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Where Information Systems Research Meets Artificial Intelligence Practice: Towards the Development of an AI Capability Framework

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Completed Research Paper

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Abstract

Information systems (IS) research has always been one of the leading applied research areas in the investigation of technology-related phenomena. Meanwhile, for the past 10 years, artificial intelligence (AI) has transformed every aspect of society more than any other technological innovation. Thus, this is the right time for IS research to foster more quality and high-impact research on AI starting by organizing the cumulated body of knowledge on AI in IS research. We propose a framework called AI capability framework that would provide pertinent and relevant guidance for conducting IS research on AI. Since AI is a fast-evolving phenomenon, this framework is founded on the main AI capabilities that shape today's fast-moving AI ecosystem. Thus, it is crucial that such a framework engages both AI research and practice into a continuous and evolving dialogue.

Keywords: Artificial intelligence, information systems, systematic literature review, AI capability framework, classification.

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Introduction

Information systems (IS) cost major companies worldwide over $1 billion per year due to innovations in technology (Stair and Reynolds 2013). The most disruptive technology that is changing every aspect of our society is artificial intelligence (AI) (Brynjolfsson and Mcafee 2017). AI is the study of how to give features of human intelligence like learning, perception, comprehension, and problem-solving capabilities to a machine (McCarthy et al. 2006). It is reshaping the people, process and technology components of IS at the individual, organizational and societal levels by making technology smarter. Consequently, any technological artefact that manifests some degree of intelligence is generally referred to as AI. AI today is referred to as weak AI because it is designed to perform specific tasks as opposed to strong AI which is expected to outperform humans in several cognitive tasks (Lu et al. 2018).

Virtual assistants like Cortana, Siri, and Alexa for personal use, and IBM Watson with more organisational functions, are just a few popular examples of AI applications that are transforming IS. AI technologies and techniques like machine learning (ML) and deep learning (DL) are also reinventing workflows and business processes by giving them the ability to take intelligent, automated, and personalised actions (Brynjolfsson and Mcafee 2017; Kokina and Davenport 2017). These transformative effects of AI on IS make both research institutions and business organisations increase their budgets for AI research in an effort to tap into the real opportunities AI can provide. Evidently, this has led to seven-times the number of publications on AI since 1996 with steady annual growth, and an exponential growth of active AI start-ups since January 2015 with 100% increase in venture capital funding (Shoham et al. 2018).

AI is a stream of research that has existed since the 1950s. Ever since, the IS field has inherited concepts originating from the AI field and has accumulated a body of knowledge around these concepts and their applications IS. Today, AI has become part of many IS especially in decision support systems (DSS), and expert systems (ES). IS research has always been one of the leading applied research areas in the investigation of technology-related phenomena. However, it has been slow at demonstrating this leadership when it comes to research on AI in the last decade given that this research area is completely dominated by the AI and computer science fields (Shoham et al. 2018). Although the IS community recognizes the emergence and importance of IS research on AI, AI as a research area is just starting to receive the attention it deserves in top-tier IS journals. That can be seen by the increasing number of calls for papers and special issues advertised on the topic.

Thus, this is right time for IS research to foster more quality and high-impact research on AI starting by organizing the cumulated body of knowledge on AI in IS research. This will enable IS researchers and practitioners clearly identify what is known about AI in IS research and the research gaps that need to be addressed. This will also help IS research focus its limited resources on the most relevant AI issues that impact the future of IS at every level. Our aim is to propose a framework that would provide pertinent and relevant guidance for conducting IS research on AI. Since AI is a fast-evolving phenomenon, this framework is founded on the main AI capabilities that shape today's fast-moving AI ecosystem. Thus, it is crucial that such a framework engages both AI research and practice into a continuous and evolving dialogue.

Classification frameworks allow for the exhaustive categorization of related items based on a predetermined system (Gerber et al. 2017). They have proven to be very useful in the IS discipline by facilitating the identification of relationships or differences between items thereby facilitating the understanding of a given topic (Beinke et al. 2018). Our proposed framework provides an effective tool for IS researchers to organize IS literature on AI in a way that allows them directly perceive the progress of IS research on AI. This would enable the IS community to continuously focus its resources on relevant high-impact topics and applications of AI. With this clear picture in mind, it would be easier for IS research to begin adapting and building IS models and theories that consider the changes brought about by AI technologies. IS practitioners on the other hand could use this framework to easily situate the role of any AI concept in contemporary IS and find its corresponding IS literature. This would facilitate their understanding, implementation and management of AI-enhanced IS, making it easier for them to innovate and take advantage of the plethora of opportunities offered by AI.

We also contribute a research agenda that highlights some of the most interesting and important research areas for the IS community based on our findings from both research and practice. To the best of our knowledge, we propose the first framework that can be used to organize the cumulative body of knowledge on AI in IS in a way that speaks to both IS research and AI practice. In section 2 that follows, we present the theoretical background that shows the convergence between IS research and AI practice and how this led to the development of our proposed framework. In section 3, we present our two-phase methodological approach towards the final framework development and the identification of relevant IS literature. In section 4, we present our final framework and how it can be used to organize IS research on AI. We use articles from the Association of Information Systems (AIS) basket of eight journals to demonstrate the use of this framework. In section 5, we discuss what we know and don't know about IS research on AI and propose a research agenda.

Theoretical Background and Development

This section presents IS research on AI for the past 10 years to identify key AI concepts that could help with the development of a classification framework for IS research on AI. This aim is to develop a preliminary framework grounded on IS, theories of intelligence, ecological psychology, management, and organisational behaviour.

Artificial Intelligence in Information Systems Research

One of the most transformative AI concepts is machine learning (ML). IS research has been conducted on how to use ML with text mining to predict the online behaviour of users (Gong et al. 2018; Fang and Jen-Hwa Hu 2018; Lycett and Radwan 2019). There are also studies on how ML can be used to profile online users (Yin et al. 2019), to detect anomalies in online content (Kumar et al. 2018; Wang et al. 2018), and to improve dynamic decision making (Meyer et al. 2014). IS research has been conducted on how to use deep learning (DL), one of the most recent AI concepts, to improve location-based social network (LBSN) recommendation systems (Guo et al. 2018). Studies have also been conducted on how it can be used to profile online users and has proven to have the ability to outperform several benchmarked ML methods (Li et al. 2016; Adamopoulos et al. 2018).

Some IS researchers have focused their efforts on how to use natural language processing (NLP) and text analytics to improve coherence and comprehension of actions that support sense-making in online discourse (Abbasi et al. 2018; Garcia-Crespo et al. 2010). Others have focused on NLP's use in designing construct identity detectors (CIDs) (Larsen and How Bong 2016), analyzing open source project requirements (Vlas and Robinson 2012), and to profiling online users (Johnson et al. 2015). Artificial neural networks (ANN or NN in short) have been researched in works on social media analytics like Twitter sentiment analysis for brands seeking to quickly generate targeted highly effective tweets (Ghiassi et al. 2016). Research has also been conducted on how it can be used to predict real-time changes in environmental conditions (Kaloop et al. 2017), and to predict product demand (Dhar et al. 2014).

In the case of computer vision, IS researchers have investigated and discussed its application in health for diagnosis and surgery (Gianchandani 2011). Scholars have also investigated the role of robots in the human society (Aleksander 2017) and discussed their potential applications in healthcare (Gianchandani 2011) and in organizational performance (You and Robert Lionel P. 2018). On a more general scale, IS research has been conducted on how intelligent agents perceive their environments using sensors and how they influence human behavior (Nunamaker Jr. et al. 2011). This summarizes what has been published on AI in leading IS journals. These publications focus on the applications of ML, DL, NLP, ANN, computer vision, robotics and intelligent agents in IS. They try to show how these AI-related concepts could enhance the ability of IS to capture relevant data, understand it, and use it to take actions such as prediction, profiling, and recommendations. However, such paucity of AI-related research in IS publication outlets confirms that despite the exponential growth of AI in the last decade, AI as a research area has not yet received the attention it deserves in leading IS journals during this time. Therefore, there is an urgent need for IS scholars to join forces and start building a cumulative body of knowledge that meets the needs of AI practices today.

One of the major research gaps in the IS literature is the absence of a framework that helps organize IS research on AI. We are referring especially to a framework that could help IS researchers clearly identify research gaps and allow practitioners find relevant IS literature on AI. Such a framework is needed urgently given the growing interest in AI by leading IS journals as reflected in the rising demand for quality publications on the subject on one hand. On the other hand, this urgency is manifested by practitioners who are under pressure to implement AI in one way or the other to stay competitive. Therefore, to conduct IS research on AI that would be relevant for both AI research and practice, it is imperative to start by organizing this body of knowledge using an adapted framework. This would guide the (1) assessment of the suitability of AI concepts in different IS applications, (2) design of AI-enhanced IS, (3) understanding of the transformative effects of AI, (4) improvement of AI research approaches and methods, (5) development of IS theories and models for AI-enhanced digital platforms, and (6) conduct of cutting-edge research on how these platforms can impact people, organizations and the broader society.

Preliminary Framework Development

We started our investigation by identifying the main AI capabilities discussed in both AI research and practice. This is because, to build a robust framework, it has to be based on the nature of AI – what makes AI what it is today and how is it achieved is the question that guides our framework development. The original definition of AI makes it very clear that learning and perception are the key capabilities of any AI (McCarthy et al. 2006). This is well aligned with theories of intelligence and ecological psychology. Intelligence has been theorized as consisting of learned connections (Thorndike et al. 1926) or bonds (Thomson 1939) that represent how well and how fast an entity can comprehend and respond to situations. This highlights the notions of learning, perception, and comprehending as being key capabilities of any AI.

According to ecological psychology, senses represent evolved adaptations to an environment through perception and require sensory systems that directly and accurately depict the environment (Piaget and Cook 1952). Perceptions, on this account, are constructed out of sensations with the aid of memory, habit, cognitive strategies, and innate plans (Reed and Jones 1979). Comprehending the environment arises in the course of a transaction between an agent and the environment in which the agent evolves (Smelser and Baltes 2001). Thus, comprehension comes only after sensing the environment, and only then can the agent make inferences and learn new connections. Thus, in our attempt to give AI human intelligence capabilities, AI should have sensory systems that allow it to perceive it environment, try to comprehending this information, then learn from it.

From these two bodies of knowledge, we can assume that any technology artifact that can perceive its environment, make sense of it, act on that knowledge, and learn from its experiences (learn) is AI. These notions of sense, comprehend, learn, and act are well-known to the fields of management, organizational and behavioral science as sensible knowledge which is knowledge perceived, understood, and produced through senses. This type of knowledge has been used by people to comprehend, act and learn in organizations (Strati 2007). Given that AI emulate human intelligence and performance, we can say AI should have sensible knowledge capabilities.

Many AI practitioners have adopted *sense, comprehend, act, and learn* as they main AI capabilities as well and have used them to classify AI concepts. Bataller and Harris (2018) describe sense as the ability AI gives a system to perceive its environment by acquiring data like images, speech, and text. Comprehend gives the system the ability to recognise, interpret and contextualise patterns to derive their true meanings. Act enables the system to take actions based on their comprehension of the physical or digital world. Learn enables the system to continuously optimize its performance by learning from the success or failure of those actions.

At this point, we can safely arrive at the supported conclusion that sense, comprehend, act, and learn are the key capabilities of any AI artifact or AI-enhanced IS today (Shanks et al. 2015; Kolbjørnsrud et al. 2017; Bowen and Morosan 2018; Adadi et al. 2019). These key capabilities form the basis of our proposed framework because every AI domain, technology or technique applied to IS today is an attempt to give the system at least of one these capabilities. Indeed, when comparing these capabilities to the main components of IS (Stair and Reynolds 2013), we realize that, in an AI-enhanced IS, input is enhanced by sense, processing by comprehend, output by act, and feedback by learn. Therefore, organizing IS research on AI based on the key capabilities of AI makes it easy to identify the technologies that enhance each IS component.

Although this framework is simple and more or less intuitive at this point, it is incomplete because we still need to determine how the IS literature will fit into each of these categories. This preliminary framework shows the points of convergence between AI research and practice but does not show the classification criteria of IS research. We could try to use the AI concepts found in our review IS research on AI in the last decade but that is not enough and incomplete compared to what has been going on in practice. For example, practitioners claim a new breed of process automation software known as robotic process automation (RPA) promises companies great returns on investments and new business opportunities (Hallikainen et al. 2018). RPA has proven to deliver better process performance and returns on investment of up to 200% (Lacity and Willcocks 2016). This is something we didn't find in our review. Thus, to develop a comprehensive framework, we need to review practitioner and field expert-based discussions on AI in practice.

Gerber et al. (2017) conducted a study on classification approaches in IS research and found that most IS scholars have embraced classification frameworks as an effective way to categorise and organise information based on a predetermined set of criteria. They identified two main types of classification approaches: intentional classification (IC) where a general or a priori classes are subdivided and heuristics are used to sort information into classes; and extensional classification (EC) where information is analysed and grouped into classes from specific to general based on perceived similarities or contrast.

These classification approaches can be formal resulting in a structured, exhaustive and exclusive classification artefact, or intuitive resulting in a non-exclusive and less strict classification artefact. We propose a semi-structured extensional classification framework that is based on sense, comprehend, act, and learn, which are the main AI capabilities that we identified and validated in both research and practice. Semi-structured because although the framework should keep the structure of the AI capabilities, the AI concepts that enable these capabilities could evolve in time. With this in mind, we believe this framework is adapted for the classification and evolution of IS research on AI given how well it ties AI concepts and capabilities to IS components.

Research Methodology

This section describes our two-phase research design used to complete the proposed framework and for the identification of relevant IS literature to organize using the framework. The first phase is broad practice-based literature review which enabled aimed at completing our knowledge on key AI concepts that could be used to complete the preliminary framework. The second phase describes how we selected the papers mapped into the framework. The idea is to make sure that our final framework organizes IS research and practice in a way that is understandable and useable by both researchers and practitioners.

Both phases make use of systematic literature reviews because this approach is a well-established research-based way to answer a specific question about the best solution to a practical problem by organizing available knowledge on the topic (Paré et al. 2015). In our case, seek to propose the best way to identify and organize IS research on AI by mapping available publications to AI concepts and capabilities. The reviews were conducted based on guidelines suggested by Webster and Watson (2002).

Phase One: Practice-Based Review

The aim of this phase is to consistently identify the most important and recurrent underlying concepts of AI in practice today so that we can use this information to build a framework for IS research on AI. To ensure exhaustivity and objectivity, we conducted a broad review of practice-based literature published online by organizations and institutions leading today's AI industry. We wanted maximum coverage to make sure we objectively capture all the main perspectives of AI by major groups of practitioners. The tech companies were selected by comparing leading companies ranked in 2018 by the Fortune 500, Forbes, and Ivy League graduates as having the most revenue, best working conditions and most attractivity for Ivy league computer science graduates. We selected companies that featured in at least two of the rankings as being the most competent to share relevant expertise on AI.

We reviewed articles from consulting firms that featured in at least two of the following 2018 rankings: Forbes's best management consulting firms, information technology (IT) implementation firms, IT technology and communication firms, IT strategy firms, growth innovation and new business model firms. We reviewed expert-driven reviews and magazines that featured in the top 10 2018 Amazon best sellers in technology e-magazines and BusinessPundit best 10 journals and magazines. Research institutions were selected based on google scholar citations and web of science rankings on the top publishing research institutions. Finally, IT industry analyst companies were selected based on their perceived impact on the IT industry and on the IS community (Bernard and Gallupe 2013).

Finally, we reviewed literature published by 17 IT companies (e.g., Apple, Microsoft, Google), 11 consulting firms (e.g. Accenture, Capgemini), 17 expert reviews and magazines (e.g. Harvard Business Review, California Management Review), 4 research institutions (e.g. Chinese Academy of Science, National Aeronautics and Space Administration), and 4 industry analyst companies (e.g. Forrester, and Gartner). To find relevant online publications, we searched the web using Google search engine and the website of the expert entity under review. "X" is the name of the target entity (e.g. Gartner, Microsoft)[1].

To analyze the data collected, we used the content analysis method as guided by Miles et al (1994), Elo and Kyngäs (2008). This method consists of three phases: preparation, organization and reporting. We chose to use this method because of the possibility it provides to enhance the understanding of data in documents by categorizing them based on words or phrases with similar meanings. It has proven to be very effective in attaining a condensed broad description of a phenomenon as well as in developing conceptual frameworks which are both objectives to be attained in this study. Figure 1 contains details on the search and selection process to ensure the approach is rigorous and reproducible.

We used an inductive content analysis approach whereby we read through all the 175 relevant articles while writing down the headings of all main aspects related to AI we identified. After this first review, we categorized the articles under their corresponding headings and merged the data that were found in similar headings under a single heading which then became categories. After verification by each author, we named the categories using content-characteristic words and made a description for them. We then each did a second review to validate each category and its content. We used AQUAD version 7.5.5.1, a Computer Assisted/Aided Qualitative Data Analysis Software (CAQDAS) to facilitate word counting and content categorization.

This review revealed practice-based AI definitions, characteristics or functions, AI capabilities or services, principles, ethics, or values, technologies, subfields, computing systems, application areas, methods, technique, branches, or computing models, dimensions, types, or categories. The AI concepts under the AI technology category, which as you can see has been referred to under different names above are similar to those found in the IS literature on AI. Using this information, we investigated each of these AI technology-related concepts or domains and used this to complete our preliminary framework. To illustrate the operationalization of this framework for the classification of IS research on AI, we mapped IS research on AI published in the AIS senior basket of eight journals into the framework. This brings us to phase two of our methodology.

Phase Two: IS Research on AI in AIS Senior Scholar Journals

The aim of this phase is to identify relevant IS research on AI found in the AIS senior basket of eight journals that would be organized using our proposed framework. We chose to use these journals because they publish content that is highly respected by the IS community and have been used in other classification and review studies (Gerber et al. 2017; Bélanger and Carter 2012; Henkel and Kranz 2018). Thus, they are well suited to authoritatively demonstrate the validity of our framework and its applicability in other IS research journals.

[1] Please contact the corresponding author for a full list of company names.

The first step in this stage was to search the databases of each of the eight journals for relevant publications using a keyword string derived from the findings in phase one. This keyword string was designed from practice to capture all relevant IS literature that that match the need of contemporary AI practices. Our first search provided us with a total of 462 articles. Using guidelines suggested by Okoli (2010), we defined our exclusion criteria.

Our first criterion was to exclude from our review all papers whose titles, abstracts or keywords do not reflect discussions on AI. These included editorial papers and papers that just passively mentioned some aspects of AI, leaving us with 309 full texts to review. With our sense, comprehend, act, and learn framework in mind, our second exclusion criterion was to eliminate any paper that did not discuss any specific AI-related concept. This left us with 67 fully reviewed IS research papers on AI. These are the papers that were then used to operationalize the final framework. Figure 1 summarizes our two-stage research design.

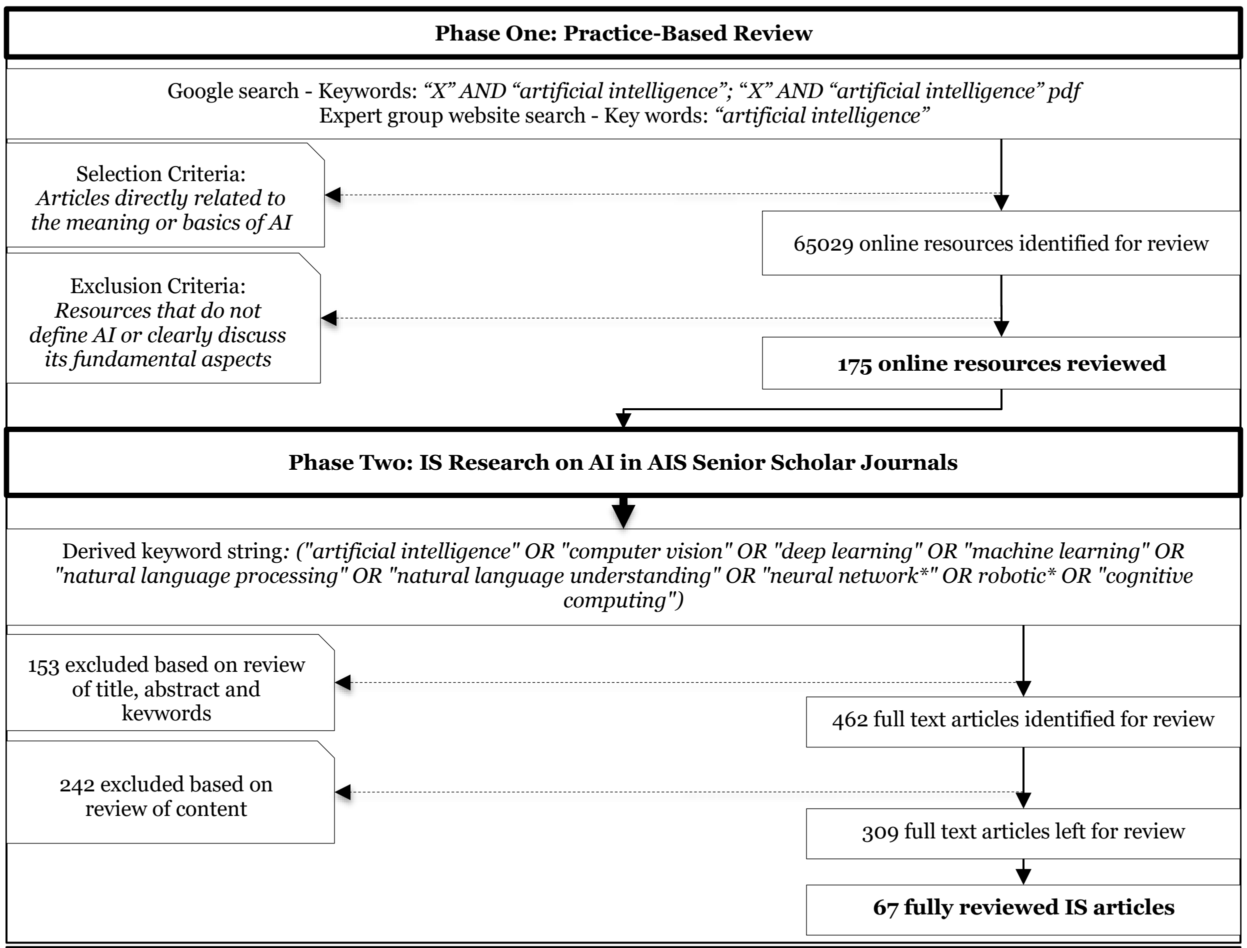

Figure 1. Literature Review Process

Results

Final Framework

Our final framework is made up of four distinct categories: *sense, comprehend, act, and learn*, which we call the AI capability framework. Each of these categories is enabled by a set of technologies, techniques or methods from different domains like mathematical modelling, genetics, and computational linguistics. In our framework, we refer to these aspects as *enablers* because they enable technological artefacts to become intelligent by manifesting these four main capabilities of AI. Figure 2 presents our final AI capability framework. We use this framework as a semi-structured extensional classification framework to organise IS research on AI published in the AIS senior basket journals and shown in Table 1.

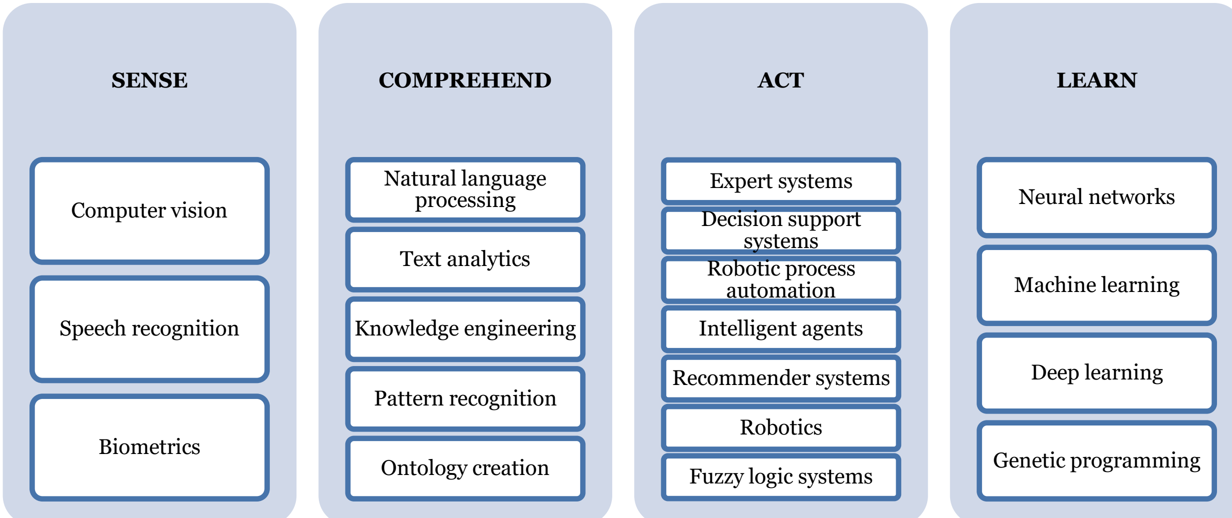

Figure 2. AI Capability Framework

Table 1. Mapping IS Research into the AI Capability Framework[2]

AI Capability	Enabler	Number of IS Research Papers per Journal								Sum
		EJIS	ISJ	ISR	JAIS	JIT	JMIS	JSIS	MISQ	
Sense	Computer vision	0	0	0	0	2	0	0	0	**2**
	Speech recognition	0	0	0	0	0	0	0	0	**0**
	Biometrics	0	0	0	0	0	0	0	0	**0**
	Subtotal	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	
Comprehend	Natural language processing	0	0	1	0	2	2	0	4	**9**
	Text analytics	0	0	0	0	0	1	0	1	**2**
	Knowledge engineering	0	0	2	0	1	5	0	0	**8**
	Pattern recognition	0	0	0	0	0	0	0	0	**0**
	Ontology creation	0	0	0	0	0	0	0	0	**0**
	Subtotal	**0**	**0**	**3**	**0**	**3**	**8**	**0**	**5**	
Act	Expert systems	0	1	6	0	2	7	1	4	**21**
	Decision support systems	0	0	1	1	0	8	1	0	**11**
	Robotic process	0	0	0	0	0	0	0	0	**0**

[2] Please contact the corresponding author for the full references.

	automation									
	Intelligent agents	0	0	1	1	0	3	1	1	**7**
	Recommender systems	0	0	0	0	0	1	0	0	**1**
	Robotics	0	0	0	1	2	0	0	0	**3**
	Fuzzy logic systems	0	0	0	1	0	0	0	0	**1**
	Subtotal	**0**	**1**	**8**	**4**	**4**	**19**	**3**	**5**	
Learn	Neural networks	0	0	1	1	0	14	1	0	**17**
	Machine learning	0	1	0	0	0	11	0	3	**15**
	Deep learning	0	0	1	0	0	2	0	0	**3**
	Genetic programming	0	0	0	0	0	6	0	0	**6**
	Subtotal	**0**	**1**	**2**	**1**	**0**	**33**	**1**	**3**	

Legend: EJIS – European Journal of Information Systems; ISJ – Information Systems Journal; ISR – Information Systems Research; JAIS – Journal of AIS; JIT – Journal of Information Technology; JMIS – Journal of MIS; JSIS – Journal of Strategic Information Systems; MISQ - MIS Quarterly

We can use intelligent conversational agents like Apple's Siri to demonstrate how the four main AI capabilities interact in the AI ecosystem. Siri uses speech/voice recognition technologies to detect or receive and translate voice commands into text. After that, it uses text mining, NLP, knowledge engineering, pattern recognition, and ontologies to understand the voice command. Once it understands the command, it takes action on its environment by executing the command such as playing the news or reading the time from your phone. Using voice recognition algorithms, Siri will continuously learn your voice characteristics so that it can meet your needs without you needing to modify the way you speak.

Sense

Sense refers to the ability of a technology artefact (hardware or software) to perceive its environment, whether digital or physical, by acquiring data from its environment. To enable this capability, practitioners have used computer vision, speech recognition, and biometrics. We identified only two publications on these enablers in the AIS basket journals, both coming from JIT.

Computer vision is an AI subfield that seeks to develop techniques that enable computer systems to perceive visual content like images and videos in their environment just like humans. Practitioners discuss its applications in providing input data for robots that interact with humans and other systems that need to recognize patterns in their environment. These include autonomous cars that need to identify and distinguish objects by the road like speed bumps, pedestrians and traffic lights, and act accordingly. It has been used to provide several other AI sensing capabilities that require image recognition, facial recognition, medical imaging, and motion capture. In the IS basket of eight journals, we identified only two publications on computer vision. One paper, published in 1986, discusses the cultural impact of computer vision on society especially in relation to employment. The other paper, published in 2011, discusses how advances in computer vision could improve healthcare practices. These are the only two articles we identified that discussed AI sensing capabilities. No article was found on speech recognition and biometrics.

Speech recognition is a subfield of computational linguistics that seeks to develop technologies and techniques that enable computer systems to recognize spoken human language. It is increasingly being used to implement voice assistants used for online searches by consumers and expected to be used for 50% of online searches by 2020. Practitioners discuss its application in facilitating search and access to online resources, especially for visually impaired people. Amazon, Apple and Google for example aim to integrate speech recognition and internet usage in their smart technologies. *Biometrics* refers to measurements and calculations made based on human characteristics to enable identification and access control. Its practical applications in AI are mostly in the domain of security. Practitioners are trying to combine biometrics with other AI enablers like neural networks to enhance the identification of unauthorized users and imposters. They also discuss several biometric traits and how AI could enhance the accuracy of the sensors.

Comprehend

Comprehend refers to the ability of AI to derive true contextual meaning of information by recognizing and interpreting identified patterns. The information is obtained from the sensing capabilities of the artefact. We identified natural language processing, text analytics, knowledge engineering, fuzzy logic, pattern recognition, and ontology creation are the main enablers of this capability. We found no articles that focused on pattern recognition or ontology creation.

Natural language processing is an AI subfield that seeks to develop methods and techniques that facilitates the understanding of human language by computer systems. Natural language understanding and generation are subtopics in NLP that focus on the analysis and generation of human language by computer systems. The main area of interest identified is how it can be used by AI to analyze and process large amounts of human language data at conversational speed while tackling language nuances. Its trending applications focus mostly on improving user experiences by using sentiment analysis to understand customers and develop targeted marketing and communication strategies. This includes its use in commercial and search virtual assistants and chatbots. In the IS literature reviewed, authors focus on how NLP can help enhance information retrieval from databases, improve information classification, coherence and understanding of online discourse by AI.

Knowledge engineering is an AI subfield that focuses on the emulation of human expert judgement and behavior. It includes topics related to knowledge acquisition, representation, validation, inferencing, explanation and justification. It forms the basis of most expert systems and decision support systems today. Practitioners discuss its applications in accurately simulating all sorts of expert human knowledge. The IS literature reviewed discusses ways to improve the acquisition and reconciliation of expert knowledge acquired from multiple sources for used in ES and DSS. It also discusses how to improve the stability and accuracy of the knowledge acquisition process, as well as how such systems could provide explanations for their actions. Finally, they discuss knowledge-based approaches to database design and how they can be used to improve process redesign.

Text analytics is a set of analytical techniques that enable AI to derive quality information from text. It is usually used by practitioners together with NLP to make sense and contextualize large amounts of data. Its is currently being used to analyze bulk emails, customer questions and comments in discussion forums, as well as for sentiment analysis of customers on social networks. Our findings in IS research discuss how text analytics can be combined with NLP for greater coherence and better understanding of actions in online discourse. They also discuss how companies can use it to perform sentiment analysis for identifying and profiling sellers.

Pattern recognition was used to describe how AI organizes and make inferences on data based on previous knowledge it acquired from its environment. Practitioners today mostly make use of machine learning algorithms to help AI make sense of their environment by recognizing patterns. These pattern recognition capabilities enable AI to make predictions and to act based on past experiences. *Ontology* was used by practitioners to describe how AI can be used to explicitly map different concepts, attributes and constraints in a given domain. Its applications were mostly discussed in relation to mapping large amounts of data in knowledge bases in the most adequate and unambiguous manner. Consulting firms discussed how ML algorithms could help implement automated ontology creation to solve challenges related to semantics and knowledge sharing in large enterprise databases.

Act

Act refers to the ability of AI to take actions in the physical or digital world based on their comprehension of information they acquire. We identified AI actions to be enables by ES, DSS, RPA, software agents, recommender systems, robotics, and fuzzy logic systems. We found no publication on RPA.

AI makes use of *expert systems* to act on its environment by emulating human expertise. This is one of the oldest and most extensively discussed application areas of AI in practice. The applications of these knowledge-based systems to solve several issues that require experts like auditing, diagnosis, and designing were discussed in the context of several industries like health and finance. We identified 21 papers on ES in our literature review. They contain research on the design of ES and the impact wrong or fraudulent input could have on system design, as well as the liability for decisions or recommendations made based on such information. Authors also investigated user acceptance of ES, the use and effect of explanations such systems provide, how to improve knowledge acquisition for them, and how to make them adapt to their users.

Practitioners also extensively discussed the application of AI technologies and techniques in rendering *decision support systems* more intelligent in their efforts to support business or organizational decision-making activities. Just like ES, DSS are knowledge-based and are increasingly required to make complex decisions. Many discussions focused on how to get DSS to make real-time decisions, especially in the fields of health, finance, and marketing. We found 11 publications on DSS in the literature review. Some presented research on how AI-enhanced DSS could support real-time planning of activities and task scheduling, and the impact of data accuracy on system learning. Others presented research on how to better generate alternatives in DSS and how this can support multicriteria decision making. Finally, we also found research on how to enhance user understanding of DSS.

We also identified *intelligent agents* as a main enabler of AI's act capabilities. These autonomous agents are programmed to act towards achieving a set of goals according to the specifications of the user. Experts discuss the growing applications of such agents in mobile access using virtual assistants like Siri, in automating workflows and business processes, and in air traffic control. The IS research we reviewed investigated its use in task automation especially in planning and scheduling tasks in enterprise supply chains.

Robots were found to be key enablers of AI actions today. Teaching robots to recognize if a certain action achieves a desired result is the main discussion by AI experts in robotics today. We found that, many experts are researching how AI robots can improve our daily lives as well as business productivity by learning and adapting to environment. Our IS literature review identifies research on emotional attachment, performance improvement, and viability on team collaborations with robots. We also found studies on the role AI robots could play in society, including the provision of smarter healthcare services.

AI industry experts are currently discussing how AI can be used to make recommendations to clients via recommender systems. They discuss its applications in e-commerce and social media advertising, especially on how to improve predictions of user preferences. In our IS literature review, the only study we found investigated how to improve the design of recommender systems by understanding social relationships between people. *Fuzzy logic* systems were discussed in practice-based literature as another type of decision support system through which AI can act. They discuss its applications in autonomous cars and in other autonomous systems where acceptable reasoning may be more appropriate than logical reasoning. For example, in choices between an autonomous car knocking down a pedestrian or crashing with the passenger.

The only paper we found on the topic in our IS literature review investigated the use of fuzzy logic in predicting changes in water level conditions. Discussions on *robotic process automation* mostly focused on how it is changing manufacturing tasks and organizations. Experts discuss its potential applications in administrative tasks and decisions making, especially rule-based processes. They also discuss its impact on future of work, in terms of cost, meaning, and value.

Learn

Learn is the ability of AI to take corrective actions that optimize its performance at any given tasks it performs over time. We found that learning in AI is enabled by NN, ML, DL, and genetic programming. These enablers play a transversal role as they correct AI's perception of and interactions with the physical and digital worlds. This, they play an active role in the *sense, comprehend,* and *act* capabilities of AI.

Artificial neural networks were one of the most discussed concepts by practitioners. These computational techniques and statistical models form the bases of most AI prediction and recommendation techniques and technologies today. They also form the basis of machine learning and deep learning. Discussions surrounded the selection of the proper learning algorithms and the appropriate cost functions for problems which varied with context. These include problems of financial risk assessment and fraud detection. In the IS literature reviewed, we found studies on how NN can be used to profile web usage in workplaces, evaluate the performance and predictive capabilities of other models, and to support document retrieval tasks. It was also researched in Twitter sentiment analysis and how it can be used for financial forecasting.

Experts also discussed *machine learning* and its applications in supervised, unsupervised, and reinforcement learning. Issues were raised concerning the datasets used for training AI in supervised learning problems, as well as the appropriate techniques for unsupervised and reinforcement learning problems. Some of the topics of interest include predicting churning rates of clients in marketing, detecting diseases in health, and enhancing the hiring process in the human resource domain. Our reviewed revealed IS research on how ML can be used to support document retrieval, test the performance of benchmarked algorithms, and to develop models to predict factors like quality of experience and advertisement performance. There are also studies on the use of ML in financial fraud detection, adaptive knowledge-based systems, web profiling, intelligent process design, and dynamic decision making.

Deep learning was discussed in relation to its feature extraction capabilities which are more advanced by those provided by benchmarked ML algorithms. It is said to provide systems with the ability to extract useful information from large amounts of unstructured data. We found discussions on its applications in self-driving cars such in recognizing obstacles, as well is its applications in automated speech translations. In the IS literature reviewed, we identified research on the use of DL to profile online system users based on sentiment analysis, and how DL can help improve personalized recommendations.

We found discussions on how *genetic programming* could be used to find solutions to complex search problems in today's business environment as applied to several contexts like autonomous cars and robotics. The algorithms derived from this programming method seem well suited to test a variety of solutions to a problem based on a set of rules and then select the best one. The literature review shows IS studies on the use of genetic programming for online user profiling, automated model discovery, and automated e-commerce negotiations. There were also studies on their use in improving web search information retrieval, and in generating alternatives by DSS.

Discussion and Research Agenda

This section is divided into two parts. In part one, we discuss our findings and how the AI capability framework contributes to IS research and AI practice. In part two, we propose a a research agenda that could help IS scholars produce valuable research papers that meet the needs of contemporary AI practices.

Discussion

We have successfully used our proposed AI capability framework to map IS research to AI practices. This framework is conceptually grounded in key AI capabilities identified in theories of intelligence, ecological psychology, management, and organizational behavior sciences. It covers all key concepts that enable the evolution of AI and provides an integrative forum for IS research to evaluate its contribution to the design and development of AI. Specifically, this framework guides the development of research on AI-enhanced IS artefacts. The framework provides a multilevel view reflecting the AI capabilities that enhance each IS component (input, process, output, feedback). *Act* has the highest number of enabling entities in the framework. Similarly, most publications in the IS literature review were under this category, majority published in JMIS and ISR. ES were the most researched enablers, followed by DSS, IA, robotics, recommender systems, and fuzzy logic systems respectively. ES are among the first IS artefacts that captured the attention of IS research on AI. Since the 90s, IS researchers have conducted studies on how to use AI to get these systems to better emulate the functions of human experts in specific domains (Kattan et al. 1993).

IS research on using AI to enhance DSS also goes way back to the 90s in an effort to improve their support in decision-making processes (Fazlollahi and Vahidov 2001). The aim has been to get the systems to develop a better understanding of their environment and to automatically improve their models accordingly. One key difference between the two systems is that DSS mostly uses quantitative models while ES emphasize logic and reasoning (Liu et al. 1990). This certainly has an impact on the choice of AI algorithms IS researchers should choose when trying to enhance these systems. IAs are also well-known to IS scholars as systems that rely on AI to evaluate contexts or situations based on input they receive from their environment and to make knowledge-based recommendations accordingly (Liu et al. 1990). Not much was found on robotics, recommender systems, and fuzzy logic systems. Research on these enablers may be found in other IS publication outlets but however need the attention of journals in this review.

The second highest number of AI enabling entities were found in the *comprehend* capability. The enabler with the highest number of publications in the review was NLP, followed by knowledge engineering and text analytics. Pattern recognition and ontology creation are yet to capture the attention of the IS basket of eight journals. Most of the publications came from JMIS and MISQ. The need for more research on NLP and text analytics is obvious as human language is increasingly being used to communicate with technology. In fact, it is expected that by 2020, about 50% of all online searches will be vocal (Kugler 2019). This is certainly not limited to online searches as that is how many people already communicate with their smart devices. Research on knowledge engineering is much needed as well given that key IS like ES and DSS are knowledge based and there is the continues need to make them human expertise skill levels.

AI learning capability enablers have also captured the attention of IS researchers, the most researched according to our literature review being NN, followed by ML, GP, and DL respectively. In this section, JMIS largely outnumbered the other publication outlets we reviewed. In IS research, NN is recognized for its ability to perform better that other statistical techniques used to provide systems with learning capabilities. Therefore, it is a good source for practitioners seeking to understand how they can make this work for them in their own ambitious AI projects. ML is also well-known to IS scholars as they have been using its techniques to explore alternative learning mechanisms. IS researchers have used it to develop systems that can learn and adapt themselves to changing environments and user needs, as well as systems that can serve as intelligent assistants for decision makers. DL on the other hand is a new field as is still gaining grounds in IS research, which may explain why there are limited publications on the topic in IS senior basket journals. Applying principles of evolution and heredity to solve complex problems are not new to the IS field either. It has already been explored as an inductive learning technique by IS researchers (Weiguo et al. 2005). The area where our reviewed IS outlets are really short on publications are on AI sensing capabilities. Only two papers were found and they were published by JAIS on computer vision. Nothing was found on speech recognition or biometrics despite their extensive use in AI practice today as sensory input systems. These enablers have the ability to enhance the input component of IS. Thus, it is important for more research to be conducted on how to do this in the most efficient manner.

Based on the classification of IS research on AI using the capability framework, it is evident that developing intelligent information systems has been a focus of IS research for over 40 years. Thus, AI is not new to the IS discipline. Much effort has been put into giving IS comprehending and learning capabilities. However, these efforts are not enough given the rapid evolution of AI in the last decade and its impact on IS.

Research Agenda

So far, we have used the AI capability framework to describe the current state of knowledge on AI and it has become evident that a considerable amount of work has been done by IS scholars in this research area. Several solutions have been proposed on how AI practices can be used to enhance IS at the individual, organizational and societal levels within different contexts. Nevertheless, the framework reveals some areas where IS research on AI still need to mature. To help achieve this maturation, we describe these research gaps and make suggestions for future research that would especially be relevant for AI practice.

The *sense* capability is the area that need the most attention from IS research as our review of eight leading journals in the field locates only two papers on the topic. Practitioners expressed the difficulty in enabling computer systems to recognize and interpret visual perceptions accurately and then act accordingly like humans do, making it a key research area for IS scholars. Also, the limited understanding of human vision limits the evolution of computer vision. Also, the infinitely varying number of objects and their representations in the physical world increases the complexity of giving visual sensing capabilities to computer systems. Although technologies developed for speech recognition enable AI sensing capabilities and empower people, practitioners highlight related privacy concerns. Speech recognition devices are always listening and possibly recording or transmitting our data at all times. Although some practitioners claim it is necessary in order for the device to respond effectively to user needs, it does not cancel the personal privacy risks attached. This exposes individuals more than ever before to potential assaults from hackers, stalkers, and even government officials or bodies (Kugler 2019). Therefore, IS research on AI could investigate how to improve privacy in and regulations on systems that use speech recognition technologies. Practitioners would also be interested in research on how to improve speech recognition accuracy of computer systems, how this can help improve customer services, and how this data can be used to create new business opportunities.

IS scholars can contribute to AI practice by conducting research on how AI can enhance the use of biometrics in securing information systems. This would be particularly interesting in the prevention of identity theft in online systems like e-commerce and social networks. As concerns AI *comprehending* capabilities, one of the challenges practitioners face is the inability of some virtual assistants like chatbots to understand client needs and provide relevant responses to their requests. Even when the chatbot clearly captures what the client says, it can have difficulties interpreting it properly as the meaning of statements may vary with client. Thus, IS scholars can contribute to AI practice by providing evidence on how NLP can help virtual assistants like chatbots can better understand user intentions and then provide an accurate answer to the request.

Also, as expert systems continue to evolve, there is the need to develop data structures, semantic models, and heuristics that could help improve the way expert knowledge is captured and represented in these systems. Thus, more IS research is needed on this issue especially in fields that require a high level of expertise and have more implicit and tacit knowledge than explicit knowledge. One of the major challenges researchers might face would be to balance the effectiveness of the solutions proposed with the performance of the system. Researchers should also consider research on knowledge representation, validation, inferencing, explanation and justification, the latter being one of the main interests of practitioners today. Big data is making text analytics more challenging as identifying facts, relationships, and assertions hidden in large textual datasets becomes more complex. Thus, IS scholars can contribute more research on how text analytics can be combined with other enablers like NLP and ML to help improve the extraction, organization, analysis and visualization of such large data sets. Practitioners would also be interested in research on how it can be used to summarize bulky information in a way that is easy to read and understand without losing key information.

For the acting and learning capabilities of AI, IS researchers have been working on related topics for many so there is a significant body of knowledge on them. However, practice would benefit from additional research on better AI techniques to help improve the predictive capabilities or recommender systems in different applications or contexts. Researchers could explore deep learning techniques given the new strengths it brings to learning capabilities of computer systems. Also, although RPA has proven very effective in performing several automated digital tasks, there is still a need for such systems to be able to produce strategic decisions. Therefore, contributions related to the decision support capabilities of RPA are needed.

Conclusion

This study presents an AI capability framework that is used to demonstrate where IS research meets AI practice. We illustrate the usefulness of this framework to both parties and its effectiveness in guiding IS research on AI using a systematic literature review of IS research on AI published in the AIS basket of eight journals. Through the AI capability enablers, the framework highlights the fact that research on AI is very interdisciplinary and requires expertise in all four capabilities that form the basis of the framework. Thus, the IS discipline cannot be a leading reference for research on the applications of AI if IS research does not equally focus on the *sense, comprehend, act, and learn* capabilities of AI. In addition, these capabilities are aligned with the key components of every IS, making IS researchers well equipped to understand the relevance and potential contributions of AI to IS. Therefore, we expect that the insights provided by the framework and our proposed research agenda contributes to the development of future IS research on AI.

This study has several limitations. First, the AI capability framework accounts only for AI concepts that fall under at least one the four underlying capabilities of the framework. Thus, using this framework to classify IS research for example systematically eliminates papers with a general discourse on AI. Secondly, our systematic review is limited to the AIS basket of eight journals. This has certainly influenced parts of our discussions and research agenda. Thus, we suggest that future research efforts attempt to organize literature from other IS outlets suing this framework so that we can arrive at something more exhaustive in the future.

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