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University Students' Research on Artificial Intelligence and Knowledge Management. A Review and Report of Multi-Case Studies

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Abstract. Leading technologies are very attractive for students preparing their theses as the completion of their studies. Such an orientation of students connected with professional experiences seems to be a crucial motivator in the research in the management and business areas where these technologies condition the development of professional activities. The goal of the paper is the analysis of students' thesis topics defended in the last 10 years in business informatics and computer science in two selected universities in Poland. Our study relies on a detailed review and analysis of qualitative data, obtained from a literature review and multi-case-study research. In the case of the artificial intelligence domain, we have identified six areas of research, namely: general AI, machine learning (ML), natural language processing (NLP), artificial neural networks (ANNs), expert systems, and hybrids. In the case of the knowledge management domain, we have recognized eleven areas of research, regarding the following sectors: e-government, technology, space exploration, social media, manufacturing, healthcare, finance, entertainment, education, e-commerce, and business. Future research will be directed toward extending the scope by including other regions and universities as well as identifying and analyzing students' motivational factors, associated with research projects and higher education.

Keywords: Artificial intelligence · Knowledge Management · Students' Research · Students' Theses.

1 Introduction

A fascination with new technologies is typical nowadays among young people. For some, it is essential for communication, exchanging media files, participating in games or just informing the "world" about their current events [1]. For more ambitious students, leading technologies can be connected with their strong interest in personal development and professional life. Especially students learning information and communication technologies (ICT) are strongly motivated to become familiar with practical solutions in various sectors. Therefore the implementation of ICT for example in business or management can be considered as an interesting research area during the preparation of their thesis oriented on important computer methods. Very often artificial intelligence (AI) and knowledge management (KM) are selected as the fields of studies finally defined as bachelor's or master's theses.

Potentially, investigations of students very often lead to prototypes of solutions that are directly connected with AI methods and direct or indirect references to KM areas [2, 3]. Therefore the understanding of the importance of these solutions among young people is widely known. Besides, topics of research representing both of the mentioned areas are strongly supported by scientific societies awarding the best thesis of students in specially organized competitions (for example Polish Artificial Intelligence Society [4], and Business Informatics Scientific Society [5]).

The goal of this paper is to summarize and classify the current state of university students' research on artificial intelligence and knowledge management. With regard to this objective, we put forward the following research question: **What topics have been the subject of university students' research in the area of artificial intelligence and knowledge management?** Our study relies on a snowballing literature review, in which we adopted the procedure elaborated by Wohlin [6], as well as the case study in which we followed the guidelines provided by Gagnon [7].

The paper is structured as follows. The second section outlines the theoretical background of the study. The third section reflects the state of the art of the research on a students' thesis; the differentiation of studies connected with ICT is discussed and various forms of defining students' research are analyzed. The next part, which is an attempt of grouping students' works with the taxonomy of subjects presented in the proposed thesis. The next two sections demonstrate an overview of student theses oriented on AI and KM from two public universities and two nonpublic higher education institutions. The findings are given in the last section.

2 Background

It is claimed that the term "artificial intelligence" (AI) was first introduced at a conference at Dartmouth College, which took place in 1956 in New Hampshire [8]. At that time, the participants represented a broad range of interests, from

abstraction of content from sensory inputs, complexity theory, language simulation, neural nets, relationship of randomness to creative thinking, to learning machines. The conference laid the foundations for a great vision which has affected research and development in almost every human activity.

In general, artificial intelligence is "the enterprise of constructing an intelligent artefact" [9]. However, this definition still needs to be further explained. In general terms, intelligence is defined twofold as: (1) "the ability to learn or understand or to deal with new or trying situations, and (2) "the ability to apply knowledge to manipulate one's environment or to think abstractly as measured by objective criteria (such as tests)" [10].

In spite of the recognition of the term "artefact," the exact denotation is still not clear due to the fact of a plethora of different understandings of the term and due to a putative usage [11]. For some, an artefact is "an object made by a human being, typically one of cultural or historical interest" [12], while in the context of computer science it is "a specific bundle of hardware and software that is assembled to fulfil information needs" [13].

Despite a short history of debates, discussions and polemics, there is still no standard definition of intelligence [14]. Having said that, one can also assume the existence of a deep passage along the notion of artificial intelligence. However, some ideas have been introduced which have brought better understanding to this field. For example, the science of artificial intelligence (AI) might be defined as "the construction of intelligent systems and their analysis" [15], or "the study of systems that act in a way that to any observer would appear to be intelligent" [16].

In many cases, AI techniques are adapted to solve simple or complex problems that are internal to more complex systems. While the former may concern the solution of the traveling salesman problem, the latter may be associated with the effort of programming the Sophia, the world's most advanced rationale robot with human traits [17]. In other words, while some systems are designed to solve particular problems, others, in contrast, are designed to behave in an intelligent way.

This separation has its reflection in two different approaches in design, so called "weak AI" and "strong AI". The former is "the art of making computers do smart things" [18], while the latter is the art of constructing objects with mental capabilities and functions that mimic the human brain. In the case of strong AI, the definition is not narrowed to the computers where so far objects are associated with robots or humanoids. However, as stated above, since the society of researchers cannot even accurately formulate the definition of the intelligence, its further classification seems to be even more obscure.

Artificial intelligence has its roots in computer science and draws from engineering, mathematics, psychology and philosophy. In the beginning, the scope solely covered the problems of developing computational methods with a consistent approach toward each problem. These problems are those which people can solve, with more or less mental effort, but the solutions of which they cannot verbalize and describe in detail. On the other hand, a properly designed and im-

plemented method reduces or even eliminates all the risk associated with human errors [19].

Nowadays, the development of artificial intelligence is associated with machine learning [20], neural networks [21], evolutionary computing [22], image recognition [23], natural language processing [24, 25], and robotics [26, 27]. Moreover, a new multidisciplinary paradigm has been introduced, namely Ambient Intelligence (AmI), combining Norman's so-called Invisible Computer and Ubiquitous Computing [28]. AmI supports the design of the next generation of AI systems that intends to add novel means of communication between the human, machine and surrounding environment in a responsive and non-intrusive way [29].

3 Student Research Projects and Theses

There are several majors of studies oriented on specialized education and the development of abilities of ICT to create and implement. Besides faculties closely connected with computer science education, there is a huge potential in terms of usability of computers in decision-making processes. Business and the broadly represented management and social sciences studies create an opportunity for students to merge domain economic knowledge with applying intelligent technologies in their future professional life. Perceiving a problem that appears during the implementation of these technologies can be very inspirational from a student's perspective. The preparation of students for research work can be initiated according to one of the following variants:

- Students more familiar with ICT and having some professional experience can independently define an area of research and sometimes even formulate their bachelor's or master's thesis;
- For students without the above abilities, a supervisor prepares a list of topics that can be discussed with particular students and with the supervisor supporting the definition of a research field, and the final thesis is formulated as a result of stronger cooperation.

Obviously, in both cases, the students are obliged to perform a literature study finished through the preparation of a report reflecting their understanding of the topic. Basically, apart from the presentation of the theoretical background of the defined problem, practical solutions are formulated. The first, theoretical chapter(s), are completed as a result of the literature review – so interpretations of AI and KM are discussed and extended by crucial classification typical for both areas. The "empirical" part refers to one of the treatments of the solution:

- investigation of the real impact, stressing of usability of AI methods or KM approaches implemented in the selected institutions or sectors;
- development of an application (rather as a prototype) supporting the determined area(s) with the employed AI methods or KM approaches;

– comparison or analysis of potentially useful AI methods or KM approaches in terms of a survey emphasizing the solution context (for example, hybridization of the applied techniques or effectiveness of the proposed improvement).

The research devoted to the student's work on AI and KM subjects has reached a moderate interest. The list of the available trends in this investigation can be expressed as follows:

1. Artificial Neural Networks (Deep Learning).
2. Autonomous Cars.
3. Biometrics.
4. Computer Vision (including Image Processing and Recognition).
5. Expert Systems.
6. Fuzzy Logic.
7. Neural Networks.
8. Robotics.
9. Natural Language Processing.
10. Smart multi-agent systems.
11. Bayesian Networks.

There are many perspectives of the more global approach to AI as the leading technology nowadays. A more systematic way of presenting the technology landscape is depicted in Figure 1. Embracing traditional AI methods (neural networks, pattern recognition, machine learning), they are connected with more modern approaches expressed as the AI technology landscape.

These topics, just to name a few, find their application in such areas as:

– Air Traffic Control.
– Construction and Manufacturing.
– Energy Sector.
– Software Engineering.
– Internet of Things.
– Medical Diagnosis.
– Remote Sensing.
– Telecommunication.

All the mentioned areas can potentially be considered as applications for students preparing their thesis.

4 Clustering of Students' Research

There is no doubt that active learning methods are commonly recognized as very effective and provide opportunities for students on their self-progress [31]. At least three forms of students' activities can be strictly connected with this concept. The first, which is not very popular but can appear during the earlier stages of studies, is participation in a students' scientific circle. It is a good model for organizing groups of more ambitious students interested in certain

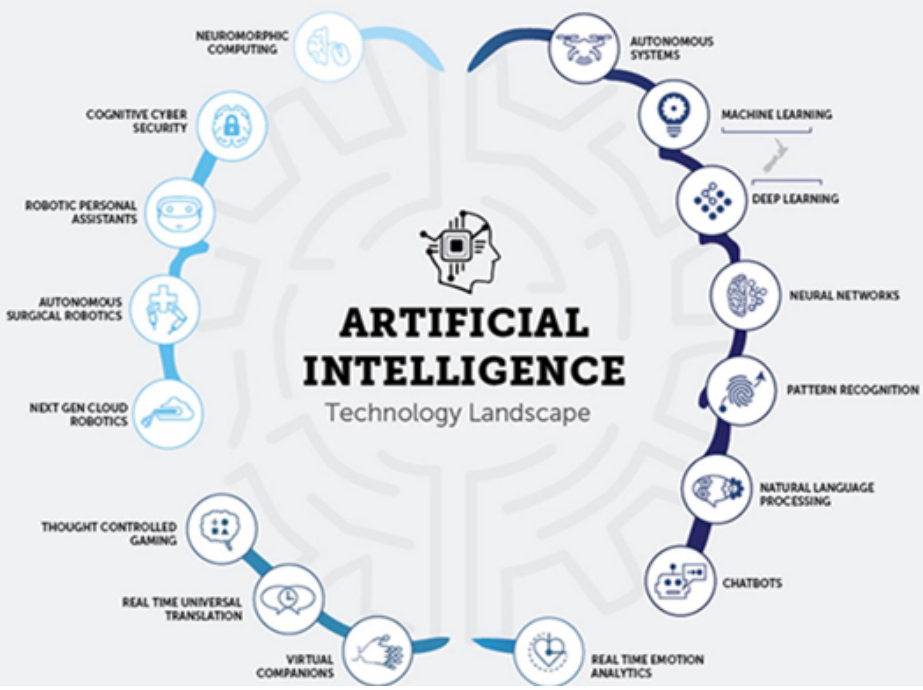

Fig. 1. Artificial Intelligence Technology Landscape. Source [30].

specific problems, where experienced researchers from a university support their work. Second, students can be asked to work on real scientific projects; tutors knowing the students' capabilities can formulate special tasks for them as part of the project. Compared to the previous two, the third is obligatory and relates to preparing a student's thesis as the result of their research agreed with the supervisor. In this section, we focus on the third one; remembering in all cases the leader of the research should respect the motivation and interest of the students.

We assume the majority of students are free to define their thesis but support and final acceptance by the supervisor is obvious. Therefore students try to express their direction in the research defining the area of interest and at least the crucial keywords and/or proposed research methods. Considering research in the areas of artificial intelligence, some trends and interests can be formulated in different ways. Initially, the main areas can be identified with artificial intelligence methods and techniques and presented in Figure 2.

Not all of the methods and techniques mentioned are acceptable to students. This is mainly due to the educational profile of the universities being taken into account in the research; practical references (in the sense of selecting a field from among the economic sciences) should be correlated with the usefulness of AI methods and techniques in the area of finance, management, etc. Therefore,

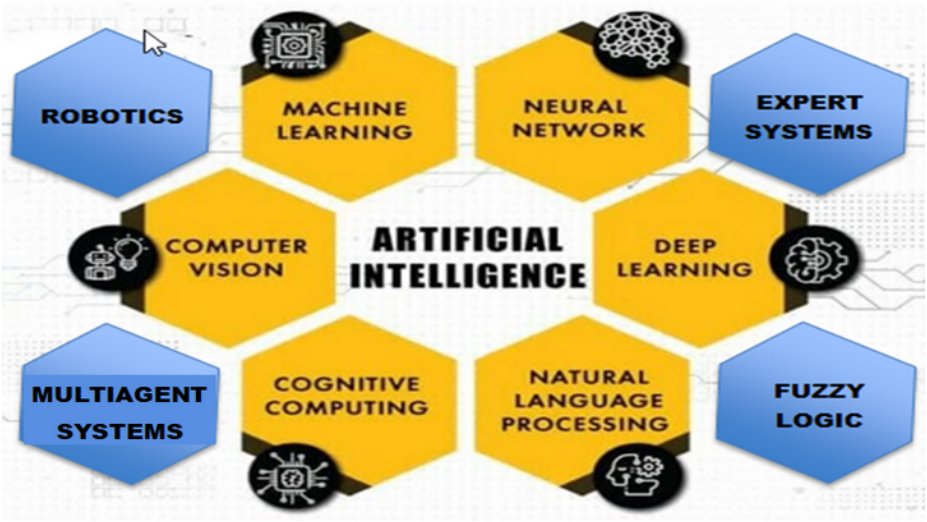

Fig. 2. AI methods and techniques potentially considered by students.

we eventually excluded from the list Robotics, Computer Vision and Cognitive Computing.

The second reason for defining their research area refers to the type of investigation. There are not many discussions about the research types addressed to students. Some of the proposals are formulated very broadly. For example, White itemizes the following list [32]: qualitative, quantitative, analytical, persuasive, cause and effect, experimental, survey, problem-solution, report research), while others are rather oriented on a specific area of study.

McCombes argues that one can consider applying the following types of research [33]: basic vs applied, exploratory vs explanatory, or inductive vs deductive research. Especially the last one seems to be closer to students' approaches in business informatics nowadays. After analysis of the topics elaborated by the students in the selected university, we decided to follow McCombes' approach with some modifications.

Therefore **basic research** is presented as a tendency to analyze the usability, effectiveness, or implementation AI methods, while **applied research** has been represented as the development of prototypes for the final solution in the selected areas. The results of clustering the topics of the bachelor's and master's theses are depicted in Figure 3.

According to the assumptions, basic as well as applied research can be connected with particular methods. The first type of research, denoted as "**AI general**," should be identified with topics without a clearly defined AI method; the last one, declared as "**hybrid research**," means theses with more than one AI method considered in the research.

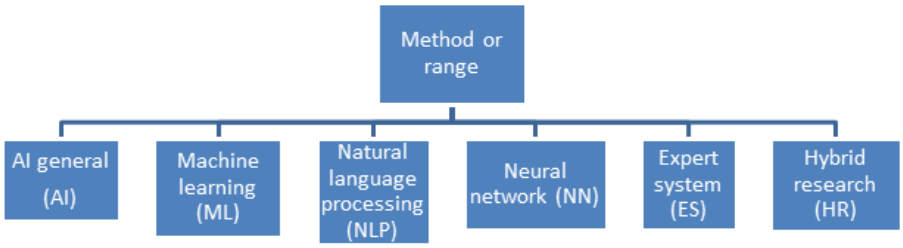

Fig. 3. Research approaches in Students' theses.

The second group of theses are related to problems of Knowledge Management [34–37]. This research area was mostly selected by students of master's degree level. The general concept of formulating topics by students is expressed in Figure 4. Several aspects could be considered in the paper but three main perspectives should be underlined: **Knowledge Management**, as the approach oriented on global services of knowledge structures in some sense overlapping **Knowledge Engineering** [38, 39], and generated knowledge bases mostly through **Data Mining** algorithms [40].

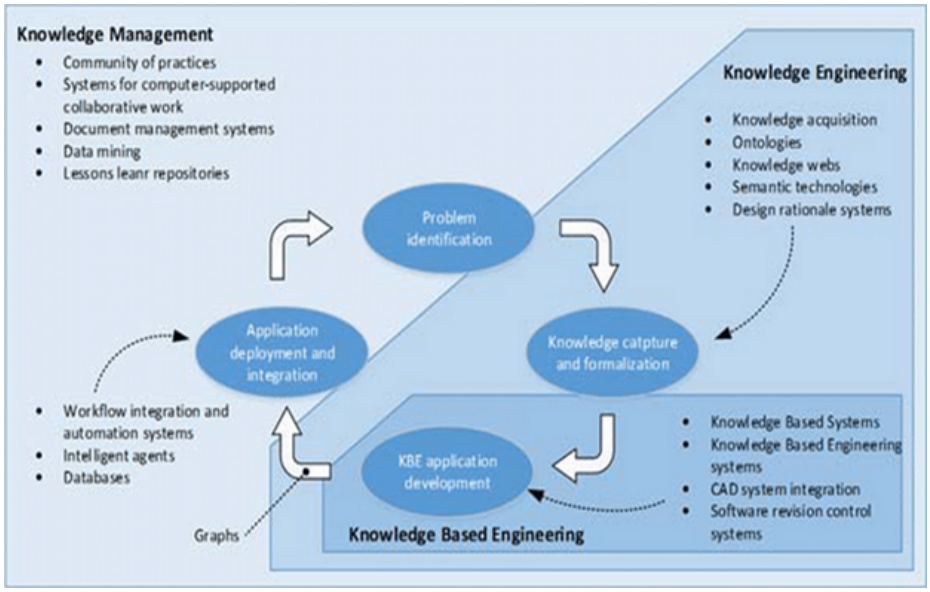

Fig. 4. Knowledge Management perspectives potentially considered by Students [41].

Summarizing, the final clustering of topics in the KM part can be divided into two groups; all more globally defined research is represented as Knowledge

Management; the others with clearly defined algorithms (mostly due to the experimental characteristics of the research) are termed Data Mining.

The last element of the students' formulated theses is connected with suggested areas of application. The potential list of sectors is proposed in Figure 5. The list is partially changed, compared to the one presented earlier.

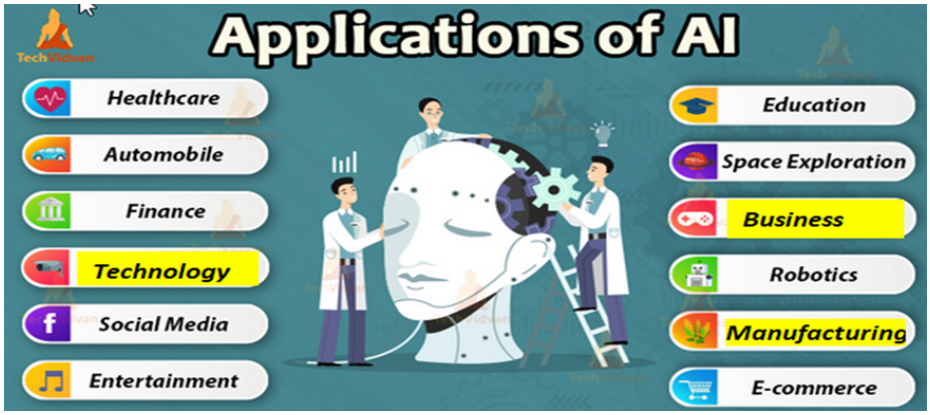

Fig. 5. Overview of potential areas of application in students' theses.

It is a very natural to define the direction of the research in accordance with the major of study. So, such areas as: technology, business, finance, manufacturing, and e-commerce are obvious in their proposals of implementation of intelligent technologies. The others arise from their interests or anticipations of their future professional life [42].

5 AI Methods in the Students' Research

As it was mentioned earlier, students can potentially formulate their thesis after discussion with a supervisor, knowing his/her area of scientific research. Sometimes, scientists propose the list of new topics or advise to become familiar with those recently elaborated. Either way, there should be real consensus between the students and supervisors in the final labeling of the thesis. This is the most common practice in universities; in some cases, students participating in some scientific activities can be motivated to join these interests with the ongoing or past projects.

In this paper, research on the topics connected with theses covering the AI and KM disciplines was performed on students of Wroclaw University of Economics and Business defending their works in the last ten years mostly in the Faculty of Management, Computer Science and Finance. About 120 theses represented AI+KM topics and detailed data are presented in the next sections; about 60% of the theses relate to the bachelor's level and the others refer to the

master's level. The criteria to qualify the theses to the earlier proposed groups involved the titles, keywords and summaries of the works. We followed the earlier proposed differentiation of AI methods and types of the theses; therefore particular were combined with the preparation of solution prototypes (so developing applications) or with general research in the method (identified with basic investigation).

Types of bachelor's theses are presented in Figure 6; the division of works oriented on developing prototypes or focusing on more general research was maintained.

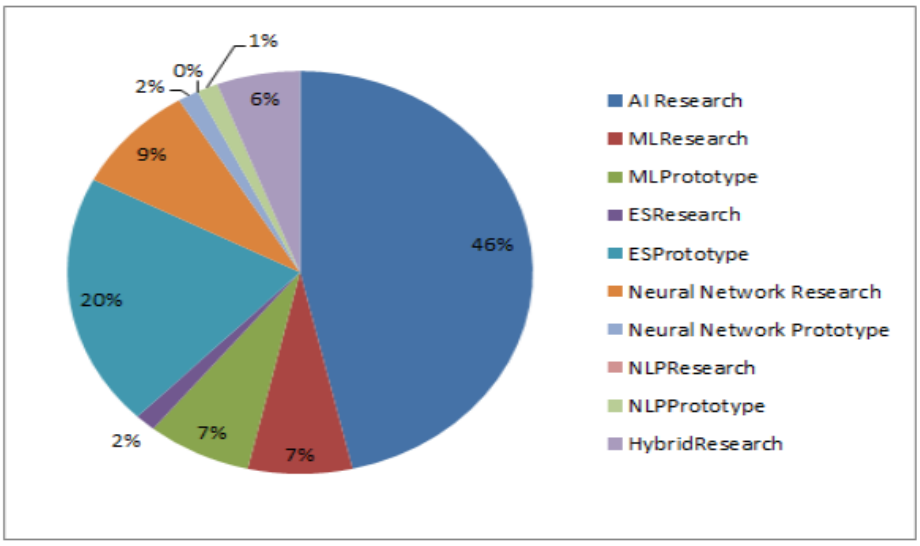

Fig. 6. Bachelor's theses presenting AI methods.

About half of the theses were devoted to fundamental research without specification of the dominant AI method. A relatively significant number of bachelor's theses were connected with the creation of prototypes of expert systems and topics on machine learning and neural networks with the preparation of prototypes and more general research.

The next implementation aspect of the research relates to applying earlier demonstrated AI methods in different sectors. The results are depicted in Figure 7. The biggest number of bachelor's theses was oriented on technology with the crucial importance of general research in AI. The next area of AI method applications in bachelor's theses was manufacturing with the increasing role of neural networks.

The second group of theses, prepared as master's work, represent the same – as previously – AI methods. The results of the topic analysis are a bit different compared to the bachelor's level. The biggest number of authors prepared their

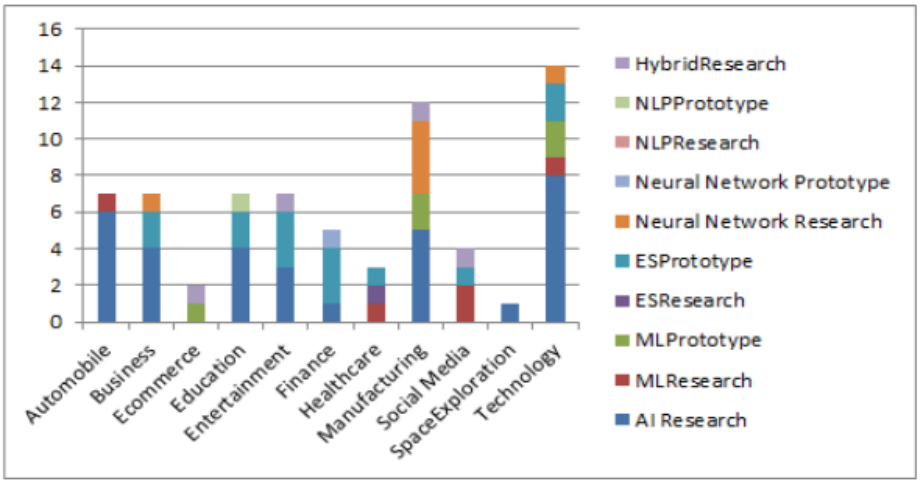

Fig. 7. Applying AI methods in bachelor's theses connected with sectors.

theses on AI basic research (it was not so dominant) but the next two groups preferred machine learning and neural networks methods.

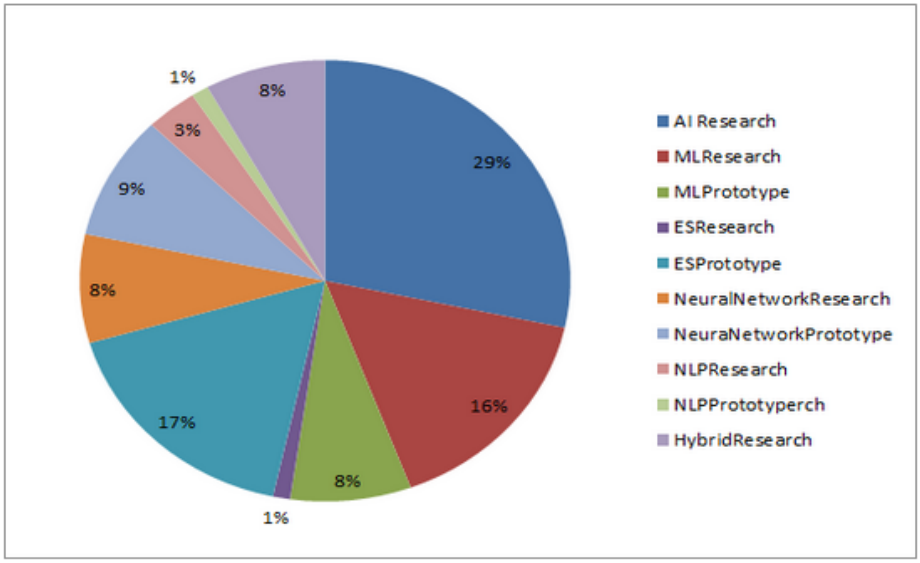

Fig. 8. Master's theses presenting AI methods.

The finance area was considered by students as the main sector in their more practical-oriented topics (preparing prototypes and performing basic research) using mostly machine learning and neural networks. The next two sectors represent technology and business. It is also worth stressing recently appeared works connected with entertainment, automobiles and space exploration.

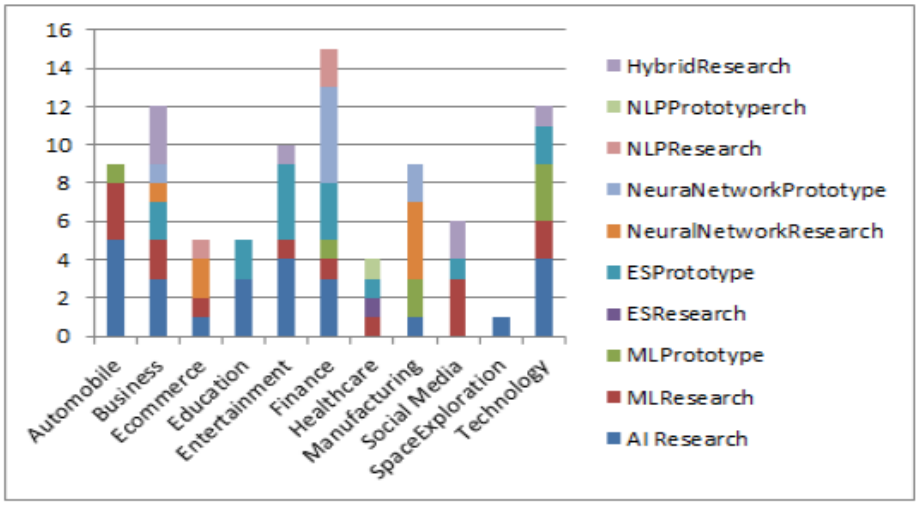

Fig. 9. Applying AI methods in master's theses connected with sectors.

The presented charts inform us about the significant and increasing importance of AI topics. Recently, the number of bachelor's as well master's theses has been relatively meaningful in all faculties.

6 Knowledge Management in the Students' Research

Knowledge management as a topic of research is very often strictly connected with AI methods. But in the case of students' theses, their topics were formulated and analyzed rather separately. It is also worth stressing that a KM orientation in students' works has been observed at the master's level. KM topics were very seldom formulated at the bachelor's level. According to the previous assumptions, two main groups of topics have been considered in this section: broadly defined Knowledge Management and formulated as supporting knowledge discovering technology, commonly known as **Data Mining** [43, 44].

The participation of these two topics is presented in Figure 10. During the whole period of the elaborated theses, almost 75% of students defined some problems rooted in Knowledge Management. The rest of the students tried to solve problems using different Data Mining algorithms (especially recently).

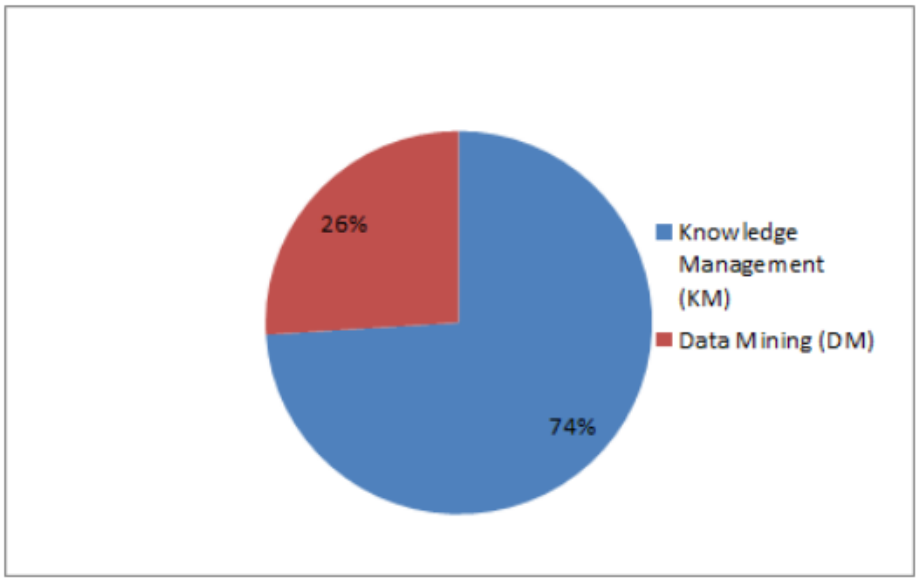

Fig. 10. Students' theses presenting Knowledge Management and Data Mining.

Knowledge Management in higher institutions is identified with surveys and the analysis of applying this concept in academic society [45–47]. On the other hand, students' experiences (especially obtained during professional work) are always connected with the concepts of knowledge acquisition or discovery. In the case of the investigated students, they tried to propose some solutions addressed to the defined areas. The list of sectors presented earlier changed: instead of the automobile sector, government appeared.

In Figure 11, students' topics connected with KM and DM are presented with these topics being applied in different sectors. Two main sectors appeared as leaders in implementing both approaches: Business and Technology. As previously, the Finance area and e-commerce with manufacturing represent the sectors of applying KM and DM in students' master's theses.

To sum up, the importance of knowledge management and data mining were confirmed in different sectors; most of the topics covered almost all earlier presented in the theses on artificial intelligence.

7 Conclusions

Based on the results from the performed study, we have formulated the following findings. Firstly, investigation of students' research when preparing their theses is performed very incidentally and rarely. Secondly, different approaches applied by students are typical when defining areas of interest. Thirdly, the proposed clustering of students' topics reflects regional and university educational/research

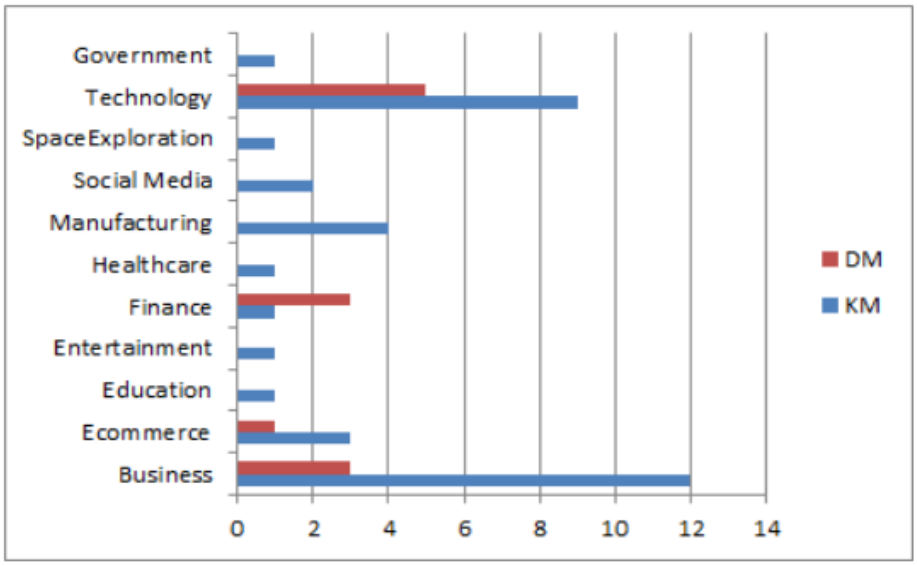

Fig. 11. Applying Knowledge Management and Data Mining in students' theses.

directions. Fourthly, the defined topics in the theses cover the majority of actual trends in AI and KM which seems to be the main determinant along with the supervisors' suggestions, students' motivations, professional experiences, and current trends in the IT sector. Last but not least, active student participation in research projects and scientific circles facilitates the topic formulation of the theses, and enhances their self-learning.

Further research will cover two areas. First, we plan to extend the study by investigating other regions and universities. Second, we aim to explore the students' motivational factors associated with research projects and higher education.

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