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Control of algorithms in industry 4.0

An explorative study on the application of control mechanisms on algorithms in industry 4.0.

Master's Thesis in the Master's Programme
Entrepreneurship and Business Design

MARIA DEL CARMEN ESPEJEL CARRIÓN
SIMON RISBERG

Department of Technology Management and Economics
Division of Entrepreneurship and Strategy
CHALMERS UNIVERSITY OF TECHNOLOGY
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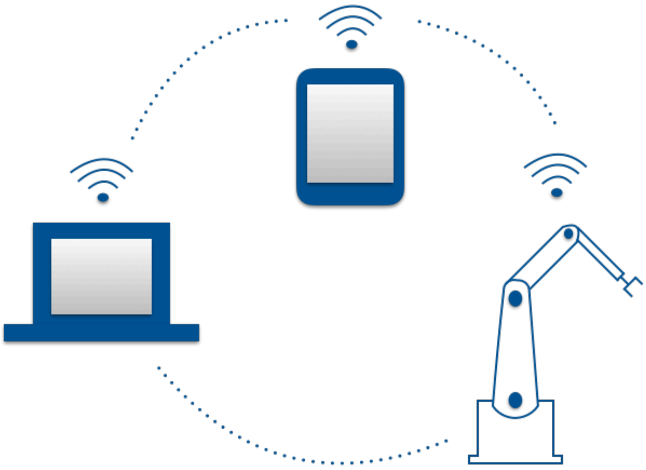

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MARIA DEL CARMEN ESPEJEL CARRIÓN
SIMON RISBERG

Tutor, Chalmers: Magnus Eriksson
Tutor, SKF Group: Karthik Venkitesh

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Department of Technology Management and Economics
Division of Entrepreneurship and Strategy
Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Telephone: + 46 (0)31-772 1000

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Maria del Carmen Espejel Carrión
Simon Risberg

Abstract

The world is on the brink of a fourth industrial revolution that is characterized by the interconnection and digitalization of machines and their environment which enables industrial companies in the manufacturing industry to create new value propositions that are based on smart products and services. At the core of this industrial revolution lies the key term called internet of things which includes a network of physical devices that are enhanced with sensors, connectivity and software. It turns regular physical devices into smart complex products that can capture and process data and turn it into valuable insights through data analytics. What drives the data analytics solution are the algorithms that are trained to solve a specific problem.

As mechanical products are turned into smart products through embedded software, traditional industrial companies do not only have to think about protecting their hardware solutions but also their software solutions. As the main driving force for data analytics are the algorithms, industrial companies are faced with the challenge of controlling them in order to stay competitive in their respective industry. However, there is an uncertainty in regard to how to control algorithms which calls for an explorative approach. Therefore, the aim of the study is to explore how industrial and software companies are applying control mechanisms and provide recommendations on how industrial companies in the manufacturing industry should apply control mechanisms on algorithms to leverage a competitive advantage.

As the phenomenon is rather nascent the study was conducted in an abductive approach and two methods of gathering information were done through a literature review and interviews. The research design used was a cross-sectional design in which two types of groups were interviewed based on qualitative research with semi-structured interviews in order to gather as much information as possible. The first group was IP professionals which helped to identify how well control mechanisms work in practice on algorithms while the second group which were software managers helped to identify the different trends in how companies that are working with algorithms in-house are applying control mechanisms on a daily basis for a competitive advantage.

With the help of the two different groups interviewed the study established the fact that due to the very nature and intangibility of algorithms, the control mechanisms had to be applied both from an internal point of view in the company as well as from an external point of view towards the environment of the company. The study also found that the different control mechanisms applied on algorithms will differ externally depending on what level of the algorithms you want to control and in which interface that an industrial company is operating with whether it is towards a software supplier, a competitive industrial company or a customer.

Keywords: *algorithm, competitive advantage, control mechanisms, data analytics, industry 4.0, internet of things, knowledge assets.*

Abbreviations

API	Application programming interface
BSD	Berkeley Software Distribution
DRM	Digital Rights Management
DTSA	Defend Trade Secrets Act
EPO	European Patent Office
EU	Europe
GPL	General Public License
IAM	Intellectual asset management
ICT	Information and communication technology
IoT	Internet of things
IP	Intellectual Property
IPRs	Intellectual Property Rights
ISO	International Organization for Standardization
IT	Information Technology
MRQ	Main research question
NDA	Non-disclosure agreement
OEM	Original Equipment Manufacturer
OT	Operational Technology
PRV	The Swedish Patent and Registration Office
PTAB	Patent Trial and Appeal Board
PTO	Patent and Trademark Office
R&D	Research and development
RQ	Sub Research question
TRIPS	The Agreement on Trade-Related Aspects of Intellectual Property Rights
UPC	Unified Patent Court
US	United States

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1. Introduction

The main focus of the master thesis is to understand how industrial companies can apply control mechanisms on algorithms in order to leverage a competitive advantage in industry 4.0. This chapter consists of different sections that outlines the background of the thesis, its problem, purpose and research questions. Furthermore, it explains in short what limitations the thesis has and it will end up with a thesis outline.

1.1. Background

Digitalization has had a huge impact in the manufacturing industry and therefore, a new era has been established which is commonly referred to as industry 4.0 (European Patent Office, 2017). Industry 4.0 is something that is characterized by the increasing digitalization and interconnection of products, value chains and business models (PwC, 2016). In this future industry, machines are interconnected and are conceived as a collaborative community that can capture data and systematically process it into information with the main goal of explaining uncertainties such as when it is time for a machine to have maintenance which is also referred to as condition monitoring (Lee, Kao and Yang, 2014).

The value of industrial companies was based on the exchange of goods which was seen as manufactured output (Vargo & Lusch, 2004). This type of value was limited due to the fact that products are made out of raw material which can be seen as a finite resource (Vargo & Lusch, 2004). However, with the emergence of the internet of things, industrial companies are able to create new complementary value propositions alongside their core hardware products that can be leveraged in the industry. These new type of value propositions are focused on induction and impetus of service (Lee, Kao and Yang, 2014).

At the heart of this industrial revolution lies a specific phenomenon which is called the internet of things. It has the ability to transform products into complex systems that combine hardware sensors, data storage, microprocessors, software and connectivity in different ways (Porter and Heppelmann, 2015). These new types of complex products will serve to alter the industry in new ways. Thus, changing the nature of the competition with the emergence of new type of entrants such as software companies who can now become a part of different industries either as suppliers or competitors (Porter and Heppelmann, 2014). The interface between the suppliers and industrial companies will be reshaped as the suppliers can both be software and hardware companies due to hardware companies providing hardware while software companies can provide software for industrial companies or develop it together with them. The software companies as suppliers can leverage their knowledge in software as a strong bargaining power towards the industrial companies as their niche becomes rather wide due to the wide application of algorithms. The software companies can also be seen as competitors if the software isn't tightly coupled with the smart hardware product which means that software companies can offer their services directly towards the end customer. At the same time the added value proposition of embedded software makes the bargaining power of customers rather low as the lock in effects become greater due to industrial companies being able to create closer relationships with the end-user through data collection and the training of algorithms thus increasing the switching costs for customers (Porter and Heppelmann, 2014).

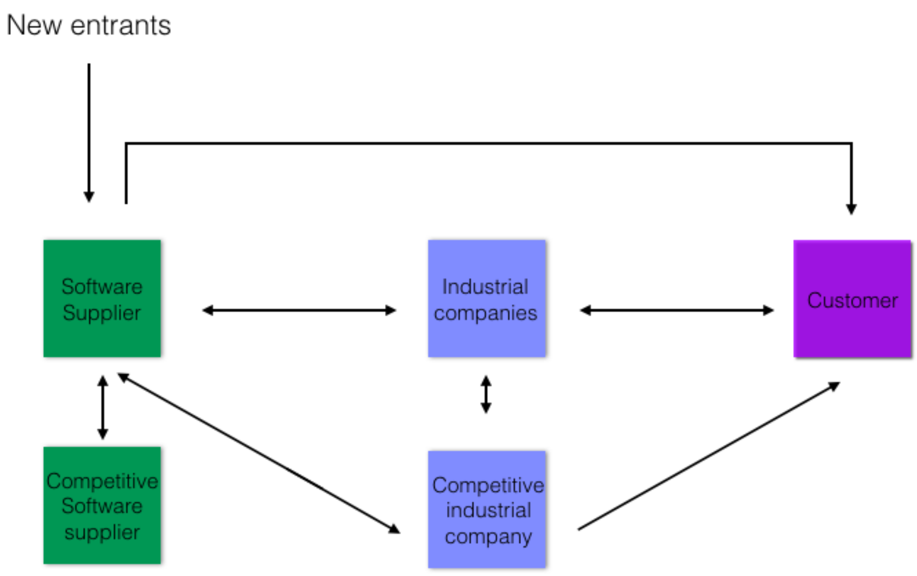

Figure 1 - Overview of industrial companies' interfaces

The true value enabler when it comes to internet of things is data analytics (European patent office, 2017). The reason for that is the fact that organizations in general want to know and need to know what is happening now, what is likely to happen next and what actions should be taken in order to get the optimal result (Levalle et al., 2011). According to a study conducted on several industrial companies by (Levalle et al., 2011) there was a mutual agreement that analytics is differentiating them from their competitors in their particular industry due to increased efficiency and a reduction of total costs.

The driving force in data analytics are algorithms as they are aggregating raw data into valuable insights and therefore there is a need to control them. A rather simple explanation of what an algorithm is, is that it can be seen as a well-defined computational procedure that takes some sort of value or values as input and produces new value out of it. It can be seen as a sequence of computational steps that transform the input into output (Cormen et al., 2001). Algorithms have been recognized as being patentable but hard to defend from being invalidated in court due to increased scrutiny based on previous court cases as well as more aggressive challenges by patent infringement defendants (Prange, 2017). There has been very little research in regard to what type of control mechanisms can be used effectively on algorithms and more so if they can be seen as a sustainable solution (Prange, 2017). As previously stated we are on the brink of a new industrial revolution where data analytics will be seen as a differentiating factor and therefore there is a need to investigate how industrial companies can build strategies around control mechanisms in order to control algorithms to keep a competitive advantage between the different interfaces in the future value chain (Levalle et al., 2011).

1.2. Prior research

An in-depth literature review has been done in order to identify previous research. The areas of interest followed a certain structure with the main goal of narrowing down the scope. First of all, a literature review was depleted in the area of industry 4.0, followed by internet of things, data analytics and finally focusing in algorithms. A focus has been of understanding all of these four different components from a business perspective. The authors have also found information about applying control on software, however in regard to algorithms the research has been very limited which called for bundling the information in order to come up with the application of control mechanisms on algorithms. Lastly, the authors read literature about competitive advantage in the industrial sector in order to understand what gives an industrial company a competitive edge.

1.2. Problem

Digitization is something that has been affecting a handful of industries and turning them into industry 4.0 (European patent office, 2017). It helps to create new value propositions for industrial companies as it gives them the opportunity to turn their mechanical products into smart software products through embedded software (Porter & Heppelmann, 2015). This means that they are not only focusing on manufacturing technique innovations anymore but have also started to move into and focus on induction and impetus of service (Lee, Kao and Yang, 2014). In the end what will differentiate one industrial company from another will be the capability of delivering highly qualitative data analytics as a service alongside their product offerings for their customers (Levalle et al., 2011). The problem arises because there is an uncertainty when it comes to the future application of control on software assets primarily algorithms in order to maintain a competitive advantage in the future industry 4.0 (Prange, 2017). So far, the authors have found very limited information about how one can practically implement control mechanisms in relation to algorithms in data analytics which calls for an explorative analysis.

1.3. Purpose

The purpose of the study is to explore how industrial companies and software companies are applying control mechanisms on their algorithms. In addition to provide recommendations on how industrial companies in the manufacturing industry 4.0 can apply control mechanisms in relation to algorithms in order to leverage their competitive advantage in the future value chain.

1.5. Research questions

MRQ: How can industrial companies in the manufacturing industry use control mechanisms on algorithms in order to leverage their competitive advantage in industry 4.0?

The main research question has been divided into two sub research questions in order to identify the applicability of the different types of control mechanisms on algorithms in theory and practice but also to investigate what trends one is seeing in algorithms when it comes to control at other companies.

RQ1: What type of control mechanisms are applicable on algorithms and how do they work in practice?

This research question will provide an understanding of what type of control mechanisms that are applicable on algorithms from a theoretical and practical point of view. In order to answer the research question the authors will have a literature review as well as interviews with IP professionals. The results obtained from this research question will help to answer research question two.

RQ2: What type of trends can be seen in the application of control mechanisms on algorithms?

This research question will provide an understanding of how software and industrial companies are applying control mechanisms in practice when it comes to algorithms. In order to answer this research question the authors will have interviews with software managers from both industrial and software companies in order to understand how companies are applying control mechanisms on algorithms.

1.6. Delimitations

The scope of the thesis will be focused on algorithms in regard to data analytics in industry 4.0. After conducting a thorough prior research, the authors noticed that there was a lack of research in the control of algorithms in data analytics. Therefore, hardware and networking related issues have been excluded. Due to time constraints, the study has been limited to a certain number of interviews with experts in intellectual property referred to as “IP professionals” as well as “software managers” which are experts in software architecture and development together with an in-depth literature review. Due to the business nature of the thesis, the authors have decided to have a general overview on the literature review when applying different control mechanisms with a particular focus in jurisdictions such as US, EU and Sweden.

1.7. Thesis outline

Chapter 1, *Introduction*, which outlines a background, some prior research done in the area, a problem definition. Moreover, it defines what the purpose is, research questions and delimitations.

Chapter 2, *Industry 4.0*, which will define and outline of the phenomena of the study.

Chapter 3, *Methodology*, describes the research strategy chosen, the research design chosen and handles the quality of the research.

Chapter 4, *Theoretical foundation*, describes the main theories and concepts guiding the research.

Chapter 5, *Research findings,* comprises the empirical data of the study which is presented and summarized. The empirical data includes interviews with IP professionals as well as interviews with software managers in order to obtain empirical data for research question one and research question two.

Chapter 6, *Analysis and discussion*, involves an analysis and discussion around the results of the thesis.

Chapter 7, *Conclusion*, gives an explanation of where the different research questions are answered and compiles the most important results of the study.

Chapter 8, *Further research*, gives an explanation for further research that should be done in this area.

2. Industry 4.0

This chapter introduces the fourth industrial revolution by going through the different revolutions that has led up to the fourth revolution, the intersection of two technologies that makes up for the new revolution and the new business models that are created in this new industry.

2.1. The four revolutions of the industry

The word "industrial revolution" can according to (Schwab, 2015) be defined as a group of technological inventions that will fundamentally alter the way we live, work and relate to one another. Up to this date, the world has gone through four industrial revolutions that have helped society develop, become more effective in leveraging its resources and thus initiate economic growth.

The first industrial revolution started in the beginning of the 1760s where society discovered that if you heat up water it will turn into steam and thus steam power was created which helped society move from an agrarian life based on farming into urbanization. The world started to rely on steam power in order to power everything from agriculture to manufacturing as well as helping people go from point A to point B with the help of railroads and steamships (Deane, 1965).

In the beginning of the 19th century *the second industrial revolution* came to be. It was characterized by division of labor in the assembly line where workers became specialized in their specific area in order to enable mass production as well as the discovery of electricity (Kanji, 1990).

What laid the basis for *the third industrial revolution* were the inventions that laid the ground for the capabilities of digitalization. Some of these inventions were mainframe computing, semiconductors, personal computing and the internet. These inventions made it possible to move from analog electronic devices to digital technology and devices thus disrupting global communications and energy (Salesforce, 2018).

Through the recent development in cyber-physical systems which can be seen as the next step of computing and the internet of things we find ourselves at *the fourth industrial revolution* which entails connected appliances, machines, things, factories and industrial environments to the internet (Bloem et al., 2014).

2.2. The intersection of OT and IT

At the core of the fourth industrial revolution lies the fusion between traditional operational technology (OT) that focuses on machines with the purpose of making different industries go around through engines rotating as well as transporting objects. On the other hand, there is information technology (IT) which has the purpose of supporting different business processes by combining different devices with each other thus providing different types of information through the internet (Bloem et al., 2014).

These two different areas have for a long time been held apart as operational technology can be seen as rather industry specific based on hardware as well as software that is used to monitor different processes (Atos, 2012). Here, one needs to have specific knowledge about the different technologies while information technology is not bound to specific industries as it handles the general information flows and connectivity which is something that has been of growing importance for several industries in this new age (Atos, 2012).

However, the information that is created by the different operational technologies in the different industries is seen as crucial as it serves as a basis for better decision making in order to increase efficiency as well as reduce a total cost expenditure in the manufacturing industry (Bloem et al., 2014). In order to gather the information from several operational technologies, information technology is necessary which means that a collaboration between the two technologies will generate create benefits for an industrial company.

2.3. New business models in the fourth industrial revolution

Due to the emergence of embedded software in products which are evolving the manufacturing industry, new business models are being created. Industrial companies are not only looking to improve the manufacturing technique anymore, but they are moving towards a focus on service as well (Lee, Kao and Yang, 2014). The specific term is called servitization and it emphasizes a stronger customer focus where combining products with services, support and knowledge are the most important elements for a competitive advantage in the future industry (Vandermerwe & Rada, 1989). Because of the service content view that the fourth industrial revolution brings to the table the business models naturally change as well towards a more network-centric view where the focus is on creating an ecosystem based on a network across the horizontal value chain (European Commission, 2016).

In this view, new type of elements are added or updated such as the value proposition, the revenue mechanism, the target market, the value network and the competitive strategy (European Commission, 2016). With these new value networks, one can no longer just examine the major competitor in a specific domain anymore, but one must also examine the network of firms that relate to that specific competitor (Kothandaraman and Wilson, 2001). The three components that will intertwine in order to create an impact in the total value chain will be value, core capabilities and relationships. In order for value to be created for the customer the firm has to fully integrate the resources to use the core capabilities of the firm. In regard to core capabilities a firm can be lucky if it has at least three or four major core capabilities. In today's environment the core capabilities of different companies are becoming narrower and sharper (Kothandaraman and Wilson, 2001). This leads us in to the last component which is relationships. In order to create customer value in today's environment one has to gather as many core capabilities as possible which one gains through relationships with companies that have different core capabilities (Kothandaraman and Wilson, 2001).

3. Methodology

This chapter consists of three main components where the first one is research strategy (3.1) that explains how the overall research strategy for the thesis has been. The second component which is the research design (3.2) focuses on what type of design that was chosen for the study and what it means, the quality of research (3.3) is the final component and assesses that the quality of the research remains stable.

3.1. Research strategy

Looking at the overall research strategy and what it means for research (Bryman and Bell, 2015) mentions that it helps to explain and tighten the link between theory and research and stresses that this is by no means a straightforward matter. The study has been conducted from an abductive approach which means that one starts with a puzzle through an observation which cannot be fully explained with current theories. This means that the authors will try to find the best explanation for the puzzle (Bryman and Bell, 2015). The reason for that is because the market in terms of algorithms is seen as rather new for the manufacturing industry compared to the software industry as they are slowly moving into new territory in which they will add on value propositions based on software which means that not much has been written in regard to control of algorithms in software in the industrial sector.

Epistemological considerations are important for the study due to it concerning the question of what is or should be regarded as acceptable knowledge in a certain discipline (Bryman and Bell, 2015). In short words it asks the question *"How can we justify that this is acceptable knowledge?".* It has the focus on the difference between the art of positivism which means that true knowledge is primarily founded on input from the senses and constructionism which means that true knowledge does not come from the senses but instead comes from the reasoning of the human mind.

Ontological considerations are also something that are important and according to (Bryman and Bell, 2015) it questions whether the social world can be viewed as something external that can exist without social actors which is a positivist approach or if it simply can't exist without social actors which can be seen as a constructionist approach. In other words, it asks the question of "*whether a phenomena or object can exist without the human mind being there to think of it".*

From an epistemological point of view the study can be seen from a constructionist point of view due to it being mainly qualitative interviews and the questions are formed in a way that the interviewees are answering the questions based on personal experiences as well as best practices which is then translated into an industrial perspective.

The study at hand is looking into how one can implement different control mechanisms on algorithms. Looking at it from an ontological perspective the study can be seen from a constructionist approach because first and foremost the object that the study is focusing on are algorithms which cannot exist by themselves without social actors being involved. Secondly, the frameworks that are being used in order to understand how to control algorithms and what it means have also been constructed by social actors which further emphasizes the constructionist approach.

3.2. Research design

When talking about the design of the study that is made for the host company it is based on a cross-sectional design. According to (Bryman & Bell, 2015) a cross-sectional design is defined as *"The collection of data on more than one case and at a single point in time in order to collect a body of qualitative or quantitative data which are then examined to detect patterns of association"*.

Going back to the study at hand it focuses on how industrial companies in the manufacturing industry should implement control mechanisms on algorithms to leverage their competitive advantage in industry 4.0. The goal of the study is to understand what control mechanisms are applicable on algorithms from a theoretical point of view and how well they work in practice. In addition, the authors want to understand how companies that are working with algorithms are dealing with the issue of managing and controlling algorithms in order to understand where the trend is heading to later provide recommendations for industrial companies in the manufacturing industry.

The journey of this study has been divided into four parts where the first one is focusing on how the authors identified the theory and what type of data had to be collected. The second part focuses on the empirical approach and describes how the authors conducted the study and what techniques were used. The third part is focusing on the data samples where the different groups who were targeted by the study are explained. The last part, which is the data analysis, goes through how the data was compared and why it was compared in the way it was.

3.2.1. Identifying the theory and required data

During the phase of identifying the theory as well as what data would be required there was a question of iteration and brainstorming due to the abductive nature of the research strategy on the basis that the control perspective on algorithms was fairly new in an industrial setting. One of the most critical parts of carrying out a research project is reviewing the literature in the chosen subject area because it provides the basis that one can use in order to justify the research questions and thus being able to build a research design (Bryman & Bell, 2015). The authors have had a supervisor both from the institution that the thesis is being written at as well as the host company that the current project is being held at. By having both supervisors from academia and the host company, the authors got help from academia which was good because the supervisor who is handed to a specific group is usually someone who is well versed in the research process (Bryman & Bell, 2015) while the supervisor from the host company helped the authors to identify the important aspects of the industry. Due to the first sub-question being "*What control mechanisms are applicable on algorithms and how do they work in practice?"* and the second sub-question being *"What type of trends can be seen in controlling algorithms?"* the authors needed to identify relevant theory in several fields such as information technology, law and industry in order to first explain how algorithms bring value to the industry as well as explain how to control them.

3.2.1.1. Internal meetings

The authors had regular internal meetings that were both formal and informal with employees and managers at the host company in order to understand the value proposition of the host company but also to understand the overall value chain in the manufacturing industry. The meetings also served as a way of defining the technological components and gathered as much information as possible in regard to them, but they also helped the authors to investigate internal documents in order to gain knowledge in the area as well as understanding their pain points of the industry in which the authors could later build upon.

3.2.1.2. Identifying literature

In order to identify literature and frameworks for the study the authors used the information about the technology gathered from the host company as well as information obtained during the education, through the authors' own research and from the supervisor at the institution. Three general parts were identified where the first part was the technological concepts behind the industry 4.0 in which the authors pictured a funnel where the authors started wide and went down to the core of what brings value in a service-based internet of things solution for industrial manufacturing companies. The first subject introduced was about the industry 4.0 and what it means for the future of the industry in regard to the change in business models. The second subject focused on Internet of Things by looking at its components, the opportunities and challenges it brings. The third subject is focused on one of the technologies that bring value in an internet of things solution which is data analytics. The last part of the funnel are the algorithms which is the fuel for data analytics in order for it to bring value in an industrial context. The second part was in regard to how to control the algorithms which was found through court cases, regulations and articles which focused on different control mechanisms, categorization of knowledge assets as well as knowledge transfer and the role of knowledge due to the very nature of algorithms. Lastly, in order to understand what defines a competitive advantage in the industrial sector the authors also defined Porter's five forces model.

3.2.2. The empirical approach

When identifying the practice, the authors used interviews in order to gather the required empirical data. The reason for this was due to the exploratory nature of the phenomena which called for combining different fields in order to answer the main research question. The empirical approach focused on two different interview subjects where the first type was "IP professionals" who had knowledge around how control mechanisms worked in a practical sense in regard to algorithms. The second type of interview focused on software managers at software companies and industrial companies as the authors' most important criteria was that the companies were developing algorithms in-house. The software managers were interviewed in order to help answer the second research question on where the trends are currently at in terms of controlling and managing algorithms inside software and industrial companies due to them having a more technical approach as well as more hands-on knowledge around algorithms than IP professionals.

3.2.2.1. Interviews

Frameworks that were used for the basis of the interviews can be divided into two different ones: the three-arena model and the intellectual building blocks. For the IP professionals, the interview template was based on the two frameworks which was the three-arena model created by (Petrusson, 2015) in order to understand how IPRs on algorithms would handle the different arenas as well as the framework for intellectual building blocks in order to capture the different control mechanisms. For the template for the software managers, the controlling innovations framework by (Petrusson, 2015) was used once again but from a more technological perspective due to the limited knowledge from the software managers about IP. In addition, the authors used theory about knowledge transfer which is being made through implicit and explicit knowledge in organizations in order to grasp the situation between developers and managers as well as gaining deeper knowledge in specific control mechanisms such as secrecy and technological control.

The authors decided to conduct the qualitative interviews in a semi-structured manner due to the explorative approach of the study and the limited research in the field. Through the semi-structured interviews, the authors could focus on a rather specific topic but at the same time leave room for the interviewees to develop their replies (Bryman & Bell, 2015). When constructing the interview templates, the authors had high emphasis on balancing the standardization and structure of the questions in order to keep the interviewees to the subject at hand but at the same time give them leeway (Patel & Davidsson, 2011). In regard to standardization one considers how much responsibility should be left to the interviewer in leading the interview and in regard to structure one has to consider to what extent the interviewee is free to interpret the questions based on their previous experiences (Patel & Davidsson, 2011). Something that was regarded as very important for the authors was the integrity and confidentiality of the interviewees which meant that all the interviewees were asked if the authors were eligible to record them as well as if they would remain anonymous in order for them to be able to answer as freely as possible (Patel & Davidsson, 2011).

3.2.3. Data sample

The interviewees were divided into two different groups where group one as previously described consisted of IP Professionals and the second group consisted of software managers at different companies that worked with algorithms in-house. Interviews took place with both of the groups during the same time period as well as during the same amount of time, 30 minutes to an hour face-to-face interview.

Overall there were 18 individuals that were interviewed where half of the interviewees were from group one and the other half of them from group two. The number of individuals interviewed were 9 individuals per group based on the reasoning that the time for this part of the research was rather limited. According to (Bryman & Bell, 2015) the part of interviewing, doing the transcription as well as analyzing the transcripts are very time consuming. These two groups served the purpose of bridging the gap between an understanding of how control mechanisms worked in practice in algorithms as well as an understanding of the trends around knowledge transfer and what control mechanisms were used on algorithms. Another purpose that the groups fulfilled was the fact of being able to answer the second part of research question one with the help of insights from IP professionals and being able to answer research question two with the help of software managers. The IP professionals ranged from individuals who were working at senior positions at companies in regard to technology and software to individuals who were working at IP consultancy firms (see appendix 10.2 & 10.3). One mutual factor was that both types of IP professionals had a vast knowledge in dealing with software in regard to intellectual property.

Looking at the second group interviewed the software managers were managers in both industrial companies that were working with embedded software as well as managers in pure software companies who were working with digital products in order to understand if there were any differences and remove any type of bias. Two important criteria were established for the software managers to make the quality of the study higher. The first criterion was that the companies that the software managers worked at had to develop their algorithms in-house as IT consultancy companies tend to develop algorithms for others which do not give them the same incentive of having control of the algorithms. The second criterion was that the companies had to be mid-sized to large-sized companies as the authors had the hypothesis that companies of that specific caliber had stronger management techniques of algorithms in place than a small sized company.

3.2.4. Data analysis

In order to analyze the data gathered from the qualitative interviews from the two interview groups the authors used thematic analysis which is seen as one of the most common strategies when it comes to analyzing qualitative data (Bryman & Bell, 2015). Themes were defined based on the frameworks as well as the literature around knowledge transfer that had been used in order to set the scene and to not get lost in the data collected.

The analysis was done separately by the two authors in order to not let personal emotions and values get in the way. When the separate analysis had been made, the authors met and discussed their individual results and created a summary for each of the different interview groups in order to get rid of unnecessary data that did not fit into the research purpose. According to Bryman & Bell (2015) one of the biggest difficulties with qualitative interviews is the fact that it can in a very fast pace generate a large amount of data due to its reliance on prose. It can easily be described as an attractive nuisance due to the attractiveness of its richness but there is a difficulty in finding a good analytical path through the richness.

3.3. Quality of research

During a business research the quality is of utmost importance. In quantitative research the most important criteria to look at is the reliability as well as the validity. However, due to qualitative research not being measurable in the same way that quantitative research is, both the reliability and the validity definitions become a little vague (Bryman & Bell, 2015). According to the definition of validity and reliability, there are absolute truths in the social world but according to (Guba & Lincoln, 1994) the social world can exist of more than one possible truth. Therefore, this study will use the framework of credibility, transferability, dependability and confirmability in order to assess the quality of the research.

From a *credibility* point of view (Bryman & Bell, 2015) are talking about whether a result can be seen as believable or not. In order to verify that the results from the explorative study were believable, the authors used the method of triangulation which entails that one has more than one method or source of data when studying and explaining a social phenomenon (Bryman & Bell, 2015). In the case of this particular study, in order to verify the data gathered for answering the first research question, the authors used both literature studies such as court cases and regulations together with interviews with IP professionals. In order to verify the data of the second research question the authors had internal meetings with the IT department at the host company as well as interviews with software managers that were working both in embedded software as well as with digital software.

Transferability is a way of checking whether or not the findings that one does in the research hold up in some other context or even the same context at some other time (Bryman & Bell, 2015). The object that is being investigated are algorithms and how to control them in regard to an industrial setting. Here, the authors noticed that there was a difference in how software and industrial companies were distributing and controlling their algorithms which means that the result is transferable to a certain extent to other domains. Due to the explorative approach of the study there is a possibility that the context will look different at a later stage as industrial companies are starting to adopt the same kind of strategies in controlling algorithms as software companies are doing.

In regard to *dependability* one is looking at the trustworthiness of the research (Bryman & Bell, 2015). To ensure that the study remains reliable and trustworthy, the authors have taken measures to protect but also keep both all the theories, court cases, transcriptions and recordings on an encrypted space that is easily accessible with a key. However, due to the confidentiality of the interviews they will not be replicable as the likelihood of the same individuals being interviewed in the same type of study is low.

Finally, *confirmability* is a criterion that recognizes that complete objectivity never can occur in a business research but still encompasses that it is important for researchers to show that they haven't let personal values gotten in the way to sway the conduct of the research and therefore the findings (Bryman & Bell, 2015). In order to live up to this criterion, the authors made sure to create open questions for both groups that were interviewed in order for the interviewees to give as open answers as possible. At the same time the authors also decided it was important for both of them to be at every interview, so the situation didn't become colored based on their respective backgrounds. When doing the analysis of the data that was gathered the authors did this separately at first and after that they met in order to reduce the objectivity as much as possible.

4. Theoretical Foundation

In this chapter, the theoretical concepts that are used to analyze and discuss the research findings are presented. The chapter is built up like a funnel where the underlying concepts that make up for industry 4.0 such as internet of things (4.1), data analytics (4.2), algorithms (4.3) are introduced. After the funnel is presented, the authors mention the theory of the knowledge economy (4.4), control of innovations (4.5) and competitive advantage (4.6) which helps to strengthen up the research in order to answer the main research questions and sub research questions.

4.1. Internet of things

4.1.1. Introduction

An important part of industry 4.0 is a technology phenomenon called internet of things which is something that have gathered a lot of traction in several industries. It has been next to impossible not to come across this term (Wortmann and Flüchter, 2015). The core concept of it all is that everyday objects can be equipped with different capabilities such as identifying, sensing, networking and processing (Whitmore, Agarwal and Da Xu, 2014). It proposes to attach technology embedded with software to everyday devices such as different type of sensors in order to gather information from the environment and therefore gain additional functionality such as being integrated to a larger network and being able to communicate with other devices (Whitmore, Agarwal and Da Xu, 2014).

4.1.2. Technology stack of the internet of things

The inventions that make up for the internet of things can be divided into core technologies which are the technologies that keeps the solution together as well as the enabling technologies which are used on top of the core technologies in order to deliver value (European patent office, 2017). In regard to the core technologies they can be defined in three different layers where the first layer is called the device layer which focuses on the specific hardware such as sensors, actuators or processors that gets added to the existing hardware components along with embedded software that manages and operates the functionality of the physical thing (Wortmann and Flüchter, 2015). The second layer is the connectivity layer which handles the communication between the device(s) and the cloud with the help of communication protocols (Wortmann and Flüchter, 2015). Lastly there is the cloud layer that serves the purpose of communicating with, provisioning and managing the connected devices through a platform that develops and executes internet of things applications (Wortmann and Flüchter, 2015).

The enabling technologies which are previously described is what helps IoT solutions bring value to the customer and differentiate one solution from the other, but they are not necessary for the solution to work. They can be divided into five parts and are located in the IoT cloud (European patent office, 2017). The first part is analytics and data management which is software that stores, processes and analyzes the data generated by the devices. There is the IoT application which is software that coordinates the interaction of people, systems and devices in a specific purpose. Process management focuses on defining, executing and monitoring process around the devices. The application platform provides developers with the tools necessary to further develop the particular IoT solution and add specific functions that ties to their needs (Porter and Heppelmann, 2015).

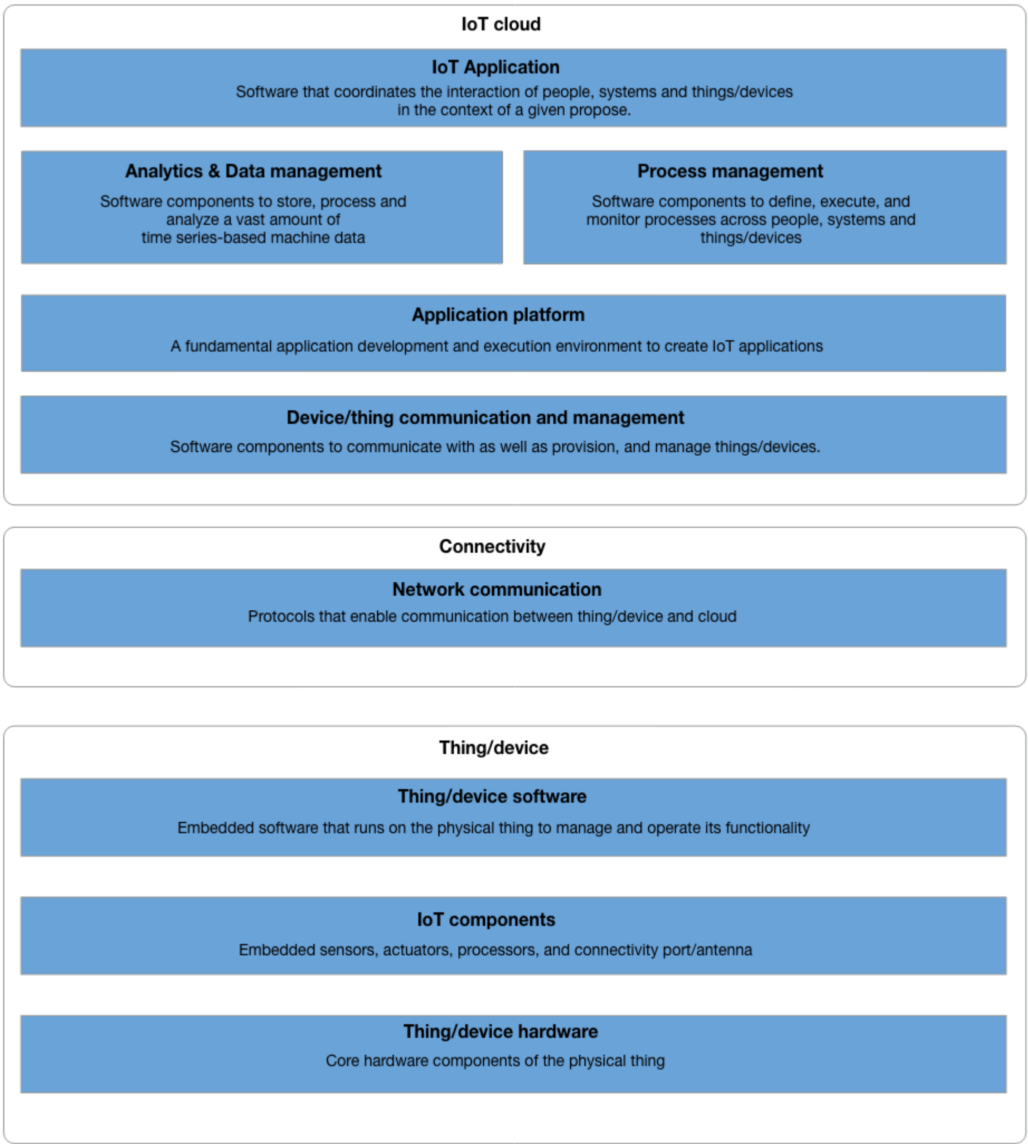

Figure 2 - IoT technology stack (Porter & Heppelmann, 2015)

4.1.3. Opportunities for industrial companies

With the help of internet of things firms will be able to create new value propositions that they have not been able to do before. It will first and foremost lead to an expansion when it comes to product differentiation as software will allow companies to customize their new smart products to fit their customers' needs which was not a possibility before when they were merely mechanical (Schmidt et al., 2015). This will serve as a way for industrial companies to provide tailor made solutions which further leads to the enhancement of differentiation and price realization (Porter & Heppelmann, 2015). Firms will be able to form stronger relationships with their customers through the capturing of their rich historical data and product usage data (Porter & Heppelmann, 2014). This data can later be used for gaining competitive advantage in the specific industry domain as it can serve as a training set for training smart algorithms in order for them to learn a certain pattern (Das, 2016). The data can also be used in order to improve the firm's own physical product when it comes to R&D (Raconteur, 2016). Due to the notion of data being there to train algorithms in order to perform pattern recognition this means that the future solutions become tailormade for a specific business need. This in time reduces the bargaining power of the buyers significantly as the switching costs then become too high (Porter & Heppelmann, 2014). It will also open up new avenues for differentiation and value-added services as well as offering superior performance, customization and customer value relative to traditional substitute products (Porter & Heppelmann, 2015).

4.1.4. Challenges for industrial companies

In terms of challenges there is a high probability of new industry entrants. As products are getting more complex by including software they also require a new type of expertise which opens doors for software companies to make a business out of it as well (Porter & Heppelmann, 2014). An example of this is the increasing need for complex algorithms in order to monitor and control different types of smart devices which is a core capability that many traditional industrial companies do not have (Spencer et al., 2004). There will also be a challenge when it comes to the standardization of software in order to reach full compatibility between the technologies in the internet of things stack (Eclipse Foundation, 2016). Due to the new opportunity of being able to turn mechanical devices into smart devices industrial companies might go overboard by adding too many functions and features thus driving up costs as well as reducing profitability (Porter & Heppelmann, 2015). Another challenge is that traditional suppliers that provided physical components will decline as software will play a bigger role than hardware due to the fact that there is a different need as the products are smartly connected. Therefore, strong new suppliers will be part of this new industry by being providers of new value that was not needed in the past such as software and analytics. A key aspect to consider here is that new suppliers can leverage the relationships with the end customer and gain access to product usage data which can provide new services to the suppliers (Porter & Heppelmann, 2015).

4.2. Big data analytics

4.2.1. A new age of analytics

One of the biggest enabling technologies when it comes to the internet of things regardless of a particular industry can be regarded as big data analytics which focuses on analyzing all of the data that is picked up from the environment by sensors and delivering some type of output (European patent office, 2017). When defining big data analytics, it can be divided into two main sub processes where the first one is data management which involves the processes and supporting technologies of acquiring and storing data that is ready to be analyzed. The second one is data analytics which refers to techniques used to analyze and acquire certain intelligence from big data (Gandomi and Haider, 2014). During the last five years, sensors have led to an unprecedented rate of data creation and therefore drives the need for data analytics in order to create value (Gandomi and Haider, 2014). Many organizations are now searching and planning for the best way to extract value from their data in order to be able to compete in their particular industry (Levalle et al., 2011).

4.2.2. The process of big data analytics

The process of extracting insights that are valuable for the company in big data analytics can be defined as five different components where the first three components are located in the data management process while the last two are located in the analytics process (Gandomi and Haider, 2014). The first one is called acquisition which is focusing on the acquisition of data through different sources such as sensors, text documents, sound or video (Cavanillas, Curry and Wahlster, 2016). In the second component which is the extraction, cleaning and annotation of the data a portion of the collected data is being chosen based on algorithms that have been created to carry out specific instructions (Gandomi and Haider, 2014). The basis of the third component is focused on the integration, aggregation and representation of data which refers to the combination of data from different sources in order to provide the user with a unified view (Lenzarini, 2002). When it comes to the analytics part it firstly consists of modelling & analysis which is focusing on the actual modelling of the infrastructure which will be used to analyze the selected and aggregated data (Buckingham Shum and Deakin Crick, 2012). Lastly, the final component of the process is called interpretation and is focused on how the organization itself is interpreting the data presented by the analytical process (Han et al., 2014).

4.2.3. The metrics of data analytics

When it comes to data analytics there is a question of what defines a competitive data analytics solution and how to characterize it. Laney (2001) developed a framework that is called the three Vs in order to explain what big data analytics is as well as it's challenges. The first one is called data velocity which refers to the speed of data processing (Deroos et al., 2011). Data variety is the second measurement in the framework and it focuses on the need to have more compatible data formats in order to create much more effective data management (Laney, 2011). Due to the recent explosion of sensors and smart devices the data in an enterprise have started to become more complex because it doesn't just include traditional relational data, but also raw semi structured and unstructured data from different sources (Deroos et al., 2011). The final characteristic of data analytics is the volume which refers to a huge volume of data because organizations record anything that they possibly can (Deroos et al., 2011).

This means that if organizations don't manage to handle the massive amount of data coming in, there is a chance of them being overwhelmed by it. However, with the right type of technology and algorithms organizations have the possibility of identifying and extracting the data that is useful for the specific area of application and leave other unnecessary data behind (Deroos et al., 2011). One could say that these three measurements present an opportunity but also an increasing challenge for organizations when they try to become as competitive as possible in their respective markets. Depending on how well the algorithms are constructed they can help with speeding up the data processing which is the velocity, they can help transform data from different sources into compatible and understandable formats which is the variety and lastly, they can find the value in large data volumes which is the volume.

4.3. Algorithms

4.3.1. The idea of algorithms

Looking at what an algorithm represents it can be seen as a procedure that takes some type of value or set of values as input. The procedure then uses the input in order to create new value in terms of an output (Cormen et al., 2001). An algorithm usually helps to solve a well-specified computational problem. At the same time the statement of the problem specifies a certain relationship between the input and the output which is the specific computational procedure for achieving that input/output relationship (Cormen et al., 2011). In order to be able to define what counts as a "correct algorithm" the algorithm has to for every input instance produce a correct output. We can then say that it solves the given computational problem (Cormen et al., 2001). As an algorithm is only seen as an instruction it means that in order for an algorithm to be useful it has to be implemented into a certain context. This context is source code which is written in a specific programming language which translates the algorithms into source code. In order for the computer to understand and execute the algorithms into action, the source code gets translated into machine code through a program called a compiler. Together, these three different components make up for the software.

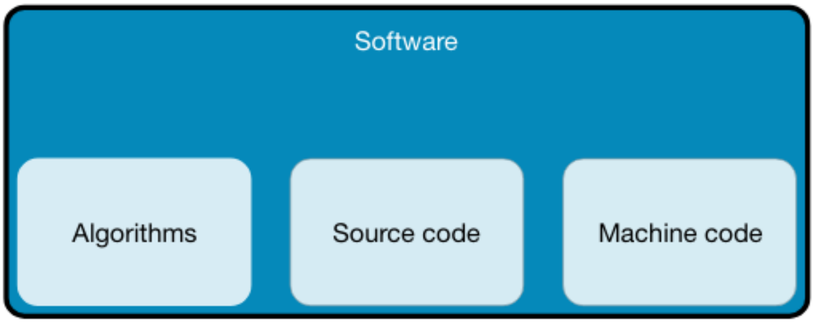

Figure 3 - Execution of an algorithm

4.3.2. Algorithms in machine learning

It has been previously stated that an algorithm can be characterized as a procedure that takes one or several input values and use these values to create new value in terms of output (Das, 2016). However, one can also train algorithms to learn from their mistakes which is commonly referred to as "machine learning" (Das, 2016). Through the help of machine learning algorithms become better in terms of accuracy and speed which in business terms translates to more accurate and efficient analytics on data. In machine learning one often talks about two separate ways of learning where the first one is called supervised learning and the second one is called unsupervised learning (Michalski, Carbonell and Mitchell, 2013). In supervised learning a system produces outputs which in the case of big data analytics can be viewed as decisions. The input is regarded as historical labeled data based on the specific application area and the system then "learns" the relationship between the input and the output based on machine learning techniques that are made up out of algorithms (Das, 2016).

On the other hand, in unsupervised learning one is reorganizing and enhancing the inputs in order to place a certain structure on unlabeled data (Michalski et al., 2013). These two types of learnings are just two different approaches when it comes to machine learning but what is seen as important value when creating a mathematical model when training the algorithms that make up for these two types of learning are the data sets used for the appropriate application area (Quiñonero-Candela, 2009). The reason for this is because in the real world the conditions in which we use the algorithms we train will differ from the conditions in which they were developed (Quiñonero-Candela, 2009).

4.3.3. Algorithms in open source

In the software community there is something called open source software which involves software developers at many different locations as well as organizations sharing code to develop and refine software on different kind of terms (Lerner and Tirole, 2003). From a business model perspective there is not so much written about open source but at the same time there are rather strong social norms and legal protections that have been crafted to discourage people from profiteering on the work of their peers (Chesbrough, 2006).

With algorithms there is no difference, here there are several basic open source toolkits that can be downloaded in order to use, train and build upon already existing algorithms. However, in order for them to work properly for a specific use case it involves a lot of knowledge first of all from the industry specific domain they are to be implemented in but also knowledge about how to tweak them in order to get the right result for the right customer which is where knowledge about a specific domain comes into play.

4.3.4. Algorithms in an industrial perspective

There has been a change when it comes to the domain of algorithms. Before, algorithms were used only for pure software products. However, due to growth of embedded software i.e. software that is embedded into hardware products the field of algorithms are becoming more interdisciplinary based (Das, 2016). This means that different types of knowledge such as computer science, business, economics, statistics and most of all it is important to as a company be armed with the necessary quantity of the specific domain knowledge in order to be able to ask the right questions to get the most value out of the constructed algorithms (Das, 2016). In the end, it is important to understand that the data in itself cannot bring value. Without algorithms that are created with the help of a knowledge specific domain to analyze the data it will remain unstructured and therefore hard to understand (Das, 2016).

4.4. Knowledge economy

4.4.1. Introduction to knowledge

The term of knowledge-based economy gives economic growth when technology and knowledge are identified (OECD, 1997). The knowledge-based economy means an increment of knowledge intensive jobs and a decisive factor is an economic growth of information in information sectors. In addition, intangible capital assets are becoming more valuable than tangible capital assets. These improvements in the economy are expressed as a fast expansion of job creation when accessing knowledge through training, education and transfer of information and knowledge. This new economy generated is expanded to the whole economy and not only to communication services, information and technology sectors (Foray, 2006). This means that specific economic characteristics of knowledge are created. Knowledge in itself is difficult to control due to it being like fluid which entails that it can easily leak out in multiple ways. It can become non-rival which means that the creator of knowledge does not have to produce more units for reaping the benefits which makes it infinite. Knowledge in itself is also cumulative which means that it can be built upon in order to spawn new goods and services (Foray, 2006). With the emergence of new technologies based in information and communication technology (ICT), many businesses are moving towards a knowledge-based economy. This new type of economy is based on reshaping businesses to generate financial value by utilizing intellectual property rights (IPRs). Therefore, new business models are created, and industrial companies are reshaping their businesses (Petrusson and Heiden, 2009).

In an industrial economy, generating and extracting has been done through production, distribution and sales of physical goods (Petrusson and Heiden, 2009). To create financial value to the firm, a material value chain has captured raw material, production, distribution, retailing and aftermarket services by a hierarchical structure. Material value chains can be based on vertical integration or horizontal integration. On the one hand, vertical integration happens when the firm controls several steps on the material value chain. On the other hand, horizontal integration occurs when the firm has control on one of the steps of the material value chain in relation to several products (Petrusson, 2004).

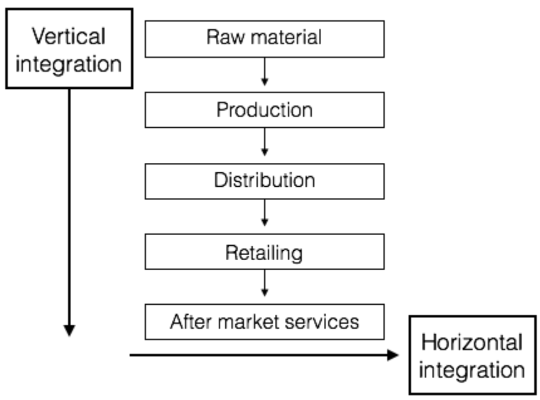

Figure 4 - The material value chain (Petrusson, 2004)

In an intellectualized economy, the value is created through the management of assets, capital and property. Assets are seen as valuable objects, property is seen as objects that can be commercially transacted and capital is seen as an object that creates financial value (Petrusson and Heiden, 2009). Therefore, an intellectual value chain is characterized for intellectual structures by the usage of intellectual building blocks based not only on offering physical products and services but also by offering virtual products and licenses. The most important aspect in an intellectual value chain is the transaction of the object that has been claimed intellectually (Petrusson, 2004). In this new economy it is crucial for a firm to be able to create structural capital based on human capital that can be transformed into different value propositions such as physical products, virtual products, license offers or services. If a firm cannot do this the risk exists that it will become a knowledge provider to other firms (Petrusson, 2004).

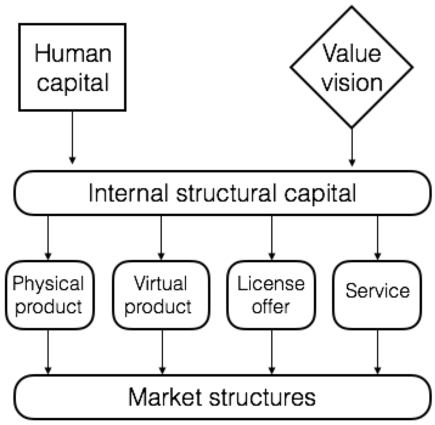

Figure 5 - Intellectual value chain (Petrusson, 2004)

4.4.2. Knowledge transfer

With the reproduction of knowledge, a problem arises in relation to technology transfer and transmission of educational and occupational skills. One type of knowledge can be tacit which refers to knowledge that is not possible to be expressed externally from the person who possess it. Therefore, this type of knowledge is difficult to transfer and reproduce. An example of this is when an employee is leaving a company due to retirement and the employee transfer his/her know-how in order to ensure that this knowledge will be transmitted to the following generations. However, due to the increment of external factors, turnover and mobility; the methods of knowledge management are affecting internal labor markets. Therefore, new ways of knowledge retention and transmission are used, and knowledge codification plays a major role here as it can be recorded and expressed in a specific language (Foray, 2006). Another type of knowledge is called explicit knowledge which is characterized by its ease to communicate and transfer (Grant, 1996).

This type of knowledge can be seen as simple instructions which is easily transferable from one person to another through the help of a document.

Knowledge is difficult to control by firms and therefore, leaks and spillovers can occur. Involuntary spillovers lead to market competition and therefore, knowledge can be used as way of creating incentives and increment performance through imitation, use and absorption of new knowledge. An example of this is when knowledge is a codified instruction, such as software, and therefore it is almost impossible to control it as practitioners and specialists are able to understand the instructions. Nonetheless, knowledge is not only based on codification, it is also based on tacit knowledge in which practical experience is required. This practical experience can give a level of control if the know-how is kept as a secret to avoid spillovers. Additionally, controlling knowledge can be done through having complementary assets that can be specific capacities to utilize this knowledge such as technological capacities (Foray, 2006).

4.4.3. Organizations and markets built on knowledge

Knowledge is also changing the way that both firms and markets are operating. Before, companies and markets were only operating on a resource-based level. Now however, they also have the opportunity to operate on a knowledge-based level. When discussing the difference between a resource-based focus of a firm and the knowledge-based focus of a firm one can see that the primary objective for a resource-based firm is to maximize the value through optimal deployment of existing resources and capabilities while developing the firm's resource base for the future (Grant, 1996). An example of these kind of resources could be regarded as manufacturing in order to be able to transfer goods to the customer in order to gain revenue (Grant, 1996). From a market perspective this meant that the main exchange medium was tangible goods in terms of products (Arora, Fosfuri & Gambardella, 2000). This meant that what gave a competitive advantage was the fact that a company had great financial capital which was gained through efficient productivity which was measured per employee in the company (Bell, 1976). A typical model that was used in this kind of thinking was for example the well-known value chain created by Michael Porter in which one focused on primary and secondary activities within the firm where both were focused towards productivity in itself and producing physical resources (Porter, 1991). The problem with this kind of thinking today is the fact that these kinds of resources that can be exemplified into raw materials are finite which means that they are not unlimited (Vargo & Lusch, 2004).

Turning to the knowledge-based focus of a firm it is also based on transferability. However, not only from an external aspect but it is also concerned with the transferability of knowledge internally. The main aim of the firm is to master the codification of knowledge in order to get a wide diffusion of knowledge through the firm (Bell, 1976). To be able to set up a wide diffusion of knowledge inside of a firm one needs proper coordination within the firm, a clear organizational structure, a spread out allocation of decision making rights, clear definition of firm's different boundaries and a good innovation structure in order to turn the knowledge into value (Grant, 1996). From a market perspective, the knowledge-based focus opens up the door for smaller actors as well because they don’t need to have substantial resources in order to make a profit because one can license their services and technology to companies that are more capable of manufacturing and commercializing the final product (Arora, Fosfuri & Gambardella, 2000). This affects the competitive advantage because companies can now solely rely on immaterial products and services that can be quite hard for competitors to imitate due to different reasons such as the fact that this kind of market is relying very strongly in the knowledge that resides inside of human capital which can be seen as operant resource in order to produce value (Constantin & Lusch, 1994).

4.5. Controlling of innovations

4.5.1. IAM framework

When working in collaborations in a knowledge-based intensive setting, such as an IT environment which is characterized by rapid growth and change in regard to algorithms in software it is important to understand what type of assets are created both internally and in collaborations. In order to handle this type of situation, in where one has the need to define what can be claimed and how to leverage it, (Petrusson, 2015) created the IAM framework which is divided into four steps.

The first step - *concerned with how to construct a proper process for claiming the intellectual assets.*

The second step - *concerned with the process of evaluating and positioning oneself towards the outside world.*

The third step - *concerned with making decisions in regard to the efforts of utilization and how to implement them.*

The fourth step - *concerned with how to manage the defined intellectual assets, intellectual property rights as well as contracts within the organization as well as with the environment.*

Figure 6 - IAM framework (Petrusson, 2015)

4.5.1.1. Categorization of intellectual assets

When it comes to the first step of the IAM framework, related to claiming knowledge assets, it follows a process where the knowledge assets need to be identified, claimed and analyzed first. Once this process is done then it is possible to claim them as property. This process starts with "the cloud" which is based on diffuse and undefined knowledge that is later turned into a clear and manageable intellectual asset list. The following figure 7 shows an example of how it is possible to turn diffuse knowledge into knowledge assets (Petrusson, 2015).

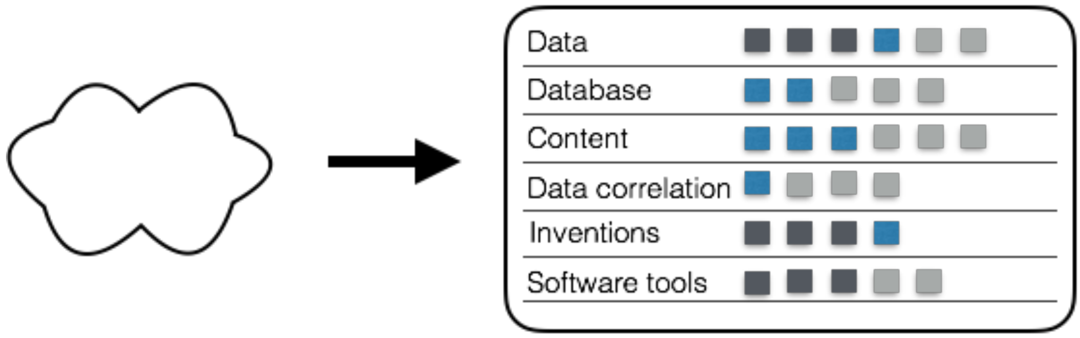

Figure 7 - Categories of knowledge assets (Petrusson, 2015)

Knowledge assets create value for society and therefore, a tool of categorizing knowledge assets have been created to capture the value of these assets. The tool captures the following knowledge assets (Petrusson, 2015):

Data - *consists of unstructured information or raw data and it can be gathered through surveys, statistical measurements and interviews. The data as a knowledge asset is possible to control as the data can be documented and collected.*

Databases - *are structured and searchable data that is organized in a systematic manner.*

Observations - *are conclusions or correlations based on empirical data collected. In order to be controlled and objectified, the observations should be concrete and clear.*

Theoretical framework - *are based on theories or models that are based on results and relationships. These types of frameworks can be utilized to create new assets an example of this is the creation of software and procedures as implementation of theory.*

Solution - *solves problems that derives from scientific research results. Technical solutions and inventions are categorized as solutions.*

Visualization - *comprises design elements such as drawings, sketches and prototypes which add value.*

Instructions - *provides advice on how certain activities need to be performed. Instructions can be carry out by people and machines such as algorithms which are implemented in software.*

Software - *is a set of systematized and automated data that executes certain activities such as being a software for implementing algorithms. This category can be divided into different subcategories where layers and code modules play an important role.*

Narrative - *is a particular story that can be materialized in interviews, studies, literature.*

Creation - *is artistic creativity connected to arts such as music, design, painting and so on.*

Algorithms as knowledge assets can be categorized as a solution, instruction and software. By applying these categories on the new assets that are created they can more easily be claimed. These knowledge assets can now be turned into intellectual property assets. It is important to understand the interplay between knowledge assets as value creation objects and intellectual property assets as legal objects. Examples of these intellectual property assets can be inventions, designs, trademark, trade secret and artistic and literary work (Petrusson, 2015).

4.5.2. Intellectual building blocks

Intellectual building blocks also referred to as intellectual building bricks are intellectual constructions that can be used as value propositions, as personification of innovation and identity in order to get financial value. The means of property claims as structural building blocks are: technical control, market power, secrecy, right based property and contracts-based property (Petrusson, 2004).

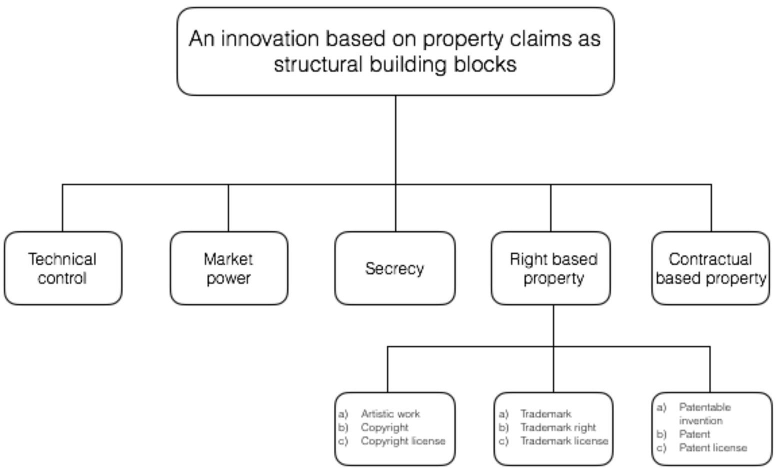

Figure 8 - Intellectual building blocks (Petrusson, 2004)

4.5.2.1. Rights based property

Intellectual property rights are the rights given to the creator or inventor of an intellectual property asset. The intellectual property rights are patents, copyright, trademarks and design rights (WTO, 2018). In an intellectualized economy, the core of the businesses is based on assets, capital and property. Therefore, businesses are utilizing intellectual property rights (IPRs) to control the innovations and extract financial value. (Petrusson and Heiden, 2009).

Patents

A patent is a document that describes an invention that is issued by a government office after filing an application and it gives an exclusive right to the inventor to use the invention for a limited amount of time, normally 20 years. When an individual has obtained a patent, it grants the individual with the right to exclude others from making, selling and distributing the invention as long as the right holder pays their yearly maintenance fee (WIPO, 2004). In addition, a patent may relate to a product, process (method) or use (WIPO, 2004). In order to be eligible for patent protection the invention needs to be patentable subject matter.
In general terms, patent protection is available for inventions that are related to all fields of technology. In order to be entitled for patent protection, the invention needs to fulfil three separate criteria (TRIPS, 1995):

1. Novelty (new) - *An invention has to be seen as new in relation to what was known before the filing date*
2. Industrial applicable (utility) - *The invention must be able to be susceptible of industrial application*
3. Inventive step (non-obviousness) **-** *The invention must have a certain leap of knowledge in terms of what is known*

In numerous countries software-related inventions can be patentable subject matter if these inventions have a technical effect (TRIPS, 1995). The software-related invention can reside as an algorithm (WIPO.int). When drafting a patent application in relation to computer software that contains specialized algorithms, its claims normally comprises apparatus and method claims which in itself is tied to a technical solution (WIPO, 2007). Moreover, the description of the patent application related to an invention in the field of computer could be potentially accompanied by flow diagrams to be understood by a person skilled in the art (PCT, 2018).

In US, algorithms are mathematical concepts and therefore, they are considered as abstract ideas by the courts which are a judicial exception for the protection for software-related inventions (USPTO, 2012). Currently, the US patent system has strengthened up after the Alice Corp v CLS Bank Itnl decision in relation to algorithms (USPTO, 2012). Before, the Alice decision, two Supreme Court cases (Bilski v. Kappos and Diamond v. Diehr) were declared invalid due to its subject matter being considered abstract. In the Alice case, there was a company called Alice Corporation that owned four patents related to computer programs and electronic methods for financial trading. They noted that a company called CLS was using similar technology. Therefore, Alice decided to accuse CLS for patent infringement. Nonetheless, CLS filed a suit against Alice stating that the claims were invalid. In 2014, the US Supreme Court declared the patents of the Alice corporation invalid due to the fact that the claims were related to an abstract idea and in order to be considered as a patent eligible subject matter, the claims implemented in the computer needed to ensure that amounted significantly more than the actual abstract idea. At the moment, the Patent Trial and Appeal Board (PTAB) in US is invalidating software patents that have been granted in the past after Alice decision because as the claims of these patents do not comprise significantly more that the abstract idea as an exception (USPTO, 2012). After the Alice case, the Patent and Trademark Office (PTO) established some guidelines for applicants in order to apply for a patent in relation to a computer related invention (See appendix 11.1.1).

In Europe, a computer-implemented invention refers to the ambiguous term of software. The board of Appeal of European Patent Office (EPO) stated that a computer algorithm can be seen as a purely mathematical exercise or as a procedure that explains how a machine is executing some tasks. An algorithm that defines a procedure always has a technical effect.
Therefore, in order for an algorithm to be considered for patent protection in Europe, the board stated that it needs to have a "further technical effect" in order to have a technical character (Enlarged Board of Appeal, 2010). In addition, a computer programme as such is not a patentable invention (EPC, 2016). For a patent to be granted for a computer-implemented invention, it needs to solve a technical problem. Moreover, an algorithm is defined as a "procedure or sequence of actions" that can be considered as a patentable invention when it is executed by a computer and provide a technical contribution (Directive 2009/24/EC). The EPO also provides guidance of patentability in relation to computer implemented inventions (See appendix 11.1.2).

One practical problem in relation to patentability of computer-implemented inventions is that there is no harmonized patent system in Europe. Nonetheless, Europe is striving for having a Unified Patent Court (UPC) that is supposed to come into force this year in which European patents will have a unitary effect. However, this court will not have any jurisdiction in relation to national patents. The national patents will be enforced through the patent office of each EU member state (UPC, 2018). In comparison, US has only one patent system that is applied by the Patent and Trademark Office (PTO) and US courts.

In Sweden, a merely program for a computer is not an invention (Swedish Patent Act, 1967). The Swedish Patent and Registration Office (PRV), mentions that a computer program can have different meanings and one of them is to be considered as a "method for solving a mathematical or logical problem, an algorithm". An algorithm can be patentable if it is used in a technical context and has a technical solution (PRV, 2018).

Copyright

Copyright protects the rights of the creators when it comes to the expression of ideas but not the ideas as such. In addition, copyright relates to literary and artistic creations and gives the owner exclusive property rights which prevents unauthorized use. There is no need for registration in order to obtain copyright protection, when the work is created it is automatically protected. The duration of copyright protection depends on national law, but it cannot be less than 50 years after the author's death. Moreover, copyright protects two types of rights; moral rights which protect and conserve authors' and creators' connection with the work and economic rights that permit the authors and creators to obtain financial reward by others for using their work. Authors can transfer their economical rights to third parties and in return receive some payment. One can transfer the economic rights in two ways: either by assignment in which the copyright property rights are transferred and the person assigned becomes the right holder or by having a license as in some countries assignment is not allowed. By licensing copyright, the owner will still have ownership but will authorize a third party to execute some activities for a period of time (WIPO, 2016).

Copyright does not protect methods, mathematical concepts or procedures and therefore it does not protect an algorithm per se. Nonetheless, copyright protects computer programs as literary work in any mode of expression (WCT, 1996). Computer programs, either in source or object code, are protected as literary works under the Berne Convention (TRIPS, 1995). In Europe, the legal protection of a computer program states that only the expression of a computer program is protected, and the ideas and principles are not protected by copyright. According to this principle, algorithms per se comprises ideas and therefore they are not protected under the European Directive (Directive 2009/24/EC). However, the copyright holder can prevent an unauthorized person from copying the code that implements an algorithm. In addition, copyright might not prevent the protection of others that implements the algorithm by using different code (Digital Single Market, 2016).

In Sweden, computer programs are protected by copyright. Moreover, the copyright that is created by an employee related to a computer program as his working tasks or by following instructions by the employer is considering to be transferred to the employer. Otherwise, it will depend on what the parties agreed on in the contract (Act on Copyright in Literary and Artistic Work, 1960).

Open source software is software that it is made available to users and it is free due to the fact that it gives to the user freedoms. Open source software is protected through copyright and the user is subject to an open source license in which the person is able to copy, modify and redistribute the code under certain conditions. The most common open source licenses are General Public License (GPL) and Berkeley Software Distribution (BSD) license (WIPO, 2018).

Trademarks

A trademark is a sign that characterizes the goods of a company to differentiate from competitors. There are different types and categories of signs such as: word marks, device marks, colored marks, audible marks, etc. The general criterion of protection is that the function of the trademark needs to be distinguished from other products or services and therefore it needs to be distinctive. The other requirement is the potential harmful effects when the trademark is misleading and infringes the public authority or morality. A trademark can be protected by use or by registration and the protection can be unlimited in time if the renewal fees are paid to the administration offices (WIPO, 2004).

Algorithms cannot be protected through trademarks directly. Nonetheless, it is possible to obtain trademark protection for software or computer programs that contain the algorithms. The international trademark classification states that all computer programs and software can be trademark protected (WIPO.int, 2018). Therefore, a trademark can protect the name of a company that develops algorithms or a product name where the algorithms form part of it. By having a trademark, the owner gets an exclusive right and by this it can prevent competitors from using it (WIPO, 2004).

Design rights

Design rights protects the appearance and non-functional features of a product. To be granted a design protection, it needs to be novel which is sometimes referred to as original (WIPO, 2004). The Council Regulation on Community designs protects the design rights if the product fulfil the criteria of novelty and individual character. Designs can have registered or unregistered protection through the Community designs (WIPO, 2012). In relation to computer programs, in Europe, design rights are protected when the program includes preparatory design work (Directive 2009/24/EC).

4.5.2.2. Secrecy

The first international agreement that protected trade secrets was the TRIPS Agreement in which the protection for undisclosed information was established. Trade secrets have a dual nature, they are confidential as they remain non-public and only known by a restricted number of people. In addition, they are commercial as they are shared with a limited number of people to have a practical value. The requirements for trade secrets are secrecy, commercial value and reasonable efforts to maintain them secret (OECD, 2015). Trade secrets give a strong competitive advantage in the marketplace by keeping information confidential and in most countries, a third party is prohibited by law to use or copy confidential or secret information in the absence of the owner's consent (Sheikh, 2018). In Europe, a harmonized Trade Secret Directive will take place in 2018 which will improve trade secret protection (Directive 2016/943).

To keep the confidentiality of a trade secret, employees in a company should sign non-disclosure agreements and non-compete clauses on their employment agreements. However, this is not enough to prevent the disclosure of confidential information once the employees have left the company. Promoting employee loyalty is a key element to protect trade secrets as a business strategy. In addition, once the employment is terminated, an exit interview is indispensable in which the employer will mention the obligations to maintain confidentiality after the employment and the consequences of breaching the obligations (Sheikh, 2018).

A complementary way for obtaining protection of algorithms is through trade secrets. Trade secrets is an effective way of controlling algorithms, same as having patents or even more important than having a patent but this will depend on the circumstances and the type of strategy that you want to apply on your business. Normally companies tend to use trade secrets in order to hide relevant information. In this case, with algorithms, it can be seen as a way to leverage their competitive advantage. An example of this is Google search engine algorithm which is kept as a trade secret (Trade secrets: the hidden IP right, 2017). The scope of the trade secrets is unlimited compared to patents. Nonetheless, legal challenges arise in different jurisdictions as the regulation of trade secrets differ from country to country. In jurisdictions where there is no legislation about trade secrets, contractual control is a way to regulate misappropriation of trade secrets.

In US, the policy of trade secrets may include a formula, program, device, method or process and it needs to enable an economic advantage to be considered as a trade secret (Trade secrets: the hidden IP right, 2017). The Defend Trade Secrets Act (DTSA) states that source code, algorithms, data sets and programs can be considered as trade secrets. In regard to algorithms, companies should make sure that they use complementary measures in order to keep the secrets safe such as physical protection that may include security networks, having documented information and by having contractual provisions (Prange, 2017). One measure to keep algorithms as a trade secret in a safe way is through an information security management standard, known as ISO 27001, with the main characteristic of managing sensitive information from a company (ISO, 2018).

4.5.2.3. Contracts based property

A contract is a tool used in the construction of a structural order with the main goal to create and extract financial value (Petrusson, 2004). The way in which firms utilize contracts is to legitimize their relationships with different type of actors in the social world. With the help of contracts, one can set up legal obligations between two or several parties to make sure that a breach by any of the parties will result in some type of remuneration for the affected parties.

Traditionally, the legal approach used was a reactive approach meaning that when a person was encountering a legal dispute, the way to move forward was to turn to a lawyer. Nonetheless due to digitalization, new types of contracts have arisen and as of the fast IT development, contracts need to be interpreted not only by lawyers but also by engineers and managers. Currently, the legal approach used is proactive law which consists of a combination of legal thinking, skills, practices and procedures that enable the recognition of different opportunities in good time in order to take an advantage from them. Furthermore, proactive law can act as a preventive action by identifying potential problems and it is also seen as a way of generating value, risk management and build up relationships by avoiding disputes and litigation (Haapio, 2006).

Proactive law has changed the way of looking at contracts, rather than being just a simple legal tool, contracts are seen as a management tool that enable value creation and collaboration to create strategies for competitive advantage (Siedel and Haapio, 2010). A lawyer tends to take into account the different elements of a contract, regulations and contractual clauses. Nonetheless, in business practices contracts are seen as a tool to achieve a successful deal and relationship (Haapio, 2006). The figures below show a clear distinction between a lawyer's view of a contract and from a business view. Figure 9 describes the elements of a contract that should be taken into account by a lawyer, these ones are divided between visible (what is agreed) and invisible terms (what is not agreed). Figure 10 states the functions of a corporate contract from a business perspective (Haapio, 2006).

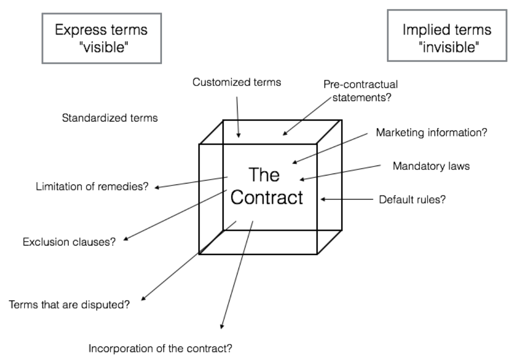

Figure 9 - Elements of contract from a lawyer's view (Siedel and Haapio, 2010).

Figure 10 - Functions of a contract from a business perspective (Siedel and Haapio, 2010).

To achieve a successful business deal, business managers and lawyers should work together in order to establish different tools to help with the contracts such as checklists, templates and processes that will be helpful for the employees in the company to use them systematically and revised contracts continuously. The challenges of the managers should be addressed when drafting a contract and to help with that one can see the contract as an analogy of a puzzle that can reflect the goals of each party. Figure 11 shows the contractual terms of the puzzle analogy. The contract in this puzzle is a combination of technical, implementation, business /financial and legal parts that needs to be coordinated together. To create a successful business deal in which all the parties are synchronized, the puzzle should be assembled together. If a firm manages to understand how the pieces fit together the firm will be able to achieve contract literacy which means that it will understand what is agreed on in a contract and therefore avoids legal gaps (Haapio, 2006).

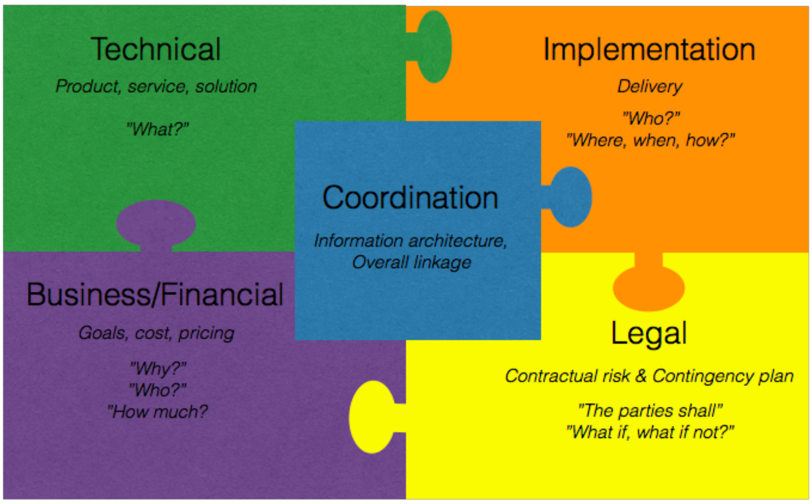

Figure 11 - Contractual terms- puzzle analogy (Siedel and Haapio, 2010).

In order to protect the algorithms through contractual means it is key to understand what is going to be the subject matter that will be licensed. Will the algorithm be regarded as an instruction, will it be regarded as software or will it be regarded as a technical solution? It is crucial that the subject matter is precisely defined. In addition, it is important to understand the nature of the IPRs before entering into a contract and this can be done through patent protection, copyright, trademarks and trade secrets (Cameron and Borenstein, 2003). If the algorithm is regarded as an instruction it can be protected as a trade secret and therefore from a contractual point of view it can be protected through non-disclosure agreements (NDAs) which keep confidential information secret to third parties (European IPR desk, 2015).

If the algorithm is implemented into software, the owner will get copyright protection and the software can be licensed to others (Bond, 2004). It will be protected through copyright which makes it eligible for software license. The three main license agreements in software relevant for the study are user license agreements in which the user of the software has a right to use the software, joint venture license agreement is done when two or more parties want to develop new technology together and the last one is open source software which is a royalty-free license based on certain terms and conditions (Bond, 2004). When the algorithm is defined as a solution it is eligible for patent protection as long as it is tied to a technical function which means that one can grant an exclusive or non-exclusive license to another party for using the same solution (Bond, 2004). Internally, a company can regulate contracts with their employees by having employment agreements that contains confidentiality clauses in which the employees cannot disclose any confidential information which can be regarded as algorithms during and after his/her employment and if the confidential information is disclosed it will comprise a breach of contract (WIPO, 2004).

4.5.2.4. Technical control

Technical control can be regarded as a way of restricting access to different assets through technological means. In an intellectualized economy, technical solutions are turned into commercial transactions through the usage of physical and virtual products (Petrusson, 2004). This can be done in a number of ways where one is to use different kind of information systems in order to try to restrict or prevent others from accessing particular content. Digital rights management (DRM) can be regarded as an example which opens up the opportunity for customers to access certain content through a digital license instead of buying the digital content (Qiong, Reihaneh and Nicholas, 2003). Another way of protecting software related components is through encryption where software asset is scrambled and the only way to access it is through a public key that is being generated based on identity (Martin, 2008). However, when the value is not only seen in the virtual products anymore but also in the components of software such as the data, databases and software a few new measures of technical control needs to be considered.

In regard to algorithms there are different ways to control them through technological measures. One example is to hide away the algorithms inside of the source code of the product and keep it proprietary for both collaborators and customers while letting them access the whole product. When developing algorithms and software code in general developers use different types of version control software which is a way of coordinating work on a software project by tracking and managing different version of the code (Loeliger, 2009). This type of software is also used to restrict access both internally where one can have different “branches” which can be seen as different versions of the code within the actual project. This means that one can have a specific version for customers as well as employees that don’t get to see the new algorithms that the team is working on.

Because of the recent advancement in program analysis and software engineering different technologies have been developed to be able to reverse-engineer software systems to discover vulnerabilities, make unauthorized modifications or stealing the intellectual property inside of the software (Cullen and Saumya, 2003). To counter this one can use something called obfuscation where one deters potential attackers by splitting up the logic of the algorithms all around the source code which makes the cost of reconstructing the high-level structure of the program prohibitively high (Cullen and Saumya, 2003).

In the world of information technology and algorithms, collaborations are seen as a very important factor. At the same time every company need to find a balance in where they still maintain a steady relationship with collaborators and customers while at the same time keeping their algorithms safe. A potential solution to this problem is by using something called an application programming interface (API) which is a way of keeping an algorithm in its own black box. Customers and collaborators that have knowledge in IT can use the API in order to send in an input that is used by the algorithms in order to calculate a desired output. During this process the actors never see what is going on in the black box, but they only see what they send in as well as what they get out.

4.5.2.5. Market power

The conceptualization of markets and firms is a relevant element for the establishment of intellectual constructions. The market is seen as a structural platform in which a property transaction is made. In addition, these property transactions gather capital from products or services. Building IPRs and proprietary control can be utilized to block competitors in the market (Petrusson, 2004). A way of establishing market control is through first mover advantages which refers to when a firm is entering a market with new offerings before anyone else. In order to get a first mover advantage, the firm has to possess some type of unique resource, foresight or simply get into the position because of luck (Lieberman and Montgomery, 1988). By having a first-mover advantage the firm manages to get strong learning effects by accumulating know-how in that company's specific market thus being able to charge premium prices (Lieberman and Montgomery, 1988). Another way of gaining market power control is by having a strong brand influence on the customers through a strong brand equity (Keller, 1993). By having a strong brand equity, the reputation of the firm increases which in turn leads to a strong installed customer base. As market power is seen as a control mechanism that is not directly tied to a specific object the same goes for the algorithms.

4.5.3. The three arena model

Intellectual property and intellectual property rights are identified as normative claims in three structural arenas: administrative arena, business arena and judicial arena. These arenas are seen as structural platforms where IP and IPRs are constructed and seen as communicative actions (Petrusson, 2004).

Firstly, the administrative arena is the platform where formal procedures occur based on regulations and policies. This arena is formed by structural persons, courts of appeal and patent offices. In addition, patent examiners and patent attorneys play a relevant role in this arena. In this arena the intellectual assets become legitimized in the eyes of other actors in the social world.

Secondly, the judicial arena is a structural platform in which judges, prosecutors and lawyers play relevant roles that ensure that if infringement happens, this can be penalized. In this arena, legislation and court cases constitute a formal procedure (Petrusson, 2004).

Thirdly, the business arena is a combination of structural platforms that of markets, innovations and firms in which patents are used as commercial transactions of property. This arena is considered to be the most important one as the main goal is creation of value to the firm.

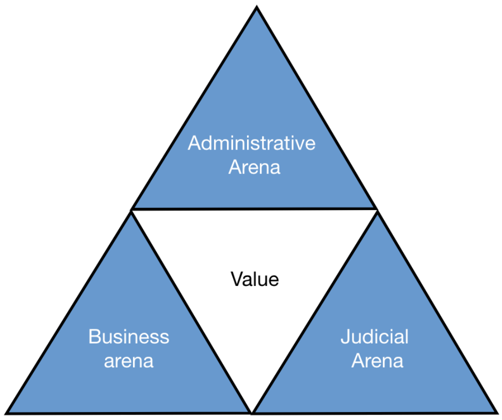

Figure 12 - Three arena model (Petrusson, 2004)

4.6. Competitive advantage in the industry

When talking about what competitive advantage means from an industrial perspective one can divide it into an internal perspective as well as an external perspective in order to understand where the competitive advantage is coming from (Heiden, 2017). From an external perspective the well-known Porter's five forces model helps to explain the position effects of the firm where the primary determinant of a sustainable competitive advantage is the firm's position within a particular industry (Heiden, 2017). From an internal perspective one is usually taking a resource-based view in order to explain a firm's capabilities as well as its resources and how they are managed and exploited for competitive advantage (Heiden, 2017).

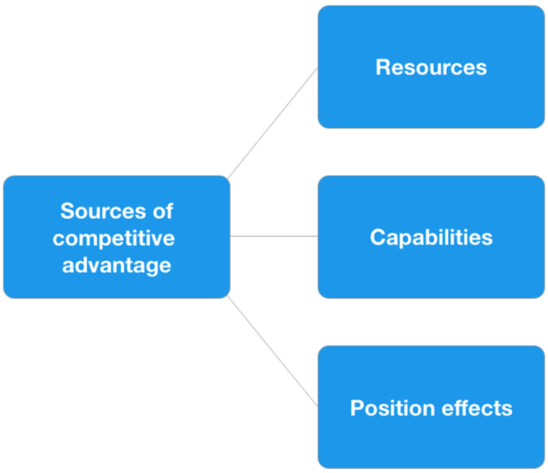

Figure 13 - Sources of competitive advantage (Heiden, 2017)

4.6.1. Competitive advantage from an external perspective

In the industrial sector, firms create value by positioning themselves towards the environment simply because the industry structure is seen as an important factor as it is influencing the rules of the game (Heiden, 2017). To understand how a firm can position itself externally, Michael Porter came up with five separate forces that a firm must manage in order to achieve business success through competitive advantage.

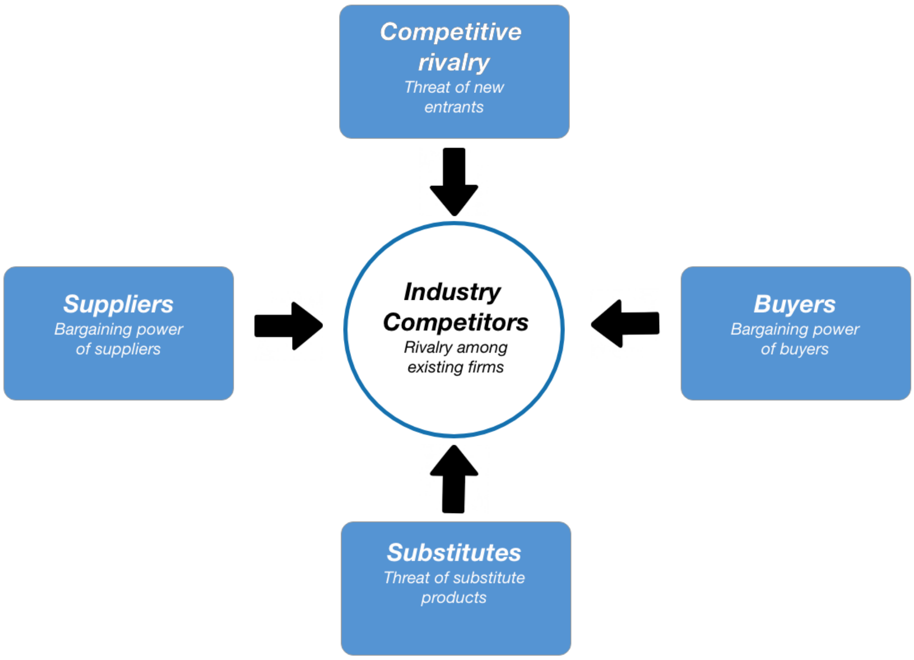

Figure 14 – Porter's five forces model (Porter, 1979)

The first force is called *threat of new entrants* and is concerned with the fact that when new entrants enter a particular industry they bring new capacity, the desire to gain market share and in some cases substantial resources (Porter, 1979). In order to counter this, a firm can set up different kind of barriers for new entrants.

The second force is called *bargaining power of suppliers* which relates to the fact that suppliers can exert bargaining power on participants in an industry by raising prices or reducing the quality of purchased goods and services thus squeezing profitability out of an industry unable to recover cost increases in its own prices (Porter, 1979). A supplier gains bargaining power if it is dominated by a few companies and is more concentrated than the industry it sells to, if it's product is unique or at least differentiated, if it is not obliged to contend with other products for sale to the industry, if it poses a credible threat of integrating forward into the industry's business and if the industry is not an important customer for the supplier group (Porter, 1979).

The third force is called *bargaining power of buyers* where buyers can force down prices, demand higher quality or more service and play competitors off each other (Porter, 1979). A customer group is powerful if it is concentrated or purchases in large volumes, if the products that the customer purchases are standardized or undifferentiated which can lead to customers switching supplier, if the products it purchases from the industry form a component of its product and represent a significant fraction of its cost, if it earns low profits which create incentives to lower its purchasing costs, if the industry's product does not save the buyer money (Porter, 1979).

The fourth and last force is called *rivalry among existing firms* where the focus is on managing the intense rivalry between similar firms that can occur by using tactics like price competition, product introduction and advertising (Porter, 1979). Some of the factors that help intensive rivalry occur is when competitors are numerous or are roughly equal in size and power, when the growth in a particular industry is slow which leads to fights about market share, when the product or service lacks differentiation or switching costs, when fixed costs are high or the product is perishable, when the capacity is normally augmented in large increments, when exit barriers are high due to specialized assets or management's loyalty to a particular business and when the rivals are diverse in strategies, origins and personalities (Porter, 1979).

4.6.2. Competitive advantage from an internal perspective

From an internal perspective, competitive advantage is gained by both having the tangible resources in terms of physical assets and financial assets as well as the capabilities which could imply value or cost advantages (Heiden, 2017). When talking about the resources, in order for them to generate any type of competitive advantage they first and foremost need to be valuable by either enabling differentiating performance or reduced costs. They also need to be rare which means that they should not be possessed by many or even by any competitors. This however, only makes the resources generate a competitive advantage.

In order for the resource to be able to generate a sustainable competitive advantage it has to be durable which means that it keeps being relevant and keep being sustained despite exploitation (Penrose, 1959). It also has to be imperfectly imitable which means that it is unobtainable or only obtainable at a higher cost or lower efficiency (Penrose, 1959). The competitive advantage as well as the sustainable competitive advantage is not enough. The resource must also enable a firm's appropriation of a competitive advantage which it does by being exploitable through an entity's organizational process.

When it comes to the capabilities of a firm they are divided into *cross-functional capabilities* which is concerned with the integration of activities from several organizational functions to realize overarching objectives, *functional capabilities* which is concerned with the integration of activities to realize he objectives of a firm's organizational functions, *activity capabilities* which is concerned with the integration of related task to perform activities in relation to a subset of a functional process, *Specialized task capabilities* which is concerned with the integration of single operations to perform specialized tasks in relation to specific processes and *single operation capabilities* which is concerned with the integration of specialized knowledge of individuals used to accomplish specialized routines.

4.7. Summary of theory

Very early on, in the research phase of the study the authors defined different theoretical components that would be crucial for the thesis. Therefore, in order to make it easier for the reader the authors have in the theory section tried to create a red thread in which there are three overarching components where the first one is a technological component that is focusing on the concepts around industry 4.0 which are internet of things, data analytics and algorithms. The second component is a component with a more legal perspective focusing on the knowledge economy as well as models that are used to control innovations. The third component has a business focus where the authors use theory in order to explain what defines a competitive advantage in the industrial sector due to the fact that the setting that the thesis is concerned with is the industrial manufacturing sector.

5. Research findings

After conducting interviews with IP professionals to understand the applicability of control mechanisms on algorithms in practice and software managers to find out where the trends in applying control mechanisms were heading, the authors obtained empirical data that helps to answer research question one and research question two.

5.1. Patterns from IP professionals

After conducting interviews with IP professionals, relevant information was obtained on which type of control mechanisms are applicable on algorithms and their insights on how to protect them in the most effective way.

5.1.1. Right based property

Patents

When interviewing the IP professionals about how they thought that patents worked on algorithms in practice the majority of them were very positive towards them due to several reasons that revolved around turning the algorithms into property in one way or another. The rest of the IP professionals either had a negative view on patenting algorithms or a rather intermediate approach. The authors noticed that the IP professionals that were positive trusted that the patent system would protect their proprietary algorithms while the IP professionals that has a negative or intermediate approach were rather uncertain if the patent system would manage to hold potential infringers away due to the difficulty in detecting potential infringements.

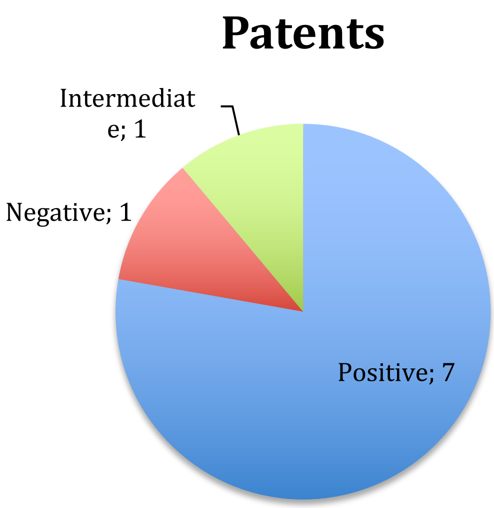

Figure 15 - Summary of views on patents

Looking back at the IP professionals that had a positive view, the authors noticed that the reasons for patenting were different in the sense that they thought that patents worked for achieving different kind of means in practice. Most of the IP professionals commented on the fact that patenting algorithms gave the proprietor exclusivity to the algorithm as long as you patented on a solution level.

"Patenting algorithms on a high level gives control and therefore you can have exclusivity"- IP professional I

"From a patent perspective when we look at software generally we look at the underlying functionality and try to patent for exclusivity. That is fairly effective if you disregard the fact that it is hard to detect infringement, but it is still effective" - IP professional G

One IP professional thought that patents worked well in practice on algorithms not mainly because of protection but rather for attracting different actors such as employees, students and investors as this was seen as a way for companies to show off that they were working with very interesting technologies which later served as a way of strengthening their capabilities as a company.

"It is good to have a patent. It is a good way of attracting people and at the same time scare away competitors". - IP professional D

The last IP professional elaborated on the fact that if one managed to build up a big patent portfolio in regard to smart solutions around the algorithms it creates trust in the company from the customers' view which helps get even more customers and keep building their installed base of customers when it comes to training their algorithms.

"If you have a bunch of patents or a well-managed database it creates confidence to your customer and your brand gains trust." - IP professional H

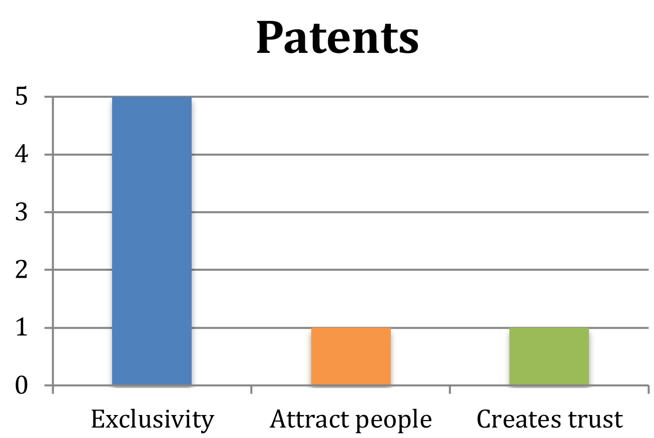

Figure 16 - Summary of IP professionals that considered that patents are effective

The IP professional that had a negative view on patenting algorithms, elaborated on the fact that it is rather hard to get wide and good patents and even if you manage to patent, someone can copy it and one would have a hard time to see if someone is infringing. The IP professional who had a more intermediate approach believed that it was good to have a wide patent as it was useful but if one would manage to invent around it there would be hard to detect infringement.

"It is very difficult to get very good patents and even if we get patents, how do we actually find out that somebody is infringing?" - IP professional F

"I mean you could almost say that it is by definition useful. On the other hand, if you ask me if it is effective in the sense that it stops people from infringing on your patent? That is very difficult" - IP professional E

Copyright

In regard to copyright a big majority of IP professionals did believe that copyright was a control mechanism that was very useful especially when it came to algorithms as they were very often implemented in the software in regard to making the whole solution work as it is supposed to. However, the authors noticed that it was not a single IP professional that said that copyright was not an effective mechanism but there was one professional that didn't have any particular thoughts around it.

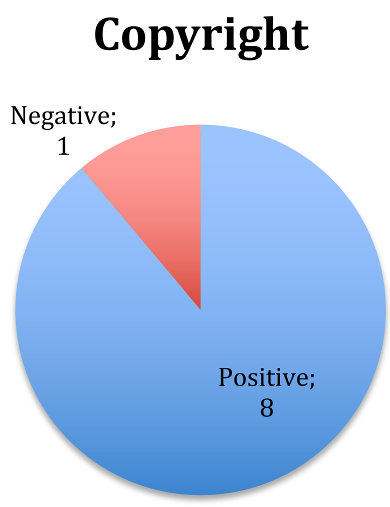

Figure 17 - Summary of views on copyright

Some IP professionals that believe in copyright protection did so as it gave them a sense of double protection that was based on the fact that one could create a layer of protection in which the actual solution of the algorithm was patented but at the same time one could also use copyright as a means of controlling the implementation of the algorithm and therefore owning the software architecture.

"*When it comes to algorithms they should be protected by both copyright and patents*" - IP professional F

"I do believe that the double protection is helpful when it comes to the code implementation and the patenting of the computer implemented invention." - IP professional A

Other IP professionals did believe that a copyright granted the company an easier way to regulate the control when it came to the algorithms that were embedded into the software by using different open source licenses in which other actors could contribute and build upon it. At the same time, they have different responsibilities towards the code depending on what type of license one was using as a company. IP professionals saw that it could be used by companies to gather new ideas and innovations from different actors such as students, developers and companies.

"Software companies will elaborate more on the open source movement. Copyright that actually protects the software implementation of that functionality." - IP Professional G

"The best example of copyright is open source which is not strictly very open because it is always based on copyright and you cannot freely do very much, but you can make it possible for many people to contribute" - IP professional E

The last IP professional that talked about the positives with copyright mentioned that it was much easier to detect if a competitor was infringing on an architectural design in which the algorithms were embedded rather than trying to detect if someone was infringing on the actual algorithm as it changes when it is being implemented into the software.

"It is possible to detect when it is a part of the overall software rather than trying to detect the algorithm as it usually changes upon implementation of the code thus not fulfilling the same purpose in the same kind of way." - IP professional B

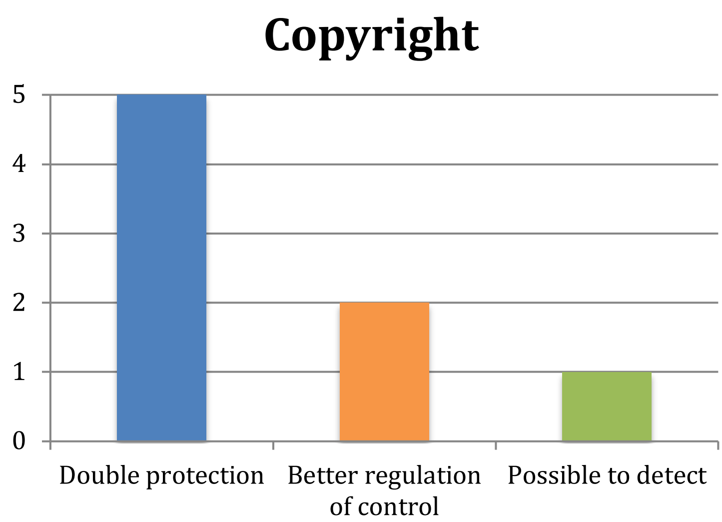

Figure 18 - Summary of IP professionals that considered that copyright is effective

There was one IP professional that did not mention copyright as an active control mechanism. When asked about it, the IP professional mentioned that copyright is a type of control mechanism that comes naturally. In addition, the IP professional agreed on the fact that copyright is something that should be leveraged more from a business perspective in regard to algorithms.

"Copyright comes natural and we understand that it is a part of the future business, but we are so used to sell our physical hardware that we do not think about that we are also selling the copyrighted stuff for example software, so we are not good to set up a value proposition and business model on the software as we are on the hardware" - IP professional D

Trademark

Trademark was a type of control mechanism that did not directly protect the algorithms as such. However, a small amount of the IP professionals interviewed said that trademarks could be used by companies as a way of either attracting customers by building up trust with them in terms of quality. They felt that it was not crucial to lose algorithms as they still had good relationships. On the other hand, a way of using trademarks was to keep competitors from stealing or infringing on their algorithms as it would give them bad reputation.

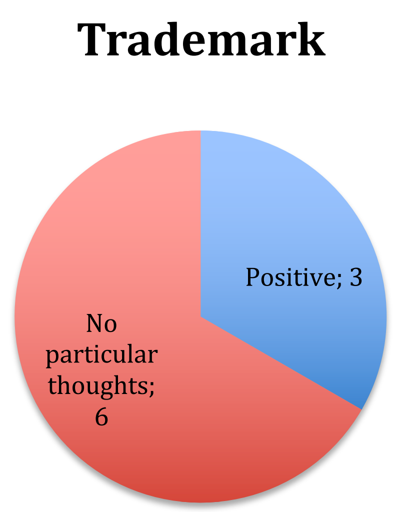

Figure 19 - Summary of views on trademark

"We provide high quality algorithms as a part of the brand. We have a brand which you have to trust" - IP professional F

"We have a trademark on how the software looks and works in order to keep copycats away. We use the trademark on the software in order to give infringers a bad reputation." - IP professional B

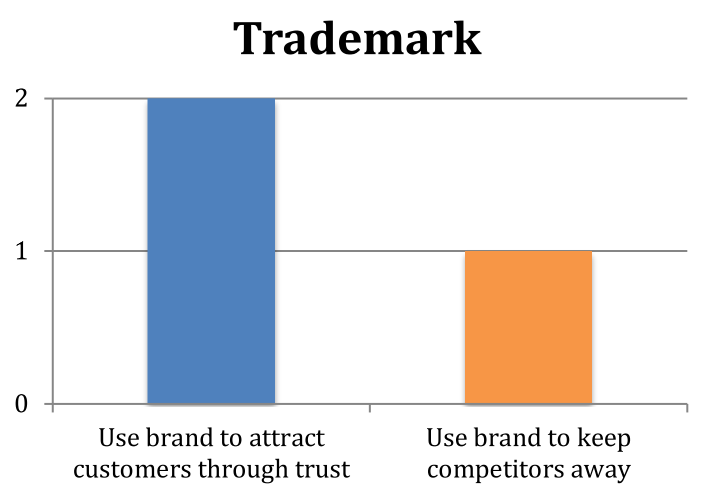

Figure 20 - Summary of IP professionals that considered that trademarks are effective

The rest of the IP professionals did not mention trademark as a way of controlling the algorithms whether it was used as a direct or indirect control mechanism.

5.1.2. Secrecy

Secrecy was also a control mechanism that was deemed powerful as well as effective by the IP professionals, especially when it came to algorithms. Secrecy was seen as a rather broad value as it was hard to imitate someone if the algorithms were kept secret and in-house. However, there were a few IP professionals that were concerned as it was hard to set up a process of trade secret management in an organization and that they felt that trade secrets weren't seen as a viable solution alone but should rather be complemented with something as a patent protection in case they would leak out.

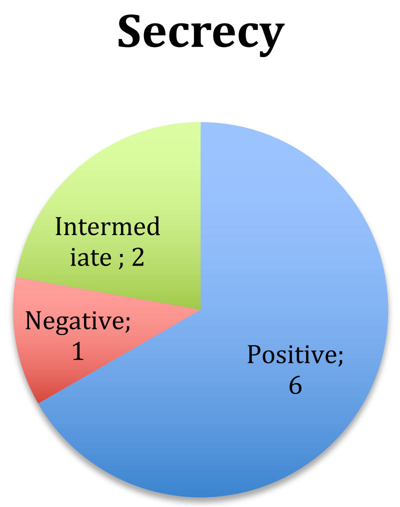

Figure 21 - Summary of views on secrecy

The term broad value was something that came up during several interviews with IP professionals. They believed that this type of mechanism was something that had a great impact on the playing field as it could take several years to imitate an algorithm depending on its complexity and if it was handled as a trade secret. The value of this control mechanism would extend above the other mechanisms as it didn't have to rely on any type of interference from the outside as well as a company at this point didn't have to think about how to claim the algorithm in order to move forward with this type of control.

"You can bury it as a trade secret to get a broad value and make an impact if it is something that is new and inventive but if somebody else would do it you wouldn't be able to see it without stealing their source code. Then it is very hard to go after anyone. A lot of people go for trade secret for the really internal stuff." - IP professional D

"With that said secrecy may be the most powerful mechanism. If you work with a trade secret approach it will definitely have an impact. I think it has a broader value than other control mechanisms as companies don't have to decide a specific strategy around it." - IP professional C

A few IP professionals said that there was a need for the employees in the firm to understand which algorithms should be regarded as a trade secret and what algorithms shouldn't be regarded as a trade secret. Something that came up in regard to this was education together with guidelines for the employees to follow in order to understand how to handle confidential information when they are developing new algorithms. IP professionals spoke about the fact that employees did not usually have a knowledge spillover on purpose, but they didn't think things through while for example being at fairs, having lunch with other people or simply holding different workshops. The emphasis should also be put on the fact that it is bad for the company if knowledge behind core algorithms leak out into the public.

"It is important to let everybody know that some algorithms are highly competitive and if stuff leaks it's bad. We try to keep everybody in the loop" - IP professional H

"To specify any documentation that describes or embodies the trade secret in question. I believe what works best is to increase awareness among the carriers of such trade secrets." - IP professional A

There was, however, one IP professional who liked the matter of having trade secrets, but the person could not really point out why this was the case. This person described it as just being a simple way of protection compared to the other type of control mechanisms.

"I don't really know why I feel that trade secrets feel good in regard to algorithms, but I just think it is the simple way of actually not having to go through a specific process." - IP professional B

Figure 22 - Summary of IP professionals that considered that secrecy is effective

The IP professional that did not have a positive view in regard to having trade secrets as one of them believed that the process of setting up a trade secret management system throughout the organization meant a lot of work which was not easy. This IP professional also said that the company managed confidential information but to say that something can be regarded as a trade secret was an entirely different and difficult process. The other IP professionals that had an intermediate approach didn't believe that having just a trade secret as a control mechanism was enough as it was also important to have a balance between having a patent of the solution of the algorithm and a trade secret of the exact formula.

"I think from our perspective we need to keep some kind of a balance between the patenting of the algorithm and the trade secret of the formula." - IP professional G

5.1.3. Contractual based property

A significant amount of the IP professionals had a very positive view in regard to contracts as they were seen as a way of utilizing the algorithms in a formal understanding between one or several parties. People respect contracts and therefore it is seen as a strong mechanism for driving behavior. There was not a single IP professional that disregarded the contracts in anyway. However, all of the IP professionals mentioned that it was important when entering into an agreement with another party when it came to the algorithms that the parties involved understood the object in question. In addition, they mentioned that the agreements should be well-written to be understood by all the parties involved.

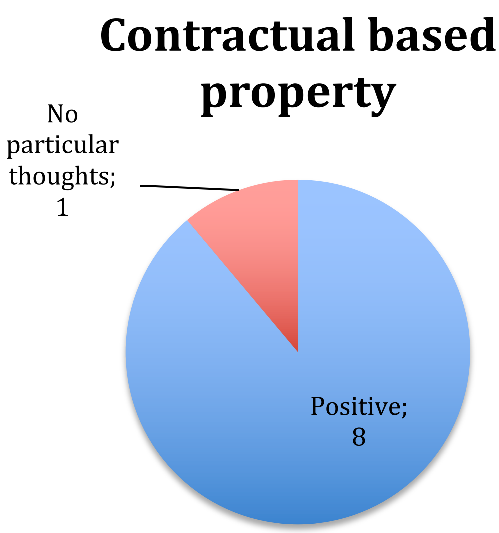

Figure 23 - Summary of views on contracts

Some of the IP professionals that thought that contracts worked very well in regard to algorithms emphasized on the fact that a contract was one of the most effective ways of controlling algorithms especially when there was more than one party involved, whether it was externally with another actor or internally with an employee or consultant. They mentioned that it was important that the contracts were well-written as there were often many people involved when it came to development and implementation of algorithms as well as the development and implementation could go very fast at times.

"Agreements are very important and IP clauses are relevant as one needs to know who owns the results and where the results should be stored" - IP professional F

"Working with the most well-established companies, we come to make a conscious decision about what to do. Try to have good contracts in place of course with your employees so if they change work, they feel that they don't spread the intellectual property they have with them when leaving the company." - IP professional B

Other IP professionals had a strong focus on the importance of contracts as of drivers of behavior from the parties involved as people in general tend to respect contracts. Moreover, the parties value to preserve a good and long-term relationship both internally as well as externally. However, they were keen on the fact that one should not solely rely on contracts as one need to claim the algorithms in some way whether it was through a patent, technical control or secrecy control.

"But in my experience people have a good respect for that. I think it is the loyalty to the company. The world is also quite small, so you can't behave in any way you want. It would damage your own brand in a sense." - IP professional D

"I would definitely say that it is better to have a contract. I think that it drives behavior definitely. The risk of consequences at least to a certain extent will drive that behavior. Then again, you can't rely solely on contracts, you can't expect contracts to be the complete toolbox." - IP professional C

At the same time, some IP professionals thought it was important that when going into a joint development with another party you need to have good symmetry internally between managers, lawyers as well as engineers in order for the contract to have real effect as they all played an integral role in understanding where the value was important in terms of foreground, background and results.

"The contract as such is only a document that is supposed to mirror something that goes on in practice. I think that the difficulty is that most of the time a contract is not clearly defined. You need to first figure out what is going to happen, and a legal person can help you formulate that in a contract. The collaboration between managers and lawyers is important." - IP professional G

"The effect of a contract is really dependent on who interprets it regularly, you need legal support from your project managers and the contract needs to be written in a useful way" - IP professional H

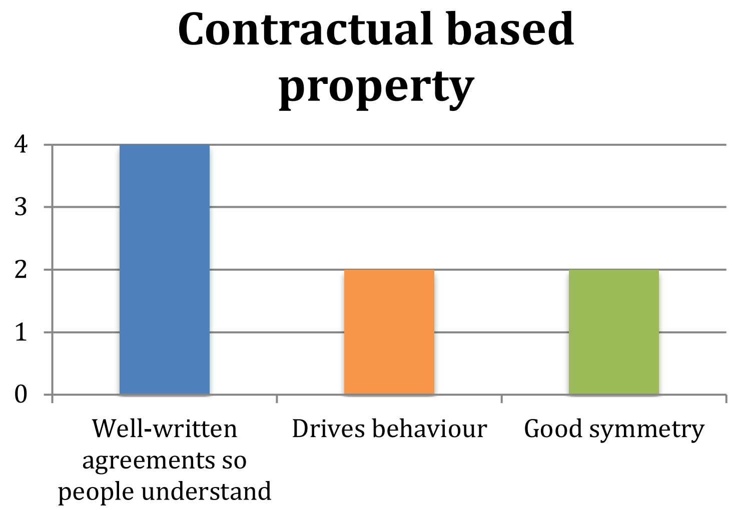

Figure 24 - Summary of IP professionals that considered that contracts are effective

5.1.4. Technical control

Almost every one of the IP professionals felt that technical control was the most effective control mechanism of them all as it could physically prevent unauthorized access to the algorithms through different means of technical control. There was not a single IP professional interviewed that had a negative view against technical control. However, one IP professional did not mention technical control at all.

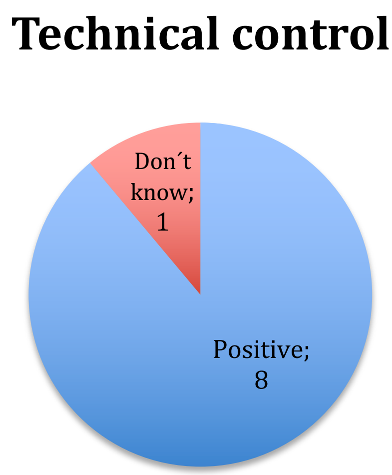

Figure 25 - Summary of views on technical control

Among the IP professionals that had a positive view, there were different thoughts around how to apply technical control on algorithms. Some IP professionals mentioned the advantage of keeping algorithms as a black box in which other actors could only use the function of the algorithm but never got to see how the algorithm is actually performed in order to transform the input into valuable output. They, however, mentioned that others could make adaptations to the algorithms through different kind of interfaces where they still never got to see the actual formula.

"The solution is often implemented through algorithms but then we keep them as a black box with an input and an output." - IP professional F

"Binary packages of code. They make the adaptations for their own software, so it is pretty much a black box delivery with the input and output defined." - IP professional G

"You can say that yes we are going to collect the information by backbox, we are going to have to do a routine for that. You can be restrictive in how you distribute specifications and so on." - IP professional H

Other IP professionals believed in the obfuscation of code when it came to joint development in which the other party had to see the source code which meant that the companies who were providing the code had key players who knew how the overall logic was built up in the source code. This way, the other party would become dependent on the company that originally produced the code in order to decipher the logic that they would need to add upon due to it depending on the complexity would take them a longer time to figure out the logic by themselves.

"One could do some kind of code obfuscation on the solutions making it trickier to figure out what the compiled code is" - IP professional A

"When it comes to software functions, the primary control mechanisms are through obfuscation because it is very natural." - IP professional C

"*When we supply code, we try to supply it obfuscated."* - IP professional D

The last IP professional that agreed that technical control was seen as a strong mechanism of keeping algorithms safe had more of a traditional approach as the person was focusing on keeping the algorithms safe based on encryptions, passwords and different kind of portals when they were having collaborations with customers, collaborators and other type of actors.

"Different kinds of passwords and encryption. I have seen companies use interfaces because people can't see what is under the hood of the programme." - IP professional B

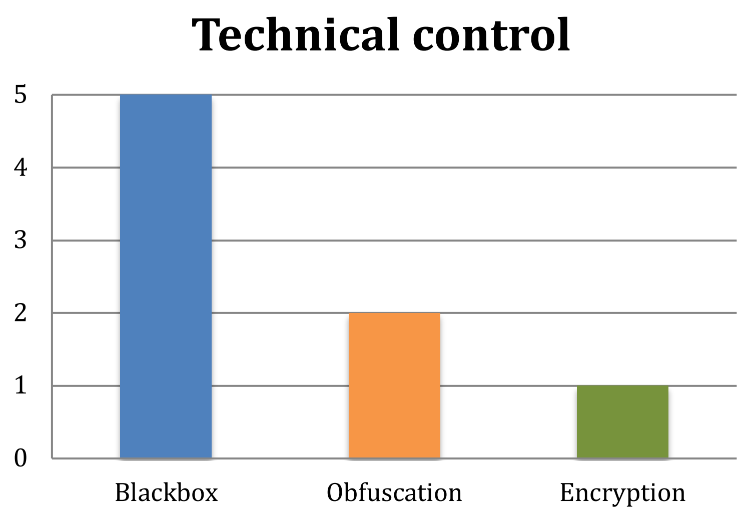

Figure 26 - Summary of IP professionals that considered that technical control is effective

5.2. Patterns from software managers

This section focuses on the second group interviewed in order to understand how different software and industrial companies are applying the different control mechanisms on their algorithms.

5.2.1. Right based control

Patents

When interviewing the different software managers, the authors noticed three specific trends that were present during several interviews. The first trend was that many of the software managers said that their company in regard to algorithms liked to obtain high level patents on the solution behind the algorithm. The second trend was that they felt it necessary to patent on a system level as well in order to not disclose the algorithms on any type of level. The last and third trend that was present was that many of the software managers put a heavy emphasis on getting more attraction from their environment such as new potential employees, investors and collaborators where they used their patents in order to reach that objective.

The managers that were focusing on obtaining patents on a high level explained that they were the best kind of patents in regard to algorithms as it did not only protect the algorithm, but it also protected the specific domain that they were operating in. Especially, since they described that algorithms tend to change upon implementation as well as there being several innovative ways to solve the same problem which meant that competitors could try to and most certainly succeed to go around the patent if it was too low level. This way, they felt that they got a much safer protection and could through this easier detect and prove infringement.

“The most high level patent is the whole idea. It’s these kinds of patents that I hate because they are very wide. But they are very good once you have them.” - Software manager B

“We do have a lot of high level patents in this company. Patenting some algorithms that we are lucky enough or smart enough to find before the competition.” - Software manager F

The second trend was the fact that most managers also focused on patenting on a system level due to the fact that they felt that it was risky to put patents on the algorithms out there even if it was on a high level. If they were very crucial patents for the company, they preferred to have it on a system level. They described it as a way of keeping the algorithms safe due to them never having to show them and they also pointed out that algorithms work better together in a collective.

”Both actually because the system wouldn’t exist without its part and some parts are crucial to keep very safe. But at the end it is the combination of the parts that are important because one plus one will become two. It is very important to patent at the system level as well.” - Software manager E

“We patent our solution on a system level because you do not want other people to basically steal the idea that your algorithm represents” - Software manager D

The last and third trend which focused on managers using their companies’ patents as a market vehicle which was explained with the fact that human capital was something that was very valuable especially when it came to the development of algorithms and their implementation into software.

Some managers even went as far as saying that they were more worried that the people behind the algorithms left the company rather than them losing the patents which lead them to focus on attracting new employees. Other managers, however, used their patents in order to attract potential collaborators or investors who wanted to work together with them or support them in any way.

“One could say that some of our algorithms are really marketing vehicles. We go out and talk about our clever patented algorithms as a way of showing the environment how innovative we are.” - Software manager B

"Then there could be stuff that you want to brag about to attract people from the outside. We do it in this way and we are clever. It is then good to have IP on it." - Software manager A

Type of control mechanism	Trends on how the control mechanism is used	Reasons
Patents	1. Patent on a conceptual level	Protect both the algorithm and the specific domain. Easier to detect and prove infringement
	2. Patent on a system level	Wider protection used for crucial patents. The algorithms are kept safe as they are never disclosed
	3. Patenting as a market a vehicle	As means of attracting employees, investors and collaborators

Figure 27 - Table of trends in patents

Copyright

In regard to copyright there were two main trends that stood out among the software managers that were interviewed. The software managers in general were not that focused on copyright as it came very natural for them to leverage and use copyright which was something that they had implemented into their everyday work. The first trend was in regard to them using their copyrighted code as a way of protecting the algorithms through sheer implementation as they were inside the code. The second trend was due to the fact that the software managers interviewed said that they leveraged their copyrighted code with their algorithms in order to be able to build upon them and make them better.

Protection of algorithms inside of the software code was something that was a very usual trend when talking to software managers. Some of the developers that worked under them even documented their algorithms directly inside the software code as that was seen as a part of the overall logic. It not only gave them a type of double protection, but they also mentioned that it was important to have control over the code base as the implementation in many cases could be seen as more valuable than the actual algorithms as they mentioned that the logic of the algorithm could change rather drastically depending on what programming language that was used.

"Well we sometimes create a document, sometimes we write it on paper, then we implement them and save them in the code basically." - Software manager D

"Some sort of documents, source code is one of them, but we do additional documents which describe the feature of the total system." - Software manager E

Most of the software managers interviewed also spoke about the importance of using open source licensed software in terms of different libraries as a way of adding new logic into the existing algorithms by training them. Most of the software managers said that there is nobody that does everything themselves but instead said that everything builds upon something and that it is only a matter of understanding how to regulate that. However, there were different views on how companies used open source licenses. There were some software managers that went safe and used open source libraries in which they didn't have to contribute or open up too much of their code base and therefore their algorithms. In addition, there were some managers that even helped others in the open source community by contributing with some of their own source code as they felt more confident that they could produce even better algorithms in-house.

"So basically, we develop ourselves, but we use lots of cup bodies software for which we either pay or they open source and we build case for open source by contributing to it, so we fix the errors in the open source software" - Software manager D

"We use open libraries to develop our software but the major parts we develop on our own. When we get the opportunity we also see to it that we contribute with our part as well" - Software manager C

"We are pretty bad at contributing to any open source projects. We just use them." - Software manager B

Type of control mechanism	Trends on how the control mechanism is used	Reasons
Copyright	1. Copyright used for implementation of algorithms	Double protection. Moreover, algorithms changed a lot when implementing so it is important to have control of the actual code base
	2. Use open source software	One can build upon the algorithms and makes them better by using open source libraries or by contributing to the open source community

Figure 28 - Table of trends in copyright

Trademark

In regard to trademarks, none of the software managers believed that trademarks could be used to control or protect the algorithms as they thought that trademarks were used more for marketing purposes.

5.2.2. Secrecy

Software managers spoke mainly about three different points in regard to how secrecy is applied in their respective companies towards their employees. The first one was that most of them worked actively in different ways to try to define algorithms as trade secrets. The second trend was that the managers kept a close circle when it came to the amount of people involved in developing a specific algorithm. The last trend was that they cared deeply about keeping the knowledge bearers around the algorithms as they were the ones who kept developing them.

Working actively with defining and claiming the algorithms internally was something that the managers found of utmost importance because without this process they felt that it was hard to apply other control mechanisms if one had not gone through this process. Depending on the company there were different ways of doing this. Some companies used a trade secret management system while others documented the algorithms in the source code. They also believed that one had to keep a balance between what one should keep as a trade secret and what one should patent and make public.

"We are an ISO 27001 company, we are using source control on our algorithms and specific persons are allowed to check in and check out code" - Software manager G

"*Of course, the interesting conflict here is always what to decide to patent and, in that sense, make public and what do you decide to keep secret? Then there are some algorithms that we keep completely secret in a system"* - Software manager B

When working with the algorithms, some software managers said that they tend to become rather complex which means that it ends up with there being specialized teams working with the algorithms. They mentioned that this gave them a sense of secrecy by default as it in the end became a closed circle of people who knew about how the algorithms actually got implemented into the code. Even the people who were in that closed circle did not really get the full picture on how everything worked in a larger context.

"We have different teams working on different things. One team is working on a particular part of the algorithm for a particular product" - Software manager F

"But you know, often there is a whole team that has implemented something and as I said the level is in the detail and the details are often implemented by the whole team, so no one might have the full picture of how it actually works." - Software manager D

Lastly, many software managers thought it was important to not let it end up in a situation in where employees wanted to leave the company as they felt that even though they added all the different control mechanisms together with secrecy some crucial knowledge always followed the employee that was leaving the company as they had worked closely with the algorithms. Therefore, they believed it was very important to take care of the knowledge bearers that worked with the algorithms as they again never could be sure what was regarded as generic knowledge around the algorithms or accumulated knowledge from the company.

"Of course, it is always a risk if someone who has been working on our algorithms leave due to knowledge and trade secrets walking out the door. Therefore, it is important for us to keep on motivating employees, so they feel that they are evolving and are an integral part of the company" - Software manager C

"It is always costly to lose knowledge in regard to algorithms. I am more concerned in how to replace that knowledge in the company. Therefore, we put emphasis on team spirit in this company" - Software manager B

An interesting exception that the authors noticed was that one of the managers were so keen at keeping their algorithms secret that they did develop everything in-house and did not have any collaborations in regard to software.

"We build everything ourselves. So even though the company is known to be a hardware company everything is smart, so all our tools are embedded with software. We have hundreds of developers in-house."

Type of control mechanism	Trends on how the control mechanism is used	Reasons
Secrecy	1. Working actively with defining algorithms as a trade secret	Process of utmost importance done through a trade secret management or by documenting the algorithms in the source code
	2. Small groups working on different parts	Algorithms tend to become complex and therefore, it is needed to have an specialised team
	3. Treating the knowledge bearers	Hard to determine company's knowledge and generic knowledge

Figure 29 - Table of trends in secrecy

5.2.3. Contractual based property

The main trends around contracts had a rather internal focus as the software managers believed that software developers were one of the biggest risks when it came to protecting algorithms as they were the ones who had created them. The first trend that the authors noticed was that the managers had exit interviews with software developers who were leaving the company. The second trend was that the managers felt that non-disclosure agreements were very important to have in place due to the applicability of algorithms. The third trend revolved around the clauses being non-compete clauses that they had both internally with their employees as well as with collaborators and customers.

According to the software managers, the algorithms were very much tied to software developers due to them being the ones who were building upon them. Therefore, it was important to have contracts with them which clearly stated what they can and cannot do with the knowledge behind the algorithms. They had respect for the contracts but at the same time they did not often fully read them through which meant that they could easily spill out the knowledge by mistake. This led the companies to take a precaution of having an exit interview with employees who were leaving the company with the focus of both getting constructive feedback in order to handle the future employees better as well as relating the contract to their work, so they know exactly what they can and cannot disclose in terms of algorithms.

"It was all an exit interview in full secrecy with the HR department. When you leave, you get this paper that says, do not forget what you signed earlier about not disclosing anything that has happened here" - Software manager D

"It is the HR department that has to take the interview because it is very important to get constructive feedback in regard to why employees leave and what was making the employees unhappy but also to remind them of what they can and cannot disclose in regard to the algorithms" - Software manager F

The second trend that the authors found from software managers was that they relied heavily on non-disclosure agreements on their employees in order for them to not disclose anything that they had built for the company. However, the software managers stated that this required having an active process between the manager and the employee in understanding and defining what they could and couldn't talk about. At the same time, the software managers said that even in the case that they would go and tell anybody about what they had done, it would first of all result in a bad reputation for the employee and the company would already have built something new at the time it got implemented at the new company.

"We all are very bounded by our contracts, so we can't really spread the knowledge when we leave. We have signed NDAs. You are bounded by law. Even if someone would tell anybody about what we do here it would end up badly for them in terms of reputation" - Software manager F

"They sign non-disclosure agreements and at the time they would come to a new company our engineers will already have come up with new algorithms" - Software manager H

Software managers finally spoke about the importance of having proper clauses in the contracts especially with the employees that created the algorithms and implemented them. A non-compete clause was something that was very important as managers felt that they could never truly distinguish between what was seen as generic knowledge in terms of the creation of the algorithms or what was seen as accumulated knowledge from the company. This way the managers felt that they at least wouldn't have to worry about them going to a direct competitor.

"We are also controlling it through contracts where we say that you are not allowed to compete with us if you in the future will be developing a similar solution" - Software manager C

"*In our contracts with our employees we do have a non-compete clause for about a year which means that they cannot develop software for a direct competitor. Then we at least get a year's head start sort to say"* - Software manager A

The authors also noticed an interesting fact from a few software managers where they were having contracts with customers where they improved their algorithms gradually in order to gain competitive advantage.

"The agreement we have is that they don't buy our product, they rent it. They pay a fee every year and part of that agreement is that we will improve our algorithms every year". - Software manager H

Type of control mechanism	Trends on how the control mechanism is used	Reasons
Contractual based property	1. Exit interviews with software developers	As means of precaution to make sure what an employee can and cannot disclose after employment. Additionally, exit interviews were used to get constructive feedback to handle future employees
	2. NDAs	To make sure that employees do not disclose relevant information. This requires an active process between managers and employees
	3. Non-compete clauses	Hard to determine generic knowledge and accumulated knowledge from the company

Figure 30 – Table of trends in contracts

5.2.4. Technical control

The technical control was something that the managers could elaborate very deeply on as this was something that they were used to everyday. Looking at it from an overview, there were three main trends that the authors defined from the interviews conducted. The first trend that was noticed by the authors was that most of the software managers used a black box on their algorithms especially when they were dealing with their customers. The authors also noticed that the way that managers applied the black box approach on their algorithms differed depending on who you asked. The second trend was accessing the whole product by licensing and some of the managers elaborated on some of the more "usual" means of technical protection as they sold licenses in order to access their whole product and never let their customers gain access to the algorithms as a black box but more giving them to the solution that where the algorithms served as the underlying force. The third trend that was ongoing was that the managers told the authors during the interview that they had a technical control internally as well in where they obfuscated the code that the algorithms were implemented in by dividing up the logic in how the algorithms were executed.

Software managers had different ways of applying the black box approach on their algorithms. Some managers worked at companies that had come up with their own programming language in which they allowed their customers to both implement them into their own software code and customize the algorithms themselves through this black box which meant that the algorithms were safely stored on the company's servers while still allowing the customers full customization. Others, were sending out binary packages which could be regarded as code that only machines can read which kept customers from understanding how the logic worked. Then there were those who used application programming interface calls in which they had the algorithms on their servers and took a license fee for giving their customers access to the different functionality that the algorithms provided.

"I mean like I said we have this language which is very powerful, and I mean it's pretty much the only way." - Software manager H

"But then we have developed it and then we store it and host it from our servers to be able to control it from our end. Then we give our customers our API so we are controlling it physically." - Software manager C

"Providing APIs to customers are a hot topic. I am not sure I can tell you much about this other than we are investigating solutions to move into this for more customization." - Software manager I

Some of the managers that were interviewed said that their company did provide a license offer for the whole digital product instead of the algorithms themselves but said that they had felt a trend in where their customers wanted to use algorithms in their own solutions as they would be less dependent on the supplier. The managers that did not provide black boxes for the exact algorithms instead said that they had started to look into potential solutions in where this was possible.

"We only sell it as a whole service. Our service is a web interface for human analysts to use and then it is an API to get data from the same database. So it is very pure service-oriented."- Software manager B

Software managers also spoke about the importance of having technical control over the algorithms internally which many of them did through obfuscating the code. From the internal point of view companies had different access right where crucial versions of the code that wasn't obfuscated were only accessible to algorithm developers while "regular" developers had access to code parts that weren't crucial for the logic that weren't obfuscated. The reason that they applied obfuscation on their code was elaborated by managers that one could never be too sure that competitors couldn't get their hands on the code especially when it came to embedded software in physical products and this way even if they did get their hands on the code with the algorithms inside it would take them a long time figuring out how the logic of the algorithms were built up.

"The more you obfuscate the actual logic, the more it will become difficult to imitate. Basically, your logic is spread all over the place in your code. No one part of the code can really provide the key to what is happening in your algorithms" - Software manager D

"We also apply obfuscation to source code, so we have branches that are for the obfuscated software and for the obfuscation" - Software manager A

Type of control mechanism	Trends on how the control mechanism is used	Reasons
Technical control	1. Blackbox	Different ways of applying blackbox: customisation by the customers but they do not see how the algorithms work and operate, by binary code and APIs
	2. Access whole product by licensing	Customers will never gain access to the algorithms as these ones are provided through a blackbox
	3. Obfuscation of the code	As it will take long time for competitors to figure out the logic of how the algorithms were built on

Figure 31 - Table of trends in technical control

5.2.5. Market power

Something that many of the software companies did in order to keep competitors away in their own domain when it came to algorithms was that they first of all strongly believed in first-mover advantage where one could build up strong relationships with customers in order to gather data to make the algorithms smarter and therefore even if algorithms were stolen the software managers felt that the company could create even better algorithms based on the data gathered from their customer relationships. The other trend that the authors noticed was that the managers said that their respective companies tended to use their brand reputation in order to attract actors such as new customers and employees which gave them a strong installed base for continuous development of new algorithms.

Due to the IT development going in a very fast rate in general the software managers believed in an agile approach in order to gain market power in which there was an importance of being out fast on the market to gain strong relationships with customers in which they could leverage their customers' data in order to make their algorithms better in terms of accuracy and efficiency as well as understanding the problem that they are having with their equipment. The managers said that at this point that if you managed to get to this point it did not matter if some algorithms leaked out as there was a continuous process of developing the algorithms in order to keep being competitive in the market.

"By being fast. Seriously everything is going down the drain these days. You can be can have hundreds of PhDs working, coming up with this smartest and brightest solution that no one can never come up with but whoever is the fastest in relationships gets the best base for creating good algorithms" - Software manager D

"We want to be close to our customers wherever they are. Are they in the smallest village in Mexico? We will be there. If we manage to build good relationships we will get a good way of developing even more efficient algorithms than before based on real life cases" - Software manager G

Managers also mentioned that the brand was something that played a big role when it came to attract different actors that were important for the development such as new customers which they leveraged customer data in order to make the algorithms more efficient as well as attracting new employees that could further develop and implement the algorithms into the overall logic.

"Having market power is very important for us as we attract talented individuals that make our algorithms better." - Software manager H

"We see the value in having a market power from two perspectives in regard to algorithms. The first one being the customers which we focus on having good relationships with in order for us to learn as much as we can to implement. The second being that we treasure the individuals who can develop the algorithms for us" - Software manager G

Type of control mechanism	Trends on how the control mechanism is used	Reasons
Market-based	1. First-mover advantage	Having strong customer relationships in order to gather data from them to create smarter algorithms
	2. Attract people	By using the brand as a mean of reputation to attract new customers and employees
	3. Being fast	Agile approach due to IT development going very fast

Figure 32 - Table of trends in market power

6. Analysis and discussion

In the analysis and discussion chapter, the authors analyze and discuss the results from both of the groups interviewed together (Chapter 5) with the theory (Chapter 4) from an industrial perspective in order to answer the main research question.

6.1. Introduction

Something that the authors noticed when analyzing the results from IP professionals and software managers was that they preferred to use several control mechanisms in order to be able to control the algorithms on both a conceptual and on a detailed level where the conceptual level was focused on the actual solution or function behind the algorithm and the detailed level focused on the instruction or formula that the algorithm performed. Patents were a control mechanism that if used correctly it could manage to give the proprietor control over the algorithm on a conceptual level. Having a technical control, copyright or secrecy worked well when one needed to have control on a rather detailed level as it gave the proprietor a way of keeping the algorithms safe through different methods. Contractual based property was something that the authors noticed being very effective in the sense that it covered protection for an algorithm both on a detailed level as well as conceptual level as long as it was used together with other control mechanisms and a defined proper knowledge asset. Lastly, the market power was interesting due to the fact that it started up on a detailed level but as a company built up their customer base, the control expanded to a conceptual level as well as one not only used customers to make the algorithms smarter but also used it to stay relevant in its own line of business.

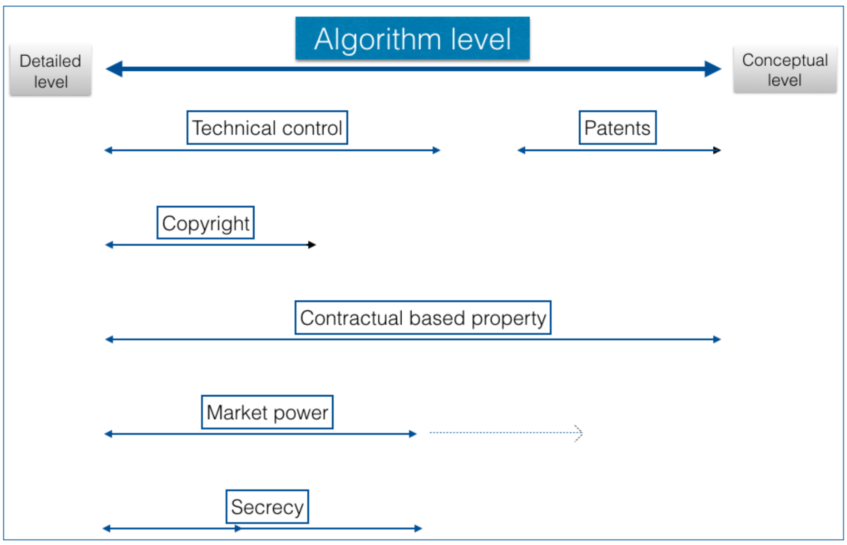

Figure 33 - Applicable control means in algorithms

However, in order to discuss the results based on the interviews conducted together with the literature review done from a perspective of competitive advantage in regard to algorithms the authors are turning back to the framework presented in the introduction. The framework is created by the authors and it is inspired by the well-known model by Porter called the five forces model in order to establish different relationships of an industrial company in the manufacturing industry. The framework focuses on *the interface with software suppliers, the interface with competitive industrial companies and the interface with customers* in order to discuss how industrial companies should apply different control mechanisms in order to leverage a competitive advantage between the different interfaces when it comes to algorithms. The authors have defined external competitive advantage where the focus will be on how to apply control mechanisms to gain good position effects.

With the help of theory, the authors also defined internal competitive advantage which is focused on how firms should apply control mechanisms on algorithms as a resource as well as an organization's capabilities of creating algorithms. The authors are, however, recognizing that the object that the study has focused on are algorithms which is seen as an abstract idea before it is characterized as either a solution, software or instruction. This means that it is pure knowledge based on human capital and can therefore be regarded as an intellectual asset (Petrusson, 2004).

The different forces are based on a tangible resource-based view in the industrial sector whereas the study is focused on intangible assets i.e. algorithms in the industrial manufacturing sector. Due to the emergence of smart devices in the industrial sector which lets software companies move into the market it has also opened up the door to new potential collaborators as well as competitors through the coalition of software as well as hardware (Porter & Heppelmann, 2014).

Due to the explorative and abductive approach of the study the authors found out, after conducting interviews with software managers from industrial companies and software companies, that there was a big difference in regard to the software managers' knowledge around strategies on how to apply different control mechanisms on algorithms depending on if they were working in an industrial setting or in a software setting. The managers that were in an industrial setting did not have as vast knowledge in regard to the strategies around how to implement control mechanisms on algorithms while the managers who had been working in a software setting had vast knowledge around these strategies.

The authors believe that the reason for this is because the area of embedded software algorithms is rather new in the industrial sector which is a new playing field that is growing. Therefore, the following discussion will be based on insights gathered from IP professionals and software managers and their experience of dealing with suppliers, customers as well as competitors. However, the main emphasis for the authors will be the insights gathered from IP professionals and software managers that were based at software companies. The authors do recognize that the software companies' place in the value chain might differ from the industrial companies' place in the value chain. However, the learnings from the study will be useful for future research because it will help industrial companies understand how to deal with the new software suppliers, competitive industrial companies and end-customers in regard to algorithms. In the model below, the industrial companies which were the main focus of the study are seen as suppliers of industrial assets to customers. The customers are seen as manufacturing companies. The software suppliers are seen as software companies who are supplying software and algorithms to the industrial companies or developing it together with them.

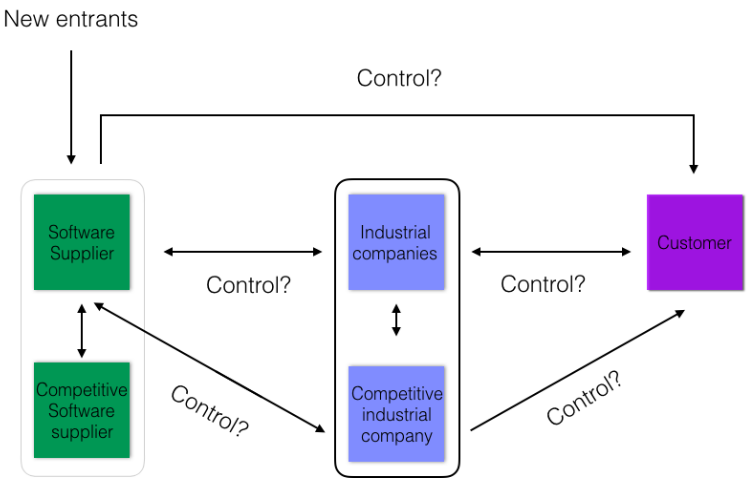

Figure 34 - Model of the different interfaces

6.2. Managing competitive industrial companies

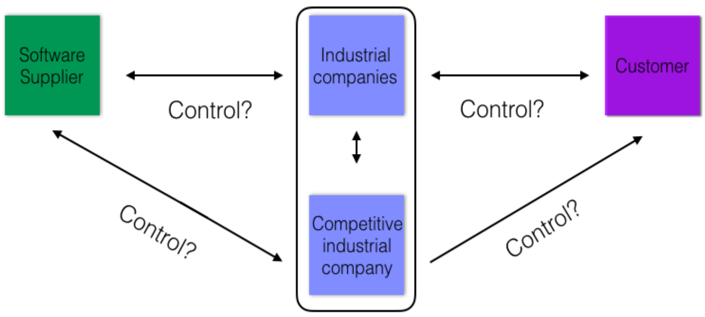

Figure 35 - Model of different interfaces with focus on competitive rivalry

In the new spectrum of industry 4.0, the competitive rivalry becomes enhanced as software algorithms are playing a larger role in the industrial sector when it comes to product differentiation in order to have the competitive edge (Porter and Heppelmann, 2015). During the interviews with both software managers as well as IP professionals, the authors noticed that in order for a company to be competitive in industry 4.0 when it came to algorithms it was important to apply control mechanisms both internally in the company as well as externally towards both collaborators, customers and competitors.

From an internal point of view a company's resources as well as its capabilities played a big role as the algorithms as a resource needed to move from unspecified, diffuse and scattered knowledge to well-defined and manageable assets to be fully utilized (Heiden, 2017). It is important to understand how to define an algorithm as it can be defined as either an instruction, software or a solution (Petrusson, 2015). If you define it as an instruction it can be protected by secrecy, if you define it as software it becomes eligible for copyright protection or/and secrecy and if you define it as a solution with a technical function it is eligible for patent protection as well as a trade secret. During the interviews with software managers, it became clear that the control mechanisms for managing both the resources in question which were the algorithms as well as the capabilities of creating the algorithms which were regarded as the employees, the control mechanisms were rather similar. The reason for this was that algorithms as an object seemed to be rather attached to the employee or employees that created them.

IP professionals thought that *secrecy* was the strongest control mechanism in order to control algorithms internally. Several software managers suggested that one would deploy a trade secret system where core algorithms are defined. Through this type of solution, a firm will be able to start a process of claiming intellectual assets in the software as well as evaluating them and therefore decide how to leverage them externally (Petrusson, 2015). It would also help to have this type of system from a legal perspective as one could in some countries' courts say that one had used reasonable efforts in order to maintain the algorithms a secret (OECD, 2015). IP professionals said that when the algorithms get claimed through a trade secret system a firm can use *contracts* in a better way for making employees understand what algorithms are important and managers can get the tools to be able to guide the employee in what can be regarded as crucial and what does not have to be regarded as crucial as most of the software managers said that knowledge spillovers did occur but not on purpose. This is due to the fact that the algorithms are difficult to control by the companies and therefore spillovers can occur (Foray, 2006).

What the authors noticed when interviewing the different software managers was that a lot of the companies' capabilities of generating value in regard to algorithms for their customers and themselves came from their human capital. Compared to the resource-based view from (Penrose, 1959) in which a company's capabilities was determined by their productive activity such as cross-functional capabilities and functional capabilities, the software managers interviewed had a more knowledge-based view in which there was a strong focus on keeping human capital as well as a strong focus on the knowledge transfer process. Some software managers said that it was crucial to write down the changes made to the algorithms for traceability as they tended to become rather complex. If anyone left, they had to prepare for a knowledge transfer process where the time would vary depending on the complexity of the algorithm as it was seen as rather tacit knowledge which meant that it could take up to a year to transfer (Grant 1996). These software managers were aiming on getting a good diffusion of the knowledge of the algorithms in the company (Bell, 1976).

Some software managers also elaborated on the fact that in order to maintain the firm's capability of producing high quality algorithms they had to continuously attract new employees that could develop these further and many of them applied *patents* on algorithms as a way of building their brand and by that attracting new employees. They were not as worried about algorithms being disclosed through patents as they felt that the key knowledge was in the human capital. It could be seen as a smart method for companies as algorithms are always developing and are getting built upon which means that they need maintenance by employees with the specific knowledge in how they work and operate as algorithms in machine learning which is an integral part of data analytics learn from their mistakes but in order to do that they need statistical models in which they learn from and these need to be carefully constructed and developed (Das, 2016).

From an external point of view, a couple of IP professionals elaborated on the fact that employees respect contracts but they themselves didn't understand the contracts sometimes which left it open for interpretation. Nonetheless, all software managers felt that it was important to use *contractual means* in order to mitigate the risk of knowledge being spread and to not lose valuable knowledge to a direct competitor. However, software managers utilized contractual means in different ways, some of them referred to having exit interviews, others non-disclosure agreements and others non-compete clauses and even a combination of them. They further pointed out that it was hard to draw the line between knowledge that was accumulated from the company's particular industry as well as the individual's own knowledge in regard to algorithms.

In order to keep competitive industrial companies from using similar solutions the software managers and IP professionals strongly suggested having a wide *patent* on the solution which gave them a protection in their specific domain. They emphasized the fact that it was much easier to defend this type of patent in the judicial arena (Petrusson, 2004) and it was easier to detect infringement. This is because they didn't have to see the actual source code of their competitors in order to claim that they were infringing on their algorithms. The authors also noticed something interesting which was that some software managers who worked at software companies used *patents* where they disclosed not so crucial algorithms as a way of attracting both customers as well as employees thus strengthening their installed base of customers as well as strengthening their capabilities of maintaining a sustainable competitive advantage in their industry. By getting more customers, they got more data which they used to train their algorithms to become more accurate and efficient (Michalski, Carbonell and Mitchell, 2013).

Most of the software managers also spoke about the importance of having an installed base in terms of the architectural design of the code in which the algorithms were implemented and therefore gained *copyright* of the whole code base. The reason for that was because the software managers emphasized that algorithms do change when they are being implemented which meant that in one way the implementation of the algorithms was in many cases more valuable than the algorithms themselves as solutions looked different depending on the customers. The implementation was dependent on what type of programming language that you used and by having a copyright protection on that implementation it serves as a type of double protection where both the algorithms and the source code gets counted in. While an algorithm according to (Cormen et al., 2001) by itself is only seen as a way to solve a computational problem it is still crucial that the implementation is correct. Some also leveraged their installed codebase through open source licenses in order to get help from the outside in order to strengthen their algorithms as the continuously got built upon to promote new types of services (Foray, 2006) which could be seen as a good way as the company can regulate the openness through the licenses and only have parts of the code open.

6.3. Managing the buyers

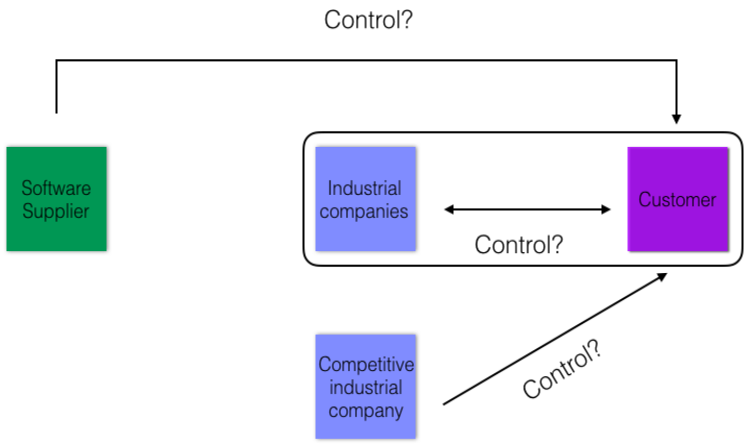

Figure 36 - Model of different interfaces with focus on buyers

Due to the emergence of the internet of things and smart objects embedded with software it allows companies to come much closer to their customers and form closer relationships with them because they are capturing the customers' rich historical and product data which brings up the switching costs for customers significantly (Porter & Heppelmann 2014). The data is then used to bring value to the customer by processing it in the IoT cloud by training the company's algorithms through machine learning and making them smarter with the help of supervised and unsupervised learning (Das, 2016).

The software managers preferred to use a form of *technical control* both as a whole product where the algorithms were embedded into the software in a virtual product and packaged it as a license offer but also on the algorithmic level in order to promote compatibility as well as customizability which turns it into two different value propositions. One where the customer could either choose to implement the whole system where they didn't have control over the customizability themselves but were rather dependent on the company to fix the customizations for them or they could choose the other one where they can call on the algorithms that are safe on the company's server whether it is in the cloud or in internal storage through an application programming interface (API) for using it in their own solutions. This solution could be seen as a very low technological control tool as it turns the algorithms into a black box.

In addition, most of the IP professionals spoke a lot about the importance of having *technical control* around algorithms as a black box because it was seen as an "easy" way for them to control what their customers had access to. First of all, when working with customers as an equipment provider for the manufacturing industry there is no reason to leverage patents on algorithms as they are held completely secret by digital means through an API.

Something that the authors also noted from most of the software managers was the focus on the importance of *market power* due to IT moving so fast. The software managers focused on speed and being first on the market with their solution and have an agile relationship with their customers in where they developed and trained the algorithms more and more to fit the customers' business needs as they become smarter and more efficient. This way, they establish themselves and their product with their algorithms on the market and society will remember them.

A small amount of IP professionals treasured building strong relationships with their customers through their *brand* but also by being close to them which gave them a strong platform to establish their intellectual constructions which in their case were their algorithms as they gathered data to train them (Petrusson, 2004).

The last part that ties both the technical control as well as the market power control together as many of the software managers had a *contract* with their customers that was based on servitization where they provided access to either their system or their algorithms directly. In the contractual agreement many of the software managers had clauses about them improving the algorithms and sending out regular updates to each of their customers in order to get greater efficiency, accuracy and speed in their analysis (Laney, 2011).

High switching costs, compatibility, and relationships is something that is characterizing the future of the industry 4.0. By using technical control on a system level and technical control on an algorithmic level the company gets product differentiation by giving their customers the opportunity to customize their solution which make the compatibility better. At the same time the switching costs become higher as the company's algorithms will learn from the data of their customers.

While being first on the market gives a strong first mover advantage for the company which helps the company gain legitimacy as well as forming new relationships which leads to smarter and better algorithms through data gathered. Lastly, the contractual agreements serve as a way of legitimizing the relationship between the two parties of what is to be expected. Industrial companies are being able to not just sell the hardware product, but they complement it with the software that comes along with it. At the same time when products become smarter it opens up the opportunity for customers to be able to backward integrate on the software side. After conducting interviews, informal meetings at the host company as well as looking into the market the authors believe that an important aspect to think about is how coupled the software product is with the hardware product as it can serve as a mechanism for keeping customers from using competitor's software on the same hardware solution as well as keeping them from backward integration through them creating their own software.

6.4. Managing the suppliers

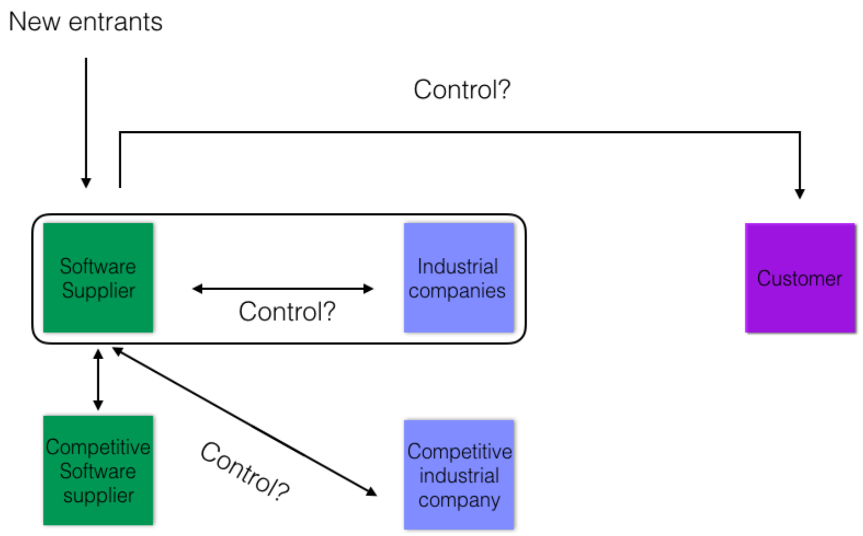

Figure 37 - Model of different interfaces with focus on suppliers

Due to the internet of things, traditional suppliers that were offering physical components to the buyers will be reshaped as of the smart connected products to software solutions. Therefore, powerful new suppliers will be the providers of software and analytics (Porter & Heppelmann, 2015). Software suppliers can now rely on services that can be quite hard to imitate due to them relying very strongly in the knowledge which resides in their human capital (Constantin and Lusch, 1994). When conducting interviews with software managers, the authors noticed that industrial companies are moving to the internet of things and therefore the main focus is not going to be only in the hardware but also in the software. As most of the traditional industrial companies do not have core capabilities in software and algorithms there is a need of having software suppliers to strengthen the value proposition for customers (Kothandaraman and Wilson, 2001). But the same one needs to understand a way of managing them as they otherwise gain too strong bargaining power (Porter & Heppelmann, 2014).

Some software managers and IP professionals mentioned the importance of *contracts* when entering into an agreement with software suppliers. It is crucial that the contract is understood and respected by all parties involved (Haapio, 2006). Some software managers pointed out that their company has a software company as a supplier and the bargaining power the supplier can be strong if the supplier does not consider that the industry which it is selling to is important, the supplier can change to another industry (Porter, 1979). According to one of the software managers interviewed in an industrial company, the *brand* can be used to attract small software suppliers as they could get more from them which means that the small software suppliers care more about having a big customer than keeping the algorithms they create. However, few software managers mentioned that one can also use the *brand* as a way of expressing *market power* in the industrial company's specific domain which could be used to raise the bar for the new entrants in the software domain. In regard to algorithms, they can be applied to almost any context as long as they have the data which makes the bargaining power of software suppliers very strong. Therefore, as mentioned above by having a well-written *contract* between the parties is essential and both parties should also act in good faith. Some IP professionals mentioned the importance of contracts when hiring an external consultant in which the right of the consultant's work during employment is owned by the company as a way to not claim the software code at a later stage and disclose the algorithms that are in the software code to their software company. The authors have noticed during informal meetings with the host company that having a close relationship through agreements with software suppliers based on trust is relevant as it speeds up the process of developing the software as the core capability of an industrial company isn't focused on software development but rather hardware development and therefore it creates value for the customer (Kothandaraman and Wilson, 2001).

The authors noticed that some IP professionals stressed on the fact that *contract* is an effective mechanism and more in this particular case when it comes to joint development. When entering into a joint development agreement it is essential that the parties involved understand the agreement (Haapio, 2006). The internet of things opens up new type of collaborations in which for the first time software companies as well as industrial companies are working together. When conducting interviews with software managers, most of them agreed on the fact that companies cannot develop everything themselves and therefore they need to collaborate. Moreover, few IP professionals mentioned that collaborations are going to benefit both parties. However, they thought it was important that you that you kept track of the background, foreground and who is the one owning the results in order to not miss out on any potential outcomes especially when working in an IT environment.

Apart from contracts some software managers have also mentioned to have a *technical control* by having the data safe on a server in order to not give the suppliers too much as there would be a risk of them forward integrating. This was also confirmed by informal meetings that the authors have had with the host company as it is very difficult to do that if you do not have access to the customers' data. Due to the software being integrated into a product, there is a possibility for software suppliers to forward integrate directly to customers through this as well if they get a hold of third party sensors. What the authors noticed based on the interviews with some software managers was that in order to keep things *secret* they did not have any software suppliers but instead they developed everything in-house.

The last control mechanism that can be applicable by industrial companies when it comes to the relationship with their software supplier is to have a wide *patent* as it grants the industrial companies the right to exclude others from making, selling and distributing the invention (WIPO, 2004). Therefore, software suppliers who are trying to forward integrate onto the end customers get blocked in the specific domain as the industrial company is active in. The majority of the IP professionals and software managers mentioned that patents are a pretty effective control mechanism that gives proprietary control and it can be used as a way of marketing in order to attract software suppliers and create trust and credibility within your customers and investors.

As of the internet of things, industrial companies will face a new type of industry entrants due to products getting more complex by including software which requires a new type of expertise and therefore, these new industry entrants can be software companies that wants to make a business out of it as well (Porter & Heppelmann, 2015). After conducting the interviews, the authors have noticed that the new entrants will be mainly software companies due to them not having the capital requirements or physical assets necessary to replace the industrial companies. Therefore, new entrants will be mentioned as software suppliers.

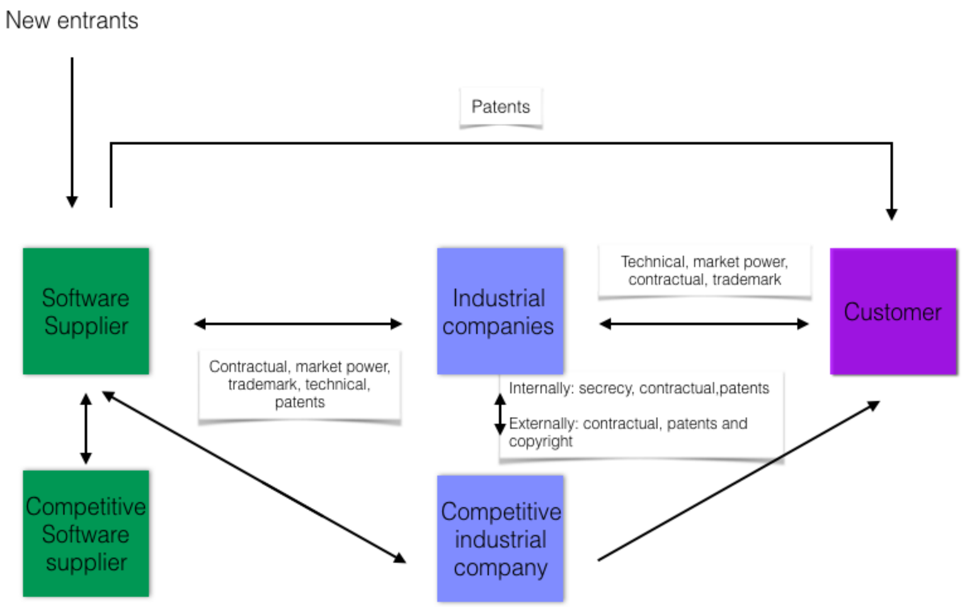

Figure 38 - Model of different interfaces with focus on applicable control mechanisms

7. Conclusion

In the following chapter the result of the research findings and the discussions will be concluded by answering the main research question and the sub-research questions.

The purpose of the study was to explore how software companies as well as industrial companies were applying control mechanisms on their algorithms in order to transfer this knowledge and provide recommendations for how industrial companies in the manufacturing industry could use control mechanisms on algorithms in order to leverage a competitive advantage in industry 4.0. In order to be able to answer the main research question which is "*How can industrial companies in the manufacturing industry use control mechanisms on algorithms in order to leverage their competitive advantage in industry 4.0?"* the two sub-research questions need to be answered.

Sub research question 1 which is focusing on "*What type of control mechanisms are applicable on algorithms and how do they work in practice?"* is answered partly in section 4.5.2 in the theory chapter where the different intellectual building blocks that are used to control knowledge assets are discussed in general as well as how they are applied specifically on algorithms. Based on the literature review made, the study found that the control mechanisms from a theoretical perspective that can be applied on algorithms are patents and copyright in regard to rights-based property, secrecy-based control, technical control and contractual based property. From a patent perspective, algorithms are possible to patent as long as they are tied to a technical function/invention. Otherwise, algorithms are seen as abstract ideas which is not counted as eligible subject matter for patents.

From the perspective of copyright just like patents it does not protect the algorithms per se but if the algorithm is implemented into source code the structure of the source code can be protected and therefore the algorithms are protected. Secrecy can be applied to algorithms as it can include a formula, program, device, method or process. Either a firm can keep it as a secret inside of the company or if the object has a certain economic value and the firm have made reasonable efforts of keeping it a secret it can be turned into a trade secret which means that in some countries litigation can occur if one has stolen a trade secret.

Contractual based property can be applied on algorithms, but it is crucial to understand how the algorithms are defined meaning if they are defined as an instruction, software or a solution. The study found that depending on what type of subject matter algorithms are defined as, the different intellectual building blocks used to protect them differ as contracts are seen as a way of legitimizing a relationship between actors as well as a transaction of knowledge assets between them. If the algorithms are defined as software they are protected by copyright and can then be licensed with the help of software licenses, if the algorithm is defined as a solution with a technical effect it is eligible for patent protection and one can have an exclusive or non-exclusive license for using the invention. However, if the algorithm is defined only as an instruction it becomes hard to transact as it can mainly be defined as a trade secret.

From the perspective of technical control several ways of applying this was identified in the theory. One way of doing this was by obfuscating the code which meant dividing up the logic of the algorithm in the source code thus making it very hard for others to reverse-engineer the algorithms. Another way of having technical control was through the distribution of APIs which is a way of turning an algorithm into a blackbox where one can use its functionality, but one can never see the process of the actual algorithm. Lastly, one could keep the algorithms safe in a digital product and restrict access to it which meant that the whole product instead served as a blackbox.

The second part of sub research question 1 is answered in section 5.1 where IP professionals were interviewed about how the control mechanisms work in practice in regard to algorithms. The authors obtained interesting results from IP professionals based on the control mechanisms as they work differently depending on if you wanted to control algorithms on a conceptual level or on a detailed level. As depicted by the result from IP professionals the majority of them were positive to most of the control mechanisms when it came to their applicability in practice. However, when it came to trademarks and design rights in rights-based property the majority of the IP professionals had no particular thoughts as these were deemed being very unusual building blocks for protecting or controlling algorithms with. The few ones who did, used trademarks indirectly to attract talent from the outside. Patents were according to the IP professionals applicable on algorithms where the majority thought that they should be used for exclusivity while few others thought that they could be used for attracting employees and create trust for different actors. Copyright was very popular with the IP professionals as they believed it could serve as a double protection together with patenting the solution, better regulate control of the algorithms as assets and it was easier to detect.

Secrecy was very popular in practice as it was described as giving companies a broad value and impact which stretched over the other control mechanisms. At the same time, in order for it to be effective the IP professionals stressed that it is important when it came to algorithms to make everyone aware of what algorithms should be regarded as a trade secret. Contractual based property was seen as very positive by the majority of the IP professionals mainly because well-written agreements were important both internally and externally, so people understood what was decided in the terms of the agreements in general when it came to software was moving more and more towards a proactive approach. It was also seen as a strong symbolic mechanism as it tended to drive behavior which means that employees and other associates respected the contracts. IP professionals, however stressed two important aspects which was that in order to contracts to work properly in regard to algorithms one needed to have a good symmetry between managers, engineers and lawyers inside the company. They also pointed out that it was of utmost importance that one had defined the algorithms as either software, instruction or solution as it changed the basis of the contracts.

Technical control was together with secrecy one of the most powerful control mechanisms but at the same time it was much easier to control in practice as one could physically restrict access to the algorithms through a different number of ways. The most notable way of restricting access to algorithms was through APIs in which other actors could access the function of the algorithms but never see the actual process. The second one was to obfuscate the code if infringers would manage to get a hold of the code which meant that they still couldn't understand the logic of the algorithms as they were spread out in the source code. Lastly, some preferred having encryption on the algorithms through different type of portals and passwords.

Sub research question 2 which focuses on "*What type of trends could be seen in controlling algorithms?"* is answered in section 5.2 where software managers from industrial companies as well as software companies were interviewed. By answering this research question the study gathered information on how companies use control mechanisms in practice on their algorithms in order to control them and gain a competitive advantage. The control mechanisms that were mainly used by software managers were rights-based property with the focus on patents and copyright, secrecy, contractual based property, technical control and market power.

The trends that were noticed in algorithms from a patent perspective was that one either patented on a conceptual level which was the solution/technical function, patented on a system level which were different solutions combined or one was using patents on algorithms as a way of attracting new human capital. In regard to copyright it was very much used as many companies preferred to have the algorithms in their source code as they upon implementation tended to change. Managers also liked to own the code infrastructure through copyright as they could leverage it in different open source cooperations with other actors and individuals to gain more value. In terms of secrecy managers worked actively with defining the algorithms as trade secrets either in a trade secret system or in the source code. They also had closed circles of people when developing new algorithms.

Lastly, they thought it was important to treat the knowledge bearers well as they treasured human capital as they thought it was hard to determine what could be seen as generic knowledge as well as knowledge accumulated by the company when it came to the algorithms. The trends for contractual based property were focused on an internal approach which regarded having exit interviews to tell employees what they could and couldn't disclose in regard to algorithms. Together with this one also applied non-disclosure agreements with non-compete clauses in order to keep valuable knowledge from falling into direct competitors' hands. From the perspective of technical control, the software managers were applying a blackbox either on the algorithms themselves through APIs or licensed out the product with algorithms hidden inside. Lastly, they obfuscated their source code which scattered the logic of their algorithms throughout the source code which made it hard for different actors to reverse-engineer them. When it came to market power the managers enjoyed having a first-mover advantage as it built strong relationships with customers thus reducing their bargaining power by making the switching costs high as the algorithms got more efficient with the help of the customers' data. They were also leveraging their reputation and market position in order to attract more employees that kept developing their algorithms thus keeping a competitive advantage over competitors.

The main research question which is *"How can industrial companies in the manufacturing industry use control mechanisms on algorithms in order to leverage their competitive advantage in industry 4.0"* is answered in chapter 6 with the help of the result from the literature review, IP professionals and the software managers. In order to understand how one can apply control mechanisms on algorithms one also had to understand that there were two different levels of an algorithm where different control mechanisms apply. The authors therefore created a framework that depicts an algorithm from a detailed level as well as a conceptual level where patents are applied on a conceptual level as they can only protect the function or solution of an algorithm while contractual based property and market power are stretching between detailed level and conceptual level as contracts can be applied on different type of objects as long as they are clearly defined while market power on algorithms grows the more customers one gets. Lastly, copyright, secrecy and technical control are applied on a detailed level because they are all concerned with controlling the algorithms on a detailed level such as the source code or the instruction. The authors also noticed during the interviews that different control mechanisms were applied in different interfaces. This meant that in order to get a competitive advantage in industry 4.0 in regard to algorithms one needs to know what type of control mechanisms one should apply in the different interfaces one can have.

Therefore, the authors also created a second framework which depicts the relationship between an industrial company and its competitive industrial company, an industrial company and its software suppliers and lastly an industrial company and its customers. Here, the authors are suggesting based on the literature review as well as the result from both the software managers and IP professionals that in the interface between an industrial company and the competitive industrial company one should apply secrecy, contractual control and patents internally. Externally one should apply contractual control, copyright and patents. In the interface between an industrial company and its customers one should apply technical control, market power, contractual control and trademarks. Lastly, in the interface between an industrial company and its software suppliers one should apply contractual control, market power, trademarks, technical control and patents.

In conclusion, the authors have noticed during the study conducted that the prior research have been very nascent which have opened up an opportunity for the authors to make an early contribution into the field by exploring the phenomena through an abductive approach and tried to find the best explanation and add value to further research. The contribution that the authors are making to the field are two models where the first one is focused on what type of control mechanisms one can apply depending on what level one wants to control the algorithms on whether it is on a conceptual or a detailed level. The second contribution that the authors are making is the model around the different interfaces that an industrial company can have in the industrial sector. Here, the authors are recommending what type of control mechanisms that an industrial company can use depending on what type of interface the company is dealing with.

8. Further research

In the chapter of further research, the authors will give suggestions for further research based on the research findings and discussions.

The study was made in an abductive approach in order to investigate how industrial companies could apply control mechanisms on algorithms in order to gain a competitive advantage in the industry 4.0. The reason that the authors chose an abductive approach was due to industrial companies being in the phase of converging into industry 4.0 where their business won't anymore just be focused on hardware but also software which means that the knowledge about the control of algorithms is rather limited.

Therefore, the authors decided to not only focus on industrial companies but also on software companies to get hands-on information on what the trends are in applying control mechanisms on algorithms. For further research that could be applied the authors feel that it could be interesting to do a similar study when the industrial companies have caught up in the development of algorithms in software where instead the focus will be on interviewing only software managers for industrial companies in order to raise the validity and the quality of the research as it could lead to an even better understanding in how to apply control mechanisms to algorithms in an industrial setting. Two interesting ways of doing this would be to either have a longitudinal study when you focus on a specific company and how they are applying control mechanisms on their algorithms or by interviewing a larger number of companies.

During the interviews with both IP professionals and the different software managers, the authors noticed that the data was also seen as an equally important asset when it came to data analytics in industry 4.0. However, due to the time constraints and the scope of the study the authors had to narrow it down to algorithms in order to not go too wide. This also opens up an opportunity for further research where one could focus on investigating the ownership and access of data in an industrial internet of things setting which could lead to a deeper understanding between the correlation of data and algorithms.

With this being said, the authors believe that in order to be competitive in the future, the industrial companies need to understand how to control the data but also how to control the control algorithms and how that correlation between them will be the future value creation in industry 4.0.

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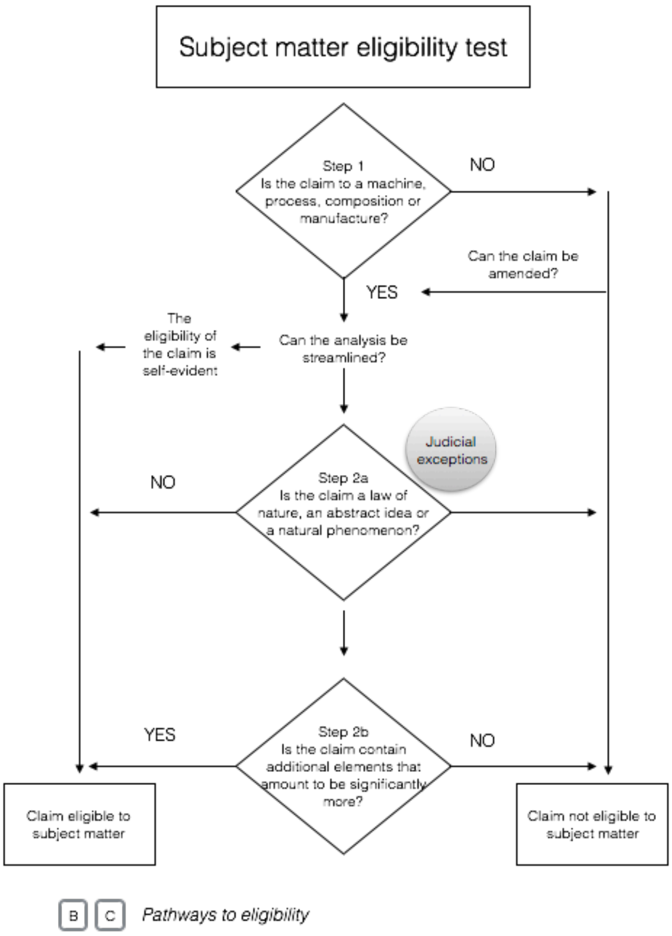
11. Appendix

11.1. Figures

11.1.1. PTO guidance on subject-matter eligibility

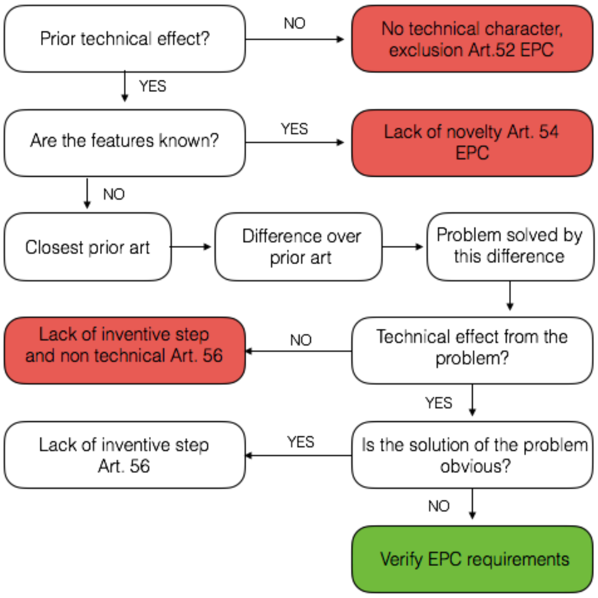
The following image explains the pathways to ensure that the subject matter is eligible for patent protection. In the case of an algorithm, it falls down on being an abstract idea and therefore in order to be qualified as eligible subject matter it needs to have additional elements which needs to amount to significantly more. Otherwise, the algorithm will not be patentable (USPTO).



PTO Guidance Figure on Subject-Matter Eligibility

11.1.2. EPO steps for determining patentability

The image below shows the steps for determining patentability and in the case of an algorithm it needs to have a technical effect and be in compliance with the requirement of being novelty and having an inventive step in order for the patent to be granted.



(Digital Single Market, 2016)

11.1.3. Summary of trends in controlling algorithms

The image below shows a summary of the trends gathered from the software managers around the control of algorithms.

11.2. IP professionals interviews

Below is the list of the IP professionals interviewed in which the authors are stating what type of position they have in order to the reader to get a perception of the interviewees.

IP professionals	**Role**
A	IP Senior manager
B	IP Director
C	Global Head of IP strategy
D	Head of IP in algorithms
E	Patent attorney
F	Director of Global IP Management
G	IP Director
H	Commercial IP Manager
I	Patent attorney

11.3. Software managers interviews

Below is the list of the software managers interviewed in which the authors are stating what type of position they have in order to the reader to get a perception of the interviewees.

Software managers	**Role**
A	Software Development Manager
B	Chief Technology Officer
C	Software Manager
D	Line Manager
E	Director of Technology Department
F	Product Software Manager
G	Manager of Software Systems

H	Line Manager
I	Line Manager

11.4. IP professionals interview template

Controlling innovations

What role do you think that algorithms will have in the future of value creation?

What type of trends do you see when it comes to strategy in patenting software algorithms?
- How do you think companies will control their software algorithms in the future?

What do you think are the underlying factors for people being able to reverse-engineer an algorithm?

How relevant is it to have an exit interview with the employee? Does this really work in practice?

What type of precautions do companies take when they are trying to keep their knowledge secret?
- Based on your experience, which type of precaution works best?

What are the most well-known cases when trade secrets have been disclosed in relation to software algorithms?

When it comes to contractual control, how effective are contracts in practice in relation to protecting the knowledge behind software algorithms?

What is the best control strategy to use in collaborations when it comes to software algorithms?
- From a practical point of view, which type of role does collaboration play when it comes to controlling software algorithms?
- What challenges can we see in having collaborations in software development in the future?

Three arena model

From your point of view, how does patent law and copyright law in general protect software algorithms? Is it this effective in practice?
- What are the biggest factors for a software patent to not be granted?

Is there a way of patenting an algorithm without disclosing the actual formula for the algorithm? How does that work?

In your experience, how does patents in regard to algorithms hold up in court?

- What are the most well-known court cases in relation to patent algorithms?

In what way do you see companies using their patented algorithms?

If companies are not patenting their software, which other ways of control are companies using and how well do they work?

- In your experience, what would you say would be the best strategy for companies when it comes to controlling their algorithms both externally and internally?

11.5. Software managers interview template

Controlling innovations

Where and how are you storing your algorithms?

Do you develop your whole software yourselves or only part of it?

- Do you have any collaborations? If so, how do they look like?
- Do you tweak your algorithms depending on the customers and if so, how does that work look like?

Do you provide different methods to other companies so that they can use your algorithms? If so, under what circumstances and what type of methods?

- How do you distribute your algorithms to customers?

How do you keep staying competitive in your line of business?

In general, what do you think is the reason why developers leave companies?

- After the employees leave the company, are you taking an exit interview?

In your experience, do you feel that it is worth it to patent the algorithms? If not, why?

Knowledge transfer

How does a general project look like when you are creating a new algorithm/function?

Have you ever encountered a situation in where you've had a knowledge spillover? If so, what type of consequences have it had for your company?

- When an employee is getting retired, how does that person transfer the knowledge?

How can one determine if a competitor is using the same type algorithm in their software as you are using in your software?

- What would you say determines if an algorithm is easy to reverse-engineer?

What do you think attract developers to switch company?