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MASTER THESIS

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I hereby declare that this master thesis as a final part of the master study in business administration awarded with the Master of Science degree is my own work. I have correctly considered work of fellow researchers. I followed the University of Twente guidance on good academic conduct.

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PREFACE

This master thesis was developed within the Master of Science programme in business administration with specialisation in purchasing and supply management at the University of Twente in Enschede (the Netherlands) during the period of April 2017 and November 2017.

My interest in artificial intelligence (AI) awakened during the lectures of the master classes regarding Industry 4.0 and digitalisation of the purchasing function. I took into account that many companies I was previously associated with did not exploit the possibilities of AI application sufficiently. Furthermore, successes in automating purchasing activities, which occurred lately, lead to a promising enhancement for the purchasing function. The potential of AI in a forthcoming digitalisation has also been considered in various scientific papers. AI in particular is acknowledged as one of the technological drivers that could transform the future. Research on AI in the field of purchasing is scarce, however, interest is rising, which anticipates relevance. Therefore, the aim of this research is to fill the gap by providing insights for academics as well as practitioners regarding the prospects of automising mechanism design based negotiations. This research should furthermore entice academics to profoundly explore the field of AI in the purchasing function.

The master thesis provided a great opportunity to explore a research field with prospect potential. Consequently, I faced challenges, which revealed opportunities to develop my skills and provided me with a good preparation of my future career. During the time of executing my thesis, I had great support from my supervisors of the business case company as well as the University of Twente. Therefore, I would like in particular express my gratitude to Prof. Dr. habil. Holger Schiele and Ines Schulze-Horn for their great support during that time. Furthermore, I would like to thank the participants of the World Café for their keen contribution.

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LIST OF ABBREVIATIONS

AGI	artificial general intelligence
AI	artificial intelligence
BATNA	best alternative to no agreement
B2B	business-to-business
E-Procurement	electronic procurement
ERP	enterprise resource planning
GNR	genetic nanotechnology robotics
Incoterms	International commercial terms
IR	information retrieval
IT	information technology
LAA	least acceptable agreement
MDO	most desired outcome
OEM	original equipment manufacturer
P2P	purchase-to-pay
PSM	purchasing and supply management
RFQ	request for quotation

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1. Introduction: The implementation of artificial intelligence in order to facilitate mechanism design-based negotiations

For companies of manufacturing and service industries, the purchasing function has grown in importance over the last decades.[1] Due to purchasing's direct impact on the bottom line, the function is a key source for achieving competitive advantage.[2] The high expectations for digitalisation is forecasting extensive potential.[3] The purchasing function as a key interface of the company with the supply network is in particular acknowledged as a core initiator for digitalisation.[4] The purchasing function of the future, which is also known as procurement 4.0, is driven by different technological trends. A promising driver of the digitalisation is artificial intelligence (AI).[5] The potential of AI in the purchasing function seems to be a relevant research field. Due to complex processes in the purchasing function, an appropriate automatisaton target needs to be chosen.

The purchasing process spans organisational boundaries – in this context, negotiations are central to reach consensus between supply chain partners while, simultaneously, meeting internal cost and quality targets.[6] Given the importance of business-to-business (B2B) negotiations, previous research has focused on various influencing factors in the negotiation process as well as their outcomes. However, literature concentrating on how negotiations are executed remains scarce.[7] Recent studies have taken up on this gap by addressing buying organisations' application of mechanism design theory in negotiations.[8]

Mechanism design theory draws on the basic premises of game theory and stipulates that, in the setting of strategic interactions between rational players, the development and implementation of economic incentives – so-called mechanisms – can lead to the achievement of desired objectives.[9] In the realm of purchasing and supply management (PSM), industrial purchasers use this idea to develop negotiation rules that provide suppliers with incentives to reduce their quotations.[10]

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[1] See Spina, Caniato, Luzzini, & Ronchi (2013), p. 1202.
[2] See Wynstra (2016), p. 201.
[3] See Oks, Fritzsche, & Lehmann (2016a), p. 1.
[4] See Glas & Kleemann (2016), p. 56.
[5] See Wahlster (2017), p. 10.
[6] See Shin & Pak (2016), p. 197.
[7] See Geiger (2017), p. 91.
[8] See Schulze-Horn (2017a), p. 34; Schulze-Horn (2017b), p. 31.
[9] See Nisan & Ronen (1999), p. 129.
[10] See Berz (2016), p. 8.

Negotiating with the help of mechanism design theory takes root in many buying organisations. A study conducted by Schulze-Horn et al. (2017b) shows that under conditions of free market forces, this negotiation approach appears to be very effective.[11] At the same time, however, the development of negotiation rules requires expert knowledge in game theory and mechanism design theory. The negotiation design usually consists of several interdependent phases, each one combining various negotiation elements, such as auctions, supplier rankings, and information feedbacks.[12] Consequently, the development of negotiation designs is a complex task. However, purchasers are usually not specialised in the study of mechanism design theory leading to a problem of applying mechanism design-based negotiations. Another difficulty is that individuals' rational decision-making is limited by their cognitive abilities, available information to solve the decision problem, and the finite amount of time to reach a decision.[13] This bounded rationality results in a limited search process, whereas individuals tend to develop satisficing instead of optimising solutions.[14] According to Simon (1955), "actual human rationality-striving can at best be an extremely crude and simplified approximation to the kind of global rationality that is implied, for example, by game-theoretic models".[15] To confront the problem of bounded rationality, previous research has suggested enhancing human decision-making performance with the help of AI.[16] Therefore, it is critical to understand how mechanism design-based negotiations can be supported by the means of AI.

AI is capable of solving issues in complex settings.[17] Current developments of AI show that the potential for optimising processes in companies by the means of AI is increasing.[18] The term AI was coined over 60 years ago.[19] Recent success in AI and the potential to optimise businesses trigger interest also for business practitioners. In particular the eras of digitalisation and industry 4.0 have initiated companies to acknowledge AI as a potential solution to gain competitive advantage.[20] Hereby, AI techniques such as machine learning, vision, robotics, speech recognition, and expert systems support the implementation of AI.[21]

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[11] See Schulze-Horn (2017b), p. 2.
[12] See Schulze-Horn (2017a), p. 33.
[13] See Simon (1955), p. 36.
[14] See Gigerenzer & Selten (2002), p. 37-39.
[15] Simon (1955), p. 101.
[16] See Klatzky (1970), p. 141.
[17] See Goertzel (2006a), p. 452.
[18] See Schildt (2017), p. 23.
[19] See Pan (2016), p. 410.
[20] See Kleemann & Glas (2017), p. 14.
[21] See Mills (2015), p. 3.

Machine learning could thereby for instance facilitate automated mechanism design-based negotiations. However, not all companies have acknowledged the relevance of machine learning.[22] The study of Balcan et al. (2005) states also in particular the potential of machine learning in mechanism designs.[23] Hence, this study is concerned with the following research question:

Could the application of AI facilitate the application of mechanism design theory in negotiations?

To show potential on implementing AI in mechanism design-based negotiations, the following sections provide a demonstration why AI is an interesting topic for the purchasing function as well as for mechanism design-based negotiations. Moreover, a business case study was executed at a German automotive OEM to identify potential AI applications and support the evidence that the integration of AI could be beneficial for mechanism design-based negotiations.

To be able to answer the research question and sub-questions, the remainder of this study is structured as follows:

The following chapter provides theoretical insights on the relevance of AI for the purchasing function. In the second section, mechanism design theory is introduced to understand why this research works on a relevant topic. In the third section, the research topic of AI is studied to understand how AI could in fact be integrated in mechanism design-based negotiations. Therefore, the topic of AI is introduced to provide some basic knowledge on that research field. To be able to answer the research question, a methodology is established that provides an approach on how to answer it. Afterwards, the results of the research are analysed to get further insights. To trigger idea development, a discussion chapter is provided on how to be capable of achieving certain milestones. For the discussion, a roadmap is drawn to plan the implementation of the analysed AI solution of the results. To understand the purpose of the study, the relevance for theory and practise are reviewed. Certain limitations were encountered, which are reported to localise potential issues and address them. Finally, a conclusion is drawn, which gives an answer to the research question.

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[22] See Wang et al. (2017), p. 3.
[23] See Balcan, Blum, Hartline, & Mansour (2005), p. 605

2. Towards Procurement 4.0: Achieving competitive advantage through the transformation of the procurement function through artificial intelligence

2.1. The necessity of procurement transformation in times of upheaval triggered by digitalisation

2.1.1. The transformation towards Procurement 4.0 in times of radical changes

While the impact of digitalisation shows an imprint on individuals in society, the changes in the industrial world have been moderate until now.[24] However, recent developments and technological advancements predict radical changes.[25] Auricchio and Kaganer (2015) defined digitalisation "as the diffusion and assimilation of digital technologies into all aspects of daily life."[26] The impact that digitalisation might cause are not certain, nonetheless, it is essential for companies to prepare proactively to stay competitive.[27] An indicator for radical changes is the pace at which technological innovations occur as well as time-to-market of the technological achievements.[28] In case a company does not adapt, there is a danger that the competitiveness could decrease due to inefficiencies in coping with future market needs.[29]

If several companies boast their businesses with new technological innovations, and other stakes are set off to gain momentum in implementing new technologies, companies that show resistance bear the risk of falling short.[30] The digitalisation era triggered various concepts to upraise where the borders are often considered as blurry. Batran et al. (2017) mentioned that the key terms in the field of digital transformation concerning Industry 4.0 were "smart factories", "3D printing", "sensors", "big data", "robotics", "cyber-physical systems" and "Internet of things", which attempt to define the transformation of businesses.[31] According to Glas and Kleemann (2016), the disruptive competitive advantage has set the scene for Industry 4.0.[32] The term Industry 4.0 was recently coined in Germany and is still relatively unknown. According to Schmidt et al. (2015) "Industry 4.0 is the

[24] See Zuehlke (2010), p. 129.
[25] See Albert, Wehinger, & Fraterman (2017), p. 51.
[26] Auricchio & Kaganer (2015), p. 32.
[27] See Oks, Fritzsche, & Lehmann (2016b), p. 1.
[28] See Batran, Erben, Schulz, & Sperl (2017), p. 17.
[29] See Feyerlein (2016), p. 57.
[30] See Tongur & Engwall (2014), p. 533.
[31] Batran et al. (2017), p. 15.
[32] See Glas & Kleemann (2016), p. 55.

superposition of several technological developments that embraces both products and processes. Industry 4.0 is related to the so-called cyber physical systems."[33] In addition, other scholars such as Sendler (2013) describe Industry 4.0 rather broadly by focusing on the linkage between physical and network services and accumulation of new technologies.[34] A survey of IfD Allensbach (a public opinion research institute in Germany) in 2015 showed that only 18% of the people in Germany were aware of the term Industry 4.0, whereas only a very small percentage of the people had advanced knowledge.[35] The opinion about the importance of Industry 4.0 is divided among experts, but the potential of the procurement function as an initiator in Industry 4.0 was recognised in the study of Glas and Kleemann (2016).[36]

Research on Procurement 4.0 showed potential in idea generation for Industry 4.0, whereas it could function as an impulse to stimulate Industry 4.0. High connectivity is vital to facilitate Industry 4.0.[37] Comparing to other functions, the procurement function is in particular suited as an initiator due to its connection to the outside world. Thereby, the procurement function would be capable to enhance external and internal processes through advanced connectivity.[38] The strategic relevance and importance of the purchasing function would increase if Procurement 4.0 establishes, whereas the traditional procurement function was overlooked many times.[39] Procurement 4.0 is only in the infancy, which is seen in the already vague terminology of the overarching topic Industry 4.0. In addition, the contribution in literature has been little so far.[40] According to Glas and Kleemann (2016): "Procurement 4.0 stands for the ultimate digitalisation and automation of the function within its company and supplier environment, but it is not limited to the use of new or enhanced technology systems."[41] The transformation of the procurement function would affect strategic and operational activities, and, influence the relationship between supplier and buyer immensely. Therefore, procurement functions with a traditional approach should already reconsider current processes and create a situation that allows digitalisation.

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[33] Schmidt et al. (2015), p. 17.
[34] See Sendler (2013), p. 8.
[35] See Glas & Kleemann (2016), p. 55.
[36] See Glas & Kleemann (2016), p. 61.
[37] See Lee, Bagheri, & Kao (2015), p. 19.
[38] See Johnson, Klassen, Leenders, & Fearon (2002), p. 77.
[39] See Bilali & Bwisa (2015), p. 669.
[40] See Mogre, Lindgreen, & Hingley (2017), p. 255.
[41] Glas & Kleemann (2016), p. 59.

The digitalisation of the procurement function provides considerable potential, but the execution might be difficult. A major issue is the data quality, which is a stringent requirement to execute a transformation towards digitalisation.[42] The digitalisation of procurement results in challenges. One challenge that has been recognised in the automotive industry is the transformation of the product market. As an automotive OEM, the case company has already been substantially affected by the digitalisation regarding its product line. The focus has been shifted from mechanical-oriented to autonomous cars with the newest technologies such as self-driving and sustainable electric motors.[43] Furthermore, the automotive industry could be reshaped largely by new concepts such as the trend of sharing economy as seen in the car-sharing concepts like Uber.[44] Companies such as Google or Tesla have changed the perception of the car,[45] whereas current automotive OEMs might become suppliers of companies such as Google in the future. To cope with the future and its uncertainty, companies and, especially, the procurement function should proactively focus on digital transformation.[46]

2.1.2. The potential of artificial intelligence in the forthcoming procurement revolution

The digitalisation as a concurrence of the real and virtual world through the integration of digital devices and processes could have extensive impact on the procurement function as already recognised in chapter 2.1.1.[47] The digitalisation umbrellas different topics and AI could be regarded as a stimulator.[48] AI as a subsection of computer sciences explores potential in computer-based automation.[49] Thereby, AI replicates human-like intelligence by means of machines and software.[50]

Predictions were made by scholars about a forthcoming AI revolution, whether these predictions are reliable and come true is uncertain.[51] The forthcoming AI revolution could affect the industry, whereas different future scenarios are possible. Albert et al. (2017) predict that the implementation of AI in companies could trigger four different projections:

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[42] See Hazen, Boone, Ezell, & Jones-Farmer (2014), p. 72.
[43] See Batran et al. (2017), p. 17.
[44] See Hamari, Sjöklint, & Ukkonen (2016), p. 2050.
[45] See Fraterman & Schnake (2017), p. 7.
[46] See Batran et al. (2017), p. 123.
[47] See Kagermann (2015), p. 23.
[48] See Paschek, Luminosu, & Draghici (2017), p. 1.
[49] See Albert et al. (2017), p. 57.
[50] See Zang, Zhang, Di, & Zhu (2015), p. 144.
[51] See Makridakis (2017), p. 47.

1. AI as a pioneer (high internal but a low external AI distribution), 2. AI in chains (low internal and low external AI distribution), 3. AI as a manager (high internal and high external AI distribution), 4. AI resistance (high external but low internal AI distribution).[52] These different scenarios indicate that AI has possible positive and negative impacts on the business world. Regarding the positive effects, the manufacturing industry could cope to a greater degree with various external factors such as the growing complexity in product lines and processes.[53] On the other hand, the development of AI-based programmes took a long time especially considering the slow progress seen in the history of AI in (see chapter 4), which highlights the challenges ahead for the realisation to pursue Industry 4.0.[54] It is noted that a long maturity period would lead to the assumption that it cannot be entitled revolution. However, high potential of AI for the procurement transformation concluded that AI is a relevant pillar of the digitalisation. Therefore, this study focuses on seeking potential AI solutions for the purchasing function. Other relevant topics for realising digitalisation and transformation are ignored to manage the scope of this study.

2.2. The category sourcing cycle reveals various application possibilities of artificial intelligence in purchasing

2.2.1. An introduction to the category sourcing cycle to uncover automation potential in the in purchasing function

The category sourcing cycle is part of the purchasing year cycle and illustrates activities realised on a category level. The purchasing year cycle embodies the category sourcing cycle as well as a purchasing department cycle, which are impacted by the supply market and the firm as seen in the paper of Schiele (in press).[55] The purchasing department cycle divides the activities by department, instead of by category level like in the category sourcing cycle. Overall, the purchasing year cycle reveals the strategy of the purchasing function. Hereby, the category sourcing cycle is reviewed to uncover possible AI-applications. The category sourcing cycle is in particular a well fit because it gives a simplified representation on the

[52] See Albert et al. (2017), p. 58.
[53] See Pan (2016), p. 411-412.
[54] See Pan (2016), p. 410.
[55] See Schiele (in press), p. 13.

sourcing cycle.[56] Furthermore, the advantage is seized to explore a group of products in a category instead of a single product.[57]

The category sourcing cycle contains six steps as seen in figure 1: 1. Demand planning, 2. Category strategy, 3. Supplier selection, 4. Contracting, 5. Executing, and 6. Evaluating.[58]

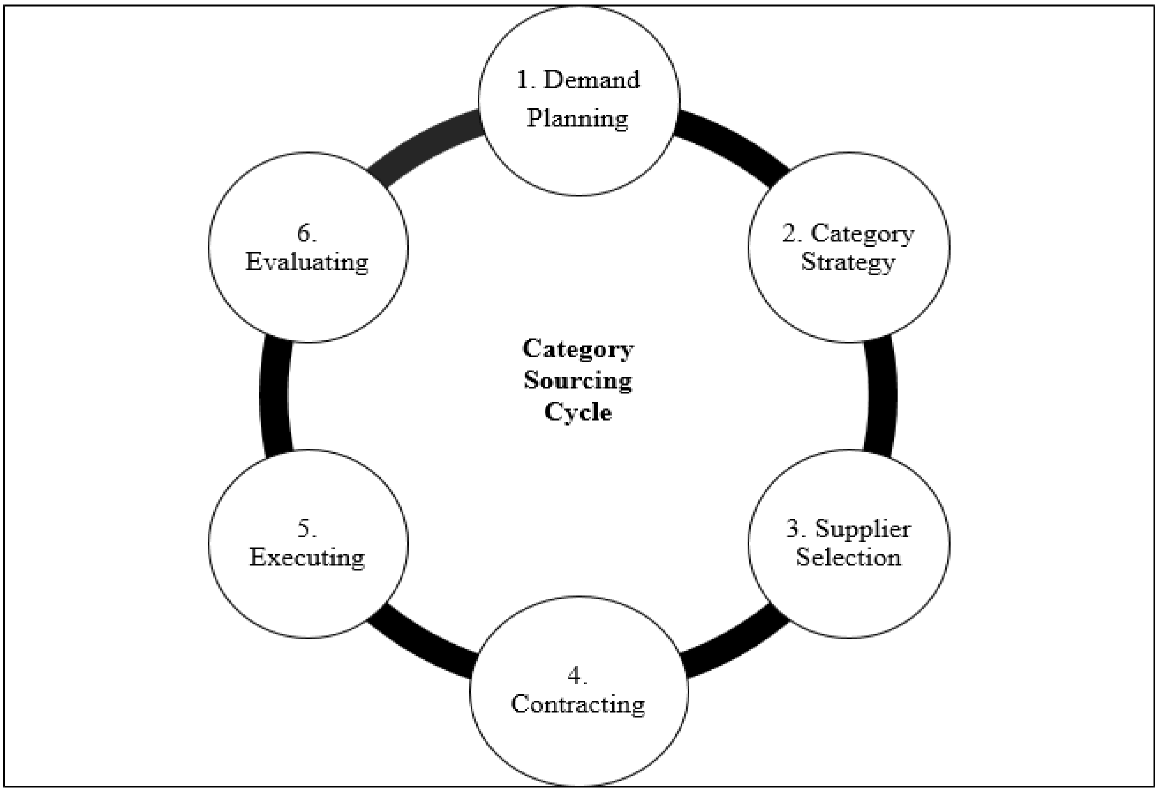

Figure 1. Category Sourcing Cycle
Source: based on Schiele (in press), p. 13

2.2.2. Demand identification and planning: Advancing forecasts through artificial intelligence methods

Demand identification and planning is a critical activity at the beginning of the purchasing year. The demand planning displays the forecasted sales and the required supplies for meeting the demanded sales volume. Forecasting supply to meet demand is difficult due to an uncertain environment.[59] Companies tend to overestimate demands what leads to a bullwhip effect, and, thereby, increasing inventory costs.[60] A bullwhip effect is a mismatch

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[56] See Sandholm et al. (2006), p. 55-56.
[57] See Hesping (2017), p. 17.
[58] See Schiele (in press), p. 13.
[59] See Fisher, Hammond, Obermeyer, & Raman (1994), p. 83.
[60] See H. Lee, Padmanabhan, & Whang (1997), p. 548.

between supply and demand resulting in an increase further upstream and adding up costs.[61] The risk of underestimating the demand also carries high opportunity costs.[62] To decrease the risk of a bullwhip effect, a demand planning tool such as a spend cube should be employed. The spend cube displays relevant data about the buying firm, the demanded products, and the selected supplier.[63] Gaining the right data has become critical for the purchasing function to make use of the spend cube for example.[64] Therefore, a supportive system for enterprise resource planning (ERP) needs to be in place to ensure an adequate outcome.[65] In particular, the automotive industry has gained experience in ERP systems and reached a "best practise" status.[66] ERP systems rely on past oriented data what could therefore lead to a sub-optimal outcome.[67] A sales forecast is implemented to counterbalance the demand planning. This solution is not ideal because it is also build up on historic data. Thereby, the focus should not solely be based on procurement spending but also include data on the external environment.[68]

The role of big data analytics could improve the planning phase by gathering great amounts of data and attach a meaning to it.[69] Thereby, relevant external data despite sales forecasts could advance demand planning even more.[70] AI techniques are integrated to gather and structure big data, as well as to provide critical insights on data.[71] According to Chen et al. (2012), big data analytics is known as "the data sets and analytical techniques in applications that are so large and complex that they require advanced and unique data storage, management, analysis, and visualisation technologies."[72] Thereby, the field of AI and big data analytics are closely related. AI could provide a better decision-making on required supplies as well as the right supplier identification by providing knowledge from big data. Furthermore, machine learning could be employed to provide improved forecasts according to Carbonneau et al. (2008).[73] Machine learning is one of the major pillars of AI and will be explained thoroughly in chapter 4. Dutta and Bose (2014) introduced a business case

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[61] See Udenio, Vatamidou, Fransoo, & Dellaert (2017), p. 980.
[62] See Frederick, Novemsky, Wang, Dhar, & Nowlis (2009), p. 554.
[63] See Schiele (in press), p. 15.
[64] See Jääskeläinen & Hirn (2016), p. 128.
[65] See Schiele (in press), p. 15.
[66] See Elragal (2014), p. 245.
[67] See Schiele (in press), p. 15.
[68] See Jääskeläinen & Hirn (2016), p. 128; Marakas (2003), p. 528.
[69] See Dutta & Bose (2015), p. 293.
[70] See Jääskeläinen & Hirn (2016), p. 128.
[71] See O'Leary (2013), p. 96.
[72] H. Chen, Chiang, & Storey (2012), p. 1165.
[73] See Carbonneau, Laframboise, & Vahidov (2008), p. 1153.

example of a company called Ramco Cements Limited, which implemented an ERP system "beyond".[74] The switch from a regular ERP to an ERP system based on big data analytics showed immense success at Ramco Cements Limited.[75] This business case shows that AI-based solutions represent opportunities to reap benefits.

2.2.3. Category strategy: Artificial intelligence as an assistance for strategic decision-making

Category strategy provides the strategy and corporate budget plan for each sourcing category.[76] Ghobadian et al. (2016) stated that sourcing is one of the major components in purchasing management.[77] In a (category) sourcing strategy, different aspects of the strategy should be illuminated to seek competitive advantage.[78] According to Arnold (1997), the following aspects should be considered[79]: 1. Value creation model (make or buy decision), 2. Sourcing object (material composition, assembled so on), 3. Supply chain model (just in sequence, on stock and so on), 4. Amount suppliers (single or multiple sourcing), 5. Locational concept (local, international or global), 6. Pooling concept (economies of scale), 7. Lever selection (different tactical moves to meet project aim). In particular, the complex environment of automotive OEMs could benefit from an approach that illuminates the sourcing strategy per category.[80]

The category sourcing strategy consists of many time-consuming aspects to consider. Therefore, optimising the category sourcing strategy could save time and enable the purchasing function to take better decisions. Hereby, a support in decision-making would be useful, because various strategic decisions need to be taken in an environment with incomplete information.[81] The strategic decisions would be advanced due to the AI solution, which provides the user with intelligent insights on the data.[82]

[74] See Dutta & Bose (2015), p. 294.
[75] See Dutta & Bose (2015), p. 304.
[76] See Schiele (in press), p. 15.
[77] See Ghobadian, Stainer, Liu, & Kiss (2016), p. 105.
[78] See Moreira & de Carvalho (2015), p. 221.
[79] See Arnold (1997), p. 93.
[80] See Moreira & de Carvalho (2015), p. 221.
[81] See Laursen (2016), p. 162.
[82] See Shim et al. (2002), p. 113.

2.2.4. Supplier identification and selection: The automation of identifying supplier characteristics

Supplier identification and selection displays the aim of selecting the best possible supplier. Hereby, purchasers release request for quotations (RFQ) to the potential suppliers.[83] However, first the potential suppliers need to be identified.

In the business case company, efforts are made to simplify the supplier identification and selection process. In case of non-critical products in which only the price influences the decision of the supplier, the process could be simplified by integrating a chatterbot in the company that has the capability to identify possible suppliers with the prices for the required product via the internet and database. In a paper of Hofmann et al. (2017), the identification of supplier characteristics and critical path in logistics chains are considered as activities to automate with AI methods.[84] Even though the focuses on logistics chains, insights for the purchasing function can be gained. Hereby, it is acknowledged that data mining as a complementary field of AI facilitates the possibility to conduct supplier identification analysis. Furthermore, an AI solution for supplier selection was researched in a paper of Nwankwo and Aiyeku (2015), revealing low acceptance to integrate such an AI solution in the purchasing function.[85] Therefore, certain actions such as training or information sessions should be in place to decrease the fear of AI.

2.2.5. Negotiation and contracting: The potential of artificial intelligence in negotiation designs and contract analysis

Negotiation and contracting are the next steps posterior to supplier identification and the selection of a supplier shortlist.[86] Negotiations could influence a firm’s profitability by increasing savings.[87] In the supplier selection a shortlist of suppliers has already been determined showing the suppliers that are able to participate in the negotiation. In the context of this paper, the term negotiation is regarded as a negotiation process, which include mechanisms to reach the best outcome for the negotiation. Mechanisms such as different types of auctions are applied to gain an optimal outcome.[88] The buyer or buying firm desires

[83] See Schiele (in press), p. 16.
[84] See Hofmann, Neukart, & Bäck (2017), p. 13.
[85] See Nwankwo & Aiyeku (2015), p. 18.
[86] See Schiele (in press), p. 17.
[87] See Martínez-de-Albéniz & Simchi-Levi (2013), p. 397.
[88] See Herweg & Schmidt (2017), p. 647.

to achieve the best deal and increase savings. However, in negotiations information about the market are imperfect and the moves of the other party are based upon estimations. To have a negotiation strategy in place, the buyer needs to determine its: LAA (least acceptable agreement), MDO (most desired outcome), and its BATNA (best alternative to no agreement).[89] This negotiation strategy will set the construct for the negotiation design to a negotiated agreement.

Creating a negotiation design with suitable mechanisms is a laborious process. Therefore, an automation with AI-applications might create value due to more ideal negotiation designs. Furthermore, certain mechanisms in the negotiation process show automation potential. For instance, (online) programmes are often applied to execute auctions, which has become one of the key trading mechanisms in e-commerce.[90] However, integrating smart systems based on AI-applications may lead to more desirable negotiation outcomes. Therefore, various scholars such as Cao et al. (2015), Idrus et al. (2017), Jonker et al. (2017), Zhang and Liu (2016) have recognised increasing interest in the field of automated negotiation systems as well as research in linking AI to negotiation systems.[91] Implementing an intelligent agent in negotiations would lead to labour savings and rational decision-making.[92] The goal is to build an intelligent agent that is able to develop the most suitable design for individual negotiations by using different mechanisms. Thereby, it is critical for the intelligent agent to learn from past negotiations to adapt its strategy by analysing responding behaviours according to Jonker et al. (2017).[93] Negotiation processes provide prospectives for AI-applications, therefore, this topic will be further addressed in this study (see chapter 4).

The phase of contracting becomes relevant as soon as a supplier “wins” a negotiation and both parties agree to start/continue business with each other. To start business with each other, a legally binding agreement in form of a contract is set up. A contract includes terms and conditions often in form of Incoterms.[94] Incoterms stand for International COmercial TERMs and were released to minimise the interpretation problem for commercial transactions. [95]

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[89] See Schiele (in press), p. 17.
[90] See Cao, Luo, Luo, & Dai (2015), p. 1.
[91] See Cao et al. (2015), p. 1; Idrus, Mahmoud, Ahmad, Yahya, & Husen (2017), p. 18; Jonker et al. (2017), p. 5070; Zhang & Liu (2016), p. 172.
[92] See Zhang & Liu (2016), p. 172.
[93] See Jonker et al. (2017), p. 5071.
[94] See Schiele (in press), p. 18.
[95] See Bergami (2013), p. 34.

Most contracts have similarities such as applying of Incoterms or other phrasings. Assessing contracts is an activity that takes up time and money. Due to the similarities of contracts, the idea occurs to automatise this activity to increase the efficiency of the company. An AI solution could analyse contracts and detect key facts such as incoterms, contract type, contract period, and so on. Thereby, the pattern recognition method might be a suitable AI-application to automatise contract analysis. According to Nagy (2016): "image-processing aspects of document processing consist of scanning the hardcopy document into a digital image, and converting the image into a symbolic representation that reflects some of its content and appearance".[96] However, Nagy (2016) also recognised that little is known about the actual use of document (contract) assessment systems in companies due to a scarce motivation to publish ideas.[97]

2.2.6. Executing: Improving e-procurement systems by intelligently showing information through the integration of artificial intelligence

Executing in the category sourcing cycle defines the activity of placing an order, which is often titled as purchase-to-pay process (P2P process).[98] The P2P process results into considerable administrative costs for what reason many companies have implemented electronic procurement (e-procurement) systems. A study of Zunk et al. (2014) revealed that e-procurement systems are widely implemented especially in the automotive industry. [99] E-procurement has been one of the drivers that changed the reputation of a very traditional function at that time.[100] An e-procurement system offers potential beyond optimising the executing phase by providing platforms of e-sourcing as well (or P2P process).[101] To make the usage of an e-procurement system easier, the system needs to transform to a simple and user-friendly programme. Hereby, AI could support the e-procurement system by individualising the user-face of the system by considering the user's interaction behaviour on the e-procurement system. An easy-to-use and easy-to-learn system would improve the user-experience and strengthen the desire to use the system.[102] AI could simplify complex

[96] Nagy (2016), p.107
[97] See Nagy (2016), p. 107.
[98] See Schiele (in press), p. 18.
[99] See Zunk, Marchner, Uitz, Lerch, & Schiele (2014), p. 19.
[100] See Presutti (2003), p. 221.
[101] See De Boer, Harink, & Heijboer (2002), p. 26.
[102] See Su, Wang, Chen, Tsou, & Cheng (2017), p. 14.

actions by showing the website information intelligently.[103] To conclude, an e-procurement system could integrate AI to individualise the interface for the user as well as showing the website information intelligently.

2.2.7. Supplier evaluation: Automating qualitative and quantitative supplier assessment to better supplier evaluation

Supplier evaluation is the last step of the category sourcing cycle, before the process starts over again. The supplier evaluation is not a mandatory activity in executing a purchase, but it is a critical step in the purchasing process.[104] Assessing the supplier after business transactions should not solely be based on low-cost but also on quality and delivery performance.[105] There are two kinds of supplier evaluation: qualitative (such as soft facts, innovative idea generation and so on) and quantitative evaluation (such as quality feedback, delivery reliability and so on).[106] The quantitative evaluation is managed via an information technology (IT) system in many cases. However, qualitative evaluation could detect more in detail specific issues or potentials of the supplier. To understand the actual performance of a supplier, qualitative and quantitative evaluation is necessary.[107] A supplier evaluation shows potential candidates for intensive collaboration, and concludes suppliers for further development.[108]

The automation of the qualitative and quantitative supplier assessment would thereby be beneficial for supplier evaluation. According to de Boer et al. (2000), intelligent systems were applied to address the issue of supplier evaluation.[109] However, possibilities in AI such a neural networks (explained in chapter 4) could maybe also facilitate supplier evaluation.

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[103] See Devedzic (2004), p. 165.
[104] See Araz & Ozkarahan (2007), p. 585.
[105] See Narasimhan, Talluri, & Mendez (2001), p. 29.
[106] See Schiele (in press), p. 19; Ho, Xu, & Dey (2010), p. 16.
[107] See Schiele (in press), p. 19.
[108] See Schiele (2012), p. 48.
[109] See De Boer et al. (2002), p. 26.

3. Mechanism design-based negotiations: Achieving competitive advantage through new or enhanced negotiation approaches by the means of artificial intelligence

3.1. Purchasing's impact on organisational profitability: The strategic relevance of the purchasing function necessitates mechanism design-based negotiations

Purchasing is a critical function, which allows the firm to increase its profitability.[110] To maintain or better the purchasing performance, scholars and practitioners are seeking for new approaches. New or advanced negotiation methods reveal hereby potential to drive for higher profitability.[111] Therefore, mechanism design theory could be exploited to transform negotiations in such a way that they are more effective as seen in the study of Schulze-Horn (2017a).[112] Mechanism design theory applies the notion of game theory. Game theory implies a game-like situation with at least two players that influence each other through certain moves, whereas in this context the players are suppliers. While the focus in game theory is solely on the game, in mechanism design theory the concept on how to achieve the best outcome of the game is questioned.[113] Assuming a negotiation situation in which the suppliers operate freely without coordinating their strategies with other players, mechanism design theory can be applied in negotiations.[114] Furthermore, the suppliers should not be aware of the exact price situation meaning that an incomplete market situation prevails to integrate mechanism design theory in negotiations.[115] However, as seen in the study of Schulze-Horn (2017b) there are certain situations that fit best for mechanism design-based negotiations.[116] The magnificent seven concept, which include transaction-oriented, no monopoly, attractiveness, impact of awarding premises, saving ability, commitment, and timescale, would support the identification of suitable negotiation projects.[117] An ideal situation for the implementation of mechanism design-based negotiations can be foreseen, if the checkpoints of the magnificent seven concept are achieved.

Through mechanism design-based negotiations, suppliers are triggered to disclose their last acceptable agreement (LAA). Incentives aligned to the negotiation situation are in place to

[110] See Cox (1996), p. 65.
[111] See Metty et al. (2005), p. 7.
[112] See Schulze-Horn (2017a), p. 34.
[113] See Maskin (2008), p. 567.
[114] See Hartline & Karlin (2007), p. 335.
[115] See Nisan & Ronen (1999), p. 129.
[116] See Schulze-Horn (2017b), p. 9.
[117] See Schulze-Horn (2017b), p. 9.

bring out the best offers from the suppliers. In the study of Roth (2002), the mechanism design theory is compared to the subject of engineering because like an engineer the mechanism designer is striving to generate mechanisms by exploiting trade as an instrument.[118] The savings can be increased by different mechanisms such as letting the suppliers perceive the scope of the competition.[119] According to Schulze-Horn (2017a), a mechanism design-based negotiations includes various elements: project identification and clarification, pre-negotiation, analysis of the sourcing situation, commitment, negotiation design, supplier briefing, and negotiation execution.[120] These are key elements for integrating mechanism designs in a negotiation and set the supplier off to provide its LAA.

To conclude, mechanism design-based negotiations show relatively high potential to position a company competitive due to the differentiated saving potential as seen in this chapter. Therefore, an increased implementation of mechanism design-based negotiations would be desired. The following chapter outlines the potential of an increased implementation of mechanism design-based negotiations through AI.

3.2. Applying artificial intelligence in mechanism design-based negotiations to address problems of bounded rationality and limited resource availability

As seen in the study of Schulze-Horn (2017a), mechanism design-based negotiations are capable of achieving effective outcomes under certain conditions.[121] To achieve an appropriate mechanism design-based negotiations, different steps need to be ensured. Each step in the mechanism design-based negotiation can include several elements such as auctions, feedback on supplier rankings, and so on. Therefore, conceptualising a mechanism design-based negotiation is complex and requires expert knowledge in this field. The purchasers, who would be responsible to conceptualise a mechanism design-based negotiation, have in general, however, no expert knowledge. Besides, purchasers are primarily responsible for other tasks and not solely focused on the execution of mechanism design-based negotiations. Another issue of integrating mechanism designs is that purchasers (and individuals in general) have only restricted capabilities of making rational

[118] See Roth (2002), p. 1341
[119] See Scheffler, Schiele, & Horn (2016), p. 11.
[120] See Schulze-Horn (2017a), p. 22-28.
[121] See Schulze-Horn (2017a), p. 27.

decisions due to their cognitive abilities.[122] To conclude, mechanism design-based negotiations reveal potential, but the integration proves to be rather difficult, since the purchasers have shown to be not fully suitable for execution.

To confront the issue of integrating individual mechanism designs into the purchasing function on a regular basis, AI indicates prospects to facilitate it. AI enables addressing problems of limited rationality through decision-making support.[123] The rationality of mechanism designs provides thereby the basics for applying a computer scientific approach. In the context of mechanism design, rationality indicates that the players, which are in this case the suppliers, aim for maximising their outcome, thereof the highest profit margin. The study of Nisan (2007) also shows that the interest of realising game-theoretic concepts with computer scientific facilitation has been a goal since the beginning of the Internet. [124] The possibility was illustrated of advancing mechanism design-based negotiations through an algorithmic framework also known as algorithm mechanism design.

Autonomous conceptualisation of mechanism designs is still not possible through algorithm mechanism design due to incomplete information. Seeking reasoning with incomplete information is one of AI's key subject matters.[125] According to Schonfield and Thielscher (2015), AI systems are "able to collect information when appropriate, withhold information from its opponents, and keep its goals secret" while regarding games.[126] Thereby, AI techniques such as machine learning enable learning with hidden information.[127] The automatisation of mechanism designs by the means of AI seems to be a relevant topic. Therefore, the next chapter will discuss the topic of AI to get an idea of how to implement automated mechanism design based negotiations.

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[122] See Simon (1955), p. 101.
[123]See Simon (1979), p. 502.
[124] See Nisan, Roughgarden, Tardos, & Vazirani (2007), p. 129.
[125] See Orlowska (2013), p. 9.
[126] See Schofield & Thielscher (2015), p. 3590.
[127] See Wang & Ji (2015), p. 4969.

4. Artificial intelligence: The imitation of intelligent human behaviour by machines

4.1. A non-technical introduction to artificial intelligence: Definition and history of artificial intelligence

4.1.1. The quintessence from various scholars regarding the definition of artificial intelligence

Various scholars have attempted to define AI but the many facets and the scope make it difficult to find a universal definition. Buchanan (2005) for instance showed the scope by describing the history of AI as "a history of fantasies, possibilities, demonstrations, and promises."[128] Even though defining AI is problematic, many scholars explored the topic. Alan Turing, who is a pioneer in the field of AI, proposed that the term AI is applicable if a machine acts humanly.[129] In accordance with Turing's statement, McCarthy and Hayes (1969) defined AI as "a computer program capable of acting intelligently".[130] Other computer scientists build upon Turing's hypothesis by suggesting that a programme needs to have the capabilities of thinking and acting like a human.[131] Haugeland (1989) for instance viewed AI in a rather philosophical way by defining it as a computer that simulates the human mind.[132] The first time the word AI appeared was in the matter of fact early on in 1956, where the first AI project was introduced to the public displaying a chess programme.[133] The publication and the AI project caused high interest in the research field of AI. McCarthy et al. (2006) – who were the researchers of the first AI project - state on the research issued in 1956 that "every aspect of learning or any other feature of intelligence can principle be so precisely described that a machine can be made to simulate it."[134] Thereby, it was revealed that learning is a critical aspect in defining AI. For a better understanding, different AI definitions are represented in table 1. Furthermore, insights in the history of AI (chapter 4.1.2) will provide the idea and opportunities.

Although research on AI has been conducted for many decades now, the context is not clearly defined and various approaches were and are conducted to describe the subject.

[128] Buchanan (2005), p. 53.
[129] See Russell & Norvig (2002), p. 5.
[130] McCarthy & Hayes (1969), p. 431.
[131] See Russell & Norvig (2002), p. 5.
[132] See Haugeland (1989), p. 2.
[133] See Russell & Norvig (2002), p. 17.
[134] McCarthy, Minsky, Rochester, & Shannon (2006), p. 12.

Serafini and Bouquet (2004) mentioned thereto that the issue in understanding the context has a long tradition in AI.[135] For some scholars, a fundamental problem is the lack of a precise definition regarding the term intelligence in general. As seen in the paper of Legg and Hutter (2007) many definitions exists, however, there is no universal definition of intelligence.[136] Since there is no standard definition of intelligence, defining AI is extremely difficult. The meaning of AI's intelligence is frequently discussed. By comparing the statement of Boden (1977) and McCarthy (2006), the different beliefs on the topic of the intelligence of AI can be recognised.[137] According to Boden (1977), the word intelligent is a misplaced term while defining AI because AI only does exactly what it is told to do.[138] However, some scholars such as McCarthy et al. (2006), consider learning as intelligent behaviour reasoning that AI is in fact intelligent.[139] However, comparing the intelligence of humans with AI could limit AI's definition by presupposing the meaning of the term. Thereby, the human-centred notion of intelligence might limit AI because it sets clear borders what is intelligent and what is not. Husbands et al. (1997) thereto follow the belief that defining intelligence while bearing in mind computational science is an ineffective approach because intelligence for a human might be something else than for a machine.[140]

For the reason that there is no standard definition for AI and the question about the true intelligence of it remains, following thoughts regarding the topic, navigates through the complexity of the subject matter. For instance, Rich (1985) stated that "AI is the study of how to make computers do things at which at the moment people are better."[141] Some decades ago, humans were better in playing chess than computer programmes. However, since 2000 even the world champion in chess playing lost against a computer. Therefore, the question arises if a chess programme should be regarded as intelligent. Applying Rich's (1985) theory would therefore indicate that a computer chess programme is not categorised as an AI-based programme anymore because it is based on a simple tree diagram logic.[142] Since the introduction of the first computer chess programme, substantial progress has been made in the field of AI-based programmes.

[135] See Serafini & Bouquet (2004), p. 42.
[136] See Legg & Hutter (2007), p. 10-11.
[137] See Boden (1979), p. 130; McCarthy et al. (2006), p. 12
[138] See Boden (1979), p. 130.
[139] See McCarthy et al. (2006), p. 12.
[140] See Husbands, Harvey, Cliff, & Miller (1997), p. 131.
[141] Rich (1985), p. 117.
[142] See Hsu (1999), p. 74.

In more complex settings such as in the game of “Go”, this simple logic of a computer chess programme is reaching its capacity limits. Search problems will derive in complex settings expressing that problems of finding a solution occur, which convert into problems for the machine to make a decision. To overcome this problem, computer scientists developed heuristic methods. Heuristic methods solve the search problem by seeking the optimal dichotomy between completeness and speed. This heuristic process paved the way for deep reinforcement learning, allowing the defeat of the world’s Go champion in March 2016.[143] Deep reinforcement learning makes it possible for a computer programme to learn how to play a game by only showing the rules of the game. Thereby, the computer programme will reach a super-human level of playing the game.[144] Due to the recentness and success of using deep reinforcement learning as a method for self-learning computer play programmes, this AI solution would still be categorised as intelligent according to the theory of Rich (1985).[145]

Various AI definitions from scholars
"Any system…that generates adaptive behaviour to meet goals in a range of environments can be said to be intelligent."[146]
"Achieving complex goals in complex environments"[147]
"Intelligence measures an agent's ability to achieve goals in a wide range of environments"[148]
"…in any real situation behavior appropriate to the ends of the system and adaptive to the demands of the environment can occur, within some limits of speed and complexitiy"[149]
"...the goal of AGI (artificial general intelligence) research as considered here is the development and demonstration of systems that exhibit the broad range of general intelligence found in humans"[150]

Table 1. Various AI definitions from scholars
Source: based on Legg and Hutter (2007), p. 31-32

143 See Pan (2016), p. 410.
144 See Mnih et al. (2015), p. 529.
145 See Rich (1985), p. 117.
146 Fogel (1995), p. 1590.
147 Goertzel (2006b), p. 452.
148 Legg & Hutter (2005), p. 1509.
149 Newell & Simon (1976), p. 116.
150 Adams et al. (2012), p. 26.

As seen in table 1, various AI definitions were disclosed by scholars. This research is based on the definition of Fogel (1995) that "any system…that generates adaptive behaviour to meet goals in a range of environments can be said to be intelligent." thereby, this definition provides enough freedom for the development of AI, however, also gives insight on the meaning of AI. [151]

4.1.2. The history of artificial intelligence from 1930s to today: The review of pivotal events

In the preliminary stage before AI was a concrete term, some fundamental events took place in the period of the 1930s to 1950s, which allowed AI-based programmes to emerge.[152] In 1931, the researcher Kurt Gödel laid the foundation for AI in his study, because he demonstrated the limitation of intelligent systems/programmes.[153] In 1937, Alan Turing – known as the father of computer science – showed the limitation of machine intelligence by the halting problem.[154] The halting problem describes if a programme will complete solving a certain input or run forever. Alan Turing's study proved that no general algorithm exists for all systems and inputs, which is able to processes every decision problem.[155] The era of computer engineering evolved in the 1940s, laying the foundation for the implementation of AI-based programmes by the means of computational power. A concept was developed illustrating two main conditions that need to be fulfilled to thrive for AI: intelligence and artefact. In 1941, a major step in computer engineering was detected showing the first programmable computer, which was an essential event especially concerning the realisation and implementation of AI-based programmes.[156] Then, McCulloch and Pitts (1943) introduced an artificial neuron model.[157] Similarities between the brain and circuits were drawn, initiating research in AI as well as the study of the brain. These similarities of the brain and circuits also triggered in-depth research in neural networks.[158]

In 1950, Alan Turing developed the Turing Test, which addresses the question "Can a machine think?"[159] Alan Turing created a hypothetical test to recognise if a machine is

[151] Fogel (1995), p. 1590.
[152] See Ertel (2011), p. 7.
[153] See Gödel (1931), p. 197.
[154] See Ertel (2011), p. 7.
[155] See Scarle (2009), p. 254.
[156] See Russell & Norvig (2002), p. 14.
[157] See McCulloch & Pitts (1943), p. 131-132.
[158] See Svozil, Kvasnicka, & Pospichal (1997), p. 44.
[159] See Saygin, Cicekli, & Akman (2000), p. 463.

intelligent or not. In this test, an interrogator in form of a person asks questions to a person as well as to a computer but the interrogator is not aware whom or what actually answers the question. If the interrogator is not able to ascertain if a machine or a person answers the questions, then the machine is categorised as intelligent.[160] Thereby, Turing believed that a machine's intelligence could be measured by the similarities of acting like a human being. This statement provided plenty of discussion points among scholars, and the opinions on the correctness or meaning vary. Moor (2003) for instance stated that Turing never claimed that passing the Turing test is an obligatory condition for a machine to be categorised as intelligent.[161] On the contrary, Block (1995) mentioned that Turing defined the intelligence of a computer and that passing the Turing test is obligatory for a machine to be regarded as intelligent.[162] Overall, the Turing test is a relevant event that partly formed the evolution of AI by triggering the idea of intelligent machines.[163]

Then in the 1950s to the end of 1960s, a time of high interest and expectations took place regarding the research field of AI.[164] The first person who introduced the concept of AI was Professor McCarthy with some fellow scholars in 1956, which is often called the birth hour of AI.[165] The initial concept of AI proposed that machines have the capacity to understand, think, learn like humans and, thereby, replicate human intelligence. In the same year, the first AI-based programme was developed that brought AI a step closer of replicating human intelligence by capable of processing pictures and symbols.[166] In 1958, McCarthy developed LISP, the first high-level computer programming language that can adjust itself.[167] The times for AI research were good and the investments on the topic were reasonably high due to a high expectation on the outcome. In 1966, Weizenbaum invented based on the research of Turing the first chatterbot, which is a bot that is able to have a conversation.[168] The chatterbot was an artificial psychotherapist named Eliza, which is the most known system from the era before the Internet.[169]

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[160] See Saygin et al. (2000), p. 465.
[161] See Moor (1976), p. 253.
[162] See Block (1995), p. 378.
[163] See Saygin et al. (2000), p. 463.
[164] See Russell & Norvig (2002), p. 17.
[165] See Pan (2016), p. 410.
[166] See Ertel (2011), p. 7.
[167] See McCarthy (1978), p. 173.
[168] See Shah, Warwick, Vallverdú, & Wu (2016), p. 278.
[169] See Shah et al. (2016), p. 281-282.

From the beginnings to the end of 1970s, the research of AI focused on exploratory processes, extending the research field of AI to: “game theory, mechanical theorem proving, machine translation, expert systems, pattern recognition, machine learning, robotics, and intelligent control” according to Pan (2016).[170] In this era, which is known as the times for knowledge-based systems, a significant number of technologies were developed. In 1972, Alain Colmerauer and Philippe Roussel developed the logic programming language Prolog.[171] Even 45 years later, Prolog is still the most essential programming language in the world, which demonstrates the importance of historic events in the evolution of AI. In the era of exploratory processes, one of the first expert system was introduced to the medical world supporting medical diagnosis. Despite some noteworthy milestones that were achieved during that time, the first major setback hit the research field of AI in 1973. The research of AI showed moderate progression in developments, and the high interest from the beginning of the research was decreasing, even though AI-based programmes were still in this infancy.[172]

In the beginning of 1980, expert systems were introduced to the industry. According to O’Keefe et al. (1986), an expert system is a system capable to operate on a human level by being capable of giving advice.[173] This re-sparked the interest in AI. Despite the success for AI in the industry, a major setback occurred during that time triggered by failing to develop an intelligent computer. The target for this project was to develop an intelligent computer, which would have been able to listen and speak. The project funds ran until 1992, whereby 850 million USD were wasted.[174] The third and so far last setback of AI was in 1984, the expectations were high for attaining human-level inferential capabilities. However, the outcome of this research was immensely overshadowed by the rise of the internet and the capabilities of search engines.[175]

In the beginning of the 1990s, the era of robotics had gained momentum. In 1997, the Japanese initiated the first international RoboCup world championship. To develop a robot able to play soccer, the technologies have to be highly advanced. Thereby, AI is a vital element in robotic research.[176] Anticipating a soccer World championship for robots

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[170] Pan (2016), p. 410.
[171] See Colmerauer & Roussel (1996), p. 332
[172] See Pan (2016), p. 409-410.
[173] See O'Keefe (1986), p. 15.
[174] See Pan (2016), p. 410.
[175] See Pan (2016), p. 410.
[176] See Kitano, Asada, Kuniyoshi, Noda, & Osawa (1997), p. 340.

illustrates that the development has reached an advanced level. In the same year, the company IBM developed a programme called Deep Blue, which managed to win in chess against the world's chess champion Garry Kasparov.[177] From 2000 to 2010, the most protruding event was the introduction of the self-driving car by Google.[178] To sum up, in 1990s up to 2010 some projects regarding AI-based programmes were launched, however the AI winter had diminished the high interest in the topic in this time significantly.[179]

From 2010 up to now (2017), the research on AI has experienced a rise in successful projects. In 2011, IBM's AI solution called Watson won against two champions of the game 'Jeopardy!' in a TV show. Hereby, the programme showed its abilities to understand spoken language fast and answer difficult questions within reasonable time.[180] In 2014, Daimler, which is a large German automotive OEM, presented the first self-driving truck on a closed highway in Germany, showing the progress of autonomous driving.[181] Furthermore, interest in deep learning emerged due to its promising outcome in classifying images.[182] AlphaGo showed also promising outcome as mentioned in chapter 4.1.1.[183] Since 2010, technological development has accelerated fast showing vast potential in the research subject of AI and AI solutions.

4.2 Different scales of artificial intelligence: The development from weak to strong artificial intelligence

4.2.1 The progress of artificial intelligence: From solving simple to addressing complex issues

The development of AI during the last decades shows the different graduations of AI. In the beginning of AI, the AI-based solutions are relatively weak, but they have strengthened considerably. Therefore, a definition of weak and strong AI will indicate and evaluate it. Chapter 4.1.2 hereby touched upon the topic of weak and strong AI because it reviews the development phases of AI.

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[177] See Campbell, Hoane, & Hsu (2002), p. 57.
[178] See Howard & Dai (2014), p. 3.
[179] See Ertel (2011), p. 7.
[180] See Ferrucci, Levas, Bagchi, Gondek, & Mueller (2013), p. 93.
[181] See Hengstler, Enkel, & Duelli (2016), p. 116.
[182] See Marmanis, Datcu, Esch, & Stilla (2016), p. 109.
[183] See Chen (2016), p. 4.

Bringsjord and Schimanski (2003) stated that weak AI focuses on artefacts featuring precise behaviours, whereas strong AI targets capabilities such as consciousness in AI solutions.[184] To get a better understanding of weak and strong AI, various gradations of AI are displayed in this chapter. The current AI developments such as in game playing (Go and Jeopardy) are major steps towards stronger AI, however, these successes are still considered as weak successes in AI. According to the study of Goertzel (2014), weak AI is also known as "narrow "AI due to the ability of high performance in a specific activity.[185] A weak AI solution is only working in a specific kind of setting. As soon as the setting is minimally changed, a human has to interfere in form of reprogramming to adapt the system to the new task. Strong AI is often referred to as artificial general intelligence (AGI), illustrating a machine able to fulfil more than super-human performance in a certain specific task,[186] but the capability to self-adapt in a complex setting. If a machine would be able to handle various task in a complex setting by means of consciousness, AI could then be considered as strong AI. Therefore, there is currently no strong AI, only developments in weak AI. In order to create a greater sense about the capabilities in weak AI as well as on the required skills to develop strong AI, the development of AI is reviewed. In the early development, AI was consequently considered as weak, but the current advancements in AI would be considered as 'stronger' weak AI. Thereby, AI-based techniques such as machine learning, data mining and processing, deep neural networks, and reinforcement learning are still embracing weak AI because of its task-oriented intelligence rather than an independent, general intelligence.[187] Hereby, the core issue of defining intelligence occurs. AI as a sub-topic of informatics is concerned with research on mechanisms of intelligent behaviour. To define intelligence it is relevant to understand the underlying mechanism.[188] According to Russel and Norvig (2003), four overarching categories classify the intelligence of a system as seen in figure 2.[189] Each classification category is endowed with an approach to demonstrate the essence of each category: think like a human, think rational, act like a human, act rational.

[184] See Bringsjord & Schimanski (2003), p. 892.
[185] See Goertzel (2014), p. 1.
[186] See Bundy (2017), p. 285.
[187] See Bringsjord & Schimanski (2003), p. 892.
[188] See Husbands et al. (1997), p. 131.
[189] See Russell & Norvig (2002), p. 5.

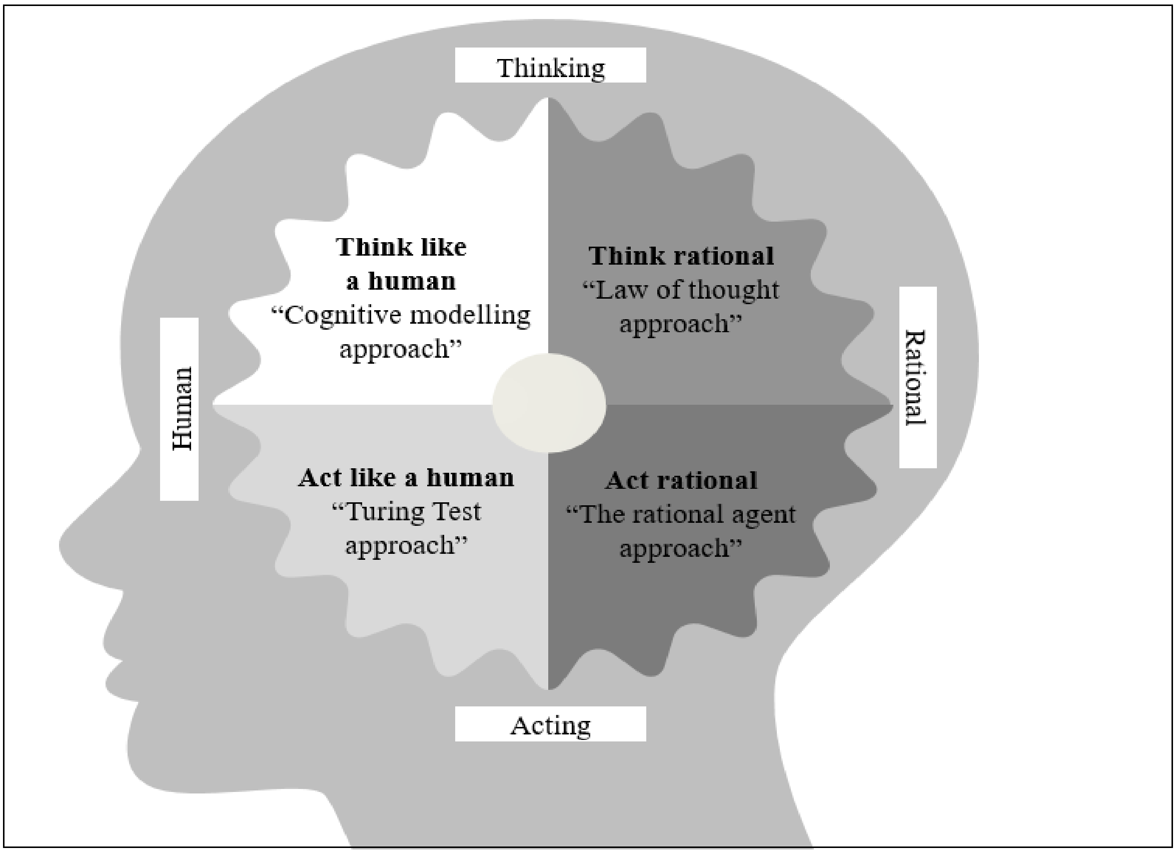

Figure 2. Computational brain: How to define intelligence
Source: based on Russel & Norvig (2003), p. 5

"Think like a human" is elucidated by the cognitive modelling approach. To determine if a machine thinks like a human, it is necessary to understand how humans actually think. Two approaches exist to understand the thought process of a human mind: 1. Introspection, which describes the process of grasping thoughts, and 2. psychological experiments. [190] The notion of the cognitive modelling approach is to replicate human behaviour regarding the thought process, and to project it on the systems underlying mechanisms.[191] Understanding the human thought process can be critical in AI. For instance, expert systems are build up by human knowledge, without understanding the thought process an expert system could not be build.[192] Despite some similarities of AI and cognitive science, the notion of real cognitive science focuses on humans or animals. However, cognitive science enriches the research field of AI.[193] Therefore, AI is incapable of thinking like a human, however, to replicate human thinking behaviour.

[190] See Russell & Norvig (2002), p. 6.
[191] See Russell & Norvig (2002), p. 6.
[192] See Someren, Barnard, & Sandberg (1994), p. 9.
[193] See Russell & Norvig (2002), p. 6.

“Think rational” is also an essential element in categorising a machine’s intelligence. Russel and Norvig (2003) apply the law of thought approach to facilitate a conception for characterising thinking rational.[194] To classify a machine as intelligent, it is required to enforce logical reasoning. A simple example for logical reasoning: when it rains, the street is getting wet; it rains, therefore the street is wet.[195] The complexity in logical reasoning is often higher. Nevertheless, machines are more capable in rational decision-making than humans. For example, computer-based personality assessment were more precise than the ones conducted from humans as seen in the study of Youyou et al. (2014).[196]

One approach to determine if a machine fulfils the category “act like a human” is the Turing test approach. The Turing test was already introduced in chapter 4.1.1. This test is an effective method to define if a machine acts like a human. According to Russel and Norvig (2003), a system needs to have following competences to pass the Turing test: natural language processing, knowledge representation, automated reasoning, and machine learning.[197] In addition, other competences are needed that do not really require intelligence, however without these the Turing test cannot be completed: computer vision and robotics.[198]

In the category of “act rational”, an agent is trivial due to its ability to perceive and act. Therefore, the rational agent approach is necessary to carry out actions to accomplish a target set by someone’s mission. The borders between rational thinking and rational acting are blurry considering that logical reasoning is a fundamental for acting rational. However, not every action involves inferences, which are part of logical reasoning. The application of rational agent approach has an advantage over the law of though approach because of its broader utilisation and its applicability for scientific development. [199]

4.2.2 Future prospect in artificial intelligence: The good, the bad, and the ugly

The development of weak AI-based programmes is on the rise. However, the realisation of strong AI with consciousness seems far away. Therefore, someone could argue that studying AI intensively might not be necessary now. However, the study of Baciu and Opre (2016) states that the acculturation of recent developments in AI might imply an uncertain AI future

[194] See Russell & Norvig (2002), p. 6.
[195] See Ertel (2011), p. 25.
[196] See Youyou, Kosinski, & Stillwell (2015), p. 1039.
[197] See Russell & Norvig (2002), p. 5.
[198] See Russell & Norvig (2002), p. 6.
[199] See Russell & Norvig (2002), p. 7-8.

such as a world with AGI for instance. [200] For instance, the AI-based creativity seemed only possible in an explorative way and not transformative in 1998 as seen in a study of Boden (1998).[201] However, AI recently showed the ability of creative work. [202]The art of AI-based programmes often illustrates certain objects close to famous artists or also art where animals fusing with the same or other objects.[203] Other AI-based novelties were already introduced in chapter 4.1.2 such as the AlphaGo programme that was able to defeat the world champion in Go, even though this advancement was not expected for years. Despite recent advancements, AI has yet to face many potential barriers and challenges. The cognitive operations challenges - namely concept comprehension, pronouncing a judgement, and reasoning – are obstacles that need to be addressed.[204] Success has been recognised especially in the area of reasoning. However, the development in the other areas is somewhat disillusioning. To overcome the issues in cognitive operations, methods such as unsupervised learning of neural networks are vital, which will be explained further in chapter 4.3.[205]

The prime subject while monitoring future prospects in AI is the topic of strong AI or rather AGI. For the realisation of AGI, the determined barriers need to be addressed. Specifically, the areas of general problem solving, automatic learning, natural language processing, planning, and creativity need to be faced to achieve a certain form of AGI according to Flasinski.[206] Advancement in these areas would push AI to a different level, and would provide a starting point for AGI. To realise advancements in these areas the research focus on AI should not just be in computer science but also include other areas such as physics, logics, psychology, linguistics, neuroscience, and biology.[207] There are different future scenarios that AI might trigger. To cope with different outcomes, it is vital to understand the different future scenarios of ‘the good’ (promising aspects), ‘the bad’ (waste of time), and ‘the ugly’ (in the direction of worst-case scenario) future of AI. Thereby, the benefits but especially the dangers of AI are localised.

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[200] See Baciu, Opre, & Riley (2016), p. 43.
[201] See Boden (1998), p. 354.
[202] See Baciu et al. (2016), p. 43.
[203] See Torre (2017), p. 1
[204] See Flasiński (2016), p. 241.
[205] See Flasiński (2016), p. 242.
[206] See Flasiński (2016), p. 243.
[207] See Flasiński (2016), p. 244.

Optimists imply that the forthcoming of AI is leading to a ‘good’, idealistic future where AI supports humans in various aspects in life. In the health sectors, for instance standalone diagnostic applications could improve a patient’s visit immensely.[208] Therefore, AI could develop to an assistant for humanity. Atkinson (2016) for instance states that “AI systems are no different than shovels or tractors: they are tools in the service of humans, and we can use them to make our lives vastly better.” [209] Scholars such as Makridakis (2017) see a more science fiction like future ahead. Makridakis (2017) expects that the revolution of genetics, nanotechnology and robotics (GNR) would pave the way for a futuristic utopia.[210] AI could lead to advancements in the science of genetics what would make it possible to adjust genes, and thereby decrease the danger of illness. In addition, Makridakis (2017) stated that gene manipulation could even lead to a decrease in aging or even stopping mortality.[211] Advancements in nanotechnology by the means of AI could lead to a major increase in wealth due to the ability of producing any product with 3D printers.[212] Fast and Horvitz (2017) regarded the development of robotics as an enrichment for humanity in as much as humans would be able to use their time freely because robots will execute every task.[213] According to Fast and Horvitz (2017), AI could also enhance areas such as “education” (for example automatic tutoring), “transportation” (for example self-driving cars), “healthcare” (for example personalised medicine), and “entertainment” (increased gaming experience through smarter games).[214] In this future, opportunist expect humans and AI to fuse allowing humans to rely on certain body part replacements with robotic limbs for instance. This fusion of humans and AI could lead to singularity, which could lead to immortality. [215]

However, some scholars on the contrary have certain doubts, and forecast that AI will not evolve to a strong form or AGI. In the ‘bad’ future of AI, no further evolvement of AI would take place and all investments and research time towards an AI future would be worthless. As seen in the research of Müller and Bostrom (2016), a reasonably high percentage of experts believe that machines will never be capable of simulating learning and other aspects of human intelligence.[216] In the history of AI, the doubt in the advancement might have been

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[208] See Schulz & Nakamoto (2013), p. 223.
[209] Atkinson (2016), p. 9.
[210] See Makridakis (2017), p. 50
[211] See Makridakis (2017), p. 50.
[212] See Makridakis (2017), p. 50.
[213] See Fast & Horvitz (2017), p. 964.
[214] Fast & Horvitz (2017), p. 964.
[215] See Fast & Horvitz (2017), p. 964.
[216] See Müller & Bostrom (2016), p. 559.

more valid in the past century than today due to recent advancements. Even though predictions were often inaccurate, and in terms of time set too positive such as an AI-based programme winning the chess championship, these achievements took place. Doubters of today rather argue that an AI-based programme will never be capable of creativity because this requires an anti-algorithmic approach.[217] However, the term creativity is difficult to classify. As mentioned in the beginning of the chapter, AI is able to draw creative paintings.[218] The lack of progress has already led to an AI winter as mentioned in chapter 4.1.1. Thereby, the danger of unsatisfying results could lead to a decrease of interest as well as investment budget regarding AI confirming the keynotes of doubters.[219]

AI offers certain opportunities, but the danger of AI should not be underestimated. As seen in the study of Müller and Bostrom (2016), experts believed that there is a probability of approximately 1/3 that the development of AI will be bad or very bad for humanity.[220] Pessimists such as Elon Musk foresee an 'ugly' future of AI ahead, in which machines could prevail and humanity would lose control over powerful AI systems.[221] An oncoming danger of AI is the impact it might have on work and on the workforce. Smarter programmes and advances in robotics could lead to a drop particular in blue-collar workers leading to massive unemployment worldwide.[222] Major problems could arise without having a strategy in place that defines how to deal with a large-scale loss of jobs. Furthermore, AI could lead to advancement in military applications.[223] The danger of robotic soldiers or killer drones sounds unreal, however, the direction of AI's development is uncertain, and all even minor possibilities should therefore be assessed.[224] The survival of humanity might be in danger if AI developments are going down the wrong road. In case of questionable appropriateness in AI's ethics, the danger of loss of life or other critical actions due to a lack of ethical reasoning might come true.[225] If AI would evolve to a danger to humanity, the topic of singularity – fusing of human and machine – poses a crucial risk.[226] Makridakis (2017) acknowledges that many scientists estimate the magnitude of risks, which might emerge from AGI or smart

[217] See Makridakis (2017), p. 50.
[218] See Torre (2017), p. 1
[219] See Makridakis (2017), p. 50.
[220] See Müller & Bostrom (2016), p. 566.
[221] See Scherer (2015), p. 357.
[222] See Nilsson (1984), p. 5.
[223] See Akuel (1990), p. 263.
[224] See Asaro (2008), p. 56.
[225] See Bostrom (2003), p. 284.
[226] See Fast & Horvitz (2017), p. 964.

machines.[227] The temptation of handing over all decisions and work to smart machines will be high in particular because of the task complexity, which would eventually lead to a society where machines have primary control. If machines have control, humanity would be reduced to a second-rate class, in which humanity could be considered as computer's pets referring to Markridakis (2017).[228]

The three scenarios discussed above show quite distinctly certain path of AI in the future. The future however could look quite differently compared to the discussed scenarios. Acknowledgments concerning AI were not all distinctively good, bad, or ugly but a combination of these scenarios. In the study of Chowdhury and Sadek (2012) the advantages and limitations were reviewed.[229] In the study it was stated that AI "can facilitate faster decision making by automating the decision making process. (…) Nevertheless, one should not forget that, like any other tool, AI methods have their limitations."[230] In the future, AI can lead to opportunities, threats and show its limitations.

4.3 Novel techniques and methods to support towards the realisation of strong artificial intelligence programmes

4.3.1. Core branches to facilitate artificial intelligence

In this research, it was recognised that AI is not that simply defined and explained. Many definitions and graduations exists. To provide a better picture on AI, the core AI techniques are acknowledged in this chapter. In figure 4, the major techniques for AI are displayed: machine learning, language processing, expert systems, vision, and robotics. However, AI has many different techniques and in figure 4 only the most active are viewed according to research of Mills (2015).[231] Hereby, the techniques mentioned in figure 4 are enablers for AI development.

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[227] See Makridakis (2017), p. 50.
[228] See Makridakis (2017), p. 51.
[229] See Chowdhury & Sadek (2012), p. 6.
[230] Chowdhury & Sadek (2012), p. 7.
[231] See Mills (2015), p. 3.

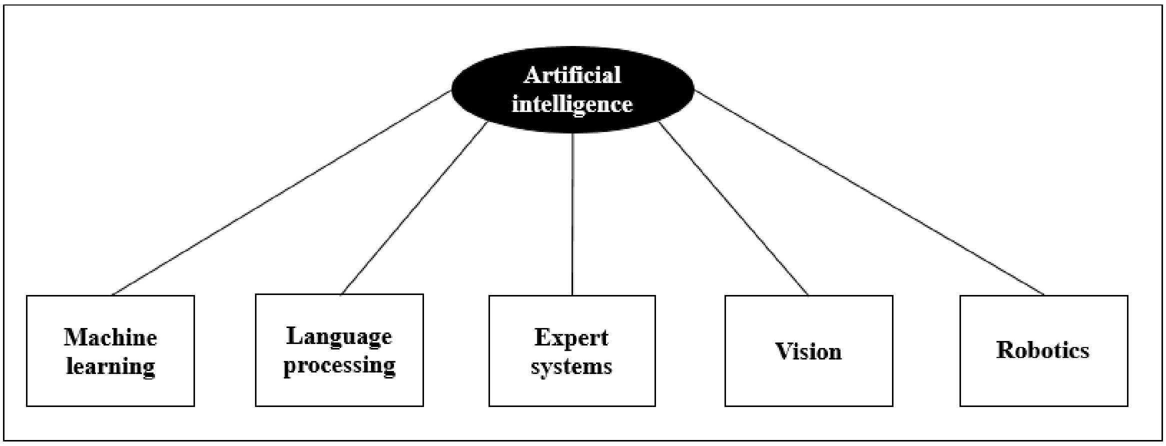

Figure 3. Core branches of AI
Source: based on Mills (2015), p. 3

Machine learning

Machine learning is triggered by the ambition to replicate human behaviour to a machine.[232] According to Michalski et al. (2013), machine learning is "the study and computer modelling of learning processes in their multiple manifestations."[233] Hereby, machine learning is aiming to predict something from previous observations.[234] Machine learning will be further reviewed in an individual chapter because of the high expectation to exploit the strength of this technique in the business case company. This subject is in particular critical for this research because it also shows linkages to game theory.[235]

Language processing

Language processing is another technique that facilitates AI. Nadkarni et al. (2011) stated that language processing was originally defined as "text information retrieval (IR), which employs highly scalable statistics-based techniques to index and search large volumes of text efficiently."[236] However, the field of language processing has broadened in the past decades, whereas language processing integrates various AI techniques to optimise the outcome. For example, a translation from Russian to English is more accurate because different AI

[232] See Natarajan (2014), p. 1.
[233] Michalski, Carbonell, & Mitchell (2013), p. 3.
[234] See Schapire (2003), p. 149.
[235] See Schapire (2003), p. 157.
[236] Nadkarni, Ohno-Machado, & Chapman (2011), p. 544.

techniques allow language processing to recognise metaphors.[237] Machine learning is for instance also a critical technique to approach problems in language processing. [238]

Expert systems

Expert systems are a relatively old AI-based technique, which are programmed with expert human reasoning.[239] However, expert systems have additionally started collecting knowledge with a set of rules for applying the knowledge base. Therefore, advancements in expert systems were achieved allowing expert systems to deal with settings that are more complex. Expert systems were successfully introduced in the fields of financial services, healthcare, and manufacturing and so on.[240]

Vision

Vision is another major aspect of research in AI.[241] It could become a critical technique regarding the belief that computing, communication and display technologies will develop further. Hereby, human-computer interaction could be advanced through vision by for instance vision based hand gesture recognition.[242] Fischler and Firschein (2014) defined vision as "the scientific discipline that addresses the problem of how we can combine sensor-derived images, previously acquired models of scene content, world knowledge, and knowledge of the imaging process to construct an explicit description or model of the surrounding environment." [243]

Robotics

Robotics and AI show a strong link in case of autonomous robots. Furthermore, the field of robotics has in particular triggered research in AI.[244] Therefore, it is also one of the major subjects discussed in the field of AI. According to Ingrand and Ghallab (2015) "Robotics is an interdisciplinary integrative field, at the confluence of several areas, ranging from

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[237] See Lehnert (2014), p. 422-423.
[238] See Nadkarni et al. (2011), p. 548.
[239] See Frank (1994), p. 2.
[240] See Naser & Alhabbash (2016), p. 83.
[241] See Horn et al. (2017), p. 21.
[242] See Rautaray & Agrawal (2015), p. 2.
[243] Fischler & Firschein (2014), p. 1.
[244] See Ingrand & Ghallab (2014), p. 63.

mechanical and electrical engineering to control theory and computer science, with recent extensions toward material physics, bioengineering or cognitive sciences."[245] A major achievement for robotics and AI would be to build an intelligent machine that is able to understand and act in an everyday world.[246]

4.3.2 Machine learning: A framework of algorithmic learning theory

4.3.2.1. An introduction to machine learning and potential problems of implementing it

The industry is demanding progressively for sophisticated processing of data volumes. To stimulate this demand from companies and consumers effectively, machine learning is a key research topic.[247] Hereby, algorithms are the framework of machine learning, which construct an inductive approach to recognise data patterns.[248] The outcome in an inductive approach are categories, which outline the raw data and suggest key topics and processes.[249] Referring to Cracknell and Reading (2014), various methods are integrated to develop algorithms that support machine learning.[250] One of these methods is for example a naïve Bayesian network, which is a statistical learning algorithm. In a naïve Bayesian network, a classifier determines the probability to which class the data belongs.[251] John and Langley (1999) state that "a naïve Bayesian classifier provides a simple approach, with clear semantics, to representing, using, and learning probabilistic knowledge."[252] Other methods such as artificial neural networks also support machine learning.[253] In artificial neural networks data learning is facilitated through data recognition and classification.[254] Further methods exists, however, to keep the scope reasonable, only the methods mentioned above are explained to give an example. The actual application of machine learning methods can in particular be recognized in the healthcare sector, manufacturing education, finance sector, marketing field and policing referring to Jordan and Mitchell (2015). [255]

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[245] Ingrand & Ghallab (2014), p.63.
[246] See Tirgul & Naik (2016), p. 1787.
[247] See Chen et al. (2014), p. 609.
[248] See Cracknell & Reading (2014), p. 22.
[249] See Thomas (2006), p. 240.
[250] See Cracknell & Reading (2014), p. 22.
[251] See John & Langley (1995), p. 338.
[252] John & Langley (1995), p. 339.
[253] See Kotsiantis, Zaharakis, & Pintelas (2007), p. 251.; Kotsiantis et al. (2007), p. 255
[254] See Jack & Nandi (2002), p. 377.
[255] See Jordan & Mitchell (2015), p. 255.

Machine learning addresses the issue of programmes that enhance themselves by gaining expertise (data) through participating in activities. Therefore, machine learning aims for programmes that possess the ability to improve performance in certain activities through data collection. An example for a potential integration of machine learning is for instance a self-driving car programme, which learns to recognise pedestrians.[256] Another example is the classification of patterns in the healthcare sector, hereby patients could be categorised via their medical history into certain sub-categories like possible heart disease category, high risk cancer category and so on.[257] Research by Ghahramani (2015) states that the application possibilities for machine learning are much larger than expected and pose opportunities for different fields. [258] Pattern classification or mapping tasks are activities that come first to mind. However, also "optimisation, decision-making, compressing data, and automatically extracting interpretable models from data" are critical activities of machine learning as determined by Ghahramani (2015).[259] Consequently, machine learning has also been acknowledged as an appropriate system for "computer vision, speech recognition, natural language processing, robot control, and more" according to Jordan and Mitchell (2015).[260] In the field of AI, machine learning has been identified as an effective way for many applications due to its ability to learn from examples of aimed input and output. Thereby, the onerous task of programming aimed responses becomes invalid because of the system's learning ability.

According to Jordan and Mitchell (2015) machine learning is one of the most expeditiously increasing technical fields nowadays. [261] The machine learning function crosses the research topics of computer science and statistics. AI and data science are seen as the key pillars for implementing machine-learning methods. Hereby, learning algorithms are main drivers for the latest developments in machine learning. The accessibility of data from online sources as well as inexpensive data processing have also an impact on improved machine learning.[262] The fundamental factor for developing a machine learning system is the availability of data. However, it is significant that the data provides knowledge or extracts inferences. A model of assumptions is created to make inferences by analysing observed data to make

[256] See Bojarski et al. (2016), p. 2.
[257] See Khan, Choi, Shin, & Kim (2008), p. 5148.
[258] See Ghahramani (2015), p. 452.
[259] Ghahramani (2015), p. 452.
[260] Jordan & Mitchell (2015), p. 255.
[261] See Jordan & Mitchell (2015), p. 255.
[262] See Jordan & Mitchell (2015), p. 255.

assumptions about unobserved data. The complexity of the models vary by type. For instance, complex models may require the application of deep neural networks, whereas some simple models work with statistical methods.[263] Deep neural networks consist of various hidden layers and are trained through new methods.[264] After all, the more complex methods in machine learning are usually applied in machine learning systems like for instance deep neural networks with high capacity possibilities.[265] The constructed models have to consider uncertainty regarding unobserved data, and therefore a precise model is vital to make forecasts or predictions.[266] To conclude, machine learning focuses on gaining information from data by showing the programme the desired approach. Many models exists that initiate machine learning as learned in this chapter, however, there is no known fast functioning algorithm for operating precisely.

Next to the algorithmic issue, there are three other problems regarding big data classification to keep in mind before applying machine learning: generalisability issues, inaccuracy through class type, and knowledge transfer problems[267] The assumption that a dataset's meaning can be projected to another without questioning if this generalisation is appropriate, may lead to an inappropriate system. Machine learning focuses on specific datasets, which may not be appropriate in other situations. Therefore, it is essential to review the robustness of classification in other datasets to ensure a valid outcome.[268] According to Drachsler et al. (2010), it is recommendable to collect several data sets from various sources for an appropriate outcome.[269] According to Suthaharan (2014), another risk occurs when the number of class types is not sufficiently dynamic for the variety of class types that the system may encounter.[270] A non-dynamic number of class types leads to an inaccuracy in the classification outcome. Teaching a machine is based on a single learning task, which may result in a problem due to a multiple learning task environment. According to Hall (1999), no single learning approach is outstanding and applicable for all situations.[271] In case machine learning is only focusing on a single learning task, the system may not be able to cope with the situation, which results in an unstable outcome.

[263] See Ghahramani (2015), p. 452.
[264] See Hinton et al. (2012), p. 82.
[265] See Chen et al. (2014), p. 609.
[266] See Ghahramani (2015), p. 452.
[267] See Suthaharan (2014), p. 71.
[268] See Suthaharan (2014), p. 71.
[269] See Drachsler et al. (2010), p. 2852.
[270] See Suthaharan (2014), p.71.
[271] See Hall (1999), p. 2.

4.3.2.2 Data mining and processing: Machine learning requires a strong data basis

Data mining is the junction of multiple disciplines such as "machine learning algorithms, pattern recognition, artificial intelligence, and other disciplines".[272] The procedure of data mining is in some cases determined as a specific case of machine learning.[273] The availability of data has grown enormously over the last decade, and has certainly reached a vast amount of data. However, the availability of data does not imply that extracted knowledge is substantial. Big data collection, therefore, only offers the possibility of acquiring knowledge, but the right analytical tools need to be in place. According to Lausch et al. (2015) data requires to be "sorted, transformed, harmonized and processed both statistically and analytically."[274]

The explosive increase of data entails efficient data collection. Consequently, automated data collection tools need to be in place to process data sufficiently. There is some confusion in data mining, whereas some papers such as the paper from Buczak and Guven (2016) consider data mining only as the particular step of applying algorithms to gather knowledge.[275] Other papers such as the study from Fayyad et al. (1996) consider data mining as the whole process of data preparation, data cleaning, and interpretation.[276] In this study, data mining includes all actions in the process of finding insights in the data, from the procedure of pre-processing the data to the execution of data mining, to the interpretation and assessment of the data. The execution of data mining includes training, testing and validation of the data.[277] This process reinforces the transformation from data to knowledge. The knowledge or patterns need to be transformed into implementation plans that support achieving a targeted goal.[278] Data mining reveals many possibilities in economic research, media research, social research, as well as in other fields. In economic research, it shows potential in risk analysis, forecasting, market and business analysis, and further opportunities by extracting information from data.[279]

Big data grants access to the potential of exploring insights through patterns or knowledge extraction for instance. The advantage of novel and advanced data mining technique is the dimensionality of data in comparison to traditional data analysis.[280] Advanced algorithms

[272] Lausch, Schmidt, & Tischendorf (2015), p. 6.
[273] See Huang, Tsou, & Lee (2006), p. 397.
[274] Lausch et al. (2015), p. 6.
[275] See Buczak & Guven (2016), p. 1154.
[276] See Fayyad, Piatetsky-Shapiro, & Smyth (1996), p. 82.
[277] See Lausch et al. (2015), p. 6.
[278] See Huang et al. (2006), p. 397.
[279] See Lausch et al. (2015), p. 11.
[280] See Lausch et al. (2015), p. 12.

need to be applied to allow adequate data mining. These algorithms have to be capable of complying with the five Vs of big data management[281]:

- Volume (data capacity is expanding, however the data tool is not able to process the increase of data, which is leading to a less efficient process)
- Variety (data is available in all different kind of forms such as images, text, sensor data, sources and so on, therefore, the algorithm needs to adapt to the data source)
- Velocity (capturing the real-time data of an incremental data stream needs to be guaranteed)
- Variability (the data structure varies as well as how the researchers want to define the meaning of the data)
- Value (the value of competitive advantage needs to be ensured that is triggered by the ability of profound decision-making, which was formerly regarded as unreachable)

To access different dimensions of data, methods need to be applied. Different data mining methods exists such as artificial immune network algorithm,[282] as well as decision trees, neural nets and so on.[283] Hereby, interesting insight from the patterns or knowledge, association rules, sequential pattern discovery, clustering, and classification are gained according to Eirinaki and Vazirgiannis (2003).[284] Knowledge discovery in data mining is a significant action. Data mining is often represented in an implicit form, which means that the interpretation of the data may require specific experience.[285] An example of data mining in use is the cognate malicious software, whereas algorithms are implemented to analyse patterns.[286] Data mining is an appropriate method, where the algorithms need to fulfil certain requirements to offer the concurrence of machine learning and data mining.

4.3.2.3 Deep Neural Networks and reinforcement learning: Significant components to deliberate machine learning

Recent developments in AI were achieved through deep neural networks, which showed almost exceptional performance. Compared to classic neural networks, deep neural networks

[281] See Fan & Bifet (2013), p. 2; Laney (2001), p. 1.
[282] See Zhang, Kusiak, Zeng, & Wei (2016), p. 308.
[283] See Huang et al. (2006), p. 397.
[284] See Eirinaki & Vazirgiannis (2003), p. 17.
[285] See Huang et al. (2006), p. 396.
[286] See Chen, Rong-Cai, Jia, & Li-Jing (2016), p. 1.

complete a bulk of sequential computational steps. The first classic neural networks is derived from the concept of the brain.[287] Haykin (1999) described neural networks as "a massively parallel distributed processor that has a natural propensity for storing experiential knowledge and making it available for use."[288] According to Silver et al. (2016), developments in deep neural networks have been accomplished in the field of classification, face recognition, and playing Atari games.[289] The introduction of neural networks offers new opportunities in machine learning. Artificial intelligence has faced many challenges, such as issues in decision-making in unmanageable search space, and complexity. The novel approach of deep neural networks shows potential in overcoming these challenges. According to Silver et al. (2016), deep neural networks lead to advancements in "general game playing, classical planning, partially observed planning, scheduling, and constraint satisfaction".[290] In addition, speech recognition, music processing, language processing and related application can be enhanced through deep neural networks.[291] Deep neural networks have exceed the performance especially in speech recognition.[292]

Deep neural networks optimise the tree search by creating a value network to seek the most effective moves. Various layers of neurones construct the deep neural network. The dimensionality allows deep neural networks to determine non-linear and vastly changing functions. To train deep neural networks, various hidden layers are inserted in the middle of input and output to liberate the training sessions.[293] Deep neural networks pervade several steps of machine learning. Human experts train deep neural networks with their expertise in the subject in question. This provides a qualitative learning phase for deep neural networks, as well as instant evaluations. Then, reinforcement learning is integrated into the networks to optimise the supervised learning phase. Therefore, the correctness of the system is improved by adjusting the policies of the network towards the right goal. Eventually, the network is taught to study by itself through trial and error.[294] One major source for the advancements in deep neural networks derives from deep reinforcement learning algorithms. Reinforcement learning concentrates on how agents can learn by interacting with their surroundings over many discrete time steps. Therefore, a critical issue in deep neural

[287] See Ripley (2007), p. 2.
[288] Haykin (1999), p. 4.
[289] See Silver et al. (2016), p. 484.
[290] Silver et al. (2016), p. 489.
[291] See Deng, Hinton, & Kingsbury (2013), p. 268. 8599
[292] See Hinton et al. (2012), p. 83.
[293] See Hinton et al. (2012), p. 84.
[294] See Silver et al. (2016), p. 484.

networks and reinforcement learning is to address the problem originating from the degree of freedom.[295]

According to Silver et al. (2016), the AlphaGo programme is a noteworthy example of the usage of neural networks. First, the game was trained by showing examples of previous games human played. Then, reinforcement learning is applied to have machine learning in place. Finally, the system plays against itself to improve its game. Compared to chess, Go is a very complex game and until now intuition was needed, therefore only humans were able to play in an expert league. The implementation of a search tree for the Go game is too simple to cope with the complexity of the game. In deep neural networks, new algorithms are programmed that offer high-performance in tree search. Finally, the programme won the Go game at the highest level of human players, which is a huge success story for AI.[296]

[295] See Jaderberg et al. (2016), p. 1.
[296] See Silver et al. (2016), p. 484.

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