Natural Language Processing for Telehealth

The natural language processing (NLP) technology can serve as an interaction between computers and humans using linguistic analysis and deep learning methods to obtain knowledge from an unstructured free text. The NLP systems have shown their uniqueness and importance in the areas of information retrieval mostly in the retrieval and processing of large amount of unstructured clinical records and return structured information by user-defined queries. In general, the NLP system is aimed at representing explicitly the knowledge that is expressed by the text written in a natural language.

1. Introduction

Remote diagnosis systems are becoming increasingly popular and accurate, with enormous advantages such as cost-effectiveness, fast and reliable decision support for medical diagnostics, and treatment and prevention of disease, illness, injury, and other physical and mental damages in human beings[1]. The rise in remote health services (or telehealth) offered by healthcare institutions coincided with the evolution of assisted living systems and environments, aiming to widen the possibility for older and disadvantaged people to access appropriate healthcare services and thus improve their health status and clinical outcome [2]. With the increase in the innovation of medical technologies, there is a need to adopt medical expert systems that will oversee and control diagnosis and treatment processes. Medical diagnostic processes carried out with the aid of computer-related technology which is on the rise daily have improved the experience and capabilities of physicians to make an effective diagnosis of diseases while employing novel signal processing techniques for analysis of patient's physiological data and deep neural networks for decision support. With the rise of artificial intelligence (AI) techniques, chatbots have appeared as a promising direction in streamlining the communication between doctors and patients [3]. Such chats are becoming increasingly popular as remote health interventions are implemented in the form of synchronous text-based dialogue systems [4]. Patients with chronic diseases could make the most advantage from the use of chatbots which can continuously monitor their condition, provide reliable up-to-date information, and remind them of taking medication [5]. For the effective use of chatbots in the healthcare domain, chatbot technology needs advanced reasoning capabilities based on the formalization of medical knowledge (semantics) and the health state of patients coupled with language vocabularies and dialogue engines [6].

2. The applications of NLP techniques

There are few applications of the NLP techniques in diagnosing diseases despite the enormous amount of text-based information, which can be retrieved from patients' self-narrations [7]. The main challenges addressed by the application of NLP for medical records are flexible formatting, structure without sentences, missing expected words and punctuation, unusual parts of speech (POS), medical jargon, and misspellings [8]. Linguistic structures such as coreferences make medical texts difficult to be interpreted [9]. Moreover, unique linguistic entities such as medical abbreviations make the inference of knowledge from medical texts much harder [10].

The extraction of knowledge from the electronic health record (EHR) is a growing area of interest in medicine, and the use of electronic medical records (EMRs) at the healthcare center and on the cloud [11] has provided a vast amount of data to be analyzed. An EMR is a digital record of health-related information that is created, collected, and managed by medical experts [12]. Compilation of existing and available medical data complications includes integrating NLP into multiple EMRs, ensuring privacy and security of patients' data [13], and clinical validation of a tool. All these can be overwhelming to medical research for improving patient care. However, the application of NLP techniques to screen patients and assist medical experts in their diagnosis would serve as a boost in successfully improving healthcare services through effective analysis of the narrative text of symptoms provided by a patient.

The successful adoption of chatbot technology has shown effective interaction between users and machines especially in various domains within the healthcare system. However, there are some limitations with some of the methods proposed in the literature such as challenges associated with the static local knowledge-based in chatbots and time consumption during training especially for a specific domain [14]. Therefore, there is a need for a future study to develop chatbot software with more scalability, increased data sharing and reusability, and an improved conversation.

The continuous growth of mobile technology has affected every facet of human life around the globe as its support of healthcare objectives through telemedicine, telehealth, and m-health [15] has helped to diagnose and treat patients at low cost especially in the developing countries, where there are limited options of diagnosis and treatment. Out of various communication media available on mobile devices, short messaging service (SMS) has proven to be unique and reliable due to its low cost, reliable delivery, personal to users, and not Internet-oriented service [16]. Considering the need to provide good medical care to everyone including rural dwellers with poor electricity and slow Internet connections, it is therefore important to integrate SMS with a medical diagnosis system, thus establishing an SMS-medical diagnosis system to best meet the needs of a common man. Considering the overall progress and research efforts made by researchers in improving e-health systems and designing decision support systems (DSS) [17][18], there is still much work to be done for effective understanding and identifying key features based on NLP for enhancing diagnosis, thus improving good health and well-being of the global society at large.

Several chatbots with medical-related applications are provided on social networking platforms such as Facebook. For example, the FLORENCE bot reminds the users when to take their medication and monitors their weight and moods. SMOKEY warns the users of bad air quality. HealthTap provides answers using a database of knowledge that contains similar questions. Google provides the Dialogflow Application Programming Interface (API) for the integration of NLP to the target applications. Woebot provides a cognitive behavior therapy service for patients with and has been tested with depression [19]. It allowed reducing their symptoms of depression as evaluated by the depression questionnaire PHQ-9. XiaoIce is a social chatbot that emphasizes emotional connection [20], while using deep learning for meaningful response dialogue tasks. Chatbots are also used in suicide prevention and cognitive behavioral therapy, aiming at-risk groups such as HARR-E and Wysa [21]. The service is delivered over SMS rather than social networks, which require very good Internet connectivity often unavailable in remote rural regions of developing countries, while the described solution focuses on the niche domain of tropical disease symptom assessment.

Summarizing the existing medical diagnosis systems (MDS) often adopts poor decisions due to interpretation of the text-based input provided by the patient. Therefore, there is a need to automate MDS for efficient diagnosis of diseases and support their decisions based on the severity of symptoms. Moreover, the medical experts need a platform to keep track of large text-based chunks of knowledge narrated by patients in a natural language, hence improving healthcare delivery for remote patients.

References

1. Nicholas A. I. Omoregbe; Israel O. Ndaman; Sanjay Misra; Olusola O. Abayomi-Alli; Robertas Damaševičius; Text Messaging-Based Medical Diagnosis Using Natural Language Processing and Fuzzy Logic. *Journal of Healthcare Engineering* **2020**, *2020*, 1-14, 10.1155/2020/8839524.

2. Maskeliūnas, R.; Damaševičius, R.; Segal, S.; A review of internet of things technologies for ambient assisted living environments. *Future Internet* **2019**, *11(12)*, 259, 10.3390/fi11120259.

3. Alan Greene; Claire C Greene; Cheryl Greene; Artificial intelligence, chatbots, and the future of medicine. *The Lancet Oncology* **2019**, *20*, 481-482, 10.1016/s1470-2045(19)30142-1.

4. Jurgita Kapočiūtė-Dzikienė; A Domain-Specific Generative Chatbot Trained from Little Data. *Applied Sciences* **2020**, *10*, 2221, 10.3390/app10072221.

5. Surya Roca; Jorge Sancho; José García; Álvaro Alesanco; Microservice chatbot architecture for chronic patient support. *Journal of Biomedical Informatics* **2019**, *102*, 103305, 10.1016/j.jbi.2019.103305.

6. Amit Sheth; Hong Yung Yip; Saeedeh Shekarpour; Extending Patient-Chatbot Experience with Internet-of-Things and Background Knowledge: Case Studies with Healthcare Applications. *IEEE Intelligent Systems* **2019**, *34*, 24-30, 10.1109/mis.2019.2905748.

7. Richard G. Jackson; Rashmi Patel; Nishamali Jayatilleke; Anna Kolliakou; Michael Ball; Genevieve Gorrell; Angus Roberts; Richard J. Dobson; Robert Stewart; Natural language processing to extract symptoms of severe mental illness from clinical text: the Clinical Record Interactive Search Comprehensive Data Extraction (CRIS-CODE) project. *BMJ Open* **2017**, *7*, e012012, 10.1136/bmjopen-2016-012012.

8. Robert Leaman; Ritu Khare; Zhiyong Lu; Challenges in clinical natural language processing for automated disorder normalization. *Journal of Biomedical Informatics* **2015**, *57*, 28-37, 10.1016/j.jbi.2015.07.010.

9. Voldemaras Žitkus; Rita Butkienė; Rimantas Butleris; Rytis Maskeliūnas; Robertas Damaševičius; Marcin Woźniak; Minimalistic Approach to Coreference Resolution in Lithuanian Medical Records. *Computational and Mathematical Methods in Medicine* **2019**, *2019*, 1-14, 10.1155/2019/9079840.

10. Mingming Lu; Yu Fang; Fengqi Yan; Maozhen Li; Incorporating Domain Knowledge into Natural Language Inference on Clinical Texts. *IEEE Access* **2019**, *7*, 57623-57632, 10.1109/access.2019.2913694.

11. Nourchène Ouerhani; Ahmed Maalel; Henda Ben Ghézela; SPeCECA: a smart pervasive chatbot for emergency case assistance based on cloud computing. *Cluster Computing* **2019**, *23*, 2471-2482, 10.1007/s10586-019-03020-1.

12. Michael V. Boland; Michael F. Chiang; Michele C. Lim; Linda Wedemeyer; K. David Epley; Colin A. McCannel; David E. Silverstone; Flora Lum; Adoption of Electronic Health Records and Preparations for Demonstrating Meaningful Use. *Ophthalmology* **2013**, *120*, 1702-1710, 10.1016/j.ophtha.2013.04.029.

13. Lei Hang; Eunchang Choi; Do-Hyeun Kim; A Novel EMR Integrity Management Based on a Medical Blockchain Platform in Hospital. *Electronics* **2019**, *8*, 467, 10.3390/electronics8040467.

14. Shafquat Hussain; Ginige Athula; Extending a Conventional Chatbot Knowledge Base to External Knowledge Source and Introducing User Based Sessions for Diabetes Education. *2018 32nd International Conference on Advanced Information Networking and Applications Workshops (WAINA)* **2018**, , , 10.1109/waina.2018.00170.

15. Elizabeth A. Krupinski; Ronald S. Weinstein; Telemedicine, Telehealth and m-Health: New Frontiers in Medical Practice. *Healthcare* **2014**, *2*, 250-252, 10.3390/healthcare2020250.

16. Ben Townsend; Jemal Abawajy; Tai-Hoon Kim; SMS-Based Medical Diagnostic Telemetry Data Transmission Protocol for Medical Sensors. *Sensors* **2011**, *11*, 4231-4243, 10.3390/s110404231.

17. Oluwatosin Mayowa Alade; Olaperi Yeside Sowunmi; Sanjay Misra; Rytis Maskeliunas; Robertas Damaševičius; A Neural Network Based Expert System for the Diagnosis of Diabetes Mellitus. *Advances in Intelligent Systems and Computing* **2018**, , , 10.1007/978-3-319-74980-8_2.

18. Nureni Ayofe Azeez; Timothy Towolawi; Charles Van Der Vyver; Sanjay Misra; Adewole Adewumi; Robertas Damaševičius; Ravin Ahuja; A Fuzzy Expert System for Diagnosing and Analyzing Human Diseases. *Advances in Intelligent Systems and Computing* **2019**, , , 10.1007/978-3-030-16681-6_47.

19. Kathleen Kara Fitzpatrick; Alison Darcy; Molly Vierhile; Delivering Cognitive Behavior Therapy to Young Adults With Symptoms of Depression and Anxiety Using a Fully Automated Conversational Agent (Woebot): A Randomized Controlled Trial. *JMIR Mental Health* **2017**, *4*, e19, 10.2196/mental.7785.

20. Li Zhou; Jianfeng Gao; Di Li; Heung-Yeung Shum; The Design and Implementation of XiaoIce, an Empathetic Social Chatbot. *Computational Linguistics* **2020**, *46*, 53-93, 10.1162/coli_a_00368.

21. Aditya Nrusimha Vaidyam; Hannah Wisniewski; John David Halamka; Matcheri S. Kashavan; John Blake Torous; Chatbots and Conversational Agents in Mental Health: A Review of the Psychiatric Landscape. *The Canadian Journal of Psychiatry* **2019**, *64*, 456-464, 10.1177/0706743719828977.