

A Survey of Mental Health Chatbots using NLP

Abha Tewari^a, abha.tewari@ves.ac.in. Amit Chhabria^a, 2018.amit.chhabria@ves.ac.in.

Ajay Singh Khalsa^{a,*}, 2018.ajay.khalsa@ves.ac.in. Sanket Chaudhary^a, 2018.sanket.chaudhary@ves.ac.in.

Harshita Kanal^a, 2018.harshita.ganpathy@ves.ac.in.

^aVivekanand Education Society's Institute of Technology, Chembur Colony, Mumbai, 400074, India

Abstract: Due to recent technological advancements, there has been a rise in digital interventions aimed at either supplementing or replacing face-to-face mental health services which include the advent of mental health chatbots, that claim to provide assistive care using a therapeutic approach. These innovations are driven by Natural Language Processing (NLP). A chatbot can be described as a computer program capable of providing smart responses to user inputs by understanding natural language using one or more NLP techniques. In this study, we discuss the application of NLP in psychotherapy and also a general analysis of existing systems was performed by comparing the responses given by the chatbot against a set of predefined user inputs pertaining to queries related to wellbeing and mental health. The general methodology involved in the creation of such chatbots includes the underlying NLP techniques like word embeddings, sentiment analysis, Models like Sequence-to-Sequence model and attention mechanism. We also propose MentalEase, a mobile application which uses NLP techniques to provide not only conversational aid but also a toolbox of helpful features to keep mental health in place. By integrating mental health assessment tools into the chatbot interface, along with regular therapy it can help patients deal with mild anxiety and depression. This can also overcome certain barriers in mental health, such as waiting lists and geographical problems that hinder attendance at face-to-face counselling appointments.

Keywords: Chatbots, Mental Healthcare, Conversational Agents, Psychotherapy

1. Introduction

As the coronavirus pandemic rapidly sweeps across the world, the resulting economic recession has negatively affected many people's mental health and created new barriers for people already suffering from mental illness and substance use disorders (Stuckler, Basu and McDaid 2011). Depression alone affects more than 264 million people according to the WHO (GBD, 2017). During this unprecedented lockdown, stress levels have been on the rise with 43 per cent of Indians suffering from depression. The World Health Organization also reports that between 2012 and 2030, India will experience economic losses of a whopping 1.03 trillion dollars from mental health conditions (Birla, 2019). In a time when physical consultations are becoming rarer, a need for a virtual assistant to comfort people and avail aid in case of adverse situations is felt. Due to attached stigma to mental health issues people hesitate to reach out and avail help, also there are other constraints like geographic boundaries and waiting lists attached. There is a significant gap in the treatment that should be available conveniently and cost-effectively, and the services available at hand. The ratio of therapists, psychiatrists, psychiatric social workers and mental health nurses to patients is 1: 10,000, even in developed countries (Kislay, 2020). The disparity in the system means that most people with mental health problems will never get the support they need. In response, technology companies have developed artificial intelligence-based applications that seek to be the first line of support for a patient's mental wellbeing, while providing privacy and anonymity. These applications, aimed at individuals, have been developed to proactively monitor patients, be prepared to listen and chat at any time, anywhere, and recommend activities that improve the well-being of users (K. Woodward et al., 2020). Chatbots are emerging as viable complementary services to provide a person with assistance, and often, some sort of companionship also known as "virtual therapists" (Cameron, 2017). If the user is feeling depressed at 2 am, they might not be able to talk

to their therapist. But a chatbot is available for them 24/7 and is eager to talk to them whenever and wherever they need a friendly ear. The structure of this manuscript is organized as follows: Section 2 talks about the survey of the literature of Natural Language Processing Techniques. In Section 3, the overview of chatbot technology is presented. From that point, Section 4 talks about the applicability of chatbots in mental health care. In Section 5 we discuss the methodology involved in the development of chatbots and the NLP techniques used. In section 6, the existing systems are compared and in section 7, we propose our application, section 8 describes the future scope and lastly, section 9 concludes the paper.

2. Recent Work in Natural Language Processing

NLP has seen an immense rise in recent years, the past year has been a revolutionary year for NLP, this happened with the introduction of the revolutionary BERT language representation model. Recently, deep learning approaches have been used across many different NLP tasks. Convolutional Neural Network (CNNs) are typically used in computer vision problems, but more recently have also found use in NLP applications. In addition, several other models, including word vector representations, window-based neural networks, repeating neural networks, long-term short-term memory models, recurrent neural networks, and others, are used to perform NLP tasks. Looking at specific NLP tasks like sentiment analysis, and named entity recognition, over the years there has been an exponential growth in accomplishing NLP tasks like emotion analysis than syntactic parsing (Janna, 2019).

3. Overview of Chatbots

A chatbot is a computer program that responds as a smart entity when conversed via text or voice and understands one or more human languages using Natural Language Processing (NLP) (Khanna, Pandey, Vashishta,

Kalia, Pradeepkumar, Das 2017). Chatbots can reach out to a massive audience on messaging services and be more efficient than humans are. At the same time, they can evolve into an efficient information-gathering tool. They make substantial savings in the operation of the customer service departments. With the further advancement of AI and machine learning, anyone may not be able to understand whether the user is communicating with a chatbot or a real-life agent (Abu, Atwell, 2007). Chatbots can mimic human conversation and can aid in places where physical accessibility is not possible. In recent years, chatbots have rapidly developed in a number of fields, including education, health care, marketing, support systems and entertainment (Adamopoulou, & Moussiades, 2020). In this paper, we focus on chatbots in Mental health.

4. Chatbots in Mental Health

Advancements in technology would also influence clinical psychology and psychotherapy. Chatbots could contribute to the enhancement of health services. Chatbots could be used progressively and become more relevant as the next generation of psychological interventions (Padma, 2020). Chatbots can be a great assistive tool for people undergoing therapy. Timely interventions by chatbots with patients can help to manage mental health conditions. Chatbots can be a viable and successful way to get mental health services while overcoming the barriers of mental health stigmas, thanks to the proliferation of smartphones and higher-speed Internet access all over the world (Bendig, Erb, Schulze, Baumeister, 2019).

5. Methodology

The following Natural language processing operations are involved in the construction of a chatbot capable of initiating comforting conversations to alleviate mental health problems.

5.1. Word Embeddings

It is possible to interpret word embeddings as a vector representation of words. These embeddings can also be learnt by models which are unsupervised. They are responsible for semantically capturing the resemblance of words and are therefore essential. In some NLP applications, such as POS tagging, they are very helpful in representing words. There are several word embedding families, including Bag of Word Based, RNN Family Based, Focus.

- Bag of words based: A Bag of Words is a very common feature extracting procedure for sentences and documents, the histogram of words in a text is looked upon in this approach, it considers each word count as a feature.
- Attention: Such Embeddings are generated by BERT, it produces state of the art results in the task of Q and A, classification tasks etc (Karani, 2018).

5.2. Sentiment Analysis

Sentiment Analysis is an automated method that extracts topics from texts programmatically and the writers' feelings about those topics (Nosotti, 2017). It is an application of NLP. Sentiment analysis, generally speaking, is the act of assessing the mood of an author or speaker with regard to a certain subject or the overall meaning. As there are numerous things one may explore, what this mindset implies differs. For instance, this may be the communicator's emotional state, the expected emotional state (Blom and Thorsen, 2013).

5.3. Naive Bayes

Naive Bayes is a probabilistic classifier, which means that the classifier returns the class c that has the highest posterior probability given the document for a document d , out of all classes $c \in C$ (Keselj, 2009). The Naive Bayes classifier assumes that all word probabilities are independent and calculates that a word's likelihood is in a class $P(\text{word } x | \text{class})$. Then, with the assumption of independent probabilities, making predictions based on using conditional probability with the following formula:

$$\hat{y} = \underset{k \in \{1, \dots, K\}}{\operatorname{argmax}} p(C_k) \prod_{i=1}^n p(x_i | C_k) \quad (1)$$

5.4. Seq to Seq Model

The objective of a sequence-to-sequence model is to map a fixed-length input with a fixed-length output where the input and output lengths can vary (Kostadinov, 2019). The model consists of three sections: encoder, vector intermediate (encoder), and decoder:

- Encoder

A stack of multiple recurring units (LSTM or GRU cells for better performance) in which each of them accepts a single element of the input sequence, gathers and propagates information for that element. The input sequence in a question-answering problem is a list of all the words from the question. Each word is portrayed as x_i , where the order of that word is i (Kostadinov, 2019). The hidden states h_i are computed using the formula:

$$h_i = f(W^{(hh)} h_{i-1} + W^{hx} x_i) \quad (2)$$

This basic formula is the product of an ordinary neural recurrent network. The necessary weights are added to the previously hidden state $h_{(i-1)}$ and the input vector x_i .

- Encoder Vector

It can be considered as the final state which is hidden, produced from the encoder part, it can encapsulate the information for the input elements. It also acts as the initial hidden state for the decoder part (Kostadinov, 2019).

- Decoder

It is a stack of various RNN, where each predicts an output y_i at a time step i . Each accepts a state from the one unit prior. The output sequence can be considered as the set of answers in a question-answer system (Kostadinov, 2019). Any hidden state h_i is computed using the formula:

$$h_i = f(W^{(hh)} h_{i-1}) \quad (3)$$

In this case, are just using the previous hidden state for the

computation of the next one. The output y_t at time step t is computed using the formula:

$$y_t = \text{softmax}(W^s h_t) \quad (4)$$

5.5. Attention

It is known that human attention mechanisms can be used regularize the corpora. A set of sequences which are labelled act as an input, the labels depend upon the average time devoted by the readers on this token or part of the sequence. The RNN then can learn the recurrent parameters and the attention function but, it can then alternate between signals from labelled sequences and attention corpora.

In order to combat the shortcomings of the seq2seq model, the attention mechanism creates an input at each decoding step, this comes directly from the encoder state. This additional input c_i to the decoder at time-step i is computed by taking a weighted sum over all the encoder hidden states h (Kostadinov, 2019).

$$c_i = \sum_{j=1}^T a_{ij} h_j \quad (5)$$

Here T is the number of hidden states or symbols in the source sentence. The weight a_{ij} for each hidden state h_j can be computed by

$$a_{ij} = \frac{\exp(e_{ij})}{\sum_{k=1}^T \exp(e_{ik})} \quad (6)$$

Attention can also be implemented using more than one heads, meaning that the output of multiple scoring functions can be used, each would have it's own parameters, in order to learn to focus on different and specific parts of the input sequence (Csaky, 2019).

6. Existing Systems

Generative chatbots are chatbots which generate a response to the user input not based upon a predefined set of answers. The response is generated from the corpus data which is large in volume. Such chatbots use models like Seq-to-Seq Model (Nuruzzaman, Hussain, 2019).

Certain chatbots are built upon **BERT**. BERT means **Bidirectional Encoder Representations from Transformations**. It is a language model technique developed by Google. It can help in better understanding the context of the words given as an input to the chatbot (van Aken, Betty, et al., 2019).

Rasa is a platform for the creation of industrial-grade chatbots which are powered by AI, and other implementations include chatbots based on the RASA framework. Developers use it to create chatbots and assistants. Action-oriented, FAQ-type chatbots, chatbots answering questions, applying business logic, and performing actions based on specified logic are typical implementations built on RASA.

Talking specifically about mental health chatbots, several implementations of mental health chatbots are available commercially, they include **Wysa** and **Woebot**. They are available in the form of android and IOS applications.

Wysa is an AI-based **virtual therapist**, who engages the user in a **friendly dialogue using a blend of Cognitive behavioural therapy and mental health practices**. Commercially available on Android phones and IOS systems as an application, Wysa protects the conversational data of the user by using **encrypted chats** and allows the user to use a concealed identity (van Aken, Betty, et al., 2019).

Another commercial implementation of a virtual therapist for mental wellbeing is **Woebot**, which is also available in the form of an iPhone and Android application. It prompts the user to log in, unlike Wysa, and then initiates a short user survey where it tries to understand the user. It also practices **Cognitive Behavioral Therapy**, an approach to treatment which helps in improving mental state. The app provides regular check-ins for the user, short pre-filled options, and a gamified experience (van Aken, Betty, et al., 2019). For the comparison between Wysa and Woebot carefully chosen set of questions are asked to both their responses are noted in Table 1.

Table 1 – Comparison of Existing Systems

User message	Wysa	Woebot
What's your name?	"My name is Wysa"	"I've had a wonderful time getting to know you better"
I feel lonely	[Asks if any negative thoughts are bothering]	"I am sorry about that. I imagine that this is making you feel isolated and down" [Further asks about the user's current state of mind]
I'm feeling depressed	"That can be hard..." [Proceeds to ask about previous coping mechanism]	[Ask the user about his current situation]
I feel tired no matter how much I sleep	[Asks what's the thought that influences how we feel]	[Delivers no direct response, asks questions related to the users' mood]
How do I feel good about myself?	"Hmm... I'd love to hear more about it. Tell me more"	[Gives tips to practice gratitude]
I feel irritated all the time	"Feeling irritated frequently can be a sign of stress"	[No direct response]
I don't have any friends	[The chatbot delivers no direct response]	"Hello, I am Woebot, do you want me to check in with you."
I'm really stressed about my work	"This sounds like a busy and stressful time. Try to make time for things that give you energy"	"It seems like you might be experiencing stress and anxiety. Did you want my help to tackle this anxiety or did you just want me to know about it? Let's start by challenging your anxious thoughts"
How do I cope with my anxiety?	"Visualize what you want to happen" [Tells to check out the toolkit provided by the app]	"Do you think this anxiety might be serving you in some way? When someone is feeling down

I don't feel like living anymore

"You are worth your life. You are loved, cared for and cherished, even though you may not feel that way right now. There are people who will be able to guide you and offer support through this tough time."
[Gives details to various helpline numbers]

or anxious, they often lose motivation to do activities, even ones they typically enjoy."

[Triggers crisis system after recognizing an emergency, recommends to reach out to a friendly, caring human who can support the user and help you stay safe during this time. Gives various helpline numbers]

The differences between Wysa and Woebot seem to be difficult to spot to conduct the comparison, each offering check-ins, frequent follow-ups, and a friendly chat. Woebot focuses more on guiding users in complete journaling activities (Meadows, Hine, & Suddaby, 2020). The conversation with woebot may seem to be one-sided. It seems a bit scripted & does not respond to many nuanced concerns (Meadows, Hine, & Suddaby, 2020). Wysa needs more information to communicate properly and asks a lot of open-ended questions. Wysa supports masked identity when talking about a user, while Woebot does not allow the same (van Aken, Betty, et al., 2019). These tools are great but they cannot replace a real therapist but could work great in conjunction with therapy for mild anxiety and depression.

7. Proposed System

7.1. Overview

The proposed system is an android application that uses the power of Deep Learning and Natural Language Processing not only to provide conversational assistance in the form of a friendly chatbot but also to provide a toolbox of useful features to maintain mental health in place. Such a system will help in overcoming certain barriers which are encountered while availing treatment especially in mental health issues which include unavailability of therapists, boundaries of geography and long waiting lists. It can act as a companion when the user needs a friendly ear to listen to him. Someone who will never judge him or make him feel uncomfortable at the same time ensuring that it only acts as an aid to professional therapy not with the intention of replacing it (Heath, 2018).

The application would provide the user with a friendly chatbot which can help people with stress, anxiety or other mental problems by initiating comforting conversations.

Sentiment analysis would be performed on the user inputs to the chatbot. The user would also have an option to talk to a professional when needed. A journal can be maintained for each conversation and the users can write about their day and their thoughts.

Sleep Tracking would also be implemented for analyzing Sleep-related health metrics. The user would be provided with a habit tracker to keep track of his habits and gain motivation. Notifications to the user to initiate the conversation every day would be sent.

The User Interface of the application would be very user friendly, easy to understand and calming at the same time. The choice of colours, fonts and design would be made such that the mere sight of the app is an enriching experience in itself.

7.2. Architecture & Methodology

A variety of natural language techniques will be applied to produce an effective response to the user's questions, including pre-processing using the bag-of-words model, processing through the SeqtoSeq model, and application of attention mechanisms, to further make the responses more precise. The user input will be sent through the chat interface, evaluating the sentiment of the user input.

Each user would be assigned a user Id and the user can use masked identity instead of actual registration and logins on the system. This technique would maintain the user's privacy.

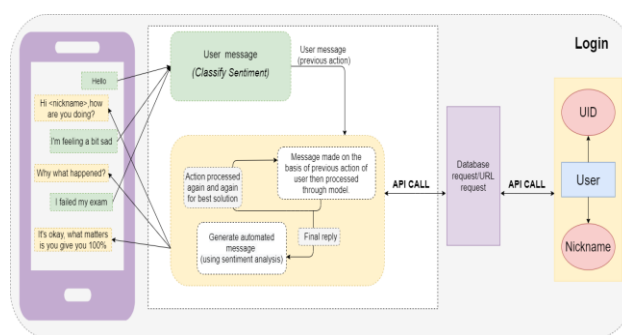


Fig. 1 - (a) Proposed Architecture

7.3. Datasets

Using Cornell Movie Dialog Corpus and OpenSubtitles Corpus [Cornell Movie-Dialogs Corpus, 2020, OpenSubtitles, 2020], the chatbot will be trained. All data consists of pairs of source-target utterances. Cornell Movie Dialog Corpus includes 220579 conversational exchanges from 617 movies between 10292 pairs of movie characters. The OpenSubtitles Corpus includes subtitles of movies created by opensubtitles.org.

8. Future Work

This field is still experimental and there is a need for a lot of research to improve their scope of applications. There is also a lack of clinical approval and testing in a controlled environment (Padma, 2020). There are also very few chatbots targeting users with complex disorders like bipolar and Obsessive-compulsive disorder (Heath, 2019). Chatbot developers need to bring the chatbots more in line with mainstream treatment.

9. Conclusion

It can be said that the field of mental health assistants and chatbots in

psychology and psychotherapeutic applications is rapidly growing. The application of cutting-edge Natural language technologies in combination with psychotherapy can lead to tools which can to a great extent fill the holes in the delivery of mental care. However, they need to be tested and tried on a large scale and viable outcomes should be documented before approving any clinical use. The various Natural Language technologies were discussed at length. Current applications of Natural Language Processing in mental care delivery was examined and It was established.

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