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COGNITIVE COMPUTING IN EDUCATION

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Cognitive computing is the new wave of Artificial Intelligence (AI), relying on traditional techniques based on expert systems and also exploiting statistics and mathematical models. In particular, cognitive computing systems can be regarded as a "more human" artificial intelligence. In fact, they mimic human reasoning methodologies, showing special capabilities in dealing with uncertainties and in solving problems that typically entail computation consuming processes. Moreover, they can evolve, exploiting the accumulated experience to learn from the past, both from errors and from successful findings. From a theoretical point of view, cognitive computing could replace existing calculators in many fields of application but hardware requirements are still high, even if the cloud infrastructure, which is expected to uphold its rapid growth in the very next future, can support their diffusion and ease the penetration of such a novel variety of systems, fostering new services as well as changes in many settled paradigms. In this paper, we focus on

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benefits that this technology can bring when applied in the education field and we make a short review of relevant experiences.

1 Introduction

Owing to new possibilities offered by cognitive computing, we can envisage the raise of a new generation of automated Information Technology (IT) systems committed to relief humans from solving a variety of problems. They will be based on human cognitive capabilities simulation, through sophisticated machine learning algorithms inherited from the field of Artificial Intelligence (AI), as well as on the imitation of the human reasoning (Mohda, 2011). In more detail, we can identify three main areas in which cognitive computing will cover a significant role, that are: advancements in computation capabilities, human-computer interactions and communication, and the evolution of the Internet of Things (IoT). In the following paragraphs we give a short overview of each of these.

Cognitive computing can successfully deal with complex tasks such as, e.g., natural language processing and classification, data mining, knowledge management, hence cognitive systems can successfully perform sophisticated duties such as relationships extraction from unstructured corpus, speech-to-text and text-to-speech conversions, pattern recognition, computer vision, machine learning, which involve research areas based on human-like reasoning techniques. From a practical point of view, cognitive computing systems owe their ability to the large amount of data they analyze and process to feed the machine learning algorithms they are based on. Such a continuous number crunching, enhances the capabilities of automated systems to derive new knowledge and to anticipate solutions for a wide range of problems. For example, a very popular technology based on such a kind of AI is employed in search engines, which provide in a seamless manner entity extraction, clustering, and classification and pull back only information that is relevant to the users, based both on personal data and on the application of patterns. As another example, let us consider the recommendation mechanisms (Pazzani & Billsus, 2007) adopted by some electronic commerce sites, which apply sophisticated machine learning algorithms to provide users with suggestions about other products that are, or even maybe, related to the ones they are viewing or have put in their wish lists, based on their preferences and on that item's purchase history.

Cognitive computing fosters new ways of interaction between humans and computers. Since cognitive computing simulates human reasoning processes translating them in suited templates, it can help machines to learn and to teach humans new concepts and/or behaviors. Such intelligent systems could be used, e.g., in training and customization, or any other activity that requires data analysis (analytics) in order to improve both processes and products (Earley, 2015).

Such innovations will also dramatically impact on interconnect technologies (Orii *et al.*, 2016) and other evolutionary trends such as the IoT (Zhang *et al.*, 2012). In fact, in a scenario in which people and things (machines) interact naturally, striving spoken language, data collection and analysis becomes essential. It is natural, therefore to collect, extract, abstracting and analyzing large amounts of data, in order to realize intelligent systems that are able to react in real time to external stimuli. In this respect, Holtel (2014) states that the main benefits coming from cognitive computing will not reside in the cognitive system itself, but in coupling the cognitive system to the IoT. This will give rise to a new engineering in which design will be driven by desired behaviors: what will make the machines rather than how they will be made. Another prospected advantage is the growing confidence in humans that machines can provide answers with an acceptable degree of trust in delicate areas, such as, e.g., medicine or economics.

To conclude, given these premises, we argue that cognitive computing will be one of the main drivers for the near future developments in many fields of application. In fact, according to Denning (2014), there are six *possibility waves to surf*, which can drive the evolution in the profession of IT that are: (*i*) an insight that opens up a new world of possibilities for dealing with a concern; (*ii*) basic science, which is a search for recurrences that explain what is going on and suggest new technologies. These searches can be triggered by the above-cited insights, while research centers, laboratories, and universities are common locations; (*iii*) a search for applications of basic science principles; (*iv*) a search for new products that embody concrete applications; (*v*) opening new markets for products supporting the applications and, finally (*vi*) the everyday use of things. All of the six items listed above matches with both the development of new cognitive computing-based services, and the adoption of such new services for the solution of old problems. This can be also deduced from the IEEE Computer Society 2022 report (Alkhatib *et al.*, 2015), stating that the top five most disruptive technologies will be: (*i*) robot as labor, (*ii*) the use of 3D printing, (*iii*) cloud computing, (*iv*) massive open online courses, and (*v*) new user interfaces. This evolutionary scenario is already taking place and all of the above-cited five points are pushed mainly by the following drivers: (*i*) use of technology for medical procedures, (*ii*) wireless/broadband connectivity, (*iii*) desire for sustainable energy sources, (*iv*) long term availability of certain energy sources, (*v*) use of big data analytics. We highlight that cognitive computing can empower all of the above-cited five drivers.

According to this general scenario, we are going to investigate how cognitive computing with related technologies and applications impact on education.

The remainder of the paper is structured as follows. In Section 2 we showcase related works on both sides of research and industry. Section 3 presents cognitive computing-based development tools and solutions. Then, in Section 4 we focus on the specific field of education. Section 5 closes the work with conclusions and a glance to the future.

2 Related works

We are increasingly talking about cognitive computing systems and this opens a new machines era (Brynjolfsson & McAfee, 2014), reflecting on both scientific research, R&D departments of industries, and products and applications as well.

2.1 Research side

In the academic research, there is a growing interest around cognitive computing and related topics. This is witnessed by the fast-growing literature in this specific area. In the following, we report some references, which cover different aspects of cognitive computing, not only the mere technological side.

In this respect, Wang *et al.* (2010) introduce the framework of a wider discipline embracing cognitive computing applications. They describe Cognitive Informatics as a transdisciplinary enquiry of computer science, information science, cognitive science and intelligence science that investigates into the internal information processing mechanisms and processes of the brain and natural intelligence, as well as their engineering applications in cognitive computing. According to Early (2015), such applications have a strict relationship with machine learning and this should contribute to the revamping of AI. In fact, on one hand, machine learning can be described as a technique for detecting patterns and surfacing information and it is mainly based on statistics and mathematical models. We can see machine learning at work every day in the technology used for searching the web, which provides quick entity extraction, clustering, and classification. From a practical point of view, machine learning uses pattern matching techniques to pull back information that's relevant to the user, individualizing the search results. On the other hand, cognitive computing is about making computers interfaces more user friendly and enabling them to understand more of what the user wants, by taking signals about what the user is trying to do and providing appropriate responses. AI encompasses all of these tools and solves a wide variety of problems, such as, e.g., writing articles, driving autonomous vehicles, detecting fraud, and diagnosing diseases. Currently, a lot of decisions that have typically been made by human beings can be made by means of AI and future research aims to enhancing such capabilities through further developments in the AI field.

Furthermore, a rapid development of cognitive computing application may also result in the investigation for a new generation of computers. In this respect, Frost *et al.* (2015) describe their Street Engine as a new, highly parallel computer architecture mimicking the micro-architecture of the human brain, distributing both memory and computation. It was designed specifically for cognitive computing, together with a specific language, also called Street Language, which is executed directly in hardware, with the aim of realizing advanced cognitive agents more power efficiently than conventional computers.

To conclude, and to have a glance on open research challenges in cognitive computing, Gutierrez and López (2015) recently made a survey where interested readers can find: (*i*) a glossary of definitions, related fields, and terms, (*ii*) a classification of current research on cognitive computing according to its objectives, (*iii*) a concise review of cognitive computing approaches, and (*iv*) open research issues. Besides, Banavar (2015) depicts the era of cognitive computing, giving an overview of the applications, the underlying capabilities, and some of the key challenges, of cognitive systems.

2.2 Industry side

From the industry side, with the objective of providing a non-proprietary definition of cognitive computing that could be used as a benchmark by IT professionals and researchers as well, by the media and technology users and buyers, a cross-disciplinary group of experts from industry, academia and the analyst community, joined the Cognitive Computing Consortium[1], whose members were gathered from a variety of company, research centers and institutions, such as, Synthesis and NextEra Research (founders) with Pivotal, Basis Technology, HP, IBM, BA Insight, CustomerMatrix, SAS, Interactions, Bebaio, Microsoft, and Universities such as, UCSF and the Babson College. It is worthwhile noticing that most of the sponsors are companies involved in big data analysis.

Moreover, several tools and platforms were created in recent years, which are going in the direction of making cognitive computing affordable and widely available. In this direction, some substantial contributions come from both private research investments, made by companies, and scientists in universities and research centers. Significant examples come from some of the greatest players in the IT market, such as, e.g.: (*i*) Cognitive Reasoning Platform (CRP) by Enterra, which claims to combine advanced computations and semantic reasoning to create a system that can sense, think, act and learn like humans; (*ii*) Deep Learning, by Microsoft, that open sourced its Computational Networks

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Toolkit (CNTK) and made it available for anyone to use in their own work on GitHub. This tool allows creating deep learning networks for different activities such as, e.g., speech recognition; (*iii*) DeepMind, by Google, that, in 2014, acquired the UK based AI company aimed to solving artificial intelligence problems. Then, in 2015, Google announced the creation of an AI that learns by itself and is able to win video games; (*iv*) IDOL (Intelligent Data Operating Layer), delivered by HP, which acquired Autonomy in 2011, within their big data software platform, offering many services and solutions for, e.g., data analysis and IoT; (*v*) Watson, by IBM, which is a technology platform using natural language processing and machine learning to reveal insights from large amounts of unstructured data.

3 Cognitive computing at work

Based on recent research experiences, in the following we will focus on the use of the IBM Watson platform (Kelly & Hamm, 2013) for it is giving a significant contribution to the recent growth of cognitive computing applications, being straight accessible without the need of investments in both costly hardware and software. Moreover, owing to the IBM Academic Initiative, universities can freely experiment Watson through the services and Application Programming Interfaces (API), made available within the IBM Bluemix platform (Kobylinski *et al.*, 2014).

In more detail, Watson is a full-featured cognitive computing system for the research and development of cognitive systems and services (Booch, 2011; Sudarsan, 2014), which can easily interoperate with other applications and legacy systems as well. It is a valuable commercial tool, empowered by the rich set of APIs within a varied catalog of building blocks available, which allow building advanced cognitive applications. For example, among the others, we cite the following boilerplates that can help enhance, scale, and accelerate human expertise: (*i*) *Concept Expansion*, which performs text analysis and can learn similar terms as well as words or phrases, based on context. Such a tool enables users to rapidly create a lexicon and a set of related terms from data sets of text fragments or collections of documents. Then, the output can be used to provide further understanding of data and improve text analytics pipelines; (*ii*) *Concept Insights*, which looks for associations of concepts inside sets of documents provided by users with a pre-existing graph of concepts based on the renowned free encyclopedia Wikipedia. Accordingly, the service identifies links of two types: *explicit links* in the case a document directly mentions a concept, and *implicit links*, which connect the input documents to relevant concepts that are not directly mentioned. This service can also search for documents that are relevant to a concept or collection of concepts by exploring both the explicit and the implicit links; (*iii*) *Dialog*, which allows developers designing the interaction mechanisms of an application with an end-user, based on a natural conversational interface. In practice, this service enables computer applications to use natural language and this capability can be profitably exploited in a variety of situations such as, e.g., automatically respond to user questions, walk users through processes or applications, or even hand-hold users through difficult tasks; (*iv*) *Natural Language Classifier*, which applies cognitive computing techniques to analyze sentences or phrases in a given corpus and return the best matching classes; (*v*) *Relationship Extraction*, which parses sentences into their various components, looking for relationships between the components; (*vi*) *Speech-to-text* and *Text-to-speech*, the former converts the human voice into the written word and the latter processes text and natural language to generate synthesized audio output complete with appropriate cadence and intonation even if on a limited set of languages; (*vii*) *Tone Analyzer*, which leverages cognitive linguistic analysis to identify tones that people show in their languages; (*viii*) *Visual Recognition*, which allows analyzing the visual appearance of images or video frames to understand what is happening in a scene. Based on machine learning technology, the semantic classifiers recognize many visual entities, such as, e.g., settings, objects, and events; (*ix*) *Tradeoff Analytics*, which helps people make better choices while taking into account multiple, often conflicting, goals that matter when making that choice.

The straight availability of such a quantity of services with advanced functionalities, opens new opportunities and enables both designers and programmers to realize unprecedented solutions. As an example, let us consider the most famous demonstration of the IBM Watson's ability, that is its successful competition in the Jeopardy! game (Gliozzo, 2011; Brown, 2012; 2013). The victory was possible, owing to the capacity to answer open questions of unlimited domain, crawling both structured and unstructured data. In most cases multiple answers emerge and the cognitive computing system provides a confidence estimation for each. The key feature is mastering the language because the game offer clues through open questions (McCord *et al.*, 2012). These clues are to be analyzed because full of subtle meanings, irony and other complexities of natural language (Lally *et al.*, 2012). From a more technological point of view, Watson owes its smartness to the DeepQA Project (Ferrucci *et al.*, 2010; Epstein *et al.*, 2012), a massively parallel probabilistic evidence-based architecture, which can also be adapted to different business applications and additional exploratory challenge problems including medicine, enterprise search, and gaming.

3.1 Cognitive computing in healthcare

Watson's Jeopardy! victory raised to a wide audience the question of the similarity between artificial intelligence and human intelligence (Detterman, 2011). Then, new landscapes can be envisaged for the exploitation of such capabilities and we make a short excursus on healthcare, for it is one of the most challenging research areas. In this respect, Ferrucci *et al.* (2012) describe how the Watson technology can be applied to healthcare for an evidence-based clinical decision support system. It will be built on the DeepQA technology, which can explore a broad range of hypotheses and their associated evidence, as well as uncover missing information that can be used in mixed-initiative dialog. The Cleveland Clinic is acting as test bed for such applications, since they launched a project based on Watson's cognitive computing capabilities (Keim, 2015), in collaboration with the Memorial Sloan Kettering Cancer Center, the MD Anderson Cancer Center (University of Texas), and the Anthem insurance company. They are investigating a new way of using unstructured medical data to develop suited decision support systems, specifically addressed to both physicians and nurses.

As already stated, recognizing and classifying images is another specific ability of cognitive systems (Teo *et al.*, 2012). This feature can be very useful in cancer pathologies, especially breast cancer, lung cancer and prostate cancer (Strickland, 2013). In fact, a cognitive system that "sees" would be able to support the doctor sparing of analyzing many hundreds of thousands of documents about the same pathology and in a little time-frame. Furthermore, it could analyze in detail every medical record of each patient by searching for similarities. This is possible developing an Electronical Medical Record (EMR) problem-oriented summary (Devarakonda *et al.*, 2014) based on analytics services, which can extract and summarize only important information, useful to the medical analysis in a specific field of investigation.

4 Cognitive computing applications in education

Another important and promising field of application for the exploitation of cognitive computing services is education. Specifically, according to the smarter university model (Coccoli *et al.*, 2014), cognitive computing-based applications and services should be adopted for administration and management, and learning activities as well. From the e-learning point of view, we report some experiences that witness how cognitive computing can be an accelerator for students' achievements, and a valuable support for the teachers. In particular: (*i*) integrating cognitive computing services in software applications can strongly enhance students' performances in computer science classes; (*ii*) studying cognitive computing behavior can lead to significant results in AI related studies; (*iii*) using a cognitive computing layer for digital interactions with students can enhance their performances and ease the teachers' job in managing classes and learning materials.

4.1 Cognitive computing services in software development

We report an interesting experience of using cognitive computing in educational settings, that is the Watson Student Showcase (Byrd, 2016) organized by IEEE jointly with IBM. Students were challenged in a competition where they had to develop apps using the cognitive computing services included in Bluemix. The first five classified *cognos* (the cognitive apps) were attributed a $ 2,000 award each and the assessment was based on specific features the apps were required to expose, such as: originality, feasibility, usefulness, and creativity. Students involved in the competition (from the North Carolina State University) delivered the following applications: (*i*) *docbot*, a mobile app that summarizes Electronic Health Record (EHR) information to streamline medical appointments. In this app, cognitive computing capabilities are used to extract and organize the most relevant information for the situation, so to provide physicians only with data relevant the required medical examination. Moreover, the application interface is mainly based on natural language processing; (*ii*) *wordinator*, which aims to facilitating the search for the most suitable word to best express own thoughts. This is also an implementation of the available natural language processing services; (*iii*) *miface*, eminently capable of capturing facial expressions, those who assume in particular situations (anger, fear, surprise, fear, loss, etc.) although numerous expressions are already present in many algorithms, some of these need to be further analyzed by the human being to not generate false positives; (*iv*) *telephony*, which is based on the classical children game called "telephone". In this game a group of friends in turn whisper something in the ear of his neighbor and finally the last one has to infer what was whispered by the first player. Except that in this application the circle of friends does not really exist and the message is repeatedly transformed by the cognitive system engine; (*v*) *stack analyze*, which was designed to relief moderators of online communities from the heavy task of reviewing hundreds and hundreds of messages to determine whether a question of a community member is appropriate or not.

Another experience carried on in Italy demonstrated how the use of the IBM Watson services within the IBM Bluemix platform can enhance students' performances in computer programming classes (Coccoli *et al.*, 2015). In more detail, the research investigates how students' achievements varied depending on the adopted technological infrastructure, in developing similar projects, based on fundamentals of computer programming, data structures and algorithm. To this aim, past collaborative learning experiences, which are duly described in Coccoli *et al.* (2010; 2011), were used as the starting point and reference to experiment teaching computer programming in a Platform as a Service (PaaS) environment (Lawton, 2008). Among the many services made available within the platform, most students have profitably used those based on cognitive computing, to empower the functionalities of their demo projects, including, e.g., speech recognition, automatic translation, file conversion, text-to-speech services for accessibility matters, and many others. In conclusion, in this context, we were able to observe that students gained core competences in computer programming faster and improved the overall quality of their products owing to better interactions and natural interfaces.

The above-cited cases demonstrate with practical learning tasks that cognitive computing can be a paramount support in computer science laboratories and related activities.

4.2 Studying cognitive systems behavior

Another interesting application of cognitive computing in education is reported by Zadrozny *et al.* (2015), which analyze and try to understand some of the Watson's functionalities. Specifically, they describe a text analytics course focused on building a simulator of IBM Watson, conducted in Spring 2014 at UNC Charlotte. They state that it is the first time that such a simulation was created in a university classroom. Their research also reports that the simulated system almost achieved a 20% accuracy on the Jeopardy! questions, which were used as a benchmark.

4.3 Cognitive computing supporting teachers

Another aspect is related to the support that teachers could get from cognitive computing-based applications in solving common students' issues such as, e.g., school dropout, individualization of learning, customization of training path, etc., due to their capability of analyzing data (Mayer-Schonberger & Cukier, 2013). According to a novel paradigm, the teacher can ask the cognitive computing-based system to "talk" with students, in order to understand what are individual strengths and weaknesses and possible issues to face up to. These will be analyzed and reported to the teacher who then will decide the best strategies, course materials, etc., to overcome those issues. This feature is natively implemented in Watson and it is known as *Ask Watson*. Specifically, the cited example represents a triage student-Watson-teacher, which makes applicable the individual learning model (Lou *et al.*, 2001). In this respect, one can ask to discover a student's style of learning (e.g., *kinaesthetic*, *visual*, *auditory*). Otherwise, one can ask to prepare a small subclass for the math or computer science Olympics so that only students with specific attitudes will be selected and then will be provided with suited material and proper training to achieve their objectives at the best of their possibilities. In more detail, the above-cited paradigm consists of recursive cycles throughout 6 steps: (*i*) the cognitive system identifies weaknesses and strengths of every student; (*ii*) the cognitive system recommends behavior and contents for students aligned to their skills and learning styles; (*iii*) the teacher selects an appropriate learning path and creates an individualized plan for each student; (*iv*) the students use the recommended content from the plan material; (*v*) the teacher monitors students' progresses and, possibly, makes slight adjustments to the plan; (*vi*) the teacher uses cognitive computing system to identify students' skills attainment aligned to the defined standards.

Moreoever, it is worthwhile noticing that, beside advanced reasoning and decision making capabilities, the interaction mechanism based on spoken language assumes a paramount importance. Specifically, the interaction consists of three steps, mapped on the relevant cognitive services: (*i*) *ask*, (*ii*) *discover*, (*iii*) *decide*, delivered in sequence. In step (*i*) the student asks the cognitive system to be guided, through the speech-to-text and text-to-speech services; in step (*ii*), the cognitive system teaches the student how to derive the answers from the questions asked through the natural language classifier and relationship extraction services; in step (*iii*) the teacher sees the results through the tradeoff analytics and delegates the cognitive system to adapt the curriculum. This mode of assistance is very promising and is already providing fruits. The application of the cognitive system has been used in (*i*) Wichita State University, which uses advanced analytics to predict potential students' chances of success: 15% boost in registration. (*ii*) Hamilton County, Tennessee's Department of Education, which uses predictive analytics to improve student achievement causing the following results: 8% increase in the graduation rate to 80% and 25% reduction in the annual drop rate; (*iii*) Seton Hall, which has used integrated marketing optimization solutions analyzing social media to understand how students move through the recruitment process: 13% enrolled increase (Frase, 2014). It would be interesting to use similar approaches to solving educational problems in schools and universities. It would be possible tracking dropouts, checking registrations and preferences in university enrolments and, finally, using the admission test data required for universities to provide a detailed analysis of the problems that students encounter during their college career (in terms of both proficiency and deficiency) and the estimated time of the degree acquisition. Moreover, this experience launched other challenges, mainly in the analysis of data and analytics.

Finally, we also cite the experience carried on by Sundararajan and Nitta (2015), which designed and realized a tutoring system for K12 students, intensively using interactivity, automatic generation of questions, and learning analytics.

Conclusions

As a conclusion, after this short survey of cognitive computing technologies applied to education, our findings are encouraging. In fact, from this preliminary analysis emerges that there is a plenty of possibilities for the use of novel cognitive computing-based solutions and cognos for improving current performances of software, as well as to design novel applications, based on a new approach and on a new human-machine interaction and communication paradigm. However, this scenario seems to be far to realize, due to the lack of infrastructural settings and to the availability of open big data in general. Moreover, we notice that the reported experiences are from United States where the education system, and related business, is quite different from the majority of other countries. As an example, let us consider the Italian situation. At the best of the authors' knowledge, cognitive computing and related issues was part of computer programming classes in a few Italian universities, i.e., Genoa, Florence, and two in Naples that is "Federico II" and "Seconda Università". They presented their findings and interesting students' project within the workshop *Head in the Clouds*, focused on cloud computing and PaaS, i.e., *Eclipse meets Bluemix*, held within the the X annual Workshop of the Italian Eclipse Community.

In addition, as a drawback, we found that one of the main problems is how to effectively train a cognitive system, which is very important for its responses accuracy. In this respect, Murtaza *et al.* (2016) showed that if the cognitive system is trained with well segmented documents, with semantically relevant titles and content consistent with the titles, then the accuracy of the response may even exceed 95%.

Given these premises, we envisage a rapid development of cognitive computing technology and related applications in the near future but this will be possible only in a complex ecosystem where the valuable data that are available within the education system, including institutions and municipalities, can be exchanged between applications and between organizations in a seamless and transparent manner.

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