

**Reminiscence Chatbot for  
patients with mild cognitive  
impairment**

*Student no.: 1457374*

**Master thesis**

Master of Science

School of Informatics

University of Edinburgh

2018

## **Abstract**

In this paper, conceptual design and actual implementation of our chatbot is detailed. The aims of this project is to develop a counselling/companion bot that effectively chats and counsels patients with mild cognitive impairment in attempt to improve their mental state. Ideas from Reminiscence therapy are particularly imported to recall memories and actively engage in conversations with the sufferers

## **Declaration**

I hereby declare that all of the work is done only by Shing Tse myself and have also read and understood the University's plagiarism guidelines

# Table of Contents

<b>1</b>	<b>Introduction</b>	<b>5</b>
<b>2</b>	<b>Background</b>	<b>7</b>
2.1	Definition of chatbot . . . . .	7
2.2	Relevant works and motivation . . . . .	8
2.3	Review of therapeutic approach . . . . .	9
2.4	Background knowledge . . . . .	10
2.4.1	Parsing and POS tagging . . . . .	10
2.4.2	Sentiment analysis . . . . .	10
2.4.3	Named entity recognition . . . . .	11
2.4.4	Naive bayes classifier for text classification . . . . .	11
<b>3</b>	<b>Methodology and conceptual design</b>	<b>13</b>
3.1	Methodology and chatbot architecture . . . . .	13
3.2	Linguistic choices and dialogue design . . . . .	14
3.3	Choice of personality of chatbot . . . . .	15
3.4	Conversational structure . . . . .	16
<b>4</b>	<b>Implementation</b>	<b>17</b>
4.1	Tools . . . . .	17
4.1.1	Graph database . . . . .	18
4.1.2	Python and libraries . . . . .	20
4.2	Core structures and modules . . . . .	21
4.2.1	Decision tree structure . . . . .	22
4.2.2	Natural Language Understanding units . . . . .	22
4.2.3	Modules . . . . .	24
4.3	Implemented dialogue tree . . . . .	25

4.3.1	Objectives and flow of chat . . . . .	25
4.3.2	First conversation . . . . .	26
4.3.3	Second and onward conversations . . . . .	30
4.3.4	Summary . . . . .	34
<b>5</b>	<b>Evaluation and usability</b>	<b>35</b>
5.1	Success metric . . . . .	35
5.2	Evaluation . . . . .	36
5.3	Usability: . . . . .	38
<b>6</b>	<b>Discussion and conclusion</b>	<b>39</b>
6.1	Biblography . . . . .	40

# Chapter 1

## Introduction

With the increasing trend in aging population, the proportion of people aged 60 or above comprised 13% of world population.

According to World Health Organization, it is expected such population is growing at a rate of about 3 per cent per year. This has raised huge concern about availability of health service for elderly and incurred great burden for medical expenses in treating mental illnesses. In particular, mental health/cognitive disorders are prevalent among elders, with depression affecting 22% to 28% of people whom age is above 60 in UK [1].

Mild cognitive impairment (MCI) ,a condition in which bearers experience difficulties in cognitive ability such as memory loss and problem solving skills with minimal impairment in instrumental activities of daily living, is often perceived as prodrome of more severe or irreversible cognitive illnesses such as dementia and Alzheimers Disease[2]. To cope with the surge of demand for psychiatric therapy for cognitive impaired sufferers. Digital intervention such as virtual assistant and chatbot have been studied recently in order to reduce burden and demand for psychiatrist. For example, Ryan companionbot [2],developed by DreamFaceTech,is a real-life chatbot that converse with dementia suffers for reminding daily routines and counselling. Kavakli, Li and Rudra (2012) used chatbot to help students overcoming exam stress [3]. The need of digital intervention has thus becoming more necessary and important with the rise of ageing population.

In this project, we first researched different approaches to counselling MCI sufferers and select suitable language style for the chatbot. This is followed by implementation and evaluation of the chatbot with certain test dialogue and human tester based on our success metric.

The goal of this project is to develop a conversational agent that serve as a companion to MCI sufferers and effectively chat with user about different topics and counselling for negative emotions while also recalling memories of the user.

# Chapter 2

## Background

In this section, we first introduce and define chatbot followed by relevant works and motivation for the project. Different therapeutic approach in treating cognitive impairment is also discusses and reviewed. Lastly, a background knowledge section is written to cover the essential knowledge for comprehening the project.

### 2.1 Definition of chatbot

Chatbot is traditionally defined as a computer program that could carry out conversation with human. Examples of chatbots include virtual assistant, Q&A bot and customer service bot. The first chatbot developed was known as ELIZA [4], developed by Joseph Weizenbaum which uses pattern matching to carry out conversation with users. However, early chatbots do not possess reasoning abilities. A more recent approach into functioning chatbot typically utilize machine learning , logic, natural language processing and database. These conversational agents could perform in more human-like manner and could cover wider range of topics. It is also noted that modern chatbots are still far from human-level reasoning ability for open domain conversation and deeper research has to be done for the possibility of intelligent bot.



## 2.2 Relevant works and motivation

With the rapid development in artificial intelligence , more and more research have been done on medical chatbots. In particular,most currently available medical chatbot focuses on mental health counselling(e.g. anxiety issues, stress and emotional problems) or virtual assistant for health service arrangment. Examples include Babylon Health ,a company specialising in health consultation service, created a online chatbot for diagnosing symptoms of users based on their chat with the aid of knowledge database. Woebot[5] is an online chatbot that use cognitive-behavioral therapy to consult users about their mental health.

In terms of therapy for cognitive inpaired sufferers, Seiji et.al 2017[6] implemented a chatbot that counsels dementia sufferers. Their dialogue system generates personalized dialogue based on detailed questionnaire written by dementia sufferers or carers on the sufferers' life history. Moreover, the chatbot could learn to generate dynamic dialogue that is reasonable and responsive to users feedback. DreamFaceTech also developed a fully functioning real-life robot (Ryanbot) that communicate with dementia sufferers as a companion. Results have shown the average number of dialogs between participants and Ryan[2] has not decayed over a period of four weeks.[2] . Despite the efforts in building chatbots for people with cognitive impairment, researchs on cognitive impairment counselling or 'companion-bot' are still at it's infancy.

This has thus inspired and motivated our direction into building a functioning chatbot that could communicate with sufferers of mild cognitive impairment and improves quality of life of the users. (e.g. mood regulation, improving memory and reduce depressive thoughts)

## 2.3 Review of therapeutic approach

To determine a proper linguistic setting and relevant therapeutic approach for counselling mild cognitive impairment sufferers, we first reviewed different style of therapy used in counselling patients with cognitive impairment.

Among different existing therapies for cognitive illnesses, one of the typical therapy is called reminiscence therapy, which asks patients to recall their memories by engaging in multiple sections of conversations. Various studies have shown that the therapy helps alleviate depressive symptoms in elderly suffering from depressive thoughts [7] which is common in MCI sufferers.

In addition , studies have also discussed the benefit of reminiscence therapy on treating cognitive disease. Reminiscence therapy could also boost or improve memory of cognitive impairment sufferers[8]. Recently, Nikitina et.al [9]have created a chatbot that uses reminiscence therapy via the use of text conversation, images and videos to talk with elderly persons. These have suggested the feasibility and suitability for using reminiscence therapy on MCI sufferers.

In cognitive-behavioral therapy (CBT), therapist engage conversation with patients and ask for their viewpoints and feelings. After identifying the thoughts from patients, therapist provide suggestions that aims at changing unhelpful thoughts or cognitive distortion[10]. In short, cognitive distortion is defined as irrational thoughts that one perceive the reality inaccurately. It is also common for MCI sufferers to endure depression , low self-esteem as a result of the side effects by the MCI symptoms. By engaging in CBT, it is perceived that mental states of MCI sufferers can be improved by providing suggestions or mechanisms to cope with irrational thoughts.

Another related therapy is known as validation therapy. It emphasizes empathy and values listening towards dementia sufferers[11][IPP]. Kitwood et.al 1997 had suggested a personal-based approach towards dementia patients. Together with all these different styles of therapy, we could take reference and design the chatbot that tailor the needs of MCI sufferers, which would be discussed in later chapters.

## 2.4 Background knowledge

In this section, essential background knowledge are briefly explained. This is because the majority of the project involves idea around machine learning (ML) and natural language processing (NLP). Before introducing our design of chatbot, it is important to clarify the terms/glossaries used in the later part of paper.

Natural language processing is a field revolves around understanding and interpreting human language by computer. For example, extracting semantics from words for text classification. While in board terms, machine learning is about letting computer to learn. In this project, we could restrict the meaning of machine learning to learn new phenomenon or predict from observed/acquired data. In today's problem, both fields are also closely related to each other.

### 2.4.1 Parsing and POS tagging

In almost all natural language processing problem , parsing is defined as the process of analysing structure of a sentence in terms of tree-like structure.

POS tagging make uses of parsing and break each part of speech tag in a word into fundamental tag (e.g. verb,noun,subject). For POS tag that can be ambiguously defined such as verb phrase and noun phrase, more complex parsing technique known as syntactic parsing is being employed. In a nutshell, syntactic parsing uses word statistics to infer the relation between words and extract the most probable POS tag in groups of word.

### 2.4.2 Sentiment analysis

Sentiment analysis is a type of algorithm used to identify and extract emotion state in human language. For example, identifying extent of negativity or positivity in dialogue or any particular emotion state ,based on different design of the sentiment analyser. Sentiment analysis can be achieved by using different approach such statistical inference or extracting meaning from knowledge base .This type of algorithm is frequently used in designing our chatbot.

### 2.4.3 Named entity recognition

Named entity recognition seeks to locate and identify named entities (e.g. location, person, organization) in a text. It is achieved by using supervised learning on annotated text. Named entity recognition is useful in information retrieval and especially in conversational agents due to its ability to identify entities which is important for natural language understanding and generation.

### 2.4.4 Naive bayes classifier for text classification

In machine learning, naive bayes classifier is a type of classifier which uses conditional probability model and bayes rule for classification. The formulation for naive bayes classifier is explained below.

Given document  $D$  and class  $C_k \in C$  where  $C$  is the possible classes, we want to use Baye's rule to compute the posterior or the probability  $P(C_k|D)$  that a document belongs to certain class.

$$p(C_k|D) = \frac{p(D|C_k) p(C)}{p(D)} \quad (2.1)$$

It is also assumed features  $x_n \in D$  are conditionally independent of each others given class  $C_k$ .

$$\begin{aligned} p(C_k|x_1, x_2, x_3, \dots, x_n) &= \frac{p(C) p(x_1, x_2, x_3, \dots, x_n|C_k)}{p(x_1, x_2, x_3, \dots, x_n)} \\ &= \frac{p(C) p(x_1|C_k) p(x_2|C_k) p(x_3|C_k) \dots p(x_n|C_k)}{p(x_1, x_2, x_3, \dots, x_n)} \end{aligned} \quad (2.2)$$

When features are represented as words in text document, each unique words is converted into a vector/id and  $p(x_n|C_k)$  is calculated by dividing occurrence of each unique word  $x_n$  in class  $C_k$  over no. of words in document classified as  $C_k$ . After acquiring the training data, the parameters in prior distribution  $P(C)$  and likelihood function  $P(x_n|C_K)$  is trained and ready for classifying unseen text. In test time, new text is classified by choosing  $C'_k$  that maximize the posterior  $P(C_k|D')$  where  $D'$  is the new document.

$$C'_k = \underset{c \in C}{\operatorname{argmax}} P(C_k|D) \quad (2.3)$$

# Chapter 3

## Methodology and conceptual design

In this section, Methodology that explains our approach and basic architecture/features of the chatbot is briefly introduced. In the second part, conceptual design that outlines the framework and important features of chatbot are then discussed and explained. A more detailed implementation and explanation of the chatbot would be included in next chapter.

### 3.1 Methodology and chatbot architecture

In the design of conversational agents, natural language generation can be achieved by the use of knowledge base or using deep learning if there are sufficient amount of data/text corpus. To create a chatbot that could respond and provide counselling service to MCI sufferers, an open domain chatbot would be best suited. However the amount text corpus related to mental health counselling is mostly unavailable to public. In addition, there are insufficient data for generating meaningful natural language using deep learning methods. Therefore, our design of chatbot has shifted to rule based approach mixed with machine learning algorithm.

In our design, conversations are mostly scripted and responses are activated based on the user's output. However apart from entirely fixed response, the chatbot could identify sentiments and respond correspondingly to a certain topic. For specific topics, machine learning algorithm is trained on hand-crafted text dialogue for intent classification. To model the flow of conversation, finite state machine is also used whenever

users want to switch from one state (topic) to another. Another key feature of the chatbot is to automatically extract , store and retrieve relationships, events on future chat section. A more detailed explanation would be included in next chapter. In the following sections, conceptual design about linguistic setting , dialogue design and conversational flow will be mentioned.

## 3.2 Linguistic choices and dialogue design

According to Alzheimer's association of UK, mild cognitive impairment patients tend to suffer mildly from one or more of these five areas:

**Memory loss:** forgetting things that happened recently.

**Reasoning:** The ability to plan, reason and problem solving.

**Attention:** Prone to distraction.

**Language:** Have difficulties in explaining and selecting appropriate language for expression.

**Visual depth perception:** Problems in interpreting 3D objects , judge distance or navigate stairs.

Choice of language and dialogue setting are thus crucial for effective communication with MCI sufferers. As shown above, MCI sufferers often struggles in communication, having troubles in finding the suitable wordings for their actual thoughts. Together with the decline in reasoning power, it is easy for MCI sufferers to develop more serious emotional problems that could affect their self esteem. With a view to this, one of the core principles in designing our chatbot is to consider their abilities to comprehend languages. That is, to avoid complex sentence structure and use only simple language. Moreover, the conversation is designed to avoid redundancy and should be as concise as possible. In terms of flow of conversation, the chatbot should also lead the role in conversation. Examples and more in-depth structures of dialogues will be included in the next chapter [IPP].

Key points for the linguistic setting of our chatbot are summarized below :

- Avoid hard or complex glossaries and use only simple words/language
- Avoid redundancy in sentence structures and use concise language

### **3.3 Choice of personality of chatbot**

As mentioned in background section, validation therapy emphasises on respecting and listen to one's thoughts and opinions. This is particularly important as MCI sufferers tend to encounter mood swing and personality changes when transiting to MCI from normal person[10]. To help encounter the detrimental effects brought about by emotional or personality changes , the chatbot is designed to promote positivity and empathetic towards thoughts and opinions by the sufferers [IPP]. The personality that chatbot conveys is designed to be as realistic and human-like as possible , emulating natural conversation by humans. This is achieved by careful design for dialogue and responses in our chatbot. The key personality of the chatbot can be summarized as the following:

- Promote positivity and empathetic as in Validation therapy.
- Personify chatbot by careful generation of dialogues and responses.
- Chatbot should emulate natural conversation and serve as companion.



### 3.4 Conversational structure

In background section, we reviewed different therapeutic approaches (Reminiscence therapy, validation therapy and CBT) in helping MCI sufferers. To create a chatbot that function as a companion while effectively communicate with MCI sufferers about their needs, we decided to combine all three approaches when considering the conversational structure. In personifying chatbot, ideas and essence from validation therapy is taken into account. To model the conversation with MCI sufferers, we should also take into account the fact that cognitively impaired persons are incapable of managing natural conversation as compared to normal people. Thus, the chatbot should lead the conversation instead of letting user to chat freely.

As mentioned in previous sections, MCI sufferers have troubles concentrating and reasoning. Ideas from CBT can therefore be incorporated to our design. CBT suggests that emotions, thoughts and behaviors are intertwined and influence each other. By identifying sentiments and asking for user's feeling and thoughts at specific question or stage of conversation, respective respond and suggestion can be given to the user for self-reflection. To explain further, the conversation is designed such that the user must activate these questions at certain point in every conversation. This is to ensure that behaviors and thoughts of users can be expressed and understood while providing assistance based on CBT theory.

Apart from decline in reasoning ability and attentiveness experienced by MCI sufferers, memory loss also causes adverse effect on the sufferers. Reminiscence could hence be used in chatbot to recall memories and boost memorization of the MCI sufferers. This is achieved by extracting and storing personal attributes(e.g. personality, hobbies, relationship, family and life event of the user) when user mentioned about these topics which is classified by naive bayes classification algorithm in Textblob. In the future conversations, the chatbot is capable to retrieve and respond accordingly.

# Chapter 4

## Implementation

In this section, structure and modules used in the chatbot are explained from macroscopic to microscopic scale. We first start by introducing the libraries and softwares used in creation of the chatbot. Next an overview of the chatbot structure is given and other details will be explained progressively.

### 4.1 Tools

In the beginning of project, different existing natural language API such as Dialogflow for creating chatbot was first considered. However, it is found that Dialogflow fails to satisfy the requirement for our intended design . To explain further, Dialogflow could not store conversations and performs unsatisfactorily in chat continuation. Since Dialogflow relies heavily on use intents and entities to continue conversation, it might be incapable for modelling in-depths conversation as different feelings couldn't be understood simply by storing entities. To resolve the problem, we decided to execute the chatbot in Python and store info in backend graph database Neo4j. Moreover, StanfordCoreNLP , an online natural language processing server written in java is used for semantic analysis in conversation.

### 4.1.1 Graph database

To store personal information extracted during conversation, different databases such as NoSQL, SQL and relational database are considered. However, it is found that graph database Neo4j is the best for automatically query relations from stored data. Moreover, Neo4j-rest client provided a simple but effective way to connect Python to Neo4j server.

In a nutshell, graph database is a kind of database which use graph structure for semantic queries with nodes, edges and properties to represent and store data. Information and labels are stored as nodes and described intrinsically. Relationships are stored as edges between nodes. Neo4j use Cypher query language to retrieve information. There are varieties of returned query depending on the Cypher script sent. On surface level, one could simply retrieve personal info of particular person but one may also retrieve mutual friends sharing the same habit as a particular person. The advantage of graph database over traditional database is that information or relationships about the user can be retrieved automatically with careful use of Cypher language, and hence reused in future conversations.

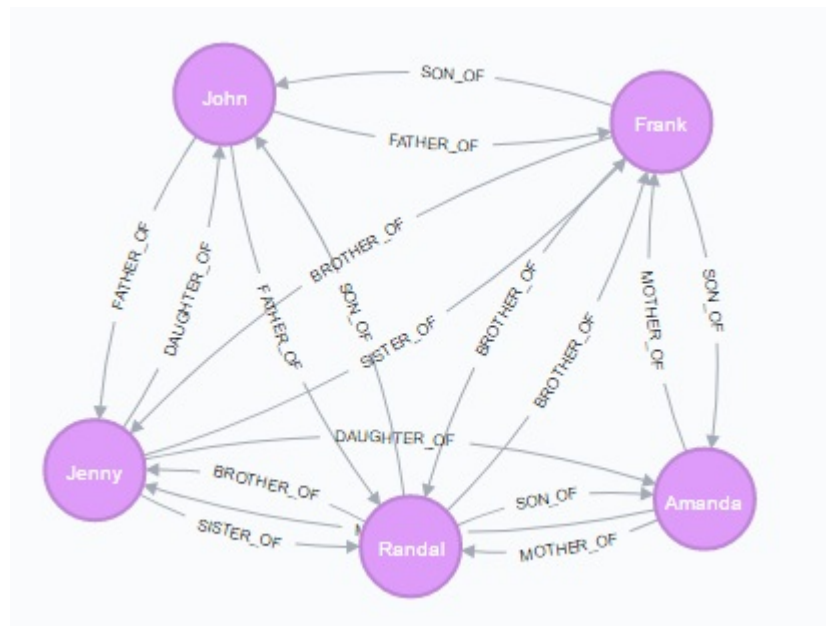


Figure 4.1: Example of graph showing relationships of a family in Neo4j

The screenshot displays the Neo4j Browser interface. On the left, a sidebar contains icons for database information, favorites, and recent queries. The main panel is titled "Database Information" and is divided into three sections: "Node Labels", "Relationship Types", and "Property Keys".

- Node Labels:** Shows a list of node labels, including "Person" and "data".
- Relationship Types:** Shows a list of relationship types, including "Knows".
- Property Keys:** Shows a list of property keys, including "age", "event", "family", "family\_hobby", "family\_pos", "feeling\_type", "from", "hobby", "key", "klout", "learn", "life event", "life\_event", "marriage", "memories", "memory", "name", "personality", "personality\_info", "pet", "prev\_state", and "previous\_chat".

On the right, a query editor shows a Cypher query: `$ MATCH (n:Person) RETURN n LIMIT 25`. Below the query, a graph visualization shows two nodes, "Taeyon" and "Janet", connected by a directed relationship labeled "Knows". The graph is displayed in a "Graph" view, with options for "Table", "Text", and "Code" views. A sidebar on the right contains icons for "Graph", "Table", "Text", and "Code".

Figure 4.2: Backend interface of the graph database Neo4j

### 4.1.2 Python and libraries

Having Neo4j as the backend database for storing personal info, the frontend and core of the chatbot is created using Python and natural language processing (NLP) libraries NLTK and StanfordCoreNLP. NLTK and StanfordCoreNLP are two distinctive NLP libraries for semantic analysis of user's response . These libraries can be used in natural language understanding part for the chatbot. To connect Python with Neo4j, Neo4jrestclient is used to store and retrieve info while in conversation with the user. This can be done by defining corresponding storing and query functions in Python.

```

22 'Query from graph database and return node id and its properties for inference'
23 from neo4jrestclient import client
24 def query_id(x):
25     q="MATCH (ee:Person) WHERE ee.who='{ }' RETURN ee".format(x)
26     result = gdb.query(q, returns=( lambda x:x['metadata']))
27     return result[0][0]['id']
28 def query_who(x):
29     q="MATCH (ee:Person) WHERE ee.name='{ }' RETURN ee.who".format(x)
30     result = gdb.query(q, returns=( lambda x:x))
31     return result[0][0]
32 def Query_id(x):
33     q="MATCH (ee:Person) WHERE ee.name='{ }' RETURN ee".format(x)
34     result = gdb.query(q, returns=( lambda x:x['metadata']))
35     return result[0][0]['id']
36 def query_info_id():
37     q="MATCH (ee:data) return ee"
38     result = gdb.query(q, returns=( lambda x:x['metadata']))
39     return result[0][0]['id']
40 def query_sentiment():
41     q="MATCH (ee:data) return ee.sentiment"
42     result=gdb.query(q,returns=( lambda x:x))
43     return result[0][0]
44 def query_stored_id():
45     c=[]
46     q="MATCH (u:Person)-[r:Knows]->(c) where u.who='user' return c"
47     result=gdb.query(q,returns=lambda x:x['metadata'])
48     for i in range(len(result[:])):
49         c.append(result[i][0]['id'])
50     return c

```

Figure 4.3: Code snippets for requesting query from Python

## 4.2 Core structures and modules

As mentioned in previous sections, the outer structure of the chatbot consists of a conversational interface made using Python connected to graph database Neo4j. The conversational interface provides a simple interface for users to communicate with the chatbot while recording conversations into chatlog. The interface is then connected to a natural language understanding (NLU) unit for semantic analysis which decides direction of conversation together with the help of different modules. To allow freedom in conversation, the interface together with NLU and different modules are all connected using finite state machine. In a nutshell, a finite state machine is structure in which users can traverse between finite no. of states when certain condition is triggered.

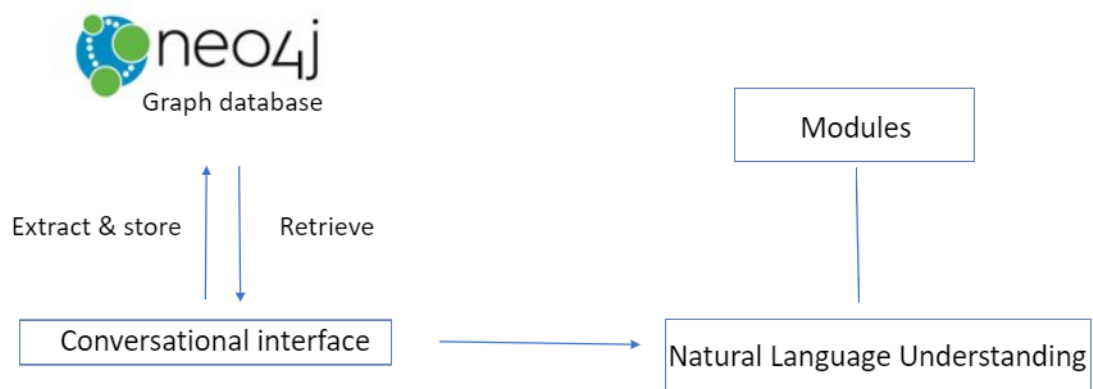


Figure 4.4: Graphical illustration of the outer structure of the chatbot

### 4.2.1 Decision tree structure

Besides the database, the other three units are connected with a finite state machine. When users type in the interface, responses from the chatbot are decided following a pre-defined decision tree. When users type in the interface, the NLU unit is responsible for understanding sentiment and intent of the text received, which determine the following action by the chatbot. Different modules then provide appropriate responses to users. However, since MCI sufferers are unlikely to engage in natural conversation. We had to restrict the freedom of conversation while allowing freedom at certain parts of the conversation. This is to ensure that users could receive enough help and effectively communicate. The illustration of decision tree structure is included in future sections. In the next subsection, NLU unit and modules are introduced.

### 4.2.2 Natural Language Understanding units

To understand the semantics of text given by the user, it involves acquisition of the knowledge which often requires the use of a knowledge base. Since our chatbot aims at close domain conversation and counselling. Such knowledge base might not be required. However, with the absence of a knowledge base, it would be hard to identify the meaning of text. Therefore, the success of our NLU units relies heavily on the structure of the decision tree dialogue. By cautiously designing the flow of conversation, we could limit the possible intents needed for classification.

#### **Key word matching:**

One of the basic techniques used for text understanding is to match keywords. This can be used in verifying narrow topics that can be summarized by one word. For example, keyword matching can be used to identify specific family members simply by looking for keywords containing son, daughter, father, mother and etc. Despite its superficiality, it could perfectly identify certain topics that only have several possibilities.

**Intent classification:**

For most of the text or dialogue, it is incapable to use key word matching for classification. This is because multiple keywords might exist in the same topic and it is unreliable to classify based on one word. Alternatively, we use naive bayes classifiers to identify intents. As the communication strategy of our chatbot focuses on counselling and listening, much of the topics revolve around personal info including hobbies, personalities, life events, memories and others. By hand-crafting training dialogue for each of the topics, we could train the naive bayes classifier for classification. In our classification algorithm, we prepared 7 sets of training data each consist of 10-20 short text for training. On test time, the classifier is capable in identifying dialogue related to personal info from short to medium length. The 7 personal topics for classification is hobby, personality, work, life event, marriage, memory and others. Despite the small size of training set, the classifier is still capable in identifying sentences contain unseen words or verbs but with similar syntactic structure. All of the training process is done using Textblob.

**Sentiment analyser:**

Sentiment analyser is another important and necessary tool used in assisting semantic understanding. In our chatbot, NLTK vader sentiment analyser is used. To help determine the direction in conversation decision tree, understanding user's feeling at a particular instant is crucial for next response. This is to allow proper setting of tone of the scripted response. Moreover, different sentiments could lead to different subtrees in the decision tree which covers a wider range of possibility in chat.

**Phrase extraction and named entity recognition:**

To extract personal info, we requires the chatbot to be able to identify POS tag in phrases given by the user. For example ,when extracting hobbies of the user, we need to identify verb phrase from the sentence .To do so, syntactic parser from Stanford-CoreNLP library is used to disambiguate and extract these complex POS tag. In addition when extracting specific entities such as name and geographic location, named entity recognizer from NLTK can be used.



### 4.2.3 Modules

Modules used in the chatbot are mostly embedded within the conversation decision tree. The modules are designed to assist conversation or perform two main functions, that is to extract, store and retrieve information and inference based on personal information. The main modules are chat module, extraction module and inference module respectively.

**Chat module:**

Chat module is a broad generalization for the strategies used in designing response dialogue. This module is used to encourage user in conversation and talking more about themselves. It could also provide positive feedback and empathetic towards negative feelings of the user which are done with the help of sentiment analyser.

**Extraction module:**

The extraction module is responsible for detecting and extracting personal info about the user when user talked about them. This is done by designing questions that would lead the user to a narrow topic that our intent classifier can be effectively utilized. The module is also capable to recognize unrecorded name, person and location entities and encourage users to talk about these entities. The module will store the info collected if user wanted to talk about. Sentiment can also be stored into database by checking user's sentiment at the different part of conversation.

**Inference module:**

The inference module handles sentiments and continues topics discussed in the previous conversation. It also actively recalls memories or events given by users in previous conversation to encourage more in-depth conversation. In subsequent conversations, the module could store the thoughts and recall it in future, thus increasing variation in chat. When users mentioned relevant name or location entities that have been mentioned in personal info, the module could generate the corresponding response based on the current sentiment of user.

## 4.3 Implemented dialogue tree

In previous sections, we first explained the conceptual design of chatbot followed by the core structure and modules necessary for performing semantic understanding and how they could be used to generate responses. In this section, a more linguistic or therapeutic approach will be considered with actual implementation of dialogue tree explained in details. This includes the sets of dialogue scripted into chatbot and the motivation and reasons behind these dialogue. First we will define the intended outcome or motivation in each step of the dialogue tree.

### 4.3.1 Objectives and flow of chat

In the first conversation, the objective is to extract personal information and chat briefly with the users about their problem. While extracting information, the chatbot also provides positive feedback and suggestion to the user. As we do not have any info about the user in first conversation, it is best to ask for information first before engaging in deep chat. At the beginning of chat, sentiment analyser detect the emotion state of user and determine the direction of chat. If the user is feeling negative, chatbot will start the branch in counselling bad emotions, followed by the extraction phrase.

In the second and future conversations, the extraction module retrieve stored information from previous section. Inference module then recall memories or info stored previously to engage in deeper conversation. If the user agrees to talk about the topic, more feelings and information can be collected and inferred in next conversation. This is repeated for every future conversations. After inference phrase, the chatbot will go on with the extraction phrase and encourage user to talk about anything. The topics are then classified using our naive bayes classifier. Feedback and responses are returned based on the topic identified.

Again at the beginning of chat, the chatbot first asks for sentiment of user to determine the direction of chat.

### 4.3.2 First conversation

In our first conversation , we start by greeting the user and ask for their emotional states. The sentiment is then identified, stored and based on the polarity of sentiment ( positive or negative), the chat module then decide the direction of chat. If sentiment is negative, the chatbot will try to identify possible reasons of negativity from users. This is done by matching key words of common reasons that lead to negativity for cognitive impairment sufferers, that is memory loss, sickness, family relationship and personal problem. After identifying, sets of positive motivation or suggestions will be returned as output. After the counselling state, the conversation will move to extraction phrase. If sentiment is positive, the chatbot will then skip to the extraction phrase. An example of emotion counselling is shown below.

```
Welcome and nice to meet you , how are you doing today?
Your response:Im feeling bad today
What makes you feel bad?
Your response:I don't really know
Bad emotions do hit us unexpectedly. But please tell me more about it
Your response:I just hate myself
What makes you think about that?
Your response:I have a bad impression about myself
Stay positive and be motivated
Your response:I see your point
I hope you are feeling better now. Please free feel to talk about anything.
```

```
Welcome and nice to meet you , how are you doing today?
Your response:I'm not feeling well
Why are you unhappy?
Your response:I guess I can't remember things
How's memory lost affecting you?
Your response:It's been affecting me seriously
Do try to go for a walk whenever there's stress, fresh air always keep our mind refreshed!
Your response:Thanks for your suggestion
I think it takes effort to handle memory problem but don't force yourself too hard.
Your response:okay
```

Figure 4.5: Examples of Chatbot response to bad sentiment in the beginning of first conversation

In the extraction phrase, the chatbot will first ask for the name of the user. Afterwards, the user is encouraged to tell anything he/she wish to. The chatbot will first ask if the user is going to talk about personal info , family or other things . The trained classifier then try to classify the topic that the user is talking about. The classifier will classify the intent as others if the topic classified does not fall within any of the other six topics. However, misclassification does also occur.

After identifying topic, series of scripted respond will be shown to user depending on the topic. Although the respond is scripted , sentiment analyser keep tracks on and determine the sentiment of user's response at particular point. This create different possibilities for continuation even for the same topic. Consider the following two figures, user is talking about personality but the chatbot respond differently to how user perceives his/her personality. The extracted info (user's thought about his/her personality) is hence stored in graph database right after user typed the response.

```

Im glad you are feeling fine, Can i have your name?
Your response:It's Sam
Nice to meet you Sam ! Could you tell me more about yourself or your family?
Your response:i want to talk about myself
Could you also tell me if you want to talk about yourself , family or other events?
Your response:It's about myself
Thanks. Please tell me more about yourself.
Your response:I hate the feeling that I always can't change
Thanks for letting me know , could you tell me more about yourself?
Your response:It's what I have told you just yet
I see your point. I hope you could stay positive and try to change bad habits.
Your response:I hope so too
It always take time to change bad habits so try progress slowly.
Your response:I see
Maybe you should also try to think positively and I hope that you could be happier.
Your response:Maybe you are right
I hope you are feeling better now, do you wish to talk about other things?

```

Figure 4.6: Chatbot response to user talking about negative self personality in extraction state

Welcome and nice to meet you , how are you doing today?  
Your response:Im feeling quite good today  
Im glad you are feeling fine, Can i have your name?  
Your response:Sam  
Nice to meet you Sam ! Could you tell me more about yourself or your family?  
Your response:sure  
Could you also tell me if you want to talk about yourself , family or other events?  
Your response:I want to talk about myself  
Thanks. Please tell me more about yourself.  
Your response:I appreciate my own personality  
Thanks for letting me know , could you tell me more about yourself?  
Your response:I like that I am always kind to people  
That's good to know. It is good to maintain positive attitudes.  
Your response:I agree  
I hope that you could keep up with this good attitude.  
Your response:Thanks  
Could you also tell me more about yourself or other things?

Figure 4.7: Chatbot response to user talking about positive self personality in extraction state

After extracting the first info, chatbot will loop again the same procedure to ask if the user want to talk about other topics until user declared intention to end. The looping structure do create boredom for the user when it's repeatedly activated. However, it is unlikely that the user will talk about the same topic. The extraction module could thus still perform counselling and understanding to user.

**Follow up dialogue:**

Despite the lack of ability to reply specifically about everything user said. The chatbot is capable to reply generally and positively to user's specific respond. As shown below includes an example of chatbot identifying topic as personal memory and chat with the user on the topic, the chatbot replied generally without being completely irrelevant to what the user have said.

```
Welcome and nice to meet you , how are you doing today?  
Your response:not bad  
Im glad you are feeling fine, Can i have your name?  
Your response:It's Sam  
Nice to meet you Sam ! Could you tell me more about yourself or your family?  
Your response:yes sure  
Could you also tell me if you want to talk about yourself , family or other events?  
Your response:I want to talk about me  
Thanks. Please tell me more about yourself.  
Your response:I used to be rich  
I guess you are talking about your memory. Please tell me more about it.  
Your response:I owned a company but now I have lost everything  
I understand your feeling. There are things that we can't control in life.  
Your response:yes i think so too  
Maybe it is a bad memory, but I hope you could cherish the positive moments in life.  
Your response:okay  
I hope you are feeling better now. Are there any particular moments that you feel bad about  
Your response:yes  
Please tell me about it.  
Your response:It's when I lost everything  
I get your feeling. I think there are things that we cant control sometimes.  
Your response:I agree  
I hope you are getting better now. Do you wish to talk about other things?
```

Figure 4.8: Chatbot response to user talking about his/her memory

### 4.3.3 Second and onward conversations

From the second conversation and onward, the chatbot could remember the topic discussed in last conversation as well as the key events that the user mentioned. At the start of the chat, the chatbot again greet and ask for sentiment of the user.

Inference module then retrieve topics and important event mentioned by the user previously. Depending on the sentiment of user, the inference module mentions the topic and important event accordingly and ask if the user wish to talk about it. If user wish to continue on the same topic, the inference module will move to a branch of conversation based on that specific topic in the decision tree. Again, the sentiment analyser works together with the inference module ( or any module) to tailor the needs of user and be as realistic as possible. After the inference phrase, the chatbot continue to extract informations from the user as in first conversation.

#### Recalling memories/info for inference:

Continue on the previous figure, user talked about memory and was negative in previous chat. The inference module then recalls about specific event that lead to the emotion and counsells the user about it. The figure shown below demonstrated the following.

```

Welcome back Sam! Nice to see you again. How're you doing today?
Your response:I'm still feeling bad today
I remembered that last time you felt bad about memory.
Your response:Yes I am
I recalled that you mentioned It 's when You lost everything that makes you feel bad.
Your response:Yes I agree, i have no money to sustain my life
Do you wish to talk more about it?
Your response:maybe
Maybe you can tell me more indepth about your memories/memorable events that you told me.
Your response:It's all out of a sudden and went bankrupt
What makes you think about this?
Your response:It's sudden
Maybe it's a bad memory. But there must be things you gained from it.
Your response:I really don't think so
I see your point.I do understand sometimes it's hard not to care about the bad memories.
Your response:Okay
Since we couldn't control it, it might be better for us to look forward.
Your response:Maybe
I hope you are feeling better now. Please feel free to tell me anything.

```

Figure 4.9: Inference module recall memories and continue conversation based on emotion of the user

**Inferring and recognizing unmentioned entities:**

Apart from inferring from recorded info and sentiments, the inference module is also capable in recognizing name and location entities that is not mentioned. When user is talking about his/her life event or memories, the inference module could recognize unmentioned person and location, thus encouraging and activating user's memory with these people or location. For example, if the user previously mentioned about studying in Edinburgh long time ago and mentioned name of a unrecorded person. The module recognize and encourage user to talk about this person.

```
Welcome back Taeyon! Nice to see you again. How're you doing today?
Your response:Im fine thanks
I'm glad as you are also feeling well today like last time.
Your response:Thanks
I think it's good to think about good memories. It does keep us motivated.
Your response:It certainly is
It seems that you have talked about life event, do you wish to continue on it?
Your response:sure why not
I remembered that you mentioned that You was graduated in University of Edinburgh long time ago be
g related to this?
Your response:I remembered that I met Janet there.
Can your tell me more about Janet?
Your response:She is nice and charming.
That's interesting to know. I hope he/she could maintain their good qualities.
Your response:yes I agree
Can you also tell me who this person is to you?
Your response:She's my wife.
What do you think about your marriage?
Your response:We had a good marriage.
Thanks. It's interesting to know more about Janet.
Your response:I'm glad you also interested in knowing more about me.
I hope this could also help you in remembering things.Let's get back to what we've previous chatte
```

Figure 4.10: Inference module recognizing unmentioned entities

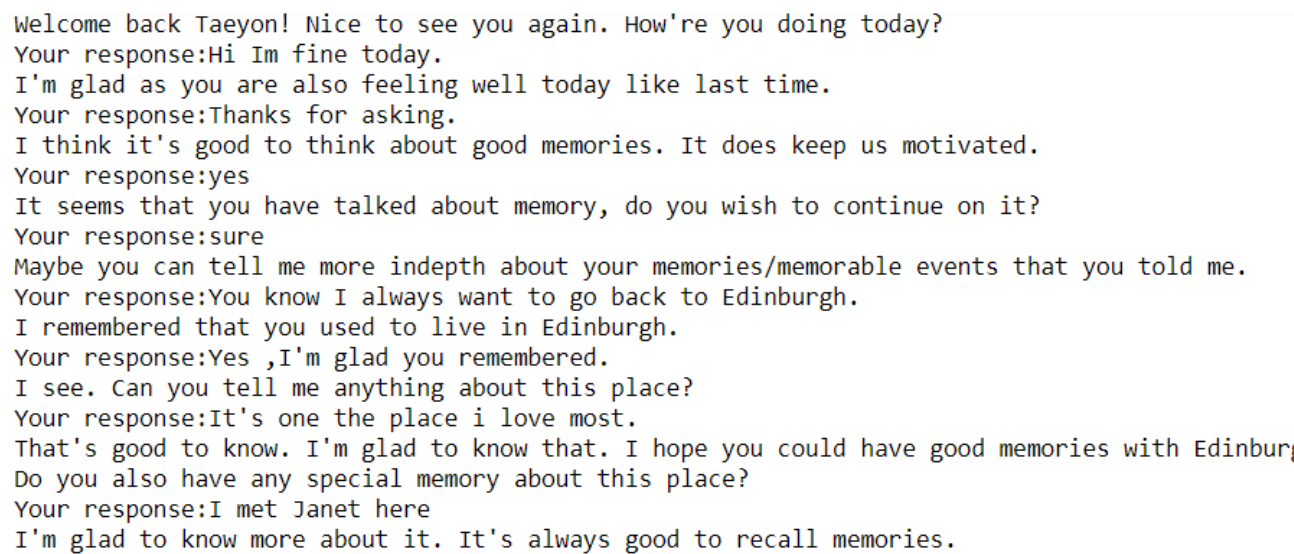


**Identify stored entities in chat and infer using their properties:**

Another features of the inference module is the ability to recognise stored entities that has been mentioned by the user during chat. The module then extract relevant properties of that entity (e.g. hobbies, personalities of the mentioned person) and as respond to users. This could make the chatbot less mechanical and increase variability in chat. Take the following as an example, when the user mentioned about things related to his wife, the chatbot recognise the entity being mentioned in the past and respond with her personality or features.

```
Welcome back Taeyon! Nice to see you again. How're you doing today?  
Your response:not bad  
I'm glad as you are also feeling well today like last time.  
Your response:Thanks  
I think it's good to think about good memories. It does keep us motivated.  
Your response:I agree  
It seems that you have talked about marriage, do you wish to continue on it?  
Your response:yes sure  
Can you tell me more about your marriage?  
Your response:I love my wife  
I heard your wife is nice and charming and hope he/she gets along well with you.  
Your response:Thanks  
I recalled that you are quite optimistic about marriage.  
Your response:I think so too  
I'm glad you are fine with your marriage. It's always hard to maintain relationship.  
Your response:It definitely is  
How do you get along with your wife/husband?  
Your response:We are good
```

Figure 4.11: Inference module detects stored entities being mentioned in chat and respond with entity's properties



Welcome back Taeyon! Nice to see you again. How're you doing today?  
Your response:Hi Im fine today.  
I'm glad as you are also feeling well today like last time.  
Your response:Thanks for asking.  
I think it's good to think about good memories. It does keep us motivated.  
Your response:yes  
It seems that you have talked about memory, do you wish to continue on it?  
Your response:sure  
Maybe you can tell me more indepth about your memories/memorable events that you told me.  
Your response:You know I always want to go back to Edinburgh.  
I remembered that you used to live in Edinburgh.  
Your response:Yes ,I'm glad you remembered.  
I see. Can you tell me anything about this place?  
Your response:It's one the place i love most.  
That's good to know. I'm glad to know that. I hope you could have good memories with Edinburgh.  
Do you also have any special memory about this place?  
Your response:I met Janet here  
I'm glad to know more about it. It's always good to recall memories.

Figure 4.12: Inference module detects stored location being mentioned in chat and respond with respect to it

**Further conversations:**

The future conversations worked as in second conversation. The chatbot first request consent from user whether he/she would like to talk about previous topics. If the user decide to talk about other topics, the chatbot will switch to extraction phrase. Below shows a demonstration for this.

```
Welcome back Taeyon! Nice to see you again. How're you doing today?
Your response:Im fine Thanks.
I'm glad as you are also feeling well today like last time.
Your response:I glad you remembered
I think it's good to think about good memories. It does keep us motivated.
Your response:It certain is
It seems that you have talked about marriage, do you wish to continue on it?
Your response:I want to talk about other things this time
I see. Please feel free to tell me about anything.
Could you tell me if it's about yourself, family or others?
Your response:It's about my son
Thanks. Please tell me more about your family members.
Your response:My son loves to swim
Thanks and what's your son's name
Your response:His name is John
Can you tell me more about him/her?
Your response:He is good at swimming.
I think that's a fascinating hobby. What makes him/her develop this hobby?
Your response:He is outgoing
That's a good motivation.
Your response:I agree with you.
That's good to know, it's always nice to develop more hobbies.
Could you also tell me more about your other family members?
```

Figure 4.13: Conversations after the second chat

**4.3.4 Summary**

In this section, we explained and detailed about the actual implementation of our chatbot including intended goal/objective in each conversations, flow of dialogue tree and in-depth explanation of the implementation. In the next chapter, we would look into evaluation of the chatbot and see if the chatbot is successful in assisting MCI sufferers.

# Chapter 5

## Evaluation and usability

In this section, we first define success metric for our chatbot to evaluate how practical it is in counselling and being a companion for mild cognitive impaired patients. In addition, usability of the chatbot, which is the accessibility and ease of use will also be studied.

### 5.1 Success metric

#### **Level of Naturalness or human-like response:**

Stepfan et.al [12] have suggested proactivity as a metric in evaluating their museum conversational agent. We could thus extend the idea of proactivity to naturalness of response and how similar it is to humans. It is also particularly important for the chatbot to resemble human. This is because MCI sufferers or other cognitive disorder sufferers need empathy and caring that doesn't look mechanical as they are often sensitive and vulnerable to the feedback from counselor. Therefore one way to access the successfulness of chatbot is to look into it's level of naturalness.

**Quality of conversation:**

As MCI sufferers often have troubles in engaging natural conversation. It is important for the chatbot to lead the conversation. Moreover, level of positivity and empathy in responses are also important criteria. Walter et.al [13] proposed different criterion for evaluating conversational agent which includes memory of past events and consistency in conversation. These two criterion can therefore be used in evaluation.

**Effectiveness of chat:**

It is important to access the level of contentment of users after each conversation. For example, whether the MCI sufferers felt satisfactory or improvement in emotional states, memory which could possibly prevent further decline in cognitive functioning.

**Control over conversation**

Despite the fact that MCI sufferers are incapable in controlling conversation, allowing high degree of freedom in conversation is crucial as they might feel impatient or even felt ignored when sufferers could not feel being concerned.

## 5.2 Evaluation

Due to time constrain, the evaluation could not be done with MCI participant. This is due to the difficulty that requesting MCI sufferers participation might require a month of time. However, the time required to develop the chatbot was longer than expected. With a view to the changes, the evaluation is now based on evaluation on test dialogue.

**Effectiveness of chat:**

From Chapter 4, examples of chat with the chatbot are demonstrated. Since the chatbot is goal-oriented and freedom in chat of users are only allowed when topic is narrowed down, this could ensure that every intended objectives are fulfilled before moving on to deeper chat. To a certain extent, this allowed the chatbot to be precise in performing the goals. Overall, the dialogue tree consists of caring part when users felt negative,

the extraction part to extract information while counselling users and also the inference module which perform counselling similar to reminiscence therapy on user. The clearly defined goals and extent of completion is what makes the chatbot effective in counselling and making users feeling content. However, it is debatable whether the degree of freedom in our chatbot is inadequate for MCI sufferers.

**Level of naturalness:**

In our conceptual design, personifying chatbot is one of the most important aspect when considering our design. As shown in Chapter 4, our chatbot could reply generally and broadly to user's response even when the semantics are not understood. One of the reason is because of the design of dialogue tree of narrowing topics down before users can freely express themselves, and hence scripting would be easier to handle. Moreover, the scripts are carefully designed such that every response would try to be as open as possible.

**Quality of conversation:**

The chatbot is able to lead the conversation due the design of dialogue tree. In addition, a lot of motive and suggestive sentences are provided by the chatbot. This could ensure that the chatbot could spread positivity to the user. Inference and counselling during extraction phrase also provide assistive response to user. To a certain extent, the user can feel being concerned.

**Control over conversation:**

This is one of the drawback in our design of chatbot. Since the dialogue tree tends to guide user to talk about a specific topic, users have limited room in determining direction of chat. However it should be noted that the user is still free to talk about range of topics (personality, hobby, life events, memory, work, marriage and others).

### 5.3 Usability:

In the implementation of chatbot, error-checking code is restricted to a few areas (name check, intent for continuation of previous topics, intent to exit and intent to talk about a topic) due to the ambiguity in defining wrong or irrelevant reply. This is particularly problematic in our design as irrelevant input could lead to errors in a subtree. Luckily as each conversational goal correspond to many subtrees, one irrelevant input would most likely not affecting the chat in later sections.

Another usability problem for chatbot is that it is impossible to check for all possibility of errors due to long length of code. For the first conversation, it is easier to check for possible errors. However with the inclusion of inference module, conversations started to be messy. Unexpected error still occur sometimes.

Due to long length of code, the chatbot is prone to internal error. This decreases the usability of the chatbot greatly as users might need to clear all the variables in database, which is impractical. The automatic error-correcting code for implementation in Python is also out of our capability.

During test time, it is observed that the problems might be able to solved in a better manner if the chatbot is demonstrated and run on Ipython notebook as code for the deleting all variables could be embedded and executed with guide. However, It might be infeasible for MCI sufferers to perform such action.

# Chapter 6

## Discussion and conclusion

In this paper, we have explained our conceptual design , actual implementation and relevant background information both in cognitive health counselling and natural language processing. The human and goal oriented approach to conceptual design established a good framework and foundation for our choice in scripting responses . Using basic knowledge and methods from natural language processing , we created unique and intriguing features for our chatbot together with the extraction and inference module. In particular for inference module, there's great potential for further research as counselling chatbot for patients with cognitive impairment is still unavailable. Moreover, the conversations generated by chatbot are able to counsell and listen to MCI sufferers which could improve their emotional states and thoughts that could lead to more serious mental disorder . The chatbot also motivates users in reusing as inference module constantly recall memories and actively engage in chat by recognizing stored entities once being mentioned. On the other hand, the chatbot suffers great usability issue. This is partly due to insufficient knowledge in software engineering and under-estimation of time allocation. Given more opportunities and resources, it might be implemented in better manner.

Conclusively, our project demonstrated originality and is effective in counselling mild cognitive impaired sufferers with the unique design. It however also suffers great problem in usability issue. Nevertheless this project could still serve as a guideline/framework for NLP/chatbot researcher for further research in counselling chatbot ,particularly in the domain of cognitive-related illnesses.



## 6.1 Bibliography

- [1] Smyth, C, (2014). Depression in old age is the next big health crisis. The Times.
- [2] Abdollahi, Hojjat, et al. "A pilot study on using an intelligent life-like robot as a companion for elderly individuals with dementia and depression." Humanoid Robotics (Humanoids), 2017 IEEE-RAS 17th International Conference on. IEEE, 2017.
- [3] Kavakli, Manolya, Manning Li, and Tarashankar Rudra. "Towards the development of a virtual counselor to tackle students' exam stress." Journal of Integrated Design and Process Science 16.1 (2012): 5-26.
- [4] Weizenbaum, Joseph. "ELIZA: a computer program for the study of natural language communication between man and machine." Communications of the ACM 9.1 (1966): 36-45.
- [5] Fitzpatrick, Kathleen Kara, Alison Darcy, and 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 4.2 (2017).
- [6] Sakakibara, Seiji, et al. "Generating personalized dialogue towards daily counseling system for home dementia care." International Conference on Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management. Springer, Cham, 2017.
- [7] Housden S. The use of reminiscence in the prevention and treatment of depression in older people living in care home: a literature review. Groupwork 2009;19:2845.
- [8] Subramaniam, Ponnusamy, and Bob Woods. "The impact of individual reminiscence therapy for people with dementia: systematic review." Expert Review of Neurotherapeutics 12.5 (2012): 545-555.

[9] Nikitina, S., Callaioli, S., and Baez, M. (n.d.). Smart Conversational Agents for Reminiscence.

[10] Field TA, Beeson ET, Jones LK (2015), "The New ABCs: A Practitioner's Guide to Neuroscience-Informed Cognitive-Behavior Therapy" (PDF), *Journal of Mental Health Counseling*, 37 (3): 206220

[11] Caselli, Richard J., et al. "Personality changes during the transition from cognitive health to mild cognitive impairment." *Journal of the American Geriatrics Society* 66.4 (2018): 671-678.

[12] Stefan Kopp, Lars Gesellensetter, Nicole C Krmer, and Ipke Wachsmuth. 2005. A conversational agent as museum guidedesign and evaluation of a real-world application. In *International Workshop on Intelligent Virtual Agents*. Springer, 329343.

[13] Walter S Lasecki, Rachel Wesley, Jeffrey Nichols, Anand Kulkarni, James F Allen, and Jeffrey P Bigham. 2013. Chorus: a crowd-powered conversational assistant

[IPP] Referenced from self Informatics Project Proposal