Chatbots and Conversational Agents: A Bibliometric Analysis

H. N. Io[1], C. B. Lee[1]
[1]Department of Accounting and Information Management, University of Macau, China
(helmondio@gmail.com)

Abstract – **Chatbots are replacing some of the jobs that are traditionally performed by human workers, such as online customer service agents and educators. From the initial stage of rule-based chatbots to the era of rapid development in artificial intelligence (AI), the performance of chatbots keeps improving. Chatbots can nowadays "chat" like a human being and they can learn from experience. The purpose of this research is to examine the past research on chatbots (also known as conversational agents) using the quantitative bibliometric analysis. The contribution of this research is to help researchers to identify research gaps for the future research agenda in chatbots. The results of the analysis found a potential research opportunity in chatbots due to the emergence of the deep learning technology. This new technology may change the direction of future research in chatbots. Several recommendations for future research are provided based on the results obtained from our analysis.**

Keywords - **Chatbot, conversational agent, bibliometric analysis**

I. INTRODUCTION

A chatbot or conversational agent (CA) is a software system that can interact or "chat" with a human user in natural language such as English [1]. The first chatbot ELIZA was designed by Joseph Weizenbaum in 1966 [2]. It was originally created to simulate a psychotherapist [3]. After ELIZA, there are different chatbots created, such as A.L.I.C.E. and Mitsuku. Most of these chatbots are developed using Artificial Intelligence Markup Language (AIML), which is a programming language that enables chatbots to recognize patterns in the input sentences, and respond with sentences from a template. Starting from 1991, many chatbots are developed for the Loebner Prize competition, which is the oldest Turing Test contest to find the chatbot considered by the judges to be the most human-like. Mitsuku and Rose are the two chatbot winners in recent years.

Chatbots are getting popular and they are now creeping into our smartphones. People spend a lot of time on the apps installed in the smartphones every day. According to a recent report by Flurry Analytics (2016) [4], the overall app usage in 2016 grew by 11 percent compared to 2015, and the time that users spent in apps grew by 69 percent. The time spent in messaging and social apps increased by 394 percent in 2016 when compared to 2015. In China, senior users of mobile phones may not know how to use every apps, however, most of them use the chatting app, like WeChat, frequently [5]. Even though they may not know how to type text messages on the mobile phones, they can use voice messages and images to express their ideas. Recent chatbots are embedded in chatting apps or webpages, which enable tasks to be accomplished through conversations, on a single mobile device instead of having a large computer and other peripheral devices, such as mouse and keyboard. These are among the important reasons why chatbots have become popular.

Chatbots are also used in many types of applications. They include applications for customer service in e-commerce websites, museum guides, language learning, or chatting for entertainment purpose. In addition, there are also some famous chatbots from tech giants, such as IBM Watson, Facebook Messenger, Microsoft XiaoIce, and Apple Siri, etc.

Chatbots have also become much more intelligent. They can understand human users very well and they can provide human-like responses. This is due to the rapid development of artificial intelligence and other related technologies. Many investors understood the potential of AI and they have made significant investments to harness the technology. Investors include: (1) Li Ka-Shing, the Hong Kong billionaire. He invested in several startups focusing on AI [6]; (2) Jack Ma, the founder of Alibaba. He invested in an Israeli startup using AI to evolve e-commerce search technologies [7]; (3) Dr. Kai-Fu Lee, a famous tech investor. He invested in several investments on AI startups that focus on the development of AI [8].

As investors start investing in AI, chatbots are likely to experience further growth and development in the future. At this point in time, it would be useful to investigate the past research in this area, and provide an update on the current research status. The information update could provide comprehensive understanding and insights into the future of chatbot research. Thus, the purpose of this study is to analyze prior research in chatbots using bibliometric approach to identify patterns and trends in this academic research area. The findings from this study could help to guide future research in this area.

The structure of this paper is as follows. After this introduction, Section II describes the bibliometric methodology used in this study and Section III presents the results of the bibliometric analysis. Section IV provides a discussion of the findings with recommendations for future research. Section V concludes this study.

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II. METHODOLOGY

Bibliometric analysis is a fundamental and powerful method to explore the patterns and future trends of a research topic. Many researchers used this method to explore the research trends in different areas, such as the role of IT innovation [9], project management research [10] and business intelligence and analytics [11]. This study used three tools for bibliometric analysis. They are: (1) Literature databases - *Web of Science (WoS)* and *ProQuest*: to collect publication information and citation report, (2) *CiteSpace*: to analyze and cluster data, and (3) *Bibliometrix*: to determine co-occurrence patterns. The sections below describe each of these tools.

1) *Literature databases*: This study uses the Web of Science to collect the publication and citation data from high quality academic literature databases, and uses ProQuest to collect publication data besides academic literature, such as newspaper, blogs, and websites, and our major focus in this study is to conduct a bibliometric analysis for chatbots in academic literature. In this study, we consider the two terms **"chatbot"** and **"conversational agent"** are interchangeable. In a typical architecture of chatbot, or a conversational agent, there is a deliberative module enabling the chatbot to chat with human beings [12]. **"Natural Language Processing"** (NLP) is a commonly used technology for the deliberative module, hence we search it as well. In addition, at the time when this study is being conducted, artificial intelligence is a hot topic widely discussed, so we would like to explore the relationship between chatbot and AI. As **"deep learning"** is playing an important role in the development of AI [13], we add it as our target searching term. We select "All years" for the timespan of the search. Then, the results are sorted by "Time Cited" from the highest to the lowest. Finally, the citation reports for the searched keywords are used to compare the relationship between them.

2) *CiteSpace*: *CiteSpace* [14] is a widely-used tool for bibliometric analysis. It was developed in 2004 and the software has continuously been updated. *CiteSpace* can visualize the co-citation networks and cluster the related articles for a specific research area so that researchers can understand the development of the research area more efficiently. In the current study, the data to be analyzed were exported from *WoS* into *CiteSpace*, since we want to investigate the research trend of chatbot in the academic world. The researchers firstly search the terms of "chatbot" and "conversational agent" using the "OR" operand, then export the result to *CiteSpace* and apply the functions of clustering keyword and generating the representation sentences from each cluster for deeper understanding of the existing research.

3) *Bibliometrix*: To avoid making bias from a single measurement tool, this study also uses bibliometrix, to generate keyword co-occurrences. In contrast to *CiteSpace*, *Bibliometrix* is a new tool for bibliometric analysis. It is a package developed based on the R software, and can build data matrices for co-citation, coupling, scientific collaboration analysis and co-word analysis [15]. In this study, we combine the terms "chatbot" and "conversational agent" as a single dataset for analysis.

III. RESULTS

A. Publication overview in literature databases

In both the databases of *WoS* and *ProQuest*, the results of all the keywords searched show an increasing trend in recent years. In *WoS*, there are 583 results found about "chatbot" and "conversational agent", while in ProQuest, 4,246 are found. Due to space constraints, we focus the results from the *WoS*. Fig. 1 shows the publication and citation report from *WoS*. From Fig. 1 (a), the results found there is a drop after 2010 and a raise after 2015 in both the publications and citations. There may be two major reasons causing the drop. One could be the global financial crisis from 2008 [16], which could have affected the research emphasis in this area. Another is the saturation in this area due to the restriction of existing technologies.

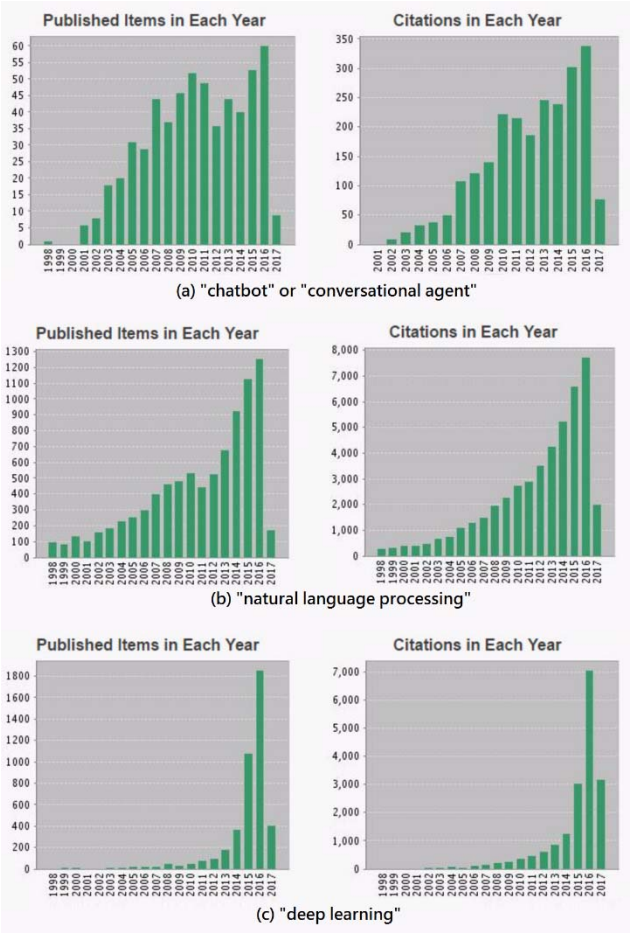

Fig. 1. Published items and citations in each year for the four keywords.

Fig. 1 (b) shows the results for "natural language processing". The results show similar patterns as Fig. 1(a).

The number of publications and citations are higher than those for "chatbot" or "conversation agents", however. This is because chatbot, or CA, is one of the applications of NLP. There are other applications, beside chatbot or CA, that use NLP. The citations for NLP, therefore, keep increasing year by year.

Fig. 1(c) shows the results for "deep learning". The results show a rapid increase in publication and citation from 2015. The study also found that among the 583 literature of chatbot or CA, only 11.84% are published after 2015 (excluding year 2015), which means most of the existing studies about chatbot and CA have not applied the new technology of deep learning published after 2015.

Fig. 2 shows the details of publications related to chatbot or CA. Among the 583 academic literature on chatbot or CA, most of them are in the areas of computer science and engineering. The major applications of chatbot are in education, psychology, and linguistics. There is still lack of academic research for other areas of application, especially in business.

Field: Research Areas	Record Count	% of 583	Bar Chart
COMPUTER SCIENCE	497	85.249 %	
ENGINEERING	127	21.784 %	
EDUCATION EDUCATIONAL RESEARCH	32	5.489 %	
TELECOMMUNICATIONS	30	5.146 %	
ROBOTICS	21	3.602 %	
PSYCHOLOGY	18	3.087 %	
LINGUISTICS	14	2.401 %	
ACOUSTICS	9	1.544 %	
IMAGING SCIENCE PHOTOGRAPHIC TECHNOLOGY	9	1.544 %	
INFORMATION SCIENCE LIBRARY SCIENCE	9	1.544 %	

Fig. 2. Research areas of "chatbot" or "conversational agent".

According to these citation reports and analysis above, we can observe there is a potential to increase research on chatbot (or CA) in the future following years due to the development of deep learning and NLP.

B. Clustering by keywords in CiteSpace

We import the 583 literature of "chatbot" and "conversational agent" from *WoS* to *CiteSpace* and generate the clustering networks, the result is shown as Fig. 3. *CiteSpace* can cluster the literature into several groups. The numbers indicated in each cluster are ordered by the size of the cluster. The larger the font size, the more numbers of articles in the cluster. The clustering phases from titles are displayed on the figure. Top titles include: conversational agent, interactive conversational agent, conversational intelligent tutoring system, opinion mining, productive talk, task interruption, virtual agent, receptionist robot, etc. The clustering result also shows a high modularity with 0.9161, which means the network is loose clustering. There are only 583 literature, but 111 clusters are generated, it tells us the existing literature are highly fragmented, researchers have dispersed their studies in different topics, and with low dependency with each other.

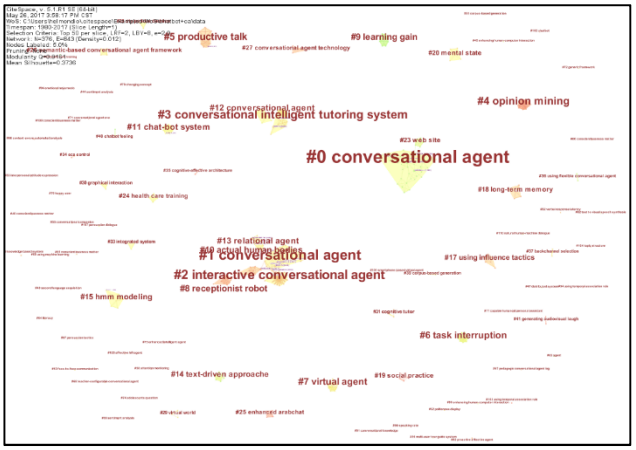

Fig. 3. Top clustering keywords for "chatbot" and "conversational agent".

C. Representation sentences in CiteSpace

CiteSpace provides a function of retrieving representation sentences from each cluster. It constructs a short summary by selecting the most representative sentences from a set of topically related documents [12].

Similar to last section, we use the same 583 literature as imported data from the *WoS*. *CiteSpace* retrieved sentences such as the following: For the cluster on "conversational agent": (1) "a ca is a computer program which interacts with a user through natural language dialogue and provides some form of service" [17], (2) "multimodal interfaces supporting ecas enable the development of novel concepts regarding human-machine interaction interfaces and provide several communication channels such as: natural speech, facial expression, and different body gestures" [18], (3) "ca technology has two points of interest to systems engineers: the use of systems engineering techniques in ca research and the application of cas in project development" [17]. For the cluster of "conversational intelligent tutoring system": (1) "this paper presents oscar, a conversational intelligent tutoring system (cits) which dynamically predicts and adapts to a student's learning style throughout the tutoring conversation" [19], (2) "oscar aims to mimic a human tutor to improve the effectiveness of the learning experience by leading a natural language tutorial and modifying the tutoring style to suit an individual's learning style", (3) "intelligent solution analysis and support have been incorporated to help students establish a deeper understanding of the topic and boost confidence".

These representative sentences help the study to identify the most important articles by different clusters, so as to understand the current research trends and future opportunities. For example, for the representative sentences from the "conversational agent" cluster, the study found the communication channels of traditional conversational agents include natural speech, facial expression, and different body gestures, so that we can compare these channels with the channels in the current and future society. It also tells us the most important

literature of applying CA, which is in a tutoring context, and it supports the finding (the major application of chatbot is in education) we have found in the previous section.

D. Keyword co-occurrences in Bibliometrix

In addition to *CiteSpace*, we also use a relative new tool – *Bibliometrix* to find the important patterns in the existing literature. Similar to before, we search the literature about "chatbot" and "conversational agent", then using R to analyze the data, we have generated a co-occurrence network as Fig. 4 shows.

In the diagram, each node (circle) represents a keyword. When there is a line between two nodes, it means these two keywords are used in a same paper. The larger the node, the more frequent it appears. From the keyword co-occurrences diagram, we can find important keywords, such as "communication", "behavior", "model", "emotion" and "design", which are related to the design and development of chatbot or CA. We also can find some of the applications of chatbots, such as "pedagogical agents" and "language emotions". However, we cannot find some popular keywords in these recent years, such as "mobile", "business intelligence", and "deep learning", etc. It implies there is a large space of research opportunity to explore in the chatbot or CA area.

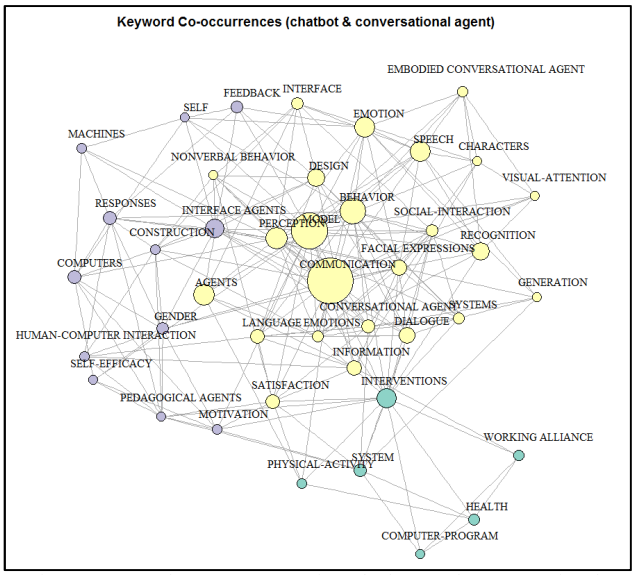

Fig. 4. Keyword co-occurrences for "chatbot" and "conversational agent".

IV. DISCUSSION

During the process of our analysis, the study made several findings. Based on these findings, the following corresponding recommendations are provided for future research:

1) From Fig. 1, the study found there was a sudden increase in research output of chatbot or CA from 2015. The increased attention could be driven by the development of artificial intelligence and related technologies. Researchers should make use of the opportunities presented by new technologies (such as deep learning) and the new trend (such as mobile chatting app) to do further research on chatbots. The reason is, in the past, the conversations between chatbots and human beings were still immature. In the AI era, however, chatbots can learn by itself and they may even know more than the human users. This may create different new form of interaction between machines and the users.

2) Previous studies mainly use classical NLP as the major technology for the deliberative module contained in the chatbot. With the recent developments in deep learning, however, researchers should pay attention to how these new technologies can change the way chatbot is developed and how they can be used in new and varied applications. A framework for developing chatbots may also be needed.

3) In the past, the communication channels of conversational agents are: natural speech, facial expression, and different body gestures. There are currently different forms of chatbot, such as mobile chat app, embedded website service, or embedded gadgets (such as car dashboard and wearable devices). Researchers could focus on the different forms of chatbots, especially those in the mobile context.

4) The study found that the current applications of chatbot are mainly in education. However, there are still a number of applications of chatbot that remain untapped. For example, businesses can use innovative ideas to develop chatbots to reduce cost and assist customers to have a better online experience.

5) Many of the existing studies about chatbot are based on the technical perspective, such as how to improve the chatbot to pass the turning test [20]. There is a dearth of research from the human or business point of view. Researchers should pay more attention on how businesses can derive benefits from the use of chatbots, how the human attitudes will be affected through the use of chatbots, what is the future role of chatbots, and other related issues.

V. CONCLUSION

This paper used bibliometric analysis to examine past research on chatbot and CA. The results are helpful in identifying the research agenda for the future. The publication information and citation report in the literature databases shows a potential opportunity on chatbot research with the emergence of deep learning technology. There are also research opportunities on applications of chatbot and CA in areas other than education, psychology, and linguistics. The results of the analyses using *CiteSpace* and *Bibliometrix* indicate that past research on chatbot and CA is highly fragmented and there is a large space of research opportunity to explore. This study proposed several suggestions for future research, which could help to understand chatbot and CA not only from

the technical point of view, but also from the business and users' point of view. The results of this study would hopefully help to encourage future research on chatbot and CA.

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