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Use of Software Agent Technology in Management Information System: A Literature Review and Classification

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ABSTRACT

Technological innovations over the years have accentuated the workings in corporate- connected organizations and different application platforms. Hence, a unified management information system (MIS) that can utilize the Web and propel programming developments is required. Software agents, the latest developments in computer software technology, can be utilized to rapidly and effortlessly build integrated information systems. Consequently, 59 research papers on the use of software agents in MIS were identified from top 40 MIS journals published between 2007 and 2017. Then, we reviewed and classified all the research papers according to two categories: application fields and application categories. The application fields consisted of eight sub-groups: manufacturing, telecommunication systems, traffic and transportation management, information filtering and gathering, electronic commerce, business process management, entertainment, and medical care; whereas the application categories consisted of three sub-groups: multi-agent systems, personal assistants, and multi-agent simulation. The research papers were further divided into journal and year of publication, and journal and application field. The objective of our research was to understand the trend of the use software agent technology in MIS by examining the published research paper beside to add knowledge and content to the information system academic discipline.

Keywords: Management Information System, Software Agent, Agent, Agent-based, Multi-agent system

Ⅰ. Introduction

The management information system (MIS) research lies at the intersection of people, organizations, and technology (Silver et al., 1995). Specifically, MIS refers to the study of how individuals, groups, and organizations evaluate, design, implement, manage, and utilize systems to generate information (Deoda,

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2015). It impacts and contributes to cognitive science, organizational theory, management theory, management science, and computer science (Hevner et al., 2008). MIS is implemented into an organization to improve the efficiency and effectiveness of the decision-making process. MIS is a people-oriented field that concentrates on service through technology. MIS works with the organization as a whole, its work systems, its people, and its development and positioning to find out the extent to which an objective can be gained with minimal effort (Silver et al., 1995). According to the Editorial Statement and Policy, Information System Research (2002), it *"further knowledge that aids in the productive application of information technology to human organizations and their managers"* (Hevner et al., 2008). As remarked by Zmud, IS researchers are also responsible for developing and communicating *"knowledge concerning both the management of information technology and the use of MIS for managerial and organization purposes"* (Zmud, 1997).

A software agent is a goal-oriented computer program that reacts to its environment and runs continuously without any direct supervision or human intervention to perform some task for its user. It represents an evolutionary phase beyond the conventional computer programs. Because of the prolonged successful research in this field, "agent" can have a number of definitions:

An agent is a persistent software entity dedicated to a specific purpose (Smith et al., 1994);

An agent is a software entity that can be delegated a task (Janca, 1995);

An agent is a computer program that implements autonomous and goal-oriented activity to achieve the objective of a particular task on behalf of authority (Nwana, 1996);

An agent is defined as a component of software or hardware that is capable of acting rigorously ignored to accomplish tasks on behalf of its user (Nwana and Ndumu, 1998);

An agent is a self-contained program competent in analyzing its own decision-making and reactions based on its own observation of the current environment in achieving one or more objectives (Jennings and Wooldridge, 1996).

The first concept of an agent was introduced by J. McCarthy and G. Selfridge in the mid- 1950s. They proposed a "soft robot," computer software that has a goal, carries out tasks, and seeks feedback from humans (Ehlert, 2001). Later, Hewitt refined the concept of an agent as *"a self- contained, interactive, and concurrently executing object, possessing internal state and communication capability"* and introduced a new term "actor" (Hewitt, 1977). Research on agents began in the 1970s (Nwana, 1996) and became a major research topic in the early 1990s (Unland, 2015). It has attracted researchers from not only the computer science discipline but also other research disciplines such as control engineering, psychology, sociology, and biology (Unland, 2015). Over three decades, research on agents has been dismissed due to the demands of dynamic and open environments and the complexity of tasks (Mostafa et al., 2017). Agents are increasingly used in a wide range of information system applications. They are ideally suited for process and workflow automation, distributed problem solving, electronic commerce, and internet application.

Business organizations are in urgent need of new and innovative IT applications that empower globalization, incorporation, expanded efficiency and rapid adaption (Hevner and Chatterjee, 2010). Currently, the trend of IT applications demonstrates interlacing

of both human and technological communities in which the use of agent act on behalf its user and cooperate on issues such as trust, security, flexibility, adaption and transparency (Kitio et al., 2008). Research on agent technologies has been taken from and contributed to various academic discipline, in the field of humanities, science and social science (Luck et al., 2003). From these points of view, it has motivated us to conduct this review on the growth of this topic in management information research.

The paper is organized as follows. We begin by explaining the research methodology used in this study. First, we present the criteria for the classification of research papers on the use of software agents in MIS development. Then, we analyze the collected research papers and present the results of their classification. We conclude by summarizing the findings, limitations, and implications of this study. We believe our investigation will highlight the importance of software agents in information system development and will provide researchers and practitioners with insight into the use of software agents in MIS.

Ⅱ. Research Methodology

The purpose of this review and of classifying the published papers is to understand the trend of the use software agent technology in MIS by examining the published research paper beside to add knowledge and content to the information system academic discipline. In this way, IS researchers are able to gain an insight on the use of software agents in MIS development. We verified the distribution of research papers on the use of software agents in MIS development by their year of publication and classified each research paper by its application field. However, considering the nature of our research on information systems, it would be difficult to delineate each paper to a specific discipline. Due to the interdisciplinary nature of IS research, IS researchers come from different academic backgrounds like information science, engineering, economics, and management science/operations research (Benbasat and Zmud, 2003). Even the research papers are gathered, from numerous journals, which include information technology, computer science, information science economics, management, and marketing. The following digital journal databases provide a comprehensive bibliography of the research paper on the use of software agent in MIS development:

- ABI/INFORMS Database
- ACM
- EBSCO Academic Search Premier
- EBSCO Business Source Premier
- IEEE/IEE Library
- Science Direct

Top 40 MIS journals were used in our research on software agents in MIS development. The top 40 MIS journals selected based on MIS Journal Rankings provided by Chapman University. The search was performed based on four descriptors: “agent,” “software agent,” “agent-based,” and “multi-agent system.” However, the following research papers, outlined in the description below, were excluded because they were unfit for our research:

1. Conference papers, master’s and doctoral dissertations, textbooks, and unpublished working papers were eliminated. Unlike these publications, papers published by academic journals were considered to be substantial and commendable because they were distributed after the associate audit

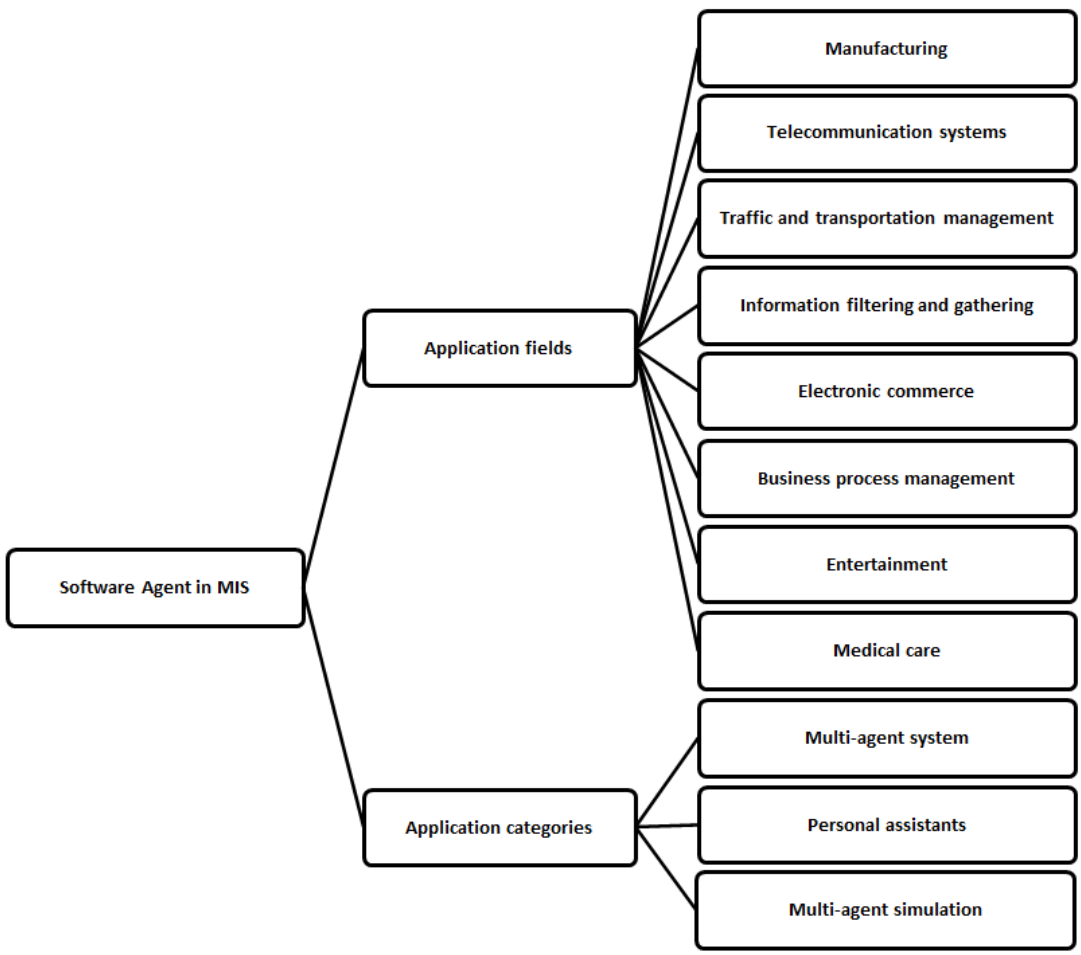
2. We searched for research articles published only between 2007 and the end of 2017 because the research on software agents in IS is parallel to emerging technology. This 10- year period is considered to be representative of software agent research.

3. Only research papers that describe how software agents could be applied were chosen

Even though this research was not exhaustive, it serves as a compendious basis for an understanding of the use of software agent technology in MIS research.

Ⅲ. Classification Method

We selected 59 research papers on software agents in record systems from top 40 journals. Each research paper was judiciously evaluated and then classified into two groups: (1) application fields and (2) application categories. We classified the research papers under the application fields into eight sub-groups and the application categories into three sub-groups. <Figure 1> illustrates the classification framework for the use of software agent in the MIS.



<Figure 1> Classification Framework

3.1. Classification Framework for Application Fields

The software developers and system designers use high-level abstraction in building complex systems to manage complexity. This is because the complex system involves changing Web relationships between its various components, for example, organizational relationships, ranging from peers to control, and short-term to ongoing (Jennings and Wooldridge, 2001). The substance of abstraction lies in maintaining information that is relevant in a given context and hiding information that is irrelevant in that context (Guttag, 2013). This enables them to manage complex issues while increasing the proficiency of complex systems. The main areas in which agent-based applications have been reported are manufacturing, process control, telecommunication systems, air traffic control, traffic and transportation management, information filtering and gathering, electronic commerce, business process management, human capital management, skills management, (mobile) workforce management, defense, entertainment, and medical care (Luck, et al., 2003). Our classification scheme adopts the Luck, et al., 2003 reference of industrial and commercial application, describes the current state-of-the-art of agent technologies and identifies trends and challenges. We classify the research papers by application fields such manufacturing, telecommunication systems, traffic and transportation management, information filtering and gathering, electronic commerce, business process management, entertainment, and medical care

3.2. Classification Framework for Application Categories

The software agent technology is helpful and engaging because of the various agents employed to simplify the process and reduce the complexity of the system. For example, an agent is capable of communicating with other agents; hence, the system developer is not required to design communication protocols and message formats. The software agent provides this capability as part of the fundamental agent mechanism. A software agent has the inherent capacity to build a model of its environment, monitor the state of that environment, reason, and make decisions based on that state. Therefore, software developers need to only customize based on the given situation. There are three main categories of the agent-based application to be identified (Klügl, 2004):

1. Multi-Agent System (MAS) is useful for cooperative problem solving or decision-making environment. This is because MAS consists of interacting agents that are consciously designed for these tasks. It can be viewed as the classical form of the MAS application spurred by the abstraction and modularity points of interest given by agents (Klügl, 2004).
2. Personal Assistants perform an assignment designated to them by a human user. For instance, when managing large amounts of in-formation, software agents improve the situation in handling the information; humans are better at providing the direction. Different cases exist for software agents for e-commerce where they may make a recommendation or transaction for the benefit of the user (Klügl, 2004).
3. Multi-Agent Simulation differs from a MAS in its aims and objectives. A simulation model demonstrates utility as the representative of another system. It also determines the behavior and structure of the original system clearly.

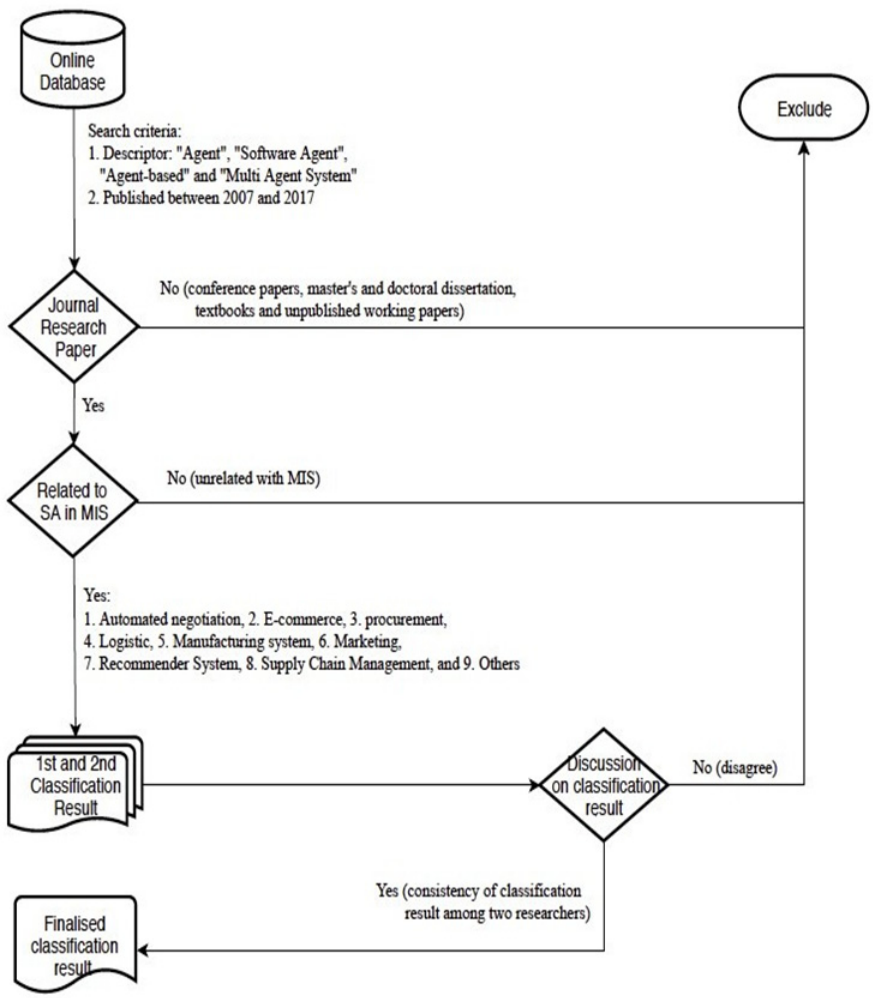
Multi-agent simulation is generally used in an artificial environment and virtual time (Klügl, 2004).

3.3. Classification Process

Each of the selected research papers is reviewed and classified according to the proposed classification framework. Next, the discussion is conducted for the final verification of the results. The classification process is composed of the following four steps:

1. Electronic database
2. Initial classification by the first researcher
3. Independent verification of classification results by the second researcher
4. Final verification of classification results discussed by the third researcher

<Figure 2> represents the selection criteria and evaluation framework. The research papers were analyzed by year of publication, by journals in which the research papers were published, and by application fields and application categories.



<Figure 2> Classification Process

Ⅳ. Classification of Research Papers

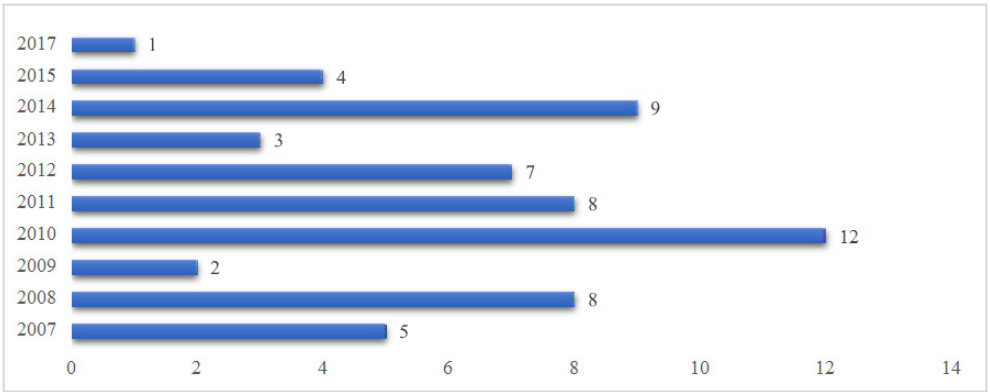
We selected a total of 59 research papers and classified them according to the classification framework as illustrated in <Table 1>. The results of our analysis will provide guidelines for future research on the use of software agent in MIS development. The details are described as follows.

4.1. Distribution by Year of Publications

<Figure 3> shows the distribution of research papers by year of publication between 2007 and 2017. Research on software agents in information systems is not very popular. <Figure 3> depicts the fluctuation in the distribution of published research papers. Between 2007 and 2008, the published research papers increased, but decreased in 2009. Surprisingly, the published research papers tremendously increased in 2010 and started to decrease a year after that until 2013. The trend is repeated between 2014 and 2017, while it increased in 2015, it decreased from 2016 to 2017. Identity crisis within the IS discipline might be a factor in this trend. As mentioned by Benbasat and Zmud (2003), *"... we are worried that the IS research community is making the discipline's*

<Table 1> Distribution of Research According to Proposed Classification Framework

Application fields	Application categories	References
Manufacturing	Multi-agent simulation	Lin and Long (2011)
	Multi-agent system	Chen and Chen (2010), Guo and Zhang (2009)
Telecommunication system	Multi-agent simulation	Jiang et al. (2010)
	Personal assistants	Lee (2007)
Information filtering and gathering	Multi-agent simulation	Schramm et al. (2010), Hostler et al. (2011)
	Multi-agent system	Stummer et al. (2015), Tapia et al. (2013)
	Personal assistants	Dhanapal (2008), Hostler et al. (2012), Kim et al. (2011), Lee and Benbasat (2010), Lee and Kwon (2008), Miao et al. (2017), Neves et al. (2014), Schiaffino and Amandi (2009), Wang and Benbasat (2008)
Electronic commerce	Multi-agent system	Chen et al. (2008), Fasli and Michalakopoulos (2008), Groves et al. (2014), Warkentin et al. (2012), Yang et al. (2009)
	Personal assistants	Cao et al. (2015), Chen and Weiss (2015), Chen et al. (2014), Hertweck et al. (2010), Huang et al. (2010), Lin et al. (2011), Louta et al. (2008), Skylogiannis et al. (2007), Vahidov et al. (2014)
Business process management	Multi-agent simulation	Coria et al. (2014), Fang and Wong (2010), Kuhn et al. (2010), Long (2014), Long and Zhang (2014), Roozmand et al. (2011), Wang et al. (2008), Wang et al. (2014)
	Multi-agent system	Borrajo et al. (2010), Dong and Srinivasan (2013), Li (2007), Li and Li (2010), Liu et al. (2011), Sharp et al. (2011), Shirazi and Soroor (2007), Sim (2012), Vengattaraman et al. (2011), Wu et al. (2010)
	Personal assistants	Kim and Cho (2010), Yu and Wong (2015)
Entertainment	Multi-agent simulation	Kwon and Kim (2017)
	Personal assistants	Lee et al. (2012), Marey Bentahar et al. (2014)
Medical care	Multi-agent system	Corchado et al. (2008)



<Figure 3> Distribution of Research Papers by Year of Publication

central identity even more ambiguous by all too frequently under-investigating phenomena intimately associated with IT-based systems and over-investigating phenomena distantly associated with IT-based systems..." (Benbasat and Zmud, 2003).

4.2. Distribution by Journal

Research papers are selected from 10 different journals. <Table 2> presents the distribution of research papers by the journal. Expert Systems with Applications published more than 50.85% (30 out of 59 research papers) of the total number of research papers, followed by Decision Support System with 13.56% (8 out of 59 research papers) of the total number of research papers. Knowledge-based System and Information Sciences both published 10.17% (6 out of 59 research papers) and shared the third place of distribution percentage. The Journal of Management Information System published 5.08% (3 out of 59 research papers), and the European Journal of Operation Research published 3.39% (2 out of 59 papers); they took the fifth place and sixth place, respectively, of distribution percentage. The remaining journals, ACM Transaction Computer-Human Interaction, Data & Knowledge

<Table 2> Distribution of Research Paper by Journal

Journal	No	Percentage (%)
Expert Systems with Application	30	50.85
Decision Support Systems	8	13.56
Knowledge-based Systems	6	10.17
Information Sciences	6	10.17
Journal of Management Information System	3	5.08
European Journal of Operational Research	2	3.39
ACM Transaction Computer Human Interaction	1	1.69
Data & Knowledge Engineering	1	1.69
IEEE Transaction on Service Computing	1	1.69
Information & Management	1	1.69
Total	59	100

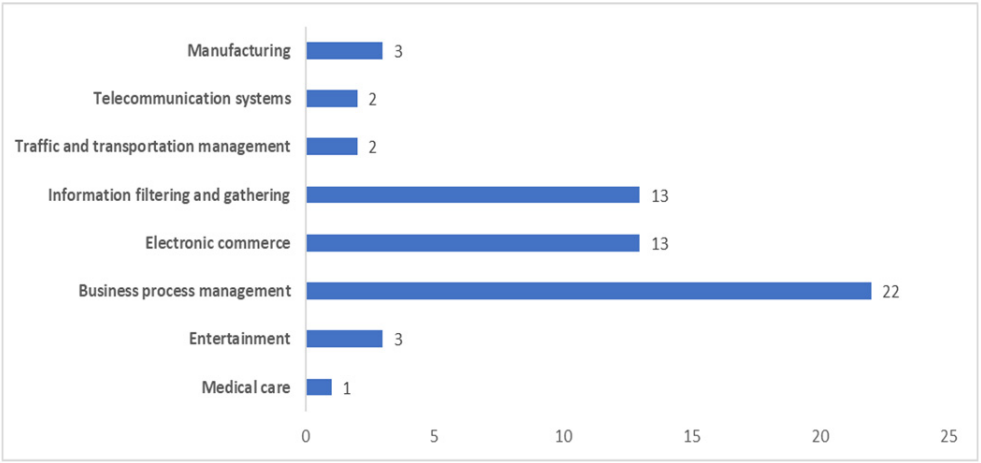
Engineering, IEEE Transaction on Service Computing, and Information & Management published 1.69% (1 out of 59 research papers) on the use of software agent in MIS Development. A significant number of research papers were published in Expert Systems and Applications. Thus, this journal primarily focuses on knowledge of the application of expert and intelligent systems by industries, governments, and universities worldwide (Ngai et al., 2009).

4.3. Distribution by Application Fields

<Figure 4> represents the distribution of research papers by application fields. The majority of the research papers were related business process management (22 out of 59 research papers, or 37.29%). One of the critical success factors for business process management based on dynamic capabilities is automation (Trkman, 2010). Automation is the use of information technology to assist or replace an employee at some of the routine task (Harmon, 2003). Embarking automation into business process management can improve business activities performance and enable enterprise-wide monitoring and coordination (Nikolaidou et al., 2001). As implication, numerous research papers conducted. Meanwhile, research on information gathering and filtering also e-commerce contributes 22.02% (13 research papers out of 59 research papers). few of them related to manufacturing, and entertainment (3 out of 59 research papers, or 5.08%), telecommunication and traffic and transportation management (2 out of 59 papers, or 3.39%), and medical care 1.69% (1 out of 59 research papers)

4.4. Distribution of Research Papers by Application Fields and Journals

<Table 3> shows the distribution by application fields and journal. Research papers related to the use of software agent in MIS are distributed across 10 journals. Expert Systems with Applications is the journal in which most papers have been published in application fields. This is because Expert Systems with Applications focuses on the knowledge of the application of expert and intelligent systems (Ngai et al., 2009). Beside Expert Systems with Applications, the top 3 application fields; business process manage-



<Figure 4> Distribution of Research Papers by Application Fields

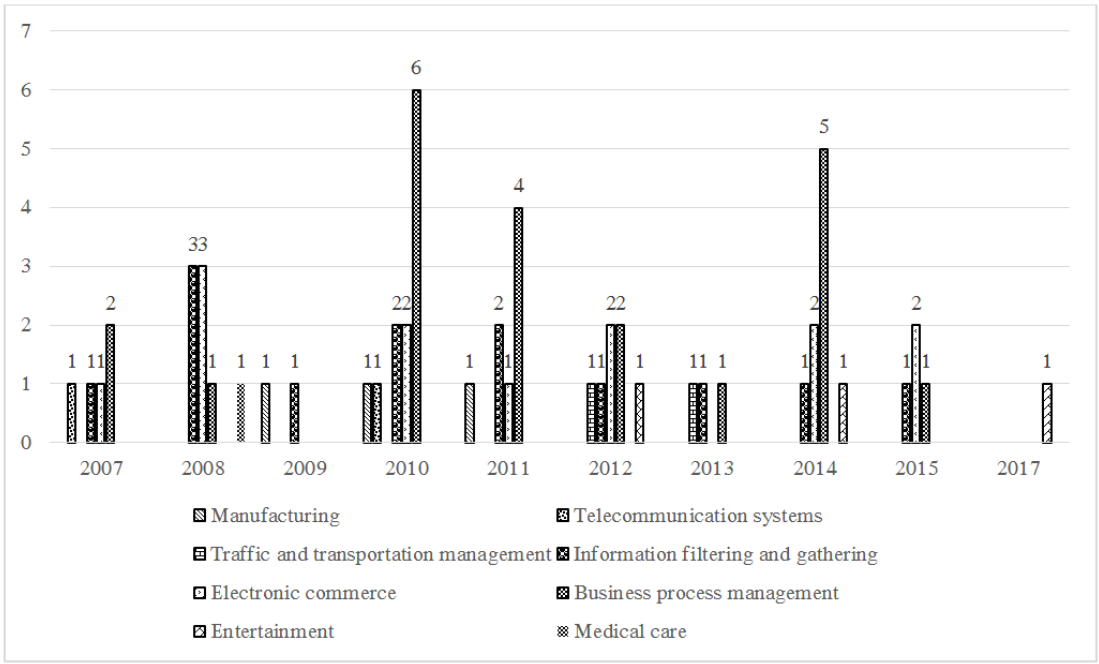
<Table 3> Distribution of Research Paper by Application Fields and Journal

Field	Journal	Amount	
Manufacturing	Expert Systems with Application	2	3
	Information Sciences	1	
Telecommunication systems	Expert Systems with Application	1	2
	Information Sciences	1	
Traffic and transportation management	Expert Systems with Application	1	1
Information filtering and gathering	ACM Transaction Computer Human Interaction	1	13
	Decision Support Systems	1	
	European Journal of Operational Research	1	
	Expert Systems with Application	5	
	Information and Management	1	
	Information Sciences	1	
	Journal of Management Information Systems	1	
	Knowledge-based Systems	2	
Electronic commerce	Data & Knowledge Engineering	1	13
	Decision Support Systems	3	
	European Journal of Operational Research	1	
	Expert Systems with Application	7	
	Journal of Management Information Systems	1	
Business process management	Decision Support Systems	2	22
	Expert Systems with Application	11	
	IEEE transactions on service computing	1	
	Information Sciences	3	
	Knowledge-based systems	4	
Entertainment	Expert Systems and Application	2	3
	Journal of Management Information Systems	1	
Medical care	Decision Support Systems	1	1
Total			59

ment, information filtering and gathering have been published at numerous journals.

4.5. Distribution of Research Papers by Publication Years Application Fields

The distribution of research papers by publication year and application field is shown in <Figure 5>. Among the application fields, business process management is interested in utilizing the software agent technology, despite there is no consistency of research trend over publication year. It started from in 2007 than tremendously increased in 2010. Later, the trend has shown inconsistency from 2011 till 2017. The inconsistency of published research papers also is shown in information filtering and gathering, and



<Figure 5> Distribution of Research Papers by Publication Year and Application Fields

electronic commerce. It is inferred that the use of a software agent in MIS considers at an early stage. Because, software agent research covers a wide-range of area which makes it challenges for IS researcher especially new researcher to understand the peculiarities and complexities of the technology (Mostafa et al., 2017).

Ⅴ. Conclusion, Research Implication and Future Work

Over the past three decades, software agent technology has attracted the attention of academics and practitioners. Software agent research is not limited to computer science; it also concerns disciplines such as control engineering, psychology, sociology, and biology. In this paper, we identified 59 papers related to the utilization of software agents in MIS, all of which were published development and furnish researchers and practitioners with insight into their utilization. The results depicted in these papers have several significant implications:

1. Research on this subject is not the top research topic in MIS compare other fields, based on previous publication rates in the top 40 MIS rank journal. Nonetheless, the awareness and exploration of this topic are important and, the task of assessing software agents in MIS will probably take time but progress in the future
2. Implementation of software agent in business process management concerns the largest of the published research paper (37.29%) discussed in this review. Follow by information filtering and gathering and, electronic commerce with 22.02%. This trend showed that the software agent plays a crucial role: business process man-

agement, where the agent used to assist or replace the human in complex and critical business activity e.g. workflow. Information filtering and gathering, where the software agent is used to analyze information and recommend the appropriate information based on the user's preference. Electronic commerce, where the software agent engaged in executing the transaction such as buy and sell good e.g. Kasbah, the marketplace or gathering information on behalf of its user such as a personal shopper that able to search availability of product online.

3. Beside electronic commerce, digital economy will be an exciting area for future research of the use of software agent technology in MIS. Thomas Mesenbourg (2001) identified three mains components of digital economy include electronic commerce: (1) e-business infrastructure, (2) e-business focus on how business is conducted and how to transform the processes over computer-mediated networks (Mesenbourg, 2000).
4. There are relatively fewer research papers on the use of software agent in manufacturing, telecommunication systems, traffic and transportation management, entertainment, and medical care. The fewer number of research papers related to these domains in MIS may due to challenges in develop agent ability to fulfill user requirement.
5. Based on these findings, our research is significant because software agent technology is slowly growing in MIS. We hope for and suggest that more research on this topic be conducted in future. Software agent technology is a promising research area as it is popular in different academic disciplines. The capability and characteristics of software agent technology will help to reduce complexity and increase efficiency.

However, this study might have some limitations and open several avenues for future research:

1. Firstly, this study was only conducted on the surveyed paper between 2007 and 2017, which was extracted based on the specific descriptors or keywords: "Agent," "Software Agent," "Agent-based," and "Multi-agent System." The research papers that mentioned utilization software agents in MIS, but without a keyword index, could not be extracted.
2. Secondly, this research was only limited to the top 40 MIS journals based on MIS journal ranking by Chapman University. There might be other journals that have published articles related to the utilization software agent in MIS, for example, a paper that relates the Geography Information System (GIS).
3. Thirdly, the classification framework could be extended to software agent characteristic, the theoretical, and methodology that been used in deployment software agent in MIS. Therefore, holistic analysis can be carried out,
4. Fourthly, the analysis method used in the study is classification and frequency. Consequently, the result was not an in-depth analysis. Therefore, for future work, we suggest using different analysis such as a bibliography or quotation analysis.
5. Lastly, non-English research papers were excluded in this review. We believe that research regarding the use of software agent in MIS might have also been conducted and published in languages other than English

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