Research Article

Systematic Mapping Study on Natural Language Processing for Social Robots

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Abstract:

Nowadays, social robots are becoming increasingly sophisticated in terms of their ability to interact with humans and possess social skills, and in this context, natural language processing (NLP) plays a critical role for robots to understand and communicate with human language. Natural Language Processing (NLP) is an interdisciplinary field used to help computers understand, interpret, and generate human language with a wide range of applications. The examination of the datasets, methods/techniques and tools, and usage of speech recognition or generation in the fields of NLP is important in understanding the developments in this field. In this study, 35 out of 92 studies in the literature collected from Web of Science were examined using a systematic mapping approach, and important findings on the use of NLP in social robots were identified. In particular, emphasis was placed on the effective evaluation of the research questions in the context of NLP in social robots. This study creates a starting point that will guide research in the field of NLP use in social robots and guide future studies.

1. Introduction

Robotics is a rapidly advancing field. Robots are becoming more diverse in what they can do and are playing significant roles in society such as performing increasingly challenging assignments and turn into our dependable team members, assistants, mentors, and friends [1]. As robot technology makes progress in various domains, there is a possibility that these machines will increasingly become part of our daily lives and play different roles in every aspect of society especially our homes. Robot technology is not only evolving, but also beginning to engage in social interaction with humans. Machines that are capable of intelligent human communication and social interaction are known as social robots [2]. The purpose of social robotics is to communicate and communicate with humans. The potential of robots to engage with people in ways that resemble human interaction is becoming more and more important as they move from being used in traditional, highly regulated areas like factories and labs to being used in homes and other social contexts [3,4]. This communication must flow naturally, just like a genuine discussion would [5]. In order to help them progress, a focus should be placed on what makes a conversation fluid and natural since social robots are embodied conversational agents. For example, sentences that are predetermined and repetitious should be avoided because they lack naturalness [6]. These can be achieved through the use of Natural Language Processing (NLP). The term Natural Language Processing refers to a wide range of automated methods for automated generation, manipulation and analysis of natural or human languages [7]. One of the fields of artificial intelligence research that is expanding most rapidly is natural language processing. Enterprise efficiency and productivity have increased by leveraging NLP technology like voice assistants, chatbots, and sentiment analysis algorithms [8]. This involves the use of various data sets, software tools, NLP techniques, and speech recognition and generation capabilities. According to Fujii and Kristiina, three key technologies are required for voice interaction with a robot: automated speech recognition (ASR) for converting human speech into text data; natural language

processing (NLP) for deciphering text data into intended speech; and dialogue management (RLS) for identifying speech content and gesture types so that the robot can respond appropriately to the user's intention [9]. The practice of utilizing algorithms to translate an audio signal into its corresponding text is known as automatic speech recognition (ASR) [10]. Also, artificial intelligence speakers, chatbots, and voice guiding have all embraced speech generation technology. Deep learning algorithms have recently advanced to the point that speech generation outputs are getting increasingly sophisticated and natural, approaching actual speech [11].

It is important to improve the interaction of social robots with humans and enable them to communicate more effectively. In this context, the datasets, language options and NLP techniques used are critical to enable robots to better understand users' language and respond naturally. Additionally, speech recognition and generation capabilities are key elements that determine robots' abilities to interact in real time. In this article, the data sets used in the NLP in social robots, the languages used, software tools, NLP techniques, speech recognition and generation usage status are examined.

2. Material and Methods

The approach used in the systematic mapping process is presented in this part to give the data sets, languages, methods/techniques and tools, the speech recognition and generation usage status for the NLP use in social robots.

This systematic mapping study was carried out based on guidelines used in other studies [12, 13] shown in Fig. 1.

The definition of research questions, search for relevant articles, screening of papers, keywording of abstracts, data extraction and mapping, and the screening process are all essential parts of the systematic mapping study. There is a final result for the process, which is the systematic map, at each stage of the procedure. Fig.1 demonstrates the systematic mapping procedure that was followed. [13].

2.1 Definition of Research Questions

This study aims to investigate the data sets utilized in the field of natural language processing in social robots, assess the languages utilized, identify the tools and methods used in NLP, and ascertain if speech recognition or generation techniques are employed. The following research questions emerged in this context.
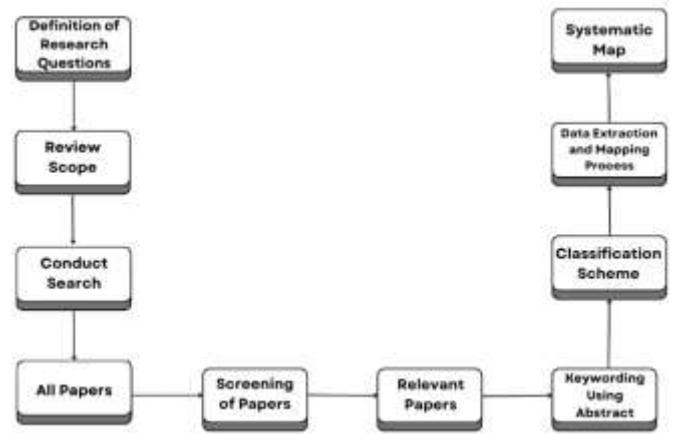

Figure 1. *The Systematic mapping process*

RQ1: What datasets have been utilized in the field of NLP?

RQ2: In what languages has NLP been implemented?

RQ3: What are the methods and techniques used in NLP studies and what special NLP tools are applied?

RQ4: What kind of speech recognition/generation methods/techniques have been utilized in the studies? Has the study implemented any form of speech recognition/generation?

2.2 Review Scope

In this context, the Web of Science database was used and English-language Journal Articles and Conference Papers were taken as basis. The year range for the papers was determined as 2019-2023.

2.3 Conduct Search

To find the primary studies, one can manually search through relevant conference proceedings or journal publications using search strings on scientific databases.

To obtain articles in this field, a search string was created using combination of keywords related to the subject with the boolean operators. The query used in WOS is as follows:
(("Natural Language Processing" or NLP*) AND robot* AND (Dialog or Conversation))

2.4 Screening of Papers

Studies that are not pertinent to addressing the study issues are eliminated using inclusion and exclusion criteria [13]. Table 1 was utilized as a selection criterion for this purpose:

In Fig. 2, the number of papers between 2019 and 2023 is displayed. Most of the articles were published in 2021 (32,3%), the next year with many

***Table 1:** Inclusion and Exclusion Criteria*

| Inclusion	Exclusion
Journal papers	Gray literature papers.
Conference papers	Review papers.
Papers published between 2019-2023.	The general introductory sentences of the abstract should explain the scope, importance and purpose of the study, rather than just stating the terms.
Papers written in English.	Papers that focus on just the emotional synthesis of the usage of NLP in social robots.
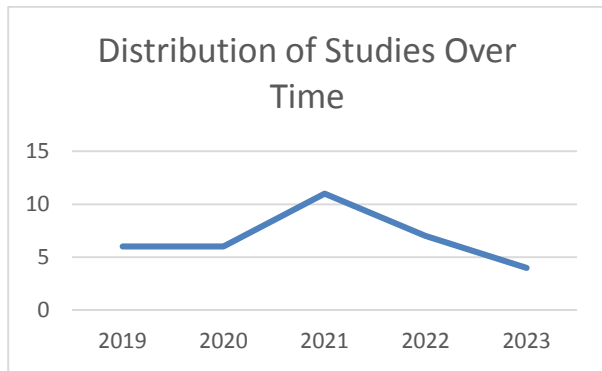
***Figure 2.** Distribution of studies over time*

articles is 2022 (20,5%) followed by 2019 and 2020 (17,6%) where 11 studies, 7 studies, and 6 studies were published, respectively. The two articles which received the most citation have been published in 2020 and 2022 [14, 15].

Fig. 3 shows the distribution of the studies. While 17 of the studies are journal articles, 18 of them are proceeding papers. The most cited journal article is the study [14] with 61 citations while the most cited proceeding paper is the study [15] with 48 citations.

2.5 Keywording of Abstracts

Two steps are involved in keywording. Read the abstracts first, then scan for key terms and ideas that capture the essence of the paper's contribution. Once this is completed, a high-level understanding of the nature and contribution of the research is developed by combining the set of keywords from several papers. This facilitates the development of a set of categories that accurately reflect the underlying population. The paper's introduction and conclusion sections can also be examined in cases when abstracts are of insufficient quality to permit the selection of relevant
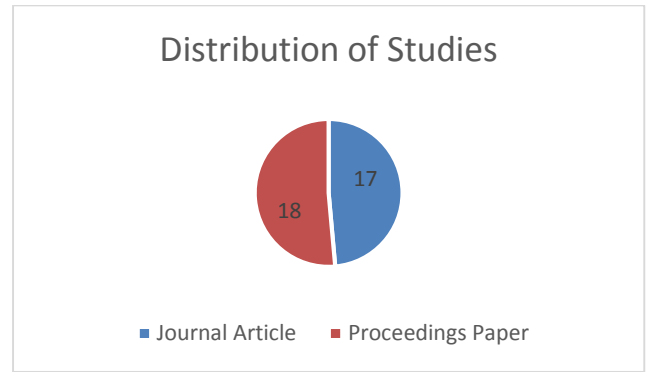
***Figure 3.** Distribution of studies*

keywords. Following selection, a final set of keywords can be clustered and utilized to generate the map's categories [13]. To look up relevant documents, the Web of Science database is utilized. There are 92 articles found on this subject. Then, studies that are not relevant are eliminated through filtering. A set of inclusion and exclusion criteria is used to choose 35 pertinent papers on this topic.
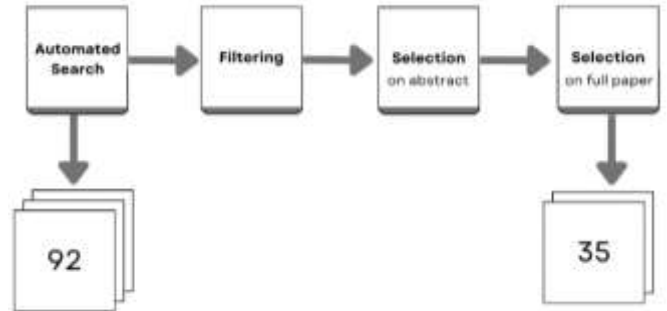
***Figure 4.** Steps in selecting relevant studies*

2.6 Data abstraction and mapping process

The appropriate articles are classified into the classification scheme, which is when the actual data extraction happens. Table 2 demonstrates how the classification scheme changes as new categories are added or current categories are merged and split during the data extraction. An Excel table was utilized in this stage to record the data extraction procedure. Every category in the classification scheme was included in the table. The frequency of publications in each category can be computed from the final table (Fig.4).

3. Results and Discussions

RQ1: What Datasets have been utilized in the field of NLP?

With the spread of studies in the field of NLP (Natural Language Processing), the use of appropriate data sets has gained great importance. Therefore, understanding what datasets are used and understanding the attributes of those datasets is a critical step for NLP researchers.

Table 2: *Classification Scheme*

| Headings	Attributes
Title	Title of the study
Abstract	Abstract of the study
Bibliometric	Year, Type, Number of Citation
RQ1	Databases used
RQ2	Languages
RQ3	Method/technique, Tool Used, Models
RQ4	Methods/techniques used for Speech Recognition or Generation

The data sets encountered in research in the field of Natural Language Processing (NLP) have yielded very diverse results due to reasons such as the diversity of the studies, their goals, language features and application areas.

The obtained dataset which are publicly available from different studies are: CDNA, CLEVR-dialog, Common Voice, ConceptNet data, ConvAI2, CoRoLa, DailyDialog, DialogRE, DialSeg 711, Doc2Dia, DREAM, DSTC, DSTC8-Track2, E-HowNet, EmpatheticDialogue, FrameNet, Frames, Franka, Emika Robot, HuRIc, Industrial Robots Domain Wizard-of-Oz dataset (IRWoZ), iDebate & iDebate18, LibriSpeech, MARCO, MiR200, MultiWOZ, MuTual, NLPCC, NLU-Benchmark, NTCIR-14, Original Food Database, OSCAR, Pepper Robot, REDDIT, refCOCO, Rockin@Home, RoDigits, Royal Spanish Academy of the Language, RSC, RSS, SCT3, SIMMC, SOAR, SquAD, Stanford Sentiment Treebank, SubTle Corpus, Subyek-Predikat-Obyek, SWITCHBOARD, Switchboard Corpus of telephone conversations, Taiwan E Hospital, TED-LIUM, TIMITSGD, TopicalChat, Twitter, VerbNet, Wall Street Journal, WISDOM X, Wikipedia, WordNet, ZYS.

RQ2: In what languages has NLP been implemented?

When the application of NLP technologies is examined, it is observed that English stands out as the most frequently used language. It can be interpreted that this situation is due to the breadth and accessibility of data and resources in English. Additionally, Japanese and Chinese languages have also been observed to be among the most widely practiced languages in this field, especially in their respective regions and due to their unique linguistic characteristics.

The most cited articles that apply NLP in English are study [14] with 61 citations and study [16] with 31 citations, respectively (Fig.5).
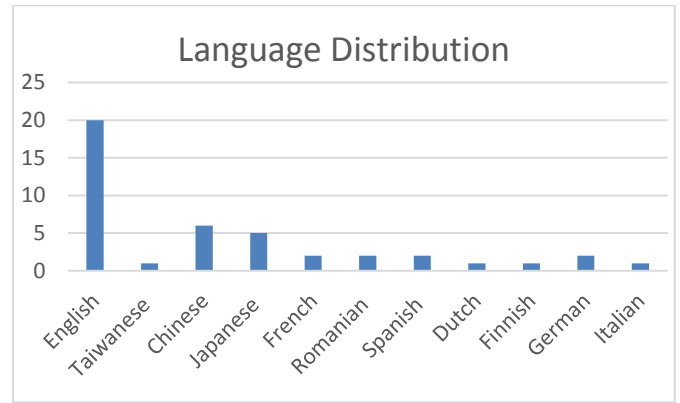
Figure 5. *Distribution of languages*

Furthermore, the most cited article that applies NLP in Japanese is the study [15] with 48 citations and for the Chinese language, is the study [17] with 38 citations.

RQ3: What are the methods and techniques used in NLP studies and what special NLP tools are applied?
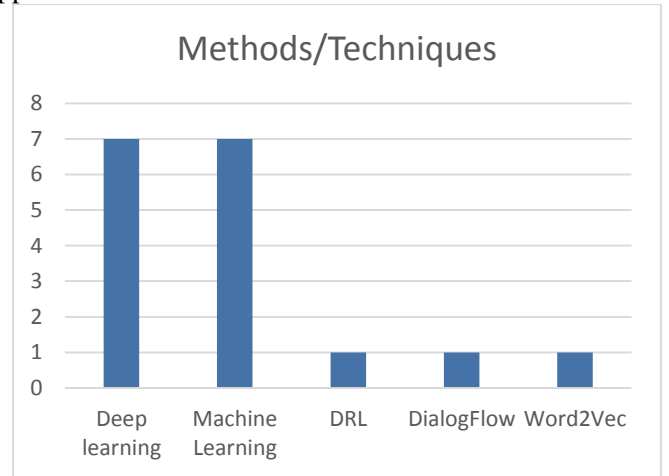
Figure 6. *Distribution of methods*

As a result of the observed articles, it is seen that the methods used in NLP studies were mostly based on Machine Learning and Deep Learning. BERT is the most widely used model in machine learning. The Bidirectional Encoder Representations from Transformers, or BERT, is one of the innovations in the field of natural language processing [18]. BERT, a language model trained on a big corpus—a huge and organized set of texts created in a natural communicative setting—was developed in 2018 by Devlin et al. of a Google team. It can be read by machines and customized for certain applications. It is one of the most widely used and well-liked NLP models [19]. The most cited study that uses BERT is [20] with 26 citations. Different versions of BERT such as SpanBERT and RoBERTa were also used in the studies. On the deep learning side, the use of models such as DeepSpeech and CNN has been

observed. In addition to these, other methods used are shown in Fig. 6.

In terms of other techniques used in NLP studies, Deep Reinforcement Learning (DRL), the combination of Deep Learning and Reinforcement learning, effectively manages challenging real-world issues in many contexts. Natural language processing (NLP), speech recognition, computer vision, and image classification have all given it a lot of attention, which has significantly enhanced its ability to solve difficult problems like perception, planning, and decision-making [21]. Dialogflow is a business that specializes in natural language conversation-based human-computer interface technology. It provides a platform for creating voice- and text-based artificially intelligent assistants ["https://dialogflow.com/."], which Google acquired in September 2016. An agent in Dialogflow is essentially a project or container that holds entities, intents, and the replies that need to be given. NLU (Natural Language Understanding) modules, often known as intents, map lexical user requests into useful information [22]. It is not enough to simply include Dialogflow in the machine learning category, as it not only includes machine learning models but also includes a broader range of NLU techniques such as natural language processing, context management, and response generation. Furthermore, Dialogflow is categorized as a more comprehensive language processing platform, independent of classical machine learning and deep learning techniques, thanks to the integration of NLU algorithms and language processing capabilities. Another technique that has been used is Word2vec which is an approach used in natural language processing (NLP). It uses a large training corpus to train a word embedding neural network model. Each word is represented by a vector in the specified vector space once the model has been trained [23]. Although it is included in the ML subset in terms of being able to learn word embeddings without explicit labels, it does not fit into the category of deep learning because it contains a simple neural network with a single hidden layer. Yet it still does not depend on either technique, as it stands on a line between classical machine learning techniques and larger-scale neural network technologies. In the field of NLP, the tools used in the studies are shown in Fig. 7. The most frequently used framework is RASA which is an open-source dialogue framework that uses cutting-edge machine-learning technology (transformers) [24]. The studies that used RASA are [9, 25, 26, 27] respectively. Another tool used for NLP is Freeling which is a multilingual language processing package available as an open-source project and offers numerous

analytic features for multiple languages [28] that is utilized by the studies [29, 30, 31]. Additionally, other special tools used for NLP studies are Amazon Comprehend, Cloud Based Systems, FOMA, Google API, IBM Watson, KALDI, Microsoft, NLTK, ROS4HRI, Stanford CoreNLP, Vosk, wit.as.
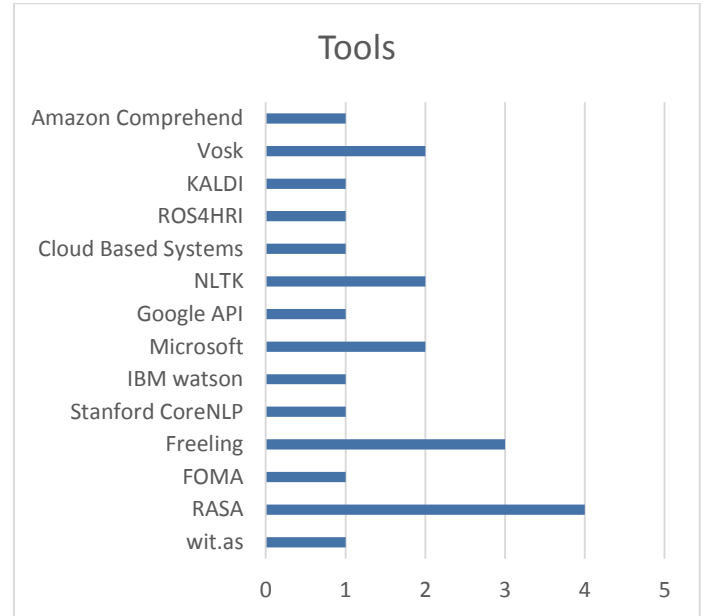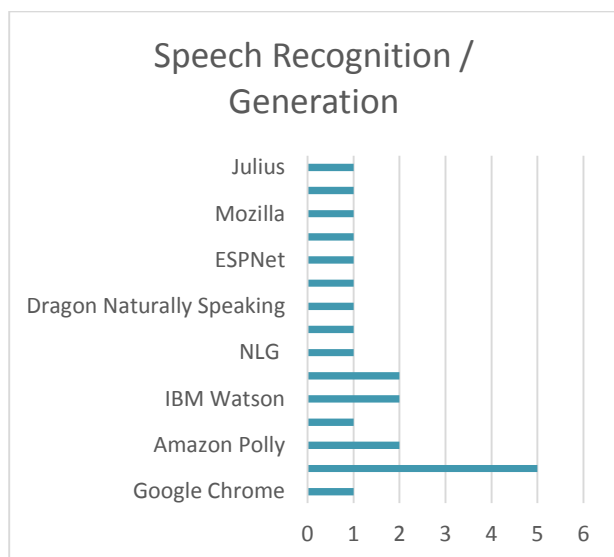

Figure 7. *Distribution of tools*

RQ4: What kind of speech recognition/generation methods/techniques have been utilized in the studies? Has the project implemented any form of speech recognition/generation?

Speech recognition technology is a significant area of study in intelligent robots that enables machines to comprehend human language for human-machine communication. As a result, the use of speech recognition software in robot control indicates the degree of automation progress. [32]. Speech recognition/generation techniques used in some articles are shown in Figure 8. It has been observed that the most used among these is Google Cloud API which was used in the studies [27, 33, 34, 35, 36]. This is followed by IBM Watson, Amazon Polly, and Microsoft Azure. NLP and speech recognition developments have improved chatbot technology significantly, especially in certain areas [37]. In addition to imitating human conversation in a more natural way than synthetic voices, chatbots may also provide other advantages including improved distributed cognition and social interaction skills [38]. Studies [9, 30, 33, 39, 40] mention chatbot usage in the field of NLP. A systematic mapping study is a slightly easy and agile technique to experience the fundamental workings of the scientific process as compared to

Figure 8. *Speech recognition/generation technologies*

studies in the literature have been reviewed through a systematic mapping process to show how they are distributed in relation to the classification scheme. The purpose of this study is to assist researchers in this sector with their decision-making processes. Out of the 92 studies that were found in this systematic mapping analysis, 35 were chosen to be representative of the sample set. The main purpose of the study is to find answers about the data sets used in NLP studies applied to social robots, the languages in which they are implemented, the methods/techniques and tools used in the studies, and the use of speech recognition/generation.

Considering all these aspects, the main findings of the study are discussed as follows. Firstly, it is noteworthy that there is no single dataset commonly used across the studies analyzed. Another significant finding indicates that NLP implementations are predominantly conducted in the English language, followed by Chinese and Japanese. Further analysis of the methods, techniques, and tools employed reveals that most of them are based on machine learning and deep learning approaches. Lastly, it has been observed that the Google Cloud API is the most frequently used tool for speech recognition and generation tasks.

In conclusion, the findings of this study are important for understanding the role of NLP technologies in interaction with social robots and establishing a base for future research. Advances in this field can help technologies such as social robots to communicate with people more effectively and meaningfully adding more value to society.

other research methodologies [41]. In this context, the process that started with data collection and extraction was concluded with the answers to the research questions. The results of this study provide important information about the data sets, languages, methods/techniques, and tools as well as the usage of speech recognition/generation in the applications of NLP studies on social robots. The study conducted revealed that no one data set was utilized consistently across the literature. Nonetheless, it has been noted that the majority of NLP applications are conducted in English. In particular, cross-cultural studies can be focused on to better understand how NLP applications perform in different languages and cultural contexts. Also, deep learning and machine learning tools, methodologies, and approaches are frequently employed. Developing artificial intelligence technology has enabled language diversity to be better addressed in NLP studies. This increases the potential to appeal to a wider audience when used in multilingual or multicultural environments, such as social robots. It has been shown that when it comes to speech recognition, a lot of researchers favor Google Cloud API. Further investigation into the factors that led to this decision and an assessment of the benefits and drawbacks of the API could be crucial. Future studies may focus on developments in the field of NLP and more effective and efficient use of artificial intelligence technology in social robot interaction, building on the results and limitations of the current studies.

4. Conclusions

In this study, several techniques, methods, tools, and datasets were identified from various studies related to relevant research questions. Numerous

Author Statements:

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