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Reviewing approaches employed in Arabic chatbots

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ABSTRACT

The field of chatbots has witnessed a remarkable evolution in recent years, marked by a transition from simplistic rule-based structures to sophisticated systems employing advanced natural language processing (NLP) techniques. While most languages benefit from NLP support, the majority of chatbot research and development has been conducted in English, leaving a notable scarcity of comparable works in Arabic. This scarcity is attributed to the myriad challenges posed by the linguistically intricate nature of Arabic, encompassing orthographic variations and diverse dialects. This study systematically reviews articles that represent implementations of Arabic chatbots, revealing a discernible shift from rule-based frameworks to the predominant adoption of machine learning (ML) and deep learning (DL) methods. The results highlight the dynamic trajectory of chatbot technology, with a notable emphasis on the pivotal role of DL, as evidenced by a significant peak in 2023. Looking forward, the study anticipates a more sophisticated future for chatbot development, driven by ongoing advancements in artificial intelligence (AI) and NLP, offering valuable insights into the current state of Arabic chatbot research and laying the foundation for continued exploration in this evolving and dynamic field

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1. INTRODUCTION

A chatbot is an intelligent conversational agent designed to replicate human communication. It engages with human users using natural language and employs learning processes as a primary focus of artificial intelligence (AI). In recent years, the scientific and business communities have shown increased interest in this field [1]. The inception of chatbot systems dates to 1966 when Weizenbaum developed the ELIZA chatbot at the Massachusetts Institute of Technology (MIT) with the aim of simulating a psychotherapist [2], using basic pattern matching [3], and a template-based answering mechanism. A few years later, exactly in 1971 at Stanford, Kenneth Colby created PARRY to simulate a patient with paranoia [4]. Subsequently, ALICE appeared in 1995 and achieved notable success by winning the Loebner Prize in the years 2000, 2001, and 2004, at the annual turing test contests. It marked a significant milestone as the first computer to attain the designation of the “most human computer” [5].

The evolution of chatbots has been remarkable in recent years [6], with a diverse array of virtual conversational agents becoming increasingly prevalent online. The landscape has transitioned from simplistic rule-based chatbots to sophisticated entities employing advanced natural language processing (NLP) techniques [7], [8]. This progression has significantly enhanced the user experience, allowing for more nuanced and context-aware interactions. Year after year, the chatbots's capabilities evolve, enabling them to comprehend and answering the user queries in a manner that closely mimics human conversation. Basic rule-based systems have given way to AI-powered chatbots that leverage machine learning (ML) algorithms and neural networks to interpret and generate human-like language [9], [10]. These advancements not only facilitate more seamless communication but also contribute to the growing integration of chatbots in various sectors, from customer service to virtual assistants [11]. As technology continues to advance, the trajectory of chatbot development promises an even more sophisticated and interactive future.

Chatbot development has made significant strides in supporting various languages using NLP. Extensive research has been conducted for English chatbots; however, research for Arabic chatbots is scarce due to numerous challenges in processing Arabic texts [12], [13]. These challenges include orthographic variations, rich morphology, high ambiguity, and the prevalence of numerous dialects. furthermore, the text written in Arabic language can be divided into three main types [14]. The Holy Quran is written using classical Arabic (CAL), often known as Quranic Arabic. The second type is modern standard Arabic (MSA), which is used in journalism, study, and literature in formal written and spoken forms. It serves as the main language of the Arab countries. The last type is dialectal Arabic (DA), often utilized in informal contexts and in both spoken and written personal communication.

Various techniques are employed to deploy a chatbot, including pattern matching (PM), AI markup learning (AIML), ML, and deep learning (DL). PM analyzes two patterns to identify if they match or do not match [15]. Where AIML is based on XML language utilized for constructing predefined patterns and responses for chatbots [16]. However, ML is a branch of AI wherein computers are programmed to enhance performance by leveraging example data or previous experiences. DL is a subset of ML, has demonstrated remarkable achievements in diverse domains, including NLP [17]. Its success lies in its ability to perform end-to-end learning, eliminating the need for feature engineering typical in traditional ML technique. DL operates with multiple hidden layers to generate predictions and employs algorithms such as recurrent neural networks (RNN) and long short-term memory networks (LSTM). This advanced technology excels in intelligent learning from extensive datasets [18].

This study reviewed 28 articles published between 2004 and 2023 that present implementations of Arabic chatbots, obtained through extensive database searches and result filtering. It highlights 9 articles for the AIML approach and 10 articles for both PM and ML/DL approaches, tracing the trajectory of created chatbots from 2004 to 2023, marked by phases and notable resurgences. A significant shift towards DL is evident, with 2020-2023 showing a peak of 3 chatbots per year, underscoring pivotal moments in the integration of DL and the advancement of chatbot technologies. This is the primary objective of this review is to identify the prevailing approach in Arabic chatbots.

The remainder of this paper is structured as follows: section 2 describes the methodology employed in conducting this study. Results in section 3 and discussions presented in section 4. In both sections the findings are summarized comprehensively and analyzed. Finally, section 5 encapsulates the conclusion, summarizing the key insights derived from the study.

2. METHOD

Different literature databases are scanned as part of the study technique, and the literature was gathered from extensively referenced computer science repositories such as Science Direct, IEEE, Google Scholar, Springer, ACM, and ACL Anthology, where the chosen period is from 2004 to 2023. The keywords used are "Arabic chatbot", "Arabic chatterbot", "Arabchat", "Arabic chat agent", "Arabic interactive agent", "Arabic conversational agent", "Arabic conversational robot", "Arabic artificial conversational" and "Arabic dialogue" [19]. The result of this searching is 683 articles, distributed as showing in Table 1. Afterwards, the findings are filtered using a set of filters, as Figure 1 shows, to keep only the documents that represent an implementation of Arabic chatbots [20]. The result is 28 papers that depict the Arabic chatbots implementation, as represented and detailed in Table 2 in appendix. The software and materials used to carry out this study include Microsoft Word for writing the content, Zotero for managing references, the Google Chrome browser for research, Foxit Pdf Reader for reading documents, and finally, an HP EliteBook 840 G8 laptop with an Intel Core i7 11th generation processor, 16GB RAM, and 1TB of storage.

Table 1 illustrates that the total number of documents amounts to 638. To refine the data, four filters were applied, resulting in a final set of 28 documents. The initial filter excluded 147 duplicate documents, followed by the removal of 291 documents based on title scrutiny. Subsequently, 186 documents were excluded after abstract scanning, and finally, 31 documents were eliminated upon full-text examination. This meticulous filtration process ensured the precision and relevance of the final findings.

Table 1. The details of searching documents results

Searching term	Google Scholar	IEEE	Springer	ACM	ACL	Science Direct
“Arabic chatbot” OR “Arabic chatterbot” OR “Arabchat” OR “Arabic chat agent” OR “Arabic interactive agent” OR “Arabic conversational agent” OR “Arabic conversational robot” OR “Arabic artificial conversational” OR “Arabic dialogue”	550	57	08	22	37	9

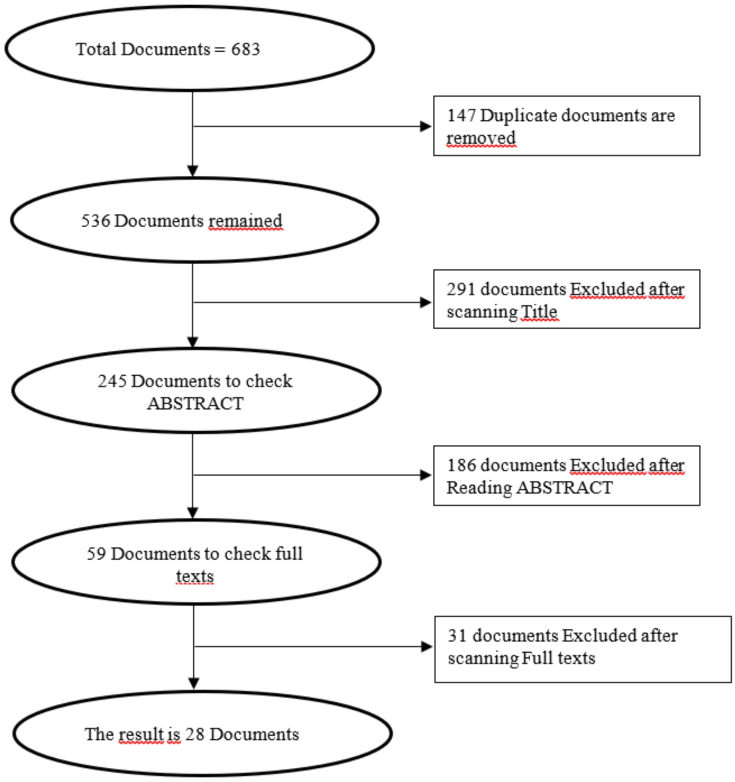

Figure 1. Flowchart illustrating the filtration process of documents

3. RESULTS AND DISCUSSION

After conducting a thorough search and filtering process, a total of 28 articles were obtained. In the upcoming sections, we will provide concise summaries of each article, categorizing them based on their respective approaches. This presentation will offer valuable statistical insights. Subsequently, we delve into a comprehensive discussion of these statistical results, providing a nuanced understanding of the collective findings and their implications in the broader context of the study.

3.1. AIML approach

AIML, stands as an XML-based scripting language dedicated to constructing chatbots and virtual assistants. Specifically tailored for encoding conversational patterns, AIML facilitates the development of rule-driven responses to user inputs. Prevalent in chatbot applications, AIML employs a mechanism of pattern recognition paired with template-based replies, offering developers a means to fashion engaging and responsive dialogues. Though straightforward, AIML has played a pivotal role in the initial phases of NLP, delivering a structured foundation for the creation of basic yet effective conversational agents. In the following, we will present the work implemented by AIML.

Shawar and Atwell [21] created. The Quran 14–114, which is Java software that uses the ALICE chatbot [22] version to function as a Quran chatbot. However, the corpus of Quran text is converted by the Java application to the AIML format that the ALICE chatbot will employ during the conversation. When the user enters an English statement or query, the chatbot provides at least one pertinent “Surahs” and “Ayahs” from the Quran using Arabic and English as a response. The chatbot has a brief dialogue because the domain of conversation is closed. hence. The contents of the Quran constrain the knowledge base, making this a retrieval-based model.

Shawar and Atwell [23] presented the Quran chatbot. It's a chatbot based on a Java program that creates an Arabic AIML file using the Quran, the holy book of Islam. The Quran contains 114 "Surahs," each of which is a set of verses called "Ayahs," totaling 6,236 in all. The user inputs in this chatbot are Arabic words in "Tashkil," a diacritical format that serves as a phonetic guide. In response, the chatbot locates the "Ayahs" in the Quran containing the input of user. Therefore, in the AIML file, the pivotal word in the "Ayahs" as category, and the "Ayahs" as template.

Brini *et al.* [24] created QASAL, an Arabic question/answering chatbot designed for answering specific and for factual questions based on the use of NooJ's linguistic environment. NooJ incorporates tools for constructing and maintaining extensive grammars and dictionaries. QASAL uses the Arabic module of NooJ and is composed of three key components. The initial one is question analysis, in which a set of linguistic techniques is applied to annotate the input text and convert it into one or more regular expressions, generating all potential matching answer pattern regular expressions. The passage retrieval as second component, which involves applying automatically generated regular expressions to the response text, identifying potential response(s). The last component, response extraction, which automatically provides response to the input question based on a concordance table. The system's overall effectiveness is constrained by the available tools in NooJ's Arabic module.

Shawar and Atwell [25], [26] developed an web question/answering (QA) using Arabic language, which is a online platform with five different web pages, each covering one of these topics: teeth care, pregnancy and mothers' issues, blood charity, blood diseases including diabetes and cholesterol, and fasting and health. The users converse with the chatbot briefly on one of the supported domains and provides answers using MSA without relying on advanced NLP techniques. The chatbot technique is based on a Java application that employ a corpus to generate default and atomic AIML files. On one hand, the atomic file contains the inquiry as a pattern and the response as a template. On the other hand, the default file employs the most significant word and the first word approach to ensure that the user's inquiry matches the relevant inquiry saved in the knowledge base. The rate of correct answers is 93%, but the variety of Arabic language characteristics, such as transforming questions into other Arabic forms, may result in no answer.

Ali and Habash [27] created BOTTA, a female chatbot, designed to support the Arabic dialect of Egypt, engages in friendly interactions with the general public. The chatbot was inspired by Rosie's English chatbot. While translating some AIML files of Rosie, others were adapted to accommodate the Arabic dialect of Egypt. BOTTA can temporarily gather basic information from users by asking questions, including name, gender, age, and nationality. This facilitates an open conversation as the chatbot can respond to a diverse range of topics. The chatbot responds to users based on prior information discussed, which is why conversations can be lengthy. However, it can't update its knowledge base or provide new responses as it is a retrieval-based approach. It relies on a predefined set of responses guided by heuristics to generate the correct answer. Additionally, the chatbot does not standardize user inputs but implements orthographic changes, such as fixing common typographical errors in the input of user. Employing this approach, BOTTA successfully corrected 85.1% of prevalent typing errors in Arabic text.

Al-Ghadhban and Al-Twairesh [28] created a chatbot named Nabiha to interact with students and provide answers to their requests regarding the offered courses in the Department of Information Technology (IT) or their academic achievements. Nabiha serves as an academic advisor at the University of King Saud and communicates in the Saudi Arabian language. She is accessible through Twitter, the web, and Android. The chatbot was tested by thirteen students, and they provided feedback through a survey to ensure its usability. Nabiha's chatbot functionality was integrated into the Pandorabots platform After utilizing a Java application to generate AIML files from the text obtained in the corpus.

Al-Madi *et al.* [29] developed ZAYCHAT, an intelligent Arabic chatbot system designed to respond to various visitor queries, particularly those from students at Jordan's Al-Zaytoonah private University and their families. This chatbot operates using the Jordanian dialect. ZAYCHAT is a web application that responds quickly and efficiently to a wide range of user requests, with a focus on supporting students and reducing the workload of university staff in areas such as admissions, academics, educational issues, and other activities, especially during challenging periods like the COVID-19 pandemic. The development process involves five phases: pre-processing, processing and extracting, response generation, integration, and user persistence. ZAYCHAT represents the first Jordanian chatbot system that utilizes the Jordanian dialect.

3.2. Pattern matching approach

Pattern matching is a computational technique widely used in various fields, including computer science and AI, to identify and recognize specific structures within data. It involves comparing input patterns against predefined templates or rules to determine similarities and make informed decisions. In programming, pattern matching simplifies complex tasks by allowing concise and expressive code for conditional branching, aiding in the efficient handling of diverse data structures. In NLP, pattern matching is essential for tasks such as text analysis, enabling systems to identify and respond to specific linguistic patterns in user input. In the following, we will present the findings that use pattern matching techniques.

Riek *et al.* [30] presented is an Arabic conversational humanoid robot designed to simulate Arabic attitudes, particularly those of Middle Eastern cultures. The humanoid robot was tested in a mall in UAE, where visitors were invited to interact with the robot and complete a prepared questionnaire. The results revealed significant regional differences in attitudes, with gulf residents showing a more favorable view of robots compared to Africans. Additionally, individuals with college degrees held less favorable views than those without one. This study underscores the importance of considering cultural and religious beliefs in the Middle East when designing robots. The robot comprises these essential components: expression generation, corpus searching, and speech recognition. Furthermore, other cognitive engines have been incorporated into the robot's capabilities, including access to online social data, which enables it to effectively engage in conversations with people.

Mavridis *et al.* [31] introduce an advanced IbnSina, which is a versatile multilingual android robot capable of engaging in conversations in both English and Arabic MSA. IbnSina interact with users through textual iputs or voice, and in response, the robot provides audio outputs using language corresponding to the input of user. The conversational abilities of IbnSina are broad and extensive. It generates human-like dialogues by accessing online sources such as stored Holy Quran and Wikipedia. This rich source of information enables IbnSina to address a wide range of topics. It can respond to general inquiries, translate words, extracting text from photos through optical character recognition (OCR) techniques., offer answers based on online data, or provide information using stored books in database. Additionally, IbnSina is equipped to offer user feedback when it encounters incorrect spellings or missing information. This makes the style of conversation with IbnSina open and conducive to longer exchanges.

Hijjawi *et al.* [32] propose ArabChat, with a classification methodology, which represents an update to the original ArabChat [33]. This enhanced version employs a novel classification approach for Arabic utterances. This method categorizes sentences into two main groups: questions and non-questions, which include declarations and directives. The advantage of the employed methodology is the reduction in the quantity of patterns needed for each guideline, leading to improved performance as it selects the appropriate rule based on the type of utterance, whether it’s a question or a not. Various subjects and compilations of function words from areas such as religion, politics, education, business, and sports have been incorporated. In addition, indirect questions and synthetic non-question sentences have been included. The classification process involves pre-processing the sentence by converting it into equal numeric tokens, which are used in WEKA’s ML toolkit. A decision tree (DT) is generated by WEKA, demonstrating its effectiveness as the best tokenized numeric dataset accurate classifier. A conventional IF-THEN classification rule is generated from the DT, enhancing its ability to effectively categorize various kinds of utterances.

Alobaidi *et al.* [34] implemented Abdullah an intelligent system for Arabic conversations tutoring (CITS), tailored for children aged 10 to 12 to teaches them the Islamic fundamental concepts. This online platform uses MSA to converse with students. It initiates conversations with students through a sequence of inquiries, subsequently discussing their answers in CAL, supported by evidences from the Hadith and Quran. The system has the capability to distinguish between user queries and responses. Moreover, it incorporates multimedia elements such as sound effects and images to enhance interaction with students to evaluate their understanding levels, allowing it to tailor the conversation accordingly. Its framework relies on a pattern matching technique, comprising a knowledge base with thematic topics, a tutorial knowledge base for evaluating individual student knowledge levels and subject proficiency, and a conversational agent scripting language for delivering instructional dialogues to learners.

Hijjawi *et al.* [35] propose ArabChat as a web interface that can communicate with students of Jordan’s Applied Science University through written MSA, ArabChat engages in an extended conversation with the user, responding based on information previously shared in the ongoing dialogue. The communication with the chatbot will continue until one of both parties ends it. ArabChat’s knowledge base comprises 1,218 utterances organized into contexts. Each context’s rules consist of patterns and corresponding textual responses. A total of 174 users took part in the ArabChat test, providing 7 inputs each. The results highlight 73.56% of the inputs of user aligned with the anticipated outputs.

Hijjawi *et al.* [36] mobile ArabChat, derived from the original ArabChat [35], serves as a mobile-based chat agent designed to provide guidance and support to students at Amman’ Applied Science University. This version is tailored for mobile devices, specifically for Android, and serves as a lightweight adaptation of the ArabChat system. Despite the challenges often encountered by individuals in Arab territories, include sluggish and unreliable internet access, along with constrained bandwidth, Mobile ArabChat is engineered to operate efficiently even under these conditions. The application employs a pattern matching approach. It comprises the same fundamental components as the ArabChat system, including a scripting language, scripting engine, and a knowledge base. Subjective feedback from users indicates a high level of satisfaction, with 96% of users expressing a preference for using mobile ArabChat on their mobile devices over the desktop version of the system. It's worth noting that mobile ArabChat does require an internet connection to function effectively.

Hijjawi *et al.* [37] enhanced ArabChat represents an upgraded iteration of ArabChat [17]. This enhanced version incorporates additional features, namely hybrid rule and utterance classification, which primarily affect the engine-level functionality. However, certain enhancements in the knowledge base and scripting language are still needed to align with evolving requirements. The hybrid rule focuses on how to respond to utterances that request information on multiple topics simultaneously. The second feature, utterance classification, is designed to differentiate between utterances that are structured as questions and those that are not. This is achieved by enhancing the patterns of the question-based rules with additional keywords, enabling more precise matching based on keywords. While it's worth noting that the original ArabChat outperformed the enhanced version in terms of the ratio of matched utterances to the total (RMUT), this was attributed to less serious users. Nevertheless, manual checking of the system's performance yielded more accurate results and demonstrated improvement. Through manual analysis of logs, it was found that enhanced ArabChat accurately manages 82% of utterances involving dual topics. However, this success rate diminishes as the number of topics in the utterance increases. Manual inspection also revealed a notable proportion of question-based utterances caused by these crucial factors: the selected domain, user preferences that lean towards asking questions rather than engaging in discussions, and the script's complexity.

Aljameel *et al.* [38], [39] LANA represents another CITS for children aged 10 to 16 with autism spectrum disorder (ASD) who have already acquired fundamental Arabic writing skills. The aim is to teaches them on science topics using MSA. Conventional teaching methods often encounter difficulties in addressing the diverse requirements of kids with ASD. In this context, LANA stands out by presenting science lessons in MSA. While it shares similarities with the Abdullah CITS, it introduces various style of learning models encompassing auditory, visual, and kinesthetic approaches. This empowers children to independently cultivate their learning skills according to their unique requirements, leveraging the algorithm of short text similarity and pattern matching. Furthermore, LANA's chatbot actively converse with children through diverse multimedia, such as images, audio and tailored instructions, all aligned with the user's preferred learning style.

Alhumoud *et al.* [40] presented an Arabic chatbot designed to assist leisure travelers in Saudi Arabia. The implementation this chatbot based on IBM Watson, and initial program written in Java. Both versions of the chatbot are operational on the Telegram platform. The results of testing revealed their high usability and effectiveness in aiding tourists. Feedback from consumers who assessed the chatbots indicated a notably high level of satisfaction, with an average simplicity rating of 99%. This suggests a general positive experience among users. Furthermore, the findings highlighted that users prefer an interface featuring interaction buttons rather than one necessitating typed request. The evaluation of the conversation experience indicated a significant preference for the button-based interface, with at least a 6% difference in favor of this approach when compared to the text-based input method.

3.3. Machine learning and deep learning approaches

ML and DL are branches of AI that focus on developing algorithms enabling systems to learn and make decisions from data. ML employs various techniques, such as regression and clustering, to recognize patterns and extract insights. On the other hand, DL, a subset of ML, involves neural networks with multiple layers (deep neural networks) to automatically learn hierarchical representations of data. While ML is versatile for diverse tasks, DL excels in complex tasks like image and speech recognition. Both ML and DL play pivotal roles in advancing AI applications across various domains. The findings that use ML/DL are presented below.

El-Jundi *et al.* [41] created the first Arabic universal language model (ULM), known as hULMonA, with the goal of enhancing the precision of text classification tasks in Arabic. Leveraging transfer learning (TL). The model is trained on a vast Arabic corpus from Wikipedia and fine-tuned for sentiment analysis tasks. They compare hULMonA's performance with bidirectional encoder representations from transformers (BERT) on various Arabic sentiment analysis datasets and showcases hULMonA's superiority. The language model is made publicly available for the community, enabling its use in different Arabic text classification tasks. The results indicate the models' excellence compared to leading alternatives. Even though the multi-lingual BERT wasn't specifically tuned for dialects, it outperforms in some tested dialect datasets.

Alshareef and Siddiqui [42] introduced an Arabic conversational agent for Gulf Arabic dialect by applying the Seq2Seq neural network approach. Where the dataset consisting of 5.2k pairs of responses gathered from Twitter. The chatbot stands out for its ability to provide immediate responses to inquiries from an many kinds of users. For the performance evaluating of the proposed system, they utilized human evaluation and the bilingual evaluation understudy (BLEU) metric, and the score achieved for the Arabic

Seq2Seq transformer-based conversational agent with pre-trained word embeddings is 25.1%. The findings suggest that the chatbot outperforms numerous conversational AI systems employing DL techniques.

Naous *et al.* [43] presented an Arabic empathy-driven chatbot. It is implemented using a proposed neural sequence generation model that combines attention and LSTM with Seq2Seq model, where the corpus used is a translation dataset of empathetic conversations in English. The suggested model effectively demonstrates empathic behavior, delivering emotional responses to user input in Arabic. The authors address the difficulties associated with constructing empathetic chatbots for Arabic, citing the language's morphological richness and limited resources compared to English. After experimenting with various model configurations, the suggested model, featuring 500 of embedding dimension, achieved state-of-the-art performance for Arabic, boasting of 0.5 and 38.6 for BLEU score and perplexity (PPL), respectively. Furthermore, the suggested model's effectiveness was further validated by human review of the generated responses, which achieved an average of 3.92 and 3.7 for fluency score and empathy score, respectively. These promising results underscore the model's capability in deducing speaker emotions and generating empathetic responses.

Yassin and Khan [44] presented "SeerahBot," which is an Arabic conversational chatbot specialized in the biography of Prophet Muhammad. The techniques used to create the chatbot are ML and NLP, with the aim of assisting users in finding answers to their questions about the Prophet's hadiths and delivering important information concerning his biography. To enhance accessibility and usability, this application was deployed on the Telegram platform. The findings of their study highlight the chatbot's remarkable accuracy and effectiveness in addressing queries related to the prophet's biography. They evaluated the chatbot's performance using a set of 200 questions pertaining to the prophet's biography, and the data collected was organized and stored in text files. The outcomes demonstrated that SeerahBot provides highly precise information with an accuracy rate of 35.71%.

Boussakssou *et al.* [45] created an Arabic chatbot application known as "midoBot," employing the Seq2Seq neural network approach. This innovative program is trained using a dataset comprising around 81,659 conversations, enabling it to engage with efficiency in discussions with humans on a variety of conventional topics. The outcomes of their work highlight the chatbot's excellence in responding to a wide range of questions and generating novel responses. Their research also revealed the effectiveness of LSTM and gated recurrent unit (GRU) combination. They observed during the training phase that LSTM required 470.78 seconds per epoch, whereas GRU took approximately 140 seconds. LSTM exhibited a higher level of accuracy, with a final accuracy score of 0.89, compared to GRU's accuracy of 0.8.

Bilquise *et al.* [46] introduce a bilingual AI-driven chatbot for the majority of Arabic students in educational institution in the United Arab Emirates. The institution has nearly 3,000 Arab students and 100 faculty members, each serving as an advisor to 25-30 students per semester. The chatbot will help reduce the workload of advisors, allowing them to concentrate on other cognitive assignments like creating study plans. The chatbot will interact with students using English or Arabic interface, providing instant responses to queries related to institutional policies and academic progression. Using NLP and neural network algorithms, the chatbot retrieves responses from trained models in Python. The models were trained on English and Arabic corpora, with a focus on 152 intents and 356 patterns. The chatbot employs three logical components-NLP, NLU, and NLG-to process queries and generate relevant responses. The graphical user interface, built with Python tkinter, facilitates user interaction. Evaluation results show an accuracy of 80% and 75% in English and Arabic, respectively, based on confidence scores and user assessments.

Boulesnane *et al.* [47] proposed a medical chatbot, called "DZchatbot," in the Algerian Arabic dialect, utilizing a Seq2Seq DL approach. This chatbot engages with patients in the Algerian dialect, offering assistance in answering general medical questions, especially those related to their health concerns during health crises like COVID-19, all while maintaining the utmost confidentiality. Additionally, the chatbot promotes healthcare prevention, continuously tracks the progress of epidemics, and contributes to their containment. The project features the implementation of three distinct Seq2Seq models, RNN as encoder and decoders, including BiLSTM, LSTM, and GRU. Following the acquisition of a comprehensive dataset containing 2,150 pairs of medical data, the chatbot demonstrated exceptional performance in effectively addressing user queries.

Issa and Hammond [48] created KalaamBot and KalimaBot, two chatbot applications. KalaamBot engages in conversations with users interactively, while KalimaBot specializes in furnishing information on Arabic words such as meaning and synonyms. These programs offer individualized assistance, boost vocabulary, facilitate dynamic discussion practice, and offer cultural insights. Designed to support Arabic language learners, the chatbots assist with pronunciation, grammar, and offer feedback on language exercises. The chatbots are developed using a sequence-to-sequence model; they analyze user input and generate a response with a probability exceeding 80%.

Alazzam *et al.* [49] build an Arabic chatbot for educational purposes using DL, specifically BiLSTM networks. The chatbot aims to answer student queries related to Ministry of Education regulations in the United Arab Emirates, such as exam schedules and term dates. The methodology involves data collection from educational websites, preprocessing using the natural language toolkit, and the implementation of a BiLSTM architecture with four layers. The model is trained using a three-stage process, and the evaluation was done with a comparison between the four-layer and five-layer BiLSTM architectures and the results shows that the architecture of five-layer outperforms the four-layer. The five-layer BiLSTM demonstrates higher accuracy, with a score of 85.2%, compared to the architecture of four-layer with 80.8% of accuracy. Additionally, the five-layer model shows superior F1-score and BLEU scores, achieving 0.899 and 0.842, respectively, while the four-layer model scores 0.836 and 0.819 in the same metrics. These results suggest that the additional layer in the BiLSTM architecture contributes to improved performance, making the five-layer configuration more suitable for Arabic chatbot applications.

Abdelhay *et al.* [50] presented MAQA, an Arabic medical bot that presents the most extensive dataset for Arabic Q&A healthcare, featuring over 430K questions spanning 20 medical specialties. Derived from diverse online sources, this dataset addresses a notable gap in oriented task chat datasets for Arabic bots. The implementation of MAQA involves models that use LSTM, transformers, and Bi-LSTM, which are DL techniques. The models' performance is thoroughly benchmarked. Notably, the transformer model stands out, surpassing conventional models. The findings reveal that Transformers reached an impressive average of 80% for the cosine similarity score and 58% for the BLEU score, exceeding both Bi-LSTM, with averages of 39% and 72% for BLEU score and cosine similarity, respectively, and LSTM, with averages of 31% and 56% for BLEU score and cosine similarity, respectively. Furthermore, the application of pre-trained word embeddings showed an additional improvement in BLEU score as well as cosine similarity.

The sector chart in Figure 2 offers a comprehensive insight into the diverse implementation techniques within the chatbot domain. Specifically, 28.6% of chatbots utilize AIML, providing rule-based structures for chatbot conversations. Pattern matching, accounting for 35.7%, played a substantial role in simpler chatbot designs, recognizing predefined user input patterns. However, the landscape shifted with the rise of ML and DL, capturing another 35.7%. ML and DL techniques, encompassing NLP and sentiment analysis, ushered in a new era of context-aware and sophisticated chatbots. These trends highlight the dynamic nature of chatbot technology, continually adapting to advancements in AI over the past two decades.

The retrieval-based approach is prevalent in this field due to its widespread usage (AIML and PM chatbots). However, its limitation lies in its inability to produce responses beyond those predefined in the chatbot's knowledge base. In contrast, the generation-based approach (ML/DL chatbots) offers versatility by generating new responses tailored to specific tasks. This approach is particularly suitable for scenarios where providing unique and contextually appropriate responses is crucial for effective interaction.

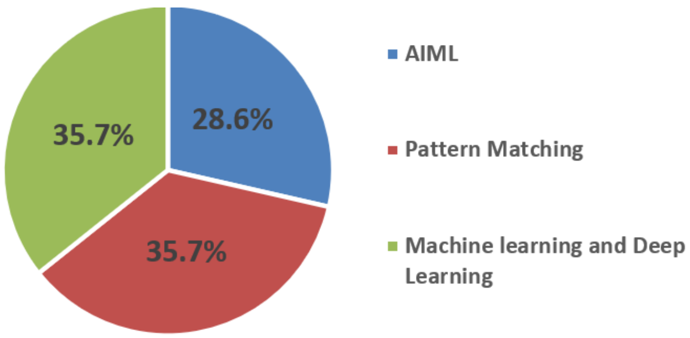

Figure 2. Chatbot Implementation: collection rates across approaches (2004-2023)

Researchers strategically select implementation methods based on the specific requirements and complexities of the tasks at hand, including within various domains such as chatbots. Recently, there is a notable shift towards a concentrated focus on DL, indicating a growing recognition of its efficacy in addressing the intricate challenges within these diverse domains. This trend reflects the evolving landscape of research priorities, aligning with the transformative potential of DL methodologies.

The curve in the Figure 3 presented illustrating the trajectory of chatbots from 2004 to 2023 delineates distinct phases in their evolution. Initiating with a modest count of 2 in 2004, a brief decline persists until 2008, succeeded by a resurgence in 2009. The subsequent years, specifically from 2009, 2011, 2013, 2016, and 2019 witness a stable phase with the chatbot count consistently at 2. Notable fluctuations mark the years 2010, 2012, 2014, 2015, 2017, and 2018, with the number varying between 0 and 1.

A significant resurgence begins in 2020, culminating in the peak of 3 chatbots and sustaining this level through 2023. Of particular significance, a majority of the chatbots implemented during these four years are underscored by DL technologies, signifying a paradigm shift towards advanced ML methodologies in shaping the landscape of conversational agents. These marked points signify pivotal moments, reflecting the dynamic integration of DL in the continual advancement of chatbot technologies.

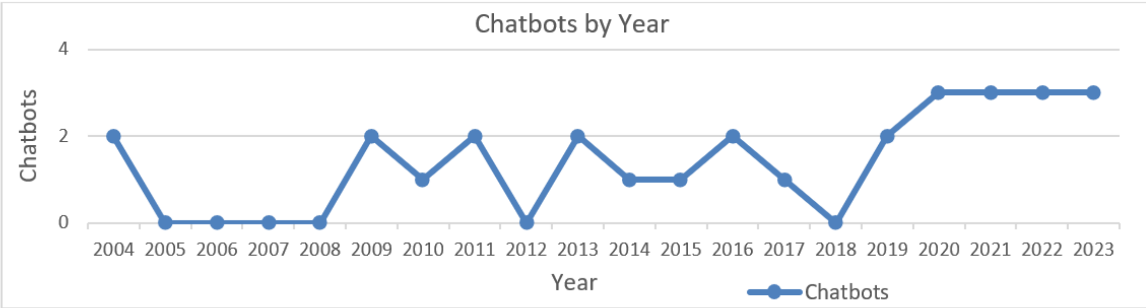

Figure 3. Number of chatbot implementations over year (2004-2023)

The research, spanning 2004 to 2023, encapsulates 19 years, culminating in the identification of a mere 28 Arabic chatbots. This scarcity of results underscores the limited development and adoption of Arabic chatbot technology within the specified timeframe. The findings highlight the need for increased attention, resources, and exploration to foster the growth and enhancement of Arabic-language chatbots in various domains.

4. CONCLUSION

The evolution of chatbots has been a fascinating journey, starting with early attempts like ELIZA and PARRY and progressing to the sophisticated and context-aware agents we see today. The transition from rule-based systems to advanced NLP techniques, powered by ML and DL, has significantly improved user interactions and expanded the integration of chatbots across various sectors. While the development of English chatbots has been extensively researched, the challenges in processing Arabic texts, with orthographic variations, rich morphology, and multiple dialects, have made the exploration of Arabic chatbots more limited. Nonetheless, the study methodically examined 28 articles focusing on the implementation of Arabic chatbots, shedding light on the progress and challenges in this specific linguistic context.

The results and discussions highlighted the diverse implementation techniques employed in the chatbot domain. The use of AIML and pattern matching played significant roles in earlier designs, but the landscape shifted with the adoption of ML and DL techniques. The concentration on DL methods, particularly from 2020 to 2023, showcased a growing recognition of their efficacy in addressing the intricate challenges within various domains, reflecting the transformative potential of these methodologies. The trajectory of chatbot development, as illustrated from 2004 to 2023, revealed distinct phases marked by fluctuations, resurgences, and a recent peak in 2023. The majority of chatbots implemented during these years were underscored by DL technologies, indicating a paradigm shift towards advanced ML methodologies in shaping the landscape of conversational agents. These pivotal moments signify the dynamic integration of DL in the continual advancement of chatbot technologies.

As we look ahead, the future of chatbot development promises even greater sophistication and interactivity, driven by ongoing advancements in AI and NLP. This study provides valuable insights into the current state of Arabic chatbot research and implementation. revealing a scarcity and lower advancement compared to chatbots in other languages concerning the application of AI technologies. There is a pressing need for developers and researchers to focus on creating more advanced Arabic chatbots, leveraging advanced input and output modalities, generative-based models, and NLP. Addressing this clear gap is crucial, particularly with the rising demand for chatbots that emulate human conversation. The Arab-speaking world presents a significant opportunity that remains largely untapped in this domain.

APPENDIX

Table 2. Details about reviewed articles in study

Document, title	Document type and year of publication	Authors	Study location	Approach (AIML, PM, ML, DL)	Indexing database
"An Arabic chatbot giving answers from the Qur'an"	Conference paper, 2004	Shawar and Atwell [21]	University of Leeds U. K	AIML	White Rose Research Via Google Scholar
"Accessing an information system by chatting"	Conference paper, 2004	Shawar and Atwell [23]	University of Leeds U. K	AIML	Springer
"An Arabic question-answering system for factoid questions"	Conference paper, 2009	Brini *et al.* [24]	University of El-Manar, Tunisia	AIML	IEEE
"A Chatbot as a natural web Interface to Arabic web QA"	Article, 2011	Shawar [25]	Arab Open University, Amman, Jordan	AIML	Learntechlib.org
"Arabic question-answering via instance-based learning from an FAQ corpus"	Conference paper, 2009	Shawar and Atwell [26]	Arab Open University, Amman, Jordan	AIML	White Rose Research Via Google Scholar
"Botta: an Arabic dialect chatbot"	Conference paper, 2016	Ali and Habash [27]	New York University Abu Dhabi	AIML	The ACL Anthology
"Nabiha: an Arabic dialect chatbot"	Article, 2020	Al-Ghadhban and Al-Twairesh [28]	King Saud University Riyadh, Kingdom of Saudi Arabia	AIML	Thesai Via Google Scholar
"An intelligent Arabic chatbot system proposed framework"	Conference paper, 2021	Al-Madi *et al.* [29]	Al-Zaytoonah Private University of Jordan	AIML	IEEE
"Ibn sina steps out: exploring arabic attitudes toward humanoid robots"	Article, 2010	Riek *et al.* [30]	Computer Laboratory, University of Cambridge, UK	PM	https://laurelriek.org Via google Scholar
"Transforming IbnSina into an advanced multilingual interactive android robot"	Conference paper, 2011	Mavridis *et al.* [31]	Interactive Robots and Media Lab, United Arab Emirates University	PM	IEEE
"User's utterance classification using machine learning for Arabic conversational agents"	Conference paper, 2013	Hijjawi *et al.* [32]	Applied Science University Amman, Jordan	PM	IEEE
"ArabChat: an Arabic conversational agent"	Doctoral thesis, 2011	Hijjawi *et al.* [33]	The Manchester Metropolitan University, U. K	PM	Google Scholar
"Abdullah: an intelligent arabic conversational tutoring system for modern islamic education"	Congress Paper, 2013	Alobaidi *et al.* [34]	The Manchester Metropolitan University, U. K	PM	IAENG Via Google Scholar
"ArabChat: an Arabic conversational agent"	Conference paper, 2014	Hijjawi *et al.* [35]	Applied Science University Amman, Jordan	PM	IEEE
"Mobile Arabchat: an Arabic mobile-based conversational agent"	Article, 2015	Hijjawi *et al.* [36]	Applied Science University Amman, Jordan	PM	semanticscholar.org
"The enhanced Arabchat: an Arabic conversational agent"	Article, 2016	Hijjawi *et al.* [37]	Applied Science University Amman, Jordan	PM	e-space Via Google Scholar
"Development of an Arabic conversational intelligent tutoring system for education of children with ASD"	Conference paper, 2017	Aljameel *et al.* [38]	The Manchester Metropolitan University, U. K	PM	IEEE
"LANA-I: an Arabic conversational intelligent tutoring system for children with ASD"	Conference paper, 2019	Aljameel *et al.* [39]	The Manchester Metropolitan University, U. K	PM	Springer

Table 2. Details about reviewed articles in study (*Continued*)

Document, title	Document type and year of publication	Authors	Study location	Approach (AIML, PM, ML, DL)	Indexing database
“Rahhal: a tourist Arabic chatbot”	Conference paper, 2022	Alhumoud *et al.* [40]	Imam Mohammad Ibn Saud Islamic University (IMSIU) Riyadh, Saudi Arabia	PM	IEEE
“hULMonA: the ULM in Arabic”	Workshop paper, 2019	El-Jundi *et al.* [41]	The American University of Beirut, Lebanon	DL	The ACL Anthology
“A seq2seq neural network based conversational agent for gulf Arabic dialect”	Conference paper, 2020	Alshareef and Siddiqui [42]	The King Abdulaziz University Jeddah, Saudi Arabia	DL	IEEE
“Empathy-driven Arabic conversational chatbot”	Workshop paper, 2020	Naous *et al.* [43]	The American University of Beirut, Lebanon	DL	The ACL Anthology
“Seerahbot: an Arabic chatbot about prophet’s biography”	Article, 2021	Yassin and Khan [44]	Taibah University, Madinah, Saudi Arabia	ML	acspublisher.com Via Google Scholar
“Chatbot in Arabic language using seq to seq model”	Article, 2022	Boussakssou *et al.* [45]	Sultan Moulay Slimane University, Beni-Mellal, Morocco	DL	Springer
“Bilingual ai-driven chatbot for academic advising”	Article, 2022	Bilquise *et al.* [46]	Higher Colleges of Technology, Dubai United Arab Emirates	DL	proquest.com
“DZchatbot: a medical assistant chatbot in the Algerian Arabic dialect using Seq2Seq model”	Conference paper, 2022	Boulesnane *et al.* [47]	Salah Boubnider University Constantine, Algeria	DL	IEEE
“KalaamBot and kalimabot: applications of chatbots in learning Arabic as a foreign language”	Chapter in the book, 2023	Issa and Hammond [48]	University Of Arizona USA	DL	IGI Global
“Arabic educational neural network chatbot”	Article, 2023	Alazzam *et al.* [49]	The British University in Dubai, United Arab Emirates	DL	Arab Journals Platform
“Deep learning for Arabic healthcare: medicalBot”	Article, 2023	Abdelhay *et al.* [50]	Cairo University, Giza, Egypt	DL	Springer

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