offices

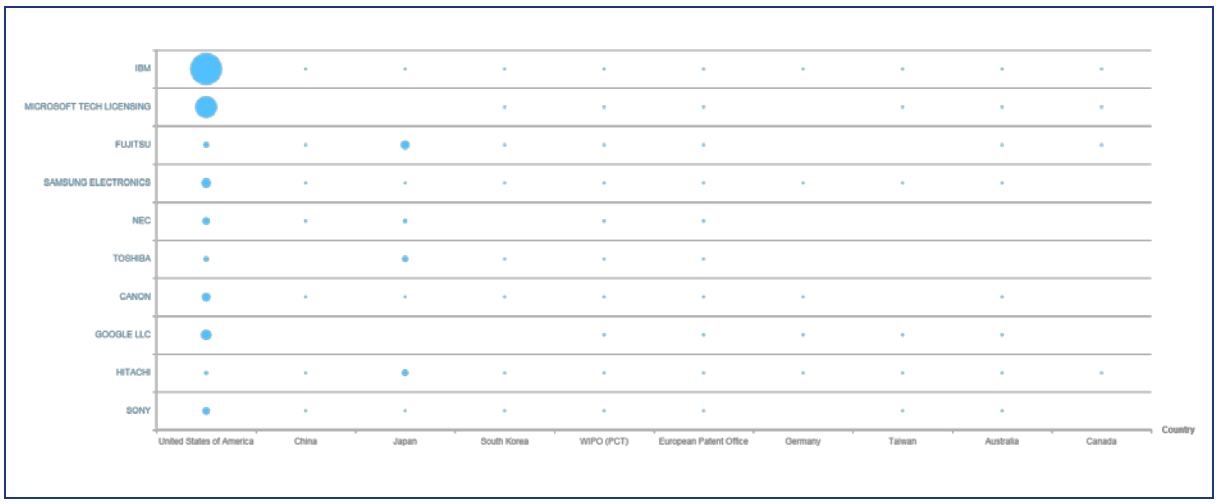


Source: Danish Technological Institute - based on Patsnap.

5.10. Overview of global leaders

The next graph is helpful for determining which geographical markets the top organizations in artificial intelligence are focusing on and looking to commercialize their products in. This indicates the most successful global markets in which the technology has penetrated.

Figure 4.10: Global leaders in artificial intelligence



Source: Danish Technological Institute - based on Patsnap.

5.11. Key business information on the top-10 global leaders

The final table illustrates that business information connected to the patent data is improving. The table provides some business indicators of the top-10 leaders in artificial intelligence. For example, the clear leader is IBM with 1.863 of the patents. IBM has 414.000 employees.

Figure 4.11: Global top-10 leaders – business information

Indicators Profile	IBM	MICROSOFT TECH LICENSING	FUJITSU	SAMSUNG ELECTRONICS	NEC	TOSHIBA	CANON	GOOGLE LLC	HITACHI	SONY
Annual Sales	$ 79,139 mill	-	$ 41,580 mill	$ 174,121 mill	$ 24,572 mill	$ 44,909 mill	$ 31,362 mill	-	$ 84,478 mill	-
Portfolio Size	1,863	1,231	827	709	667	676	635	650	606	565
Employee Number	414,400	-	155,069	93,200	107,729	153,492	197,673	-	303,887	-
Market Cap	$ 156,874 mill	-	$ 11,137 mill	$ 148,466 mill	$ 5,870 mill	$ 7,918 mill	$ 21,834 mill	-	$ 25,119 mill	-
Portfolio Value	$ 443 mill	$ 451 mill	$ 112 mill	$ 97 mill	$ 138 mill	$ 90 mill	$ 231 mill	$ 335 mill	$ 41 mill	$ 286 mill
R&D Expense	$ 5,226 mill	-	$ 181 mill	$ 6,371 mill	$ 2,650 mill	$ 3,240 mill	-	-	$ 3,268 mill	-
R&D Expense %	6.60%	-	0.44%	3.66%	10.79%	7.22%	-	-	3.87%	-

Source: Danish Technological Institute - based on Patsnap.

Annex 1 Top 10 Global and European Patent Holders

ICT - Top 10 European Patent Holders

IA	Wireless	Cyber Security	Virtual and Argumented Reality
Siemens (DE)	Ericsson (SW)	Ericsson (SE)	Nokia Tech (FI)
IBM (USA)	Philips (NL)	Siemens (DE)	Philips (NL)
Daimler Chrysler (DE)	Alcatel Lucent (FR)	Alcatel Lucent (FR)	Siemens (DE)
Robert Bosch GMBH (DE)	Nokia (FI)	Nokia Tech (FI)	Microsoft Tech Licensing (USA)
Google LLC (USA)	Nokia Tech (FI)	Nokia (FI)	Sony Mobile Communication (JAPAN)
Thomson Licensing (UK)	Nokia Solutions & Networks (FI)	IBM (USA)	Thomson Licensing (UK)
Bayerische Motoren Werke (DE)	Siemens (DE)	Philips (NL)	Alcatel Lucent (FR)
Philips (NL)	Thomson Licensing (UK)	SAP SE (DE)	Audi (DE)
Samsung Electronics (Korea)	Sony Mobile (Japan)	Microsoft (USA)	Nokia (FI)
Ricoh (Japan)	Robert Bosch GMBH (DE)	Gemalto (NL)	Microsoft Tech LLC

ICT - Top 10 Global Patent Holders

IA	Wireless Communication	Cyber Security	Virtual and Argumented Reality
IBM (USA)	QualComm (USA)	IBM (USA)	Microsoft Tech Licensing (USA)
Microsoft Tech Licensing (USA)	Samsung Electronics (Korea)	Microsoft Tech Licensing (USA)	Samsung electronics (Korea)
Fujitsu (Japan)	LG electronics (Korea)	Cisco Systems (USA)	IBM (USA)
Samsung Electronics (Korea)	Erisson (SW)	Samsung Electronics (Korea)	Konami (Japan)
NEC (Japan)	Panasonic (Japan)	Ericsson (SE)	Sony (Japan)
Toshiba (Japan)	ETRI (Korea)	Huawei (Korea)	LG Electronics (Korea)
Canon (Japan)	NEC (Japan)	Intel (ISA)	ETRI (Korea)
Google LLC (USA)	Blackberry (Canada)	Qualcomm (USA)	Google LLC (USA)
Hitachi (Japan)	Intel (USA)	ETRI (Korea)	INTEL (USA)
Sony (Japan)	Huawei (Korea)	Fujitsu (Japan)	QualComm (USA)

Material , Production and Nanotechnology - Top 10 European Patent Holders

Automation & Robotics	**Nanotechnology**	**Additive manufacturing & 3D printing**	**Drones**	**Satellites**
Siemens (DE)	Commissariat a Lenergie (FR)	Siemens (DE)	BAE Systems (UK)	Siemens (DE)
Daimler Crysler (DE)	CNRS (FR)	Hewlett Packard (USA)	Daimler Chrysler (DE)	ZF Friedrichshafen (DE)
Fraunhofer Institutes (DE)	BASF (DE)	MTU Aero Engines (DE)	Dolch Stefan (DE)	DLR (DE)
ABB Group (SE)	Philips (NL)	CL Schuterechtsv ERW (DE)	Airbus Defence & Space (FR)	Thales Group (FR)
Kuka Roboter (DE)	Siemens (DE)	Beyerische Motor Werk (DE)	MBDA Deutchland GMBH (DE)	CNES (FR)
DLR (DE)	Loreal Corp (DE)	Fraunhofer Institute (DE)	Siemens (DE)	Renault (FR)
Bayerische Motoren Werke (DE)	Fraunhofer Institutes (DE)	Robert Bosch GMBH (DE)	Diehl Defence GMBH (DE)	Astrium (Airbus) (FR)
Peugeot & CIE (FR)	Akema (IT)	SEOS Electro Optical syst (DE)	Politecnico di Torino (IT)	Robert Bosch GMBH (DE)
FANUC (Japan)	Merck (DE)	Tech Resaussoc for future additive MPG (Japan)		Alcatel (FR)
Telefunken Patentverw (DE)	Robert Bosch GMBH (DE)	Daimler-Chrysler (DE)		

Material , Production and Nanotechnology - Top 10 Global Patent Holders

Automation & Robotics	**Nanotechnology**	**Additive manufacturing & 3D printing**	**Drones**	**Satellites**
Samsun electronics (Korea)	Samsung Electronics (Korea)	Hewlett-Packard (USA)	Sz Dji Tech (China)	NEC (Japan)
FANUC (Japan)	KAIST (Korea)	3D Systems (USA)	Shenzhen Dajiang Innovation Tech (China)	Mitchbishi Electric (Japan)
Honda (Japan)	Samsung SDI (Korea)	Stratesys (USA)	State Grid Corporation of China	Oanasonic (Japan)
Yaskawa Electric Co. (Japan)	Korea University (Korea)	Seiko Epson (Japan)	Amazon (USA)	Sony (Japan)
Hitachi (Japan)	Yonsei University (Korea)	Ricoh (Japan)	Boeing (USA)	ETRI (Korea)
Panasonic (Japan)	KIMM (Korea)	Xerox (USA)	Beihang University (China)	QualComm (USA)
Toshiba (Japan)		General Electric (USA)	EWATT Aerospace (China)	Toshiba (Japan)
Toyota (Japan)		Canon (Japan)	IBM (USA)	Daewoo Electronics (Korea)
Mitsybishi Denki (Japan)		United Technologies Corporation (USA)	Korea Aerospace (Korea)	Seiko Epson (Japan)
Sony (Japan)		Kinpo Electronics (Taiwan)	Honeywell (USA)	Samsung Electronics (Korea)

Optical - Top 10 European patent holders

Sensors	Photonics
Robert Bossch GMBH (DE)	Philips (NL)
Seimens (DE)	Commissariat a l'Energie (FR)
Philips (NL)	CNRS (FR)
Continental AG (DE)	Siemens (DE)
Daimler Chrysler (DE)	Siemens Healthcare (DE)
Volkwagen Group (DE)	Fraunhofer Institutes (DE)
Schlumberger (DE)	Alcatel Lucent (FR)
Fraunhofer Instituttes (DE)	Max Planck (DE)
Infineon Technologies (DE)	Philips Introp & Standard (NL)
ABB Group (SE)	STMicroelectronics R&D (Swiss)

Optical - Top 10 Global patent holders

Sensors	Photonics
Canon (Japan)	Philips (NL)
Panasonic (Japan)	General Electric (USA)
Samsung electronics (Korea)	Samsung Electronics (Korea)
Toyota (Japan)	Commissariat a L'Energie (FR)
Robert Bosch GMBH (DE)	University of California (USA)
Toshiba (Japan)	NTT (Japan)
Hyundai Motor company (Korea)	MIT (USA)
Hitachi (Japan)	IBM (USA)
Denso (Japan)	Toshiba (USA)
Mitsybishi Electric (Japan)	Canon (Japan)