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Online Mental Health Therapy Application with Machine Learning

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Abstract

Online Therapy is emerging to provide a more cost efficient treatment of mental health disorder along with traditional face-to-face therapy. Yet, there is no efficient systems and application providing best therapies with the employment of artificial intelligence. Most of the online therapy platforms, such as Woebot, Chatbot, and BetterHelp, offer a platform for patient-to-therapy matching and do not really offering online treatment. AI Therapy, an online therapy with artificial intelligence for voice and video generation, have implemented artificial intelligence to improve the treatment experience, yet, they do not make use of AI to improve the accuracy and predict the best online treatment to the user. Our online mental health therapy with artificial intelligence ("The system") offers the symptom-to-best therapy matching aiming to improve the prevalence and accuracy of mental health diagnosis. The system also aims to provide the best therapy with different depression severity along with the personality of our users. Depression is used as the main subject of the system in this stage to reduce the complexity of varies mental disorders and it provide a mean to rescue the most common mental illness among students in Hong Kong. The system employed PHQ-9, a standardized online depression severity questionnaire, and the Big Five personality traits, a model based on common language descriptors of personality, as an input and predict the best therapy to our users. The treatments are selected in mindfulness-based stress reduction, a widely used treatment in order to address and treat a range of symptoms and concerns. The result of the system is (1) more than 93% of our user have improvement in their depression severity (2) more than 80% of our user are satisfied with the system in the feedback. This project is contributing to the online therapy in the way to improve the prevalence and accuracy of online mental health diagnosis with the best therapy suggestion.

Acknowledgement

I would like to express my deepest appreciation to those who helped and gave suggestions to my final year project. I would like to express my special thanks of gratitude to Dr T. W. Chim, who guided me in my final year project and gave many inspiring suggestions, advice, and encouragement throughout the project.

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Abbreviations

PHQ-9	Patient Health Questionnaire – 9
AI	Artificial Intelligence
US	United State
UCLA	University of California at Los Angeles
NICE	National Institute for Health and Care Excellence
CCBT	Computerised Cognitive Behavioral Therapy
PRIME-MD	Primary Care Evaluation of Mental Disorders
OCEAN	Openness to experience, conscientiousness, extroversion, agreeableness and neuroticism
ANN	Artificial Neural Network
GPU	Graphics Processing Unite
CPU	Central Processing Unite

Online Mental Health Therapy Application with Artificial Intelligence

1. Introduction

People with mental health problem usually seek for help or advice from mental health profession such as therapist [9]. By chatting or doing some tasks, therapist can figure out which disorder you are likely suffering by observing a patient's thoughts, behaviors, symptoms, stresses, past experiences and other aspects and offer appropriate therapy [9]. This is especially important in helping the patient to feel better in the current situation, strengthen your confidence, cope with symptoms and handle some strong emotions like fear, grief or anger [9]. Along with the growing demand of mental health therapist, there seems to have shortage in mental health care services. There are nearly one in five adults in the United State had diagnosable mental disorder within the past year, nearly 10 million people, which is serious enough to affect their daily functions [11]. However, more than half of the countries in the US have no mental health professional. Therefore, more people may prefer an easier, more efficient, and cheaper way to receive mental health services – online therapy.

According to Melissa, Kimberly, David & Kathryn [4], online therapy has been descripted as e-therapy, online counselling, e-mail therapy, Internet-based therapy, and similar terminology. It is defined as provision of mental health services through the Internet [1]. Online therapy began 42 years ago when the first simulated psychotherapy session occurs between Stanford and UCLA until the most recent online Patient-to-Therapist diagnosis [3]. Online therapy improved a lots in the past 4 decades and provided varies services including mental health advice, online depression support group, online based volunteer crisis center, psychological consultation and online therapy work thought a chat service [3]. The integration of internet with psychology therapy has been viewed as one of the most controversial topic among mental health professionals in the past 25 years [6]. The problem of bringing psychotherapy online, some people argue about, includes working alliance between patient and therapist, ethical and legal issue, insufficient training, and clinical issue with the absence of nonverbal cues from the therapist [1][2][3][4][8]. However, according to Cook and Doyle [1], there are several published studies' finding have similar outcome between traditional, face-to-face therapy and online therapy. This statement is also supported by different researches by James [5] and Melissa, Kimberly, David and Kathryn [4]. The research paper of Cook and

Doyle [1] also stated that there are overwhelming comments from participants believe that the online therapy was positive experience with advantage over face-to-face counselling. They feel more confident when compared to having therapy in traditional social situation [1]. Last but not the least, the National Institute for Health and Care Excellence (NICE) has approved the use of computerised cognitive behavioural therapy (CCBT) for treatment of depression, generalised anxiety disorder and panic disorder and suggest that it can just be as effective as having face-to-face therapy [2].

There are many advantages of having online therapy as suggested by different research papers. Firstly, as the online therapy is lack of gating features, which is the normal barrier to friendship due to variety of elements such as appearance, internet-based relationship can be formed more quickly and deeper than real life friendship [1]. Anonymity is one of the major advantages of online therapy as it eliminates the fear of rejection that may prevent disclosure in face-to-face relationship, user usually perform more frankly [1][2]. This is especially significant for the person who is lonely and socially anxious and have difficulty in establishing face-to-face relationships. Moreover, online therapy can be easily accessible as it eliminates the necessity of travel to the clinic [2][3]. Other advantages include shorter waiting times for referrals, discreet and confidential and affordable [2][3].

Today, with the wide spread of Internet access as well as the improvement of internet technologies, we can access unlimited online resources for different purposes. As a result, increasing amount of online therapy software and websites appears on the Internet. AI-Therapy, one of the leading online therapy available in the market, has obtained great success in the field and is offering customized experience for user based on their symptoms [12]. They provide different lessons which can help you to target your anxiety effectively. The website includes pre-recorded sound file by two clinical psychologists that explain the programme and the treatment strategies [12]. It uses different section to monitor user's mental health in different stage. For instance, pre-questionnaires that system learn about the patient and figure out the specific symptoms and post-questionnaires that compare the symptom before and after the therapy [12]. Different exercises and experiments are provided in order to monitor users' improvement throughout the therapy [12]. This personalized and interactive model can provide efficient therapy to different individuals. However, AI Therapy only make use of Artificial Intelligence (AI) in voice generation and personalization but not in training the symptom-

therapy relationship. Other online therapy examples include Woebot, a Chatbot therapist using inbox conversation to provide treatment, Talkspace, an online platform for online counselling, and BetterHelp, a platform for matching licensed, board-accredited therapists. All of the online therapy above have a common feature - they only provide a platform for patient-therapist matching.

In this project, we introduce a new direction for online mental health therapy with machine learning. It provides a more dynamical way for patients to obtain the best therapy based on their specific situation and their personality. The objectives of this project are (1) improve the prevalence and accuracy of mental health diagnosis (2) provide the best symptom-to-therapy matching. This project use Patient Health Questionnaire (PHQ), a widely accepted set of question designed to facilitate the recognition and diagnosis of the most common mental disorder in primary care patients, as the input [7]. The Big Five Inventory, a 44-item inventory that measures individual on the Big Five Factors of personality, is also employed to predict the best therapy [18]. After obtaining the result of PHQ-9 and Big Five Inventory, we can match these results with different mindfulness therapies with neural network, a machine learning algorithm using for classification. The dynamic feature of neural network can provide the patient with the best symptom and traits to therapy matching and improve the accuracy of mental health diagnosis automatically. The neural network can be trained by the feedback system and users' improvement in terms of depression severity.

In the remaining part of the paper, we first present the scope of the project and its importance and benefits in online therapy industry. Then we discuss the methodology and implementation of the programming languages, framework, and libraries used in the project. Next, we will discuss the result and experienment regarding the user satisfaction and accuracy of the system. After that, we describe the potential risks and challenges we may be facing due to the nature of the project and how we are going to mitigate those problem. We close by a conclusion and future direction of the project.

This project is contributing to the online therapy in the way to improve the prevalence and accuracy of online mental health diagnosis with the best therapy suggestion.

2. Scope

In this part, we will introduce three items included in this project: PHQ-9 questionnaire, Big Five Inventory, and mindfulness therapies. PHQ-9, a standardized online depression severity testing, will be used as the input of the system. Big Five Inventory, a 44-item inventory that measures individual on the Big Five Factors of personality, will also considered in order to provide the best therapy to users. These two result will be used as the input of a neural network which will further analyse and conclude the best mindfulness therapy depends on their depression severity and traits.

2.1. Patient Health Quetionnaire-9 (PHQ-9)

This project aims to provide a better online mental health therapy with artificial intelligence and machine learning. The project offers a more dynamic way for "symptom-'level of depression'-therapy matching" by employing neural network. Because of the complexity of the project, we will only focus on PHQ-9 Depression Severity and open for further exploration for future researches on similar online therapy model. Depression severity is selected as it is one of the most prevalence psychiatric disorder in Hong Kong [13]. PHQ-9 is a self-administered version of PRIME-MD diagnostic instrument for common mental disorders. PHQ-9 offers a questionnaire includes 9 questions and employed 4-point Likert-type responses with 0 representing "Not at all" and 3 representing "Nearly every day". According to the research by Lsobel [13], PHQ-9 demonstrated reliability, convergent/discriminant validity, and responsiveness to change. To calculate the PHQ-9 Score from the questionnaire, the system can simply add up the score from question 1 to question 9. The severity of PHQ-9 Score can then be transform to the severity of depression by the Severity Score Table (see Table 1).

PHQ-9 Score	Depression Severity	Proposed Treatment Actions
0 – 4	None	None
5 – 9	Mild	Watchful waiting; repeat PHQ-9 at follow-up
10 – 14	Moderate	Treatment plan, considering counseling, follow-up and/or pharmacotherapy
15 – 19	Moderately Severe	Immediate initiation of pharmacotherapy and/or psychotherapy
20 – 27	Severe	Immediate initiation of pharmacotherapy and, if severe impairment or poor response to therapy, expedited referral to a mental health specialist for psychotherapy and/or collaborative management

Table 1. Severity Score Table of PHQ-9

2.2. The Big Five Personality Traits

Other than PHQ-9, we will use Big Five Inventory to analyse user's traits. It will be used as an input of our system. The big five personality theory is suggested by Lewis Goldberg describing personality in five primary factors [20]. These five factors includes (i) Openness to experience, (ii) Conscientiousness, (iii) Extroversion, (iv) Agreeableness, and (v) Neuroticism, or OCEAN in short. This theory is further validated by Paul Costa and Robert McCrae in terms of the completeness [21]. Big Five Inventory, a 44-item inventory that measures individual traits on the Big Five Factors of personality, is employed in order to investigate user's level of five traits [18]. The score is calculated according to the instruction in the questionnaire. The big five personality trait is employed in the system as there are several research papers suggested that there is a strong relationship between big five traits and mindfulness therapies [22] [23]. Robert and Akihiko [22] suggested that mindfulness was negatively associated with neuroticism and positively associated with consciousness while Tamara [23] suggested that all of the five traits display appreciable relationship with mindfulness therapies. Therefore, the system will examine all the five personality elements and is expected to provide a better mindfulness therapy to users as stated in one of our aim for this project.

2.3. Mindfulness-Based Stress Reduction Therapies

After the mental health diagnosis by PHQ-9 and user's personality traits analysis by the Big Five Inventory, the result will be used for severity & traits – to – therapy matching. This matching aims to provide a dynamic way to offer the best therapy for different levels of mental disorder for different personality traits. Mindfulness-based stress reduction therapy is moderately effective for improving depression and mood symptoms, and it's an effective self-help treatment for depression [24] [26]. It is a promising intervention for treating anxiety and mood disorder in clinical populations [24]. In the following sub sections, we are going to discuss about the two types of mindfulness practices included in this system with 10 exercises in total as suggested by Courtney [25].

2.3.1. Focus Mindfulness Therapies

Focus mindfulness therapies emphasis the observation of oneself and look inward to experience their mind [25]. Participants are required to focus on a single object and focus on one experience. To improve the effectiveness, it is helpful for the participants to use particular stimuli to keep themselves grounded in the moment [25]. There are six most common focus mindfulness therapies as concluded by Courtney [25]. They are the breath, body scan, object meditation, mindful eating, walking mediation, and mindful stretching. Details of each therapy will be included in the system in order to guild the users to offer a self-guided therapy.

2.3.2. Awareness Mindfulness Therapies

Unlike focus mindfulness therapies, awareness mindfulness therapies emphasis on external matters [25]. The therapies observe the mind from the outside perspective similar to being a third person and observe themselves. It is useful for oneself to describe themselves without self-centred experience and without attaching judgement. In this project, we will include two awareness mindfulness therapies which is simply watching and worry or urge surfing. Instruction of these two therapies will be descripted in the system so that users can conduct the therapy themselves.

3. Methodology (Hardware e.g. configuration, software, technique, feasibility assessment)

In the system, there are four phrases to provide the best therapy with different levels of depression. [Phase 1] The system requests user to complete the Big Five Inventory questionnaire. [Phase 2] The system uses PHQ-9 questionnaire to decide the severity of depression of the user. [Phase 3] The results from phase 1 and 2 will be used as an input of a neural network which perform the matching and suggest the best mindfulness therapy based on the user's depression severity and traits. [Phase 4] The user login to system again and perform PHQ-9 again. By comparing the depression severity level before and after the delivery of therapy, the system can either all this result to the database or just simply ignore it if the therapy did not help the paitent. Now, we are going to discuss the 4 phrases and justify the reason of using neural network below.

3.1. Phase 1: The Input of Big Five Inventory

In phase 1, the system will request the user to complete a one-time traits test, the Big Five Inventory. User need to complete 44 questions in which each question is related to one of the five traits. The score of the traits will be calculated according to the instruction of the questionnaire. This scoring will be used as an input of a neural network. Combining with PHQ-9 result, we can predict the best therapy for the user. Phase 1 is a one-time measure, which means that users only need to finish the 44 questions for the first login.

3.2. Phase 2: The Input of PHQ-9 Depression Severity

In phase 2, we are going to measure the depression severity of the users using of PHQ-9 Questionnaire. 4-point Likert-type responses is employed with 0 representing "Not at all" and 3 representing "Nearly every day". To calculate the PHQ-9 Score from the questionnaire, the system can simply add up the score from question 1 to question 9. The severity of PHQ-9 Score can then be transform to the severity of depression by the Severity Score Table (see Table 1).

3.3. Phase 3: Best Therapy Matching by Neural Network

In phase 3, the severity level of depression and traits will be further analysed by a neural network. In this phase, the result obtained in phase 1 and 2 will be used as the input of a neural network and the output will be the best therapy (see Figure 1).

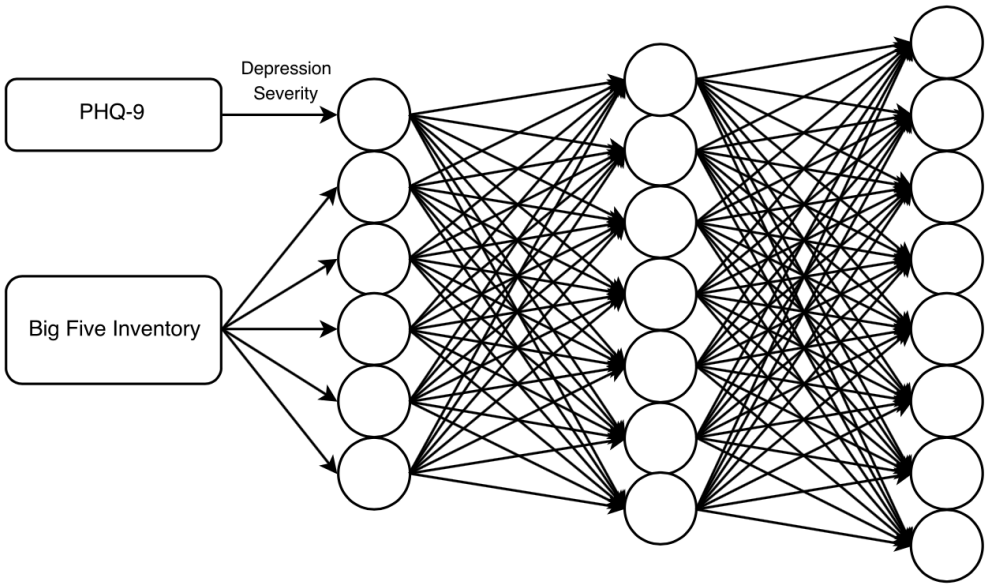

Figure 1. Neural network for severity of depression - to - best therapy matching

As the 8 mindfulness-based stress reduction therapies do not indicate the relationship between traits and best therapy, using neural network can analyse the relationship or weighting of the best therapy with different level of depression. This offers the dynamic nature of the matching by training the network. Detail of neural network and training the system will be discussed in the later part of this section.

3.4. Phase 4: Feedback system

In phase 4, user will go through a feedback system which aims to update the database and provide the new training data for the neural network. The neural network will generate a suitable therapy to the user based on the input of PHQ-9, big five personality score, and the trained neural network. After that, the system will store the predicted therapy in the SQL database for further usage. In the next user login, the system will diagnose the depression severity of the user. If the depression severity score has significant improvement, the system

will update the corresponding row in the database and set it as training data for the system. This step plays a significant role in improving the accuracy of the system. All the training data is retrieved from real user experience and only the useful data will be included in the training data set.

3.5. Brief Introduction of Neural Network

The system will implement a neural network, which is especially efficient for multiple classes classification, as discussed above. In the remaining part of this section, we are going to discuss how neural network can offer the functionality. We are going to use our neural network (i.e. depression severity & traits – to – therapy matching) to demonstrate the working steps and terminology of neural network (see Figure 1).

3.5.1. Architecture and Stages of Neural Network

Artificial Neural Network (ANN) is the biologically inspired simulations performed on a computer to perform different tasks, including multiple classes classification [15]. An artificial neuron is a node with multiple input and one output (see Figure 3). In our neural network, we have six input (i.e. X1, X2, …, X6) representing the depression severity and big five traits. Each of the input have a specific weighting to the neuron. The sign of weight (whether it is a positive or negative number) representing the positive or negative relationship between the input and the neuron, and the magnitude refers to strength of the input to the neuron (i.e. W1, W2, …, W6). For instance, if X1, or depression severity, have a positive and great effect on the neuron, W1 will be positive and larger, vice versa. The artificial neuron will then calculate the sum of the inputs and bias with the following equation:

$$sum = \sum_{i=1}^{n} \mathrm{Xi} * \mathrm{Wi} + \mathrm{b}$$

Figure 2. Equation of Summer in neural network

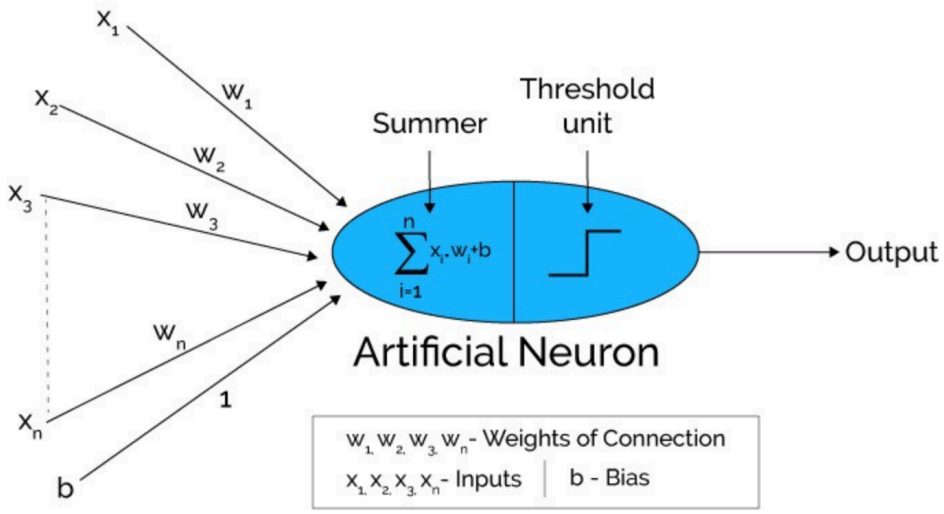

Figure 3. The architecture of Artificial Neural Network (ANN)

The sum will be put into an activation function, sigmoid, to get the desired output. Sigmoid hyperbolic is a function which can be represented by a 'S' shaped curve (see figure 4). The sigmoid function can transform any value to an approximate output range from 0 to 1. Moreover, when the input of the function is 0, the output after going through the sigmoid would be 0.5, which can simply treat as the probability or likelihood of the case represented by the neuron network. For instance, if we get 0.1 for the first type of therapy, this therapy is not likely to be the best treatment. Similarly, if we get 0.9 for a type of therapy, it is very like that this therapy is the best match to the input. Therefore, we can first sort the probability of the 9 mindfulness therapies and deliver the one with highest probability.

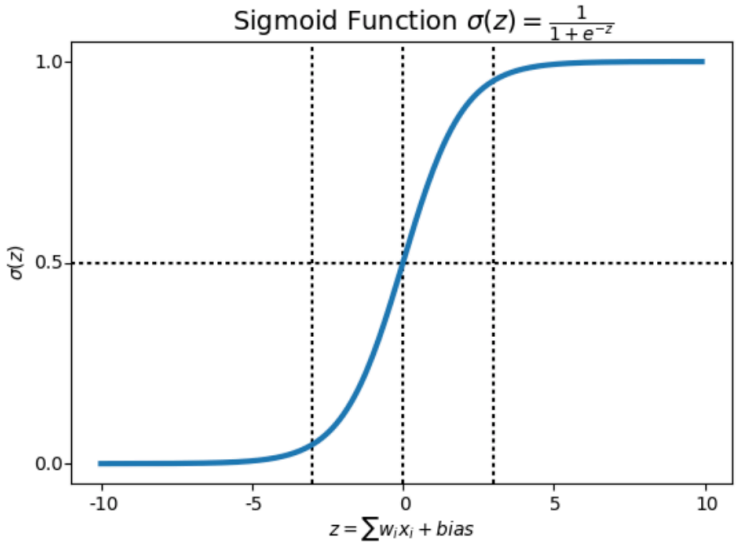

Figure 4. Sigmoid Function with 'S' shaped curve

In this system, we have employed multi-layer perceptron, a type of ANN architectures. The multi-layer perceptron contains the input layer, hidden layer, and the output later. For the hidden layer in between the input layer, the neurons are used to transform input into something that output unit may need in some way [15]. According to Doug [16], the most common approach to obtain the optimal size of neurons in the hidden layer is to have number of neurons between the size of the input and size of the output layer. Therefore, we have selected 7 neural in both neural networks.

3.5.2. Training of Neural Network – Back Propagation

After the processes discussed above, we can do the matching between PHQ-9 and Big Five Inventory input, and therapies. To train the system, we have implemented back propagation, a simplest training algorithm for training model and an extension of gradient based delta learning rule [15]. Gradient descent is a learning rule used to change the weight of the network by calculating the different between actual output from target output. Back propagation use the feature of gradient descent in multiple layer, from output layer to hidden layer and input later, and change the weight between each layer correspondingly (see Figure 5).

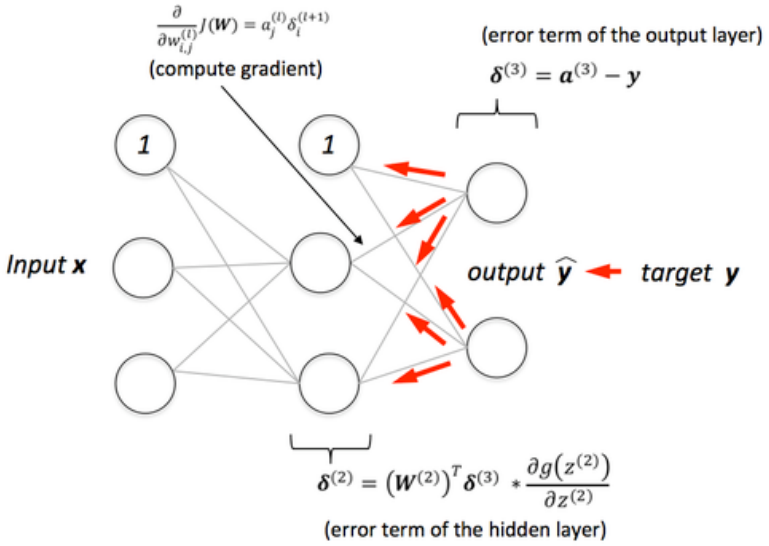

Figure 5. Back propagation of three later model

To better illustrate the concept of back propagation, we can refer to the a 3-dimension error surface regarding two weights (see Figure 6). As you can see in the figure, there are a point with lowest error which is when W1 and W2 are both equal to zero. At this point, the system can perform the best classification as the error approximate, if not equals, to zero. We will take a deeper look into a case where we start our system with W1 and W2 at somewhere like 1.5 and 1.5 respectively as shown in Figure 6. The system will calculate the derivative of this error with respect to the change of W1 and W2. We then minus a portion of this derivative which can move the point towards to the optimal point, which is the lowest error point (0, 0) (see Figure 7). After several training of the weighting between different neurons in different layers, the system can result the optimal weighting and provide the best classification.

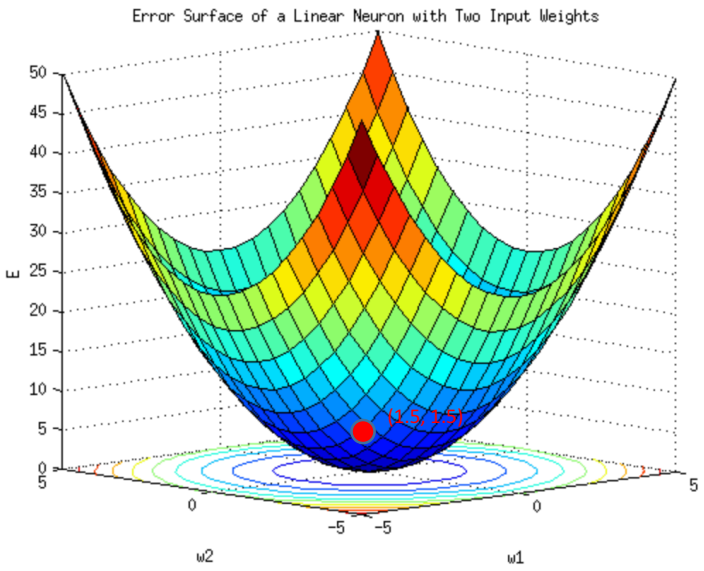

Figure 6. Error surface of a linear neuron with two input weights

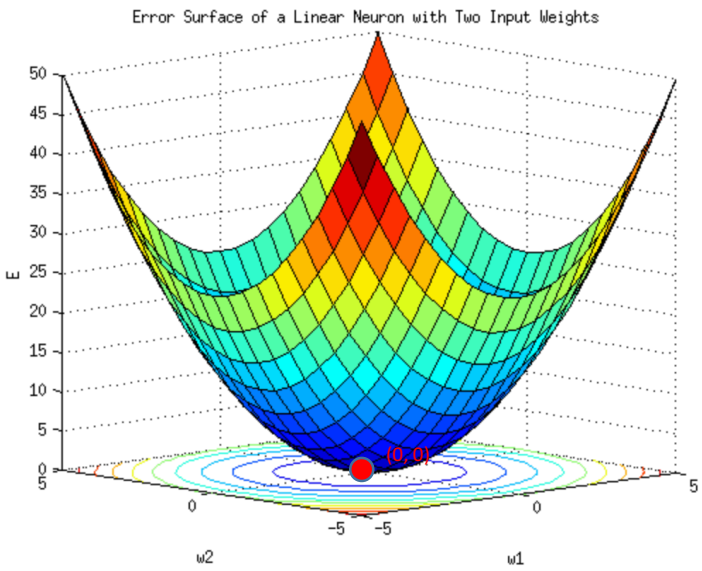

Figure 7. Error surface of a linear neuron after training

3.6. Tensorflow

In this project, Tensorflow, an open-source software library for dataflow programming from Google, is employed to build the neural network [17]. This library performs especially well for machines learning tasks, including neural network applications. Tensorflow is used for numerical computations with the help of data flow graphs and offers varies advantage for artificial intelligence applications. Google has developed many of their "smart" product with Tensorflow, including Google search, Google Photos, and Google Translate [17]. Here are 5 main advantage to develop a AI system with Tensorflow. Firstly, Tensorflow offers high flexibility. This is a highly flexible model as it provides different models and different version of the same model that can be served simultaneously. In other words, programmer can use different components in Tensorflow that suit their data flow graph or all parts if it is suitable. This highly modular nature can suit wide range of data flow graph. Secondly, it offers high portability. Machine learning with Tensorflow is possible to run on laptop without having any other hardware support. Tensorflow runs on GPUs, CPUs, desktops, servers, and mobile computing platforms [17]. Programmers can develop a training model as part of the application which deliver the portable feature. Thirdly, it enhances the efficiency of research and production. Programming is not required to rewriting codes and they can simply apply their ideas on the existing program easily. This provide the reusability and make the production process faster. Fourthly, it provides auto differentiation. As discussed above, differentiation is employed to calculate the slope of the error-to-weights graph in gradient based learning

algorithm and to perform back propagation. Every application with neural network should have the differentiation part for adjusting the weighting in order to find the optimal weightings. With auto differentiation, programmer only need to define the computational architecture of the model combined with the objective function and Tensorflow will perform differentiation automatically. Lastly, Tensorflow makes use of your available hardware with its advanced support for threads, asynchronous computation, and queues, which offers the best performance [17].

3.7. Feedback System and Training Data

To train the data in the neural network, different source of training data is used. The neural network will be initialized by same weighting among the weights between the input layer and the therapy layer. This is because we are not sure about their relationship and it is better to have further training by the feedback from the users. Feedback training is employed to evaluate the effectiveness of the therapy regarding the severity of depression and the five traits. The feedback system employed 10-point Likert-type responses with 0 representing "Not useful", 5 representing "Somehow useful" and 10 representing "Extremely usually". By referring to the feedback, we can calculate the error from the system output and expected output. This would provide a indicator of user satisfaction of the system.

Moreover, we will train the system by referring to their depression severity improvement. This can be done by comparing the most updated PHQ-9 result by the user's history. As mentioned above, the data with depression severity improvement will be used as the training data of the system in the future. As a result, we can train the system to provide the best therapy for different depression severity. A very important point to be noticed is that the suggestion is only for reference and we will suggest users with severe depression to visit professional therapist.

3.8. Database configuration

In this project, we have employed MySQL, an open-source relational database management system, as our database in order to store users' data. The MySQL database is stored and run at local computer and open for connection only for local PHP file. Which, in

other words, means that the database only open for private connection. User can interact with the database by connecting to the local computer and executing the PHP file in local computer. This aim to provide a better security for the database. In the database, there are only one table named “therapy” which stored the id, depression severity score, the score of the big five traits, the predicted therapy and the training therapy for system training. To configure and update the data in the database, user can input the corresponding field in the webpage (see Figure 8).

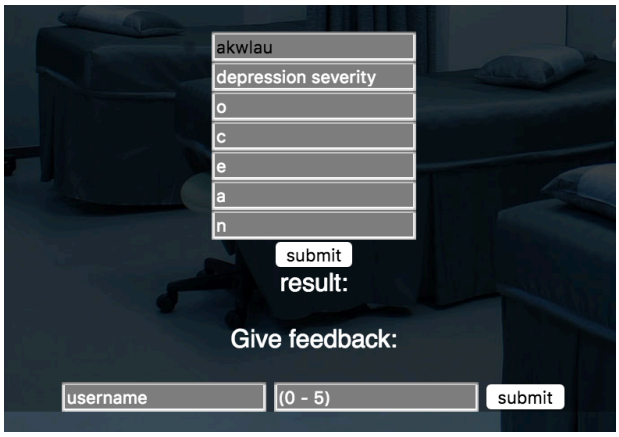

Figure 8. Webpage for User to Connect to and Update the MySQL Database

By inputting the username, depression severity, and the big five traits of the user, the database will either create a new row for the user if the username do not exist or the database will update the depression severity and the big five traits for the specific user. After that, the php server will execute a command and run the “therapy_predict” python program (therapy_predict.py) which return the predicted best therapy from the trained neural network. The result will be displayed in the result field of the webpage.

After going through the therapy, users are required to give feedback for further analysis. The feedback will be used in the user acceptance testing for performance analysis. Details will be discussed in latter section.

On the other hand, users are required to fill in again the depression severity questionnaire for the next login. By comparing the depression severity improvement, those who have significant improvement will be saved as training data for next neural network training.

3.9. Automation of System Training

One of the major feature of this system is the automatic system training with embedded machine learning algorithm. The neural network need to be retrain in a timely manner such that the system can deliver the most updated prediction with latest trained weight and bias in the neural network. Therefore, "crontab" is employed to provide this functionality. Crontab, or in long the CRON TABle, is a table contains the schedule of "cron" entried that need to be executed in a specified schedule or times [28]. For instance, "0 0 * * * python3 therapy_predict.py" referring to execute "python3 therapy_predict.py" every day at 12:00am.

4. Result and Discussion

In the section of methodology, we proposed the major architecture and algorithm to be employed in the system. To indicate and measure the efficiency and acceptancy, we will discuss the expected result in this section. The expected result will be tested base on three perspectives. The first testing relies on the neural network testing with test case. The second testing is user acceptance testing which test the acceptancy of the system based on the online nature of therapy. The third testing is the improvement testing which test if our users have improvement after the the treatment. The details and results will be discussed in the following sub sections.

4.1. Neural Network Testing

In this sub section, we will evaluate the neural network, or in other words the accuracy of the trained neural network, and the functionalities and correctness of the system.

To examine the accuracy of the neural network, we can use different test case and compare the expected result with the ideal result. In other words, we will first train the system so that it can have different trained weighting. We can then use different test case to see if the system can analyze the result from the Big Five Inventory and PHQ-9 and predict the expected result in the testing data set. We will have a deeper discussion in section 4.1.1. After that, we can see evaluate the functionalities of the system. For instance, we will go through some test

case and examine if the system can suggest the best mindfulness-based stress reduction therapy and deliver appropriate instruction. On the other hand, the automatic training process of the neural network can be further tested by using different set of training data. The expected result would be that the system can suggest a therapy as the best therapy by the two inputs. It should also perform automatic training of neural system by different training data input.

4.1.1. Neural Network Evaluation

In this section, we will discuss the several performance indicators and show the training statistics of the system. We will first talk about the changes of biases and weights in first and second fully connected network (see Figure 9). After that, we will illustrate the improvement of the loss, or in other words the different between predicted and expected result. It will be followed by the accuracy of the system in different slides of one training session. The result explained in this report have been run in 2100 steps.

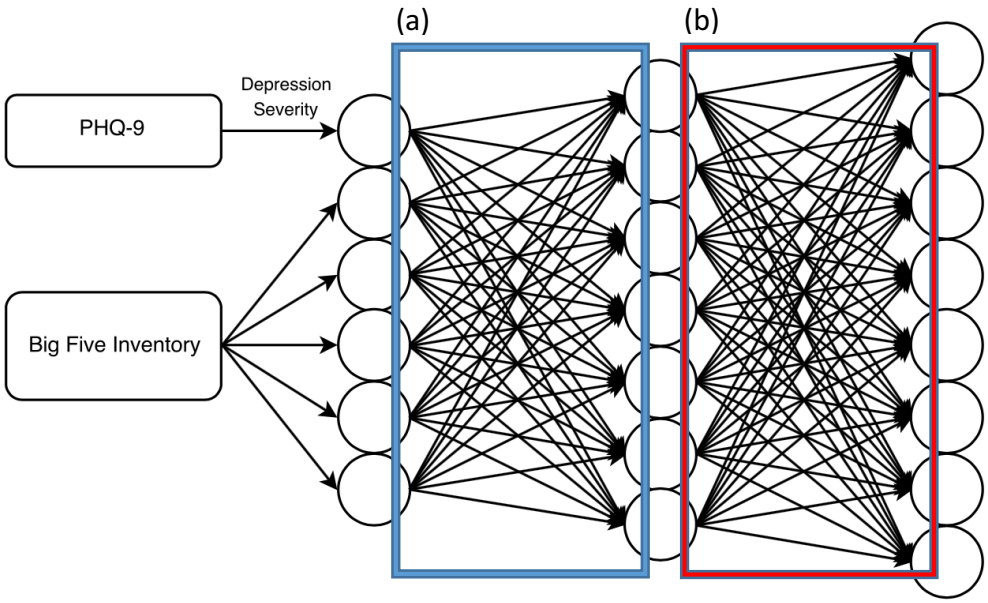

Figure 9. (a) Layer 1 and (b) Layer 2 of the Neural Network

4.1.1.1. Layer 1 Biases and Weights

Layer 1 biases and weights have fluctuated a lot and either increase or decrease a lot at the very beginning of the training (see Figure 10, 11). Before 1000 steps of training, the biases

and weights are changing dramatically due to the back propagation training in order to fit the new coming data. However, when the system starts to be well trained, the biases and weights become more steady and the plot tends to be flattened. This is an indicator that showing the system is well-trained in an efficient way because the system learns very fast in the beginning and the weight and biases become more stable in the latter stage of the training. After the 2100 steps of training, the biases and weights of the system is predicted to be flattened and ready to receive new input with more accurate therapy predictions.

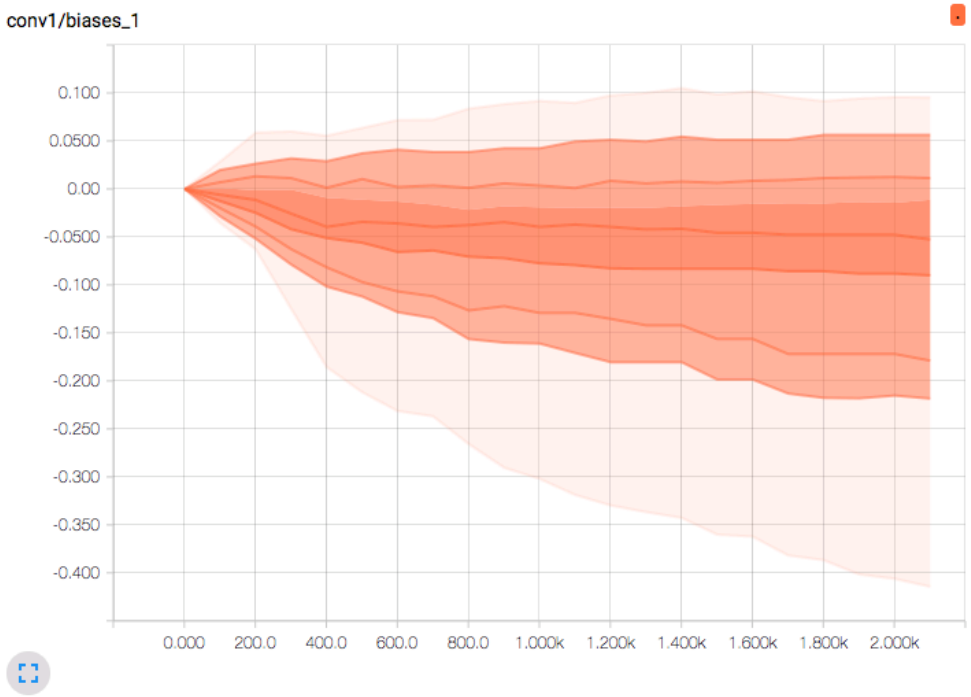

Figure 10. Layer 1 Biases in 2100 Steps of Training

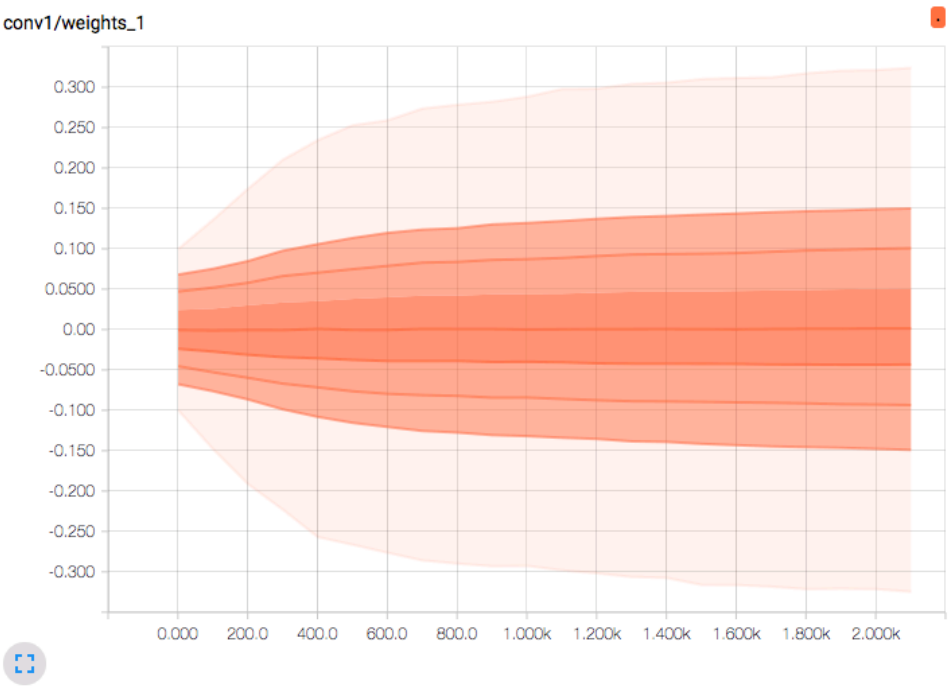

Figure 11. Layer 1 Weights in 2100 Steps of Training

4.1.1.2. Layer 2 Biases and Weights

Biases and weights in layer 2 have a similar situation as those in layer 1. Layer 2 biases and weights have fluctuated a lot and either increase or decrease a lot at the very beginning of the training (see Figure 12, 13). Before 600 steps of training, the biases have changed a lot while weights have a flatter start in the beginning. This is because Tensorflow have configured to train the weights in first layer first to boost the efficiency and reduce the CPU consumption on the local computer. Both of them have been flattened after 600 steps. The result is predicted as layer two have a more reliable input from layer one, which in other words the data is begin screened by layer and have a pretty good prediction. The work of layer 2 is only to optimise the classification process. Therefore, layer 2 have a more stable and weights and biases.

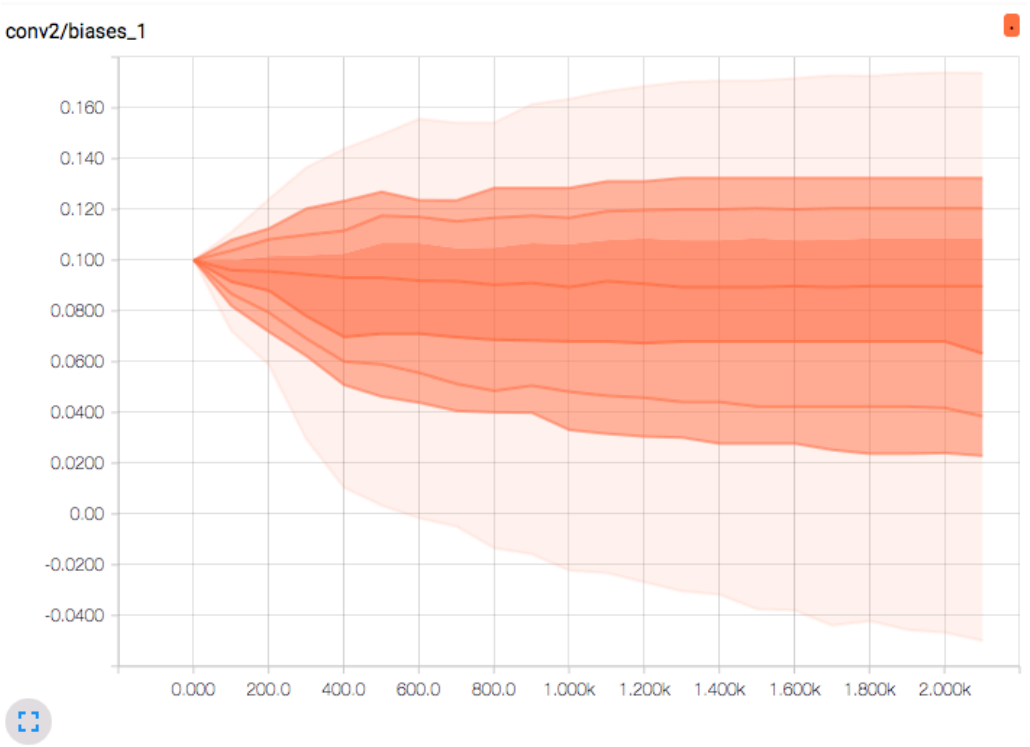

Figure 12. Layer 2 Biases in 2100 Steps of Training

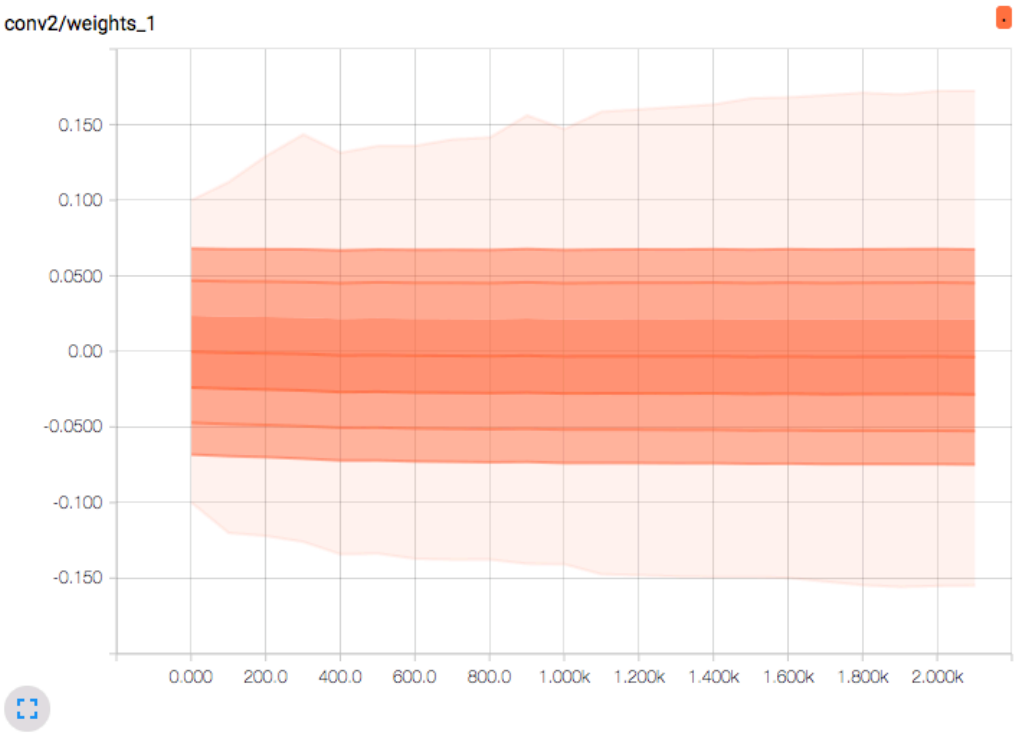

Figure 13. Layer 2 Weights in 2100 Steps of Training

4.1.1.3. Total Loss Improvement

In this part, we will have an overview on how the loss, or the different between the predicted and expected result, have been improved in the 2000 steps of training. The loss of the system has been improved very steadily (see Figure 14). As the checkpoint is saved every 100 steps, the graph may look a bit smooth. However, note that the real curve is much fluctuated than the one in Figure 14. Therefore, this figure only gives an overview and trend of the loss of the system. As you can see, the loss starts with a very high loss value, 6.42. After 1000 steps of training, the decrease in total loss have been reduced or the curve is more flattened. After 1600 steps of training, the system is very stable and the total loss value is close to 1. This can be explained by error surface shown in the previous section of this report (see Figure 6). The 3-D visualization of the error surface is in a inversed bell-shape. The point on it representing the weights of a neural. It changes the value dramatically in the beginning due to the great slope. After that, it will be stabilized and stop at the bottom of the error surface. This can illustrate that the graph is flattening and loss of the bottom of the surface error should be somewhere nearby 1.

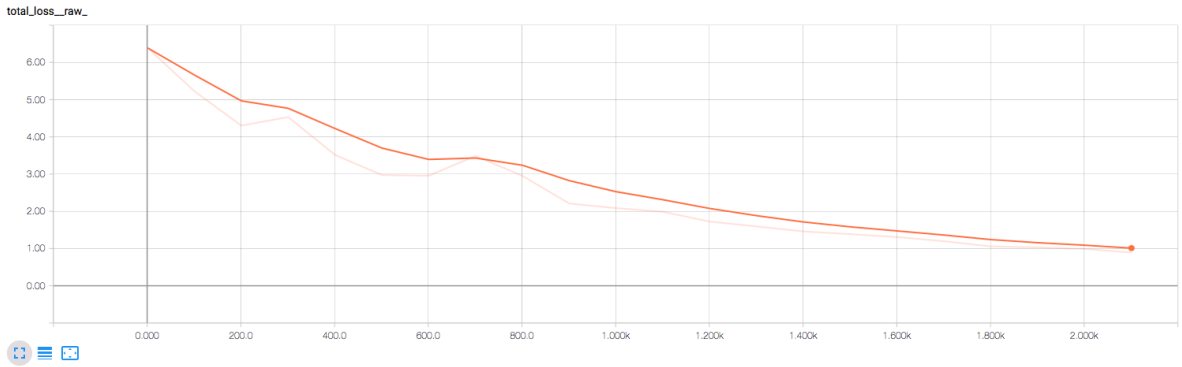

Figure 14. Total loss in 2100 Steps of Training

4.1.1.4. Evaluation in Accuracy of the System

In order to evaluate the system during training, a python program is developed. The program randomly selects training data set from database with expected result. After that, the system will input each row in the system and predict the best therapy with the trained neural network. The programme will count the mated result, if the predicted therapy matches with the expected therapy, and show in percentage.

To evaluate the accuracy of the system during training, we have train the system with 2100 steps and run the evaluation programme each 100 steps. The table below have recorded the time and the calculated accuracy at different steps (see Table 2). It is obvious that the system has improved drastically in the 2100 steps of training, from 4.163% in the beginning to 93.754% after 2100 steps of training.

Also, you may refer to the graph visualization of the data to have a better overview of the improvement (see Figure 15). As you may notice that, the accuracy has improved a lot in the beginning and accelerated in the middle of the training. At the end of the training process, the accuracy is very close to 100% and start to flattened. At this point of view, 2100 steps should be sufficient to provide a very accuracy prediction after the training.

Attempt (in every 100 steps)	Time	Accuracy
1	23:58:07	4.163 %
2	00:01:14	15.344 %
3	00:04:25	23.123 %
4	00:07:28	34.987 %
5	00:10:38	42.735 %
6	00:13:42	54.412 %
7	00:16:52	61.555 %
8	00:20:07	69.443 %
9	00:23:14	76.723 %
10	00:26:26	79.423 %
11	00:29:36	81.843 %
12	00:32:48	84.734 %
13	00:35:58	85.438 %
14	00:38:04	87.322 %
15	00:41:14	88.344 %
16	00:44:31	89.433 %
17	00:47:44	90.742 %
18	00:50:52	92.433 %
19	00:52:21	93.740 %
20	00:56:29	93.750 %
21	00:58:44	93.754 %

Table 2. Improvement in Accuracy of the System during System Training

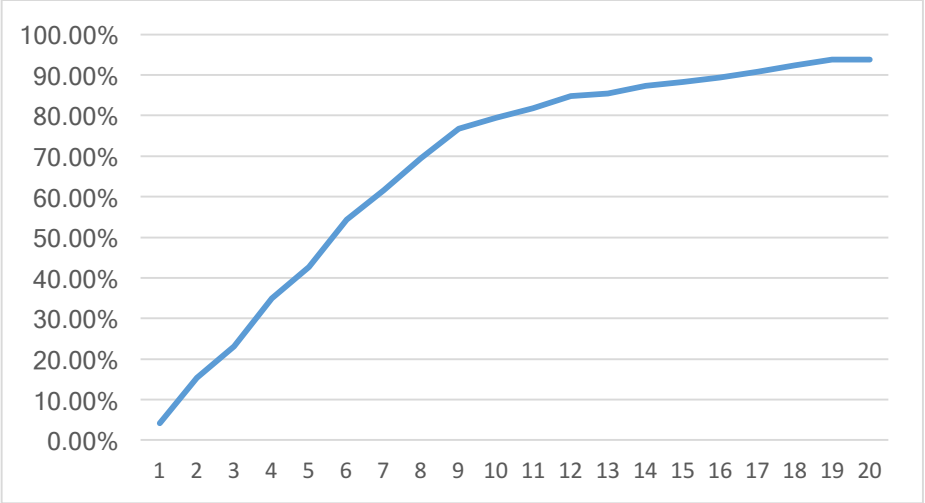

Figure 15. Table 2. Improvement in Accuracy of the System during System Training

4.1.2. Functionality Testing

In order to guarantee the usability of the system, we have employed the functionality testing of the system. Functionality testing is a typical software testing method in which the system is tested to ensure that it conforms with all the planned features [27]. The functionality testing employed in the project is mainly focus on the execution of the trained neural network, such as if the system can deliver the suitable result to our users, and if the neural network can train itself in a timely manner.

Regarding (i), our system can deliver a usable result from the input of depression severity level and the scores of the big five traits. When the user browse to the website, they are required to fill in two questionnaires (PHQ-9 and big five traits) (see Figure 9). The scores will be send to the local server via GET ajax techniques. In this experiment, we have used the following input:

Username:	anson lau
Depression Severity:	13
Big Five:	Openness to Experience: 33, Conscientiousness: 17, Extraversion: 18, Agreeableness: 23, and Neuroticism: 23

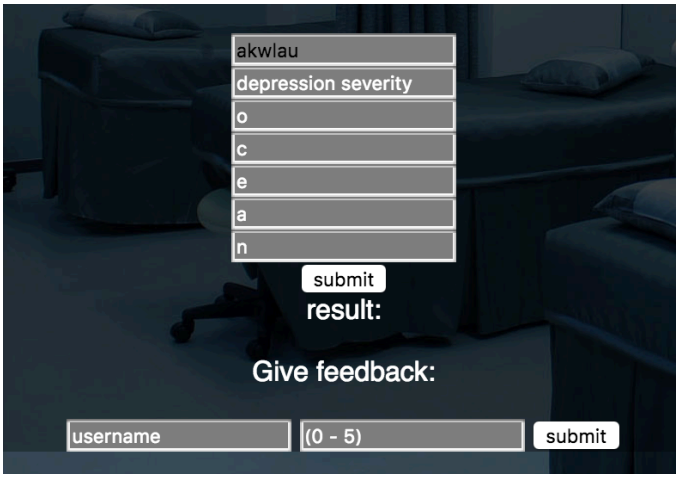

Figure 16. User Provides the Depression and Severity Level

In the server server side of the system, a predict therapy python program will be run and calculate the best therapy based on the provided input. The result will be sent back to client website by ajax response and displayed at the corresponding field (see Figure 10). The result is as follow: Therapy 5.

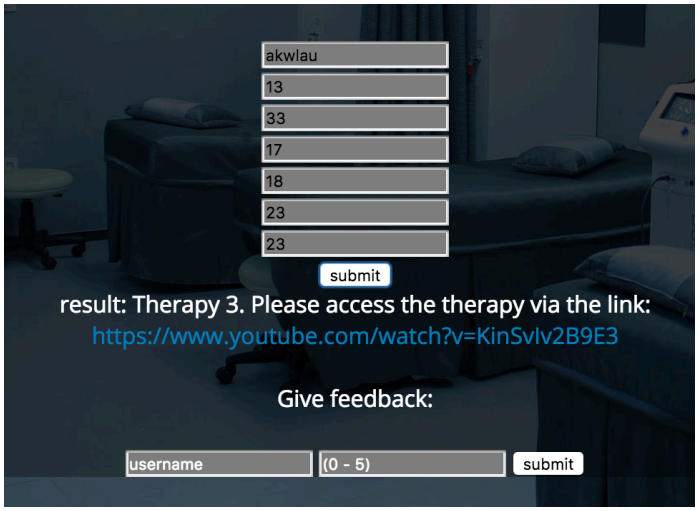

Figure 17. User Get the Result by Ajax Technique

Also, we can check if the database has correctly added user “anson lau” with corresponding input (e.g. depression severity, five five traits and suggested therapy). As shown in Firgure 11., the user is successfully created with corresponding input.

☐	Edit	Copy	Delete	164	Kwong Hin Wai	25	50	43	38	45	37	9	9	-1
☐	Edit	Copy	Delete	165	anson lau	13	33	17	18	23	23	-1	5	-1
☐	Edit	Copy	Delete	166	anson	13	33	17	18	23	23	-1	5	-1

Figure 18. User "anson lau" is Added into Database with Correct Values

Therefore, the system can provide a correct and efficient function for responding to users input, database configuration, and deliver the predicted result to the user.

4.2. User Acceptance Testing

To test the user acceptance and the efficiency of the therapies of the online therapy, the system has been released to the public for free beta trial on the internet. This is so important as it indicates the efficiency of the system offering the best mindfulness-based stress reduction therapies and test if the system suit the real-world usage. Firstly, user need to go through the system input by completing the Big Five Inventory and PHQ-9. Then, they will be offered the best therapy estimated by the system. They are required to give the feedback after finishing the therapy. The expected result would be more than 70% of users accept the online therapy with 4 or more point in a 5 Likert rating feedback scale.

In order to collect user's feedback, user can visit the webpage and input the username together with the user's feedback score in 4 Likert rating (see Figure 12).

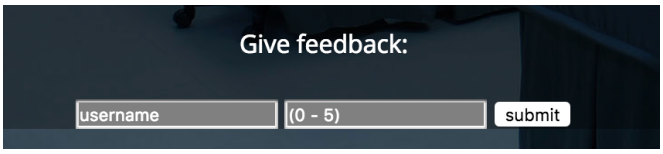

Figure 19. Feedback Field of the Website

Then, the database will have the feedback score stored in the "feedback" column (see Figure 13).

Edit	Copy	Delete	164	Kwong Hin Wai	25	50	43	38	45	37	9	9	-1
Edit	Copy	Delete	165	anson lau	13	33	17	18	23	23	-1	5	4
Edit	Copy	Delete	166	anson	13	33	17	18	23	23	-1	5	-1

Figure 20. Feedback Score from User is Stored in Database

We have analysed the data and of all the 48 data in our database. The result is stated in Table 2. According to the figure, there are no users rated 1 for the system after going through the therapy. Also, there are only few of the users rated 2 and 3 after the delivery of mindfulness therapy. Meanwhile, there are 36 users (~80%) in total rated 4 or 5 for the system.

This can simply translate as around 80% of the users, who have rated the system, are satisfied with the system and think that the system is useful for them. This also means that the result of user acceptance testing satisfied the expected result as stated before the development of this project.

Score	1	2	3	4	5	NA
Number of data	0	4	5	24	12	3

Table 3. Statistics of Feedback Score after Receiving the Therapy

4.3. Depression Severity Improvement Testing

To test the effectiveness of the system, history of different users will be recorded for further analysis. In the beginning of every matching, users are required to go through the PHQ-9 questionnaire and diagnose the depression severity. This record will be saved to the database. After several trail, we can analysis the improvement in mood symptom of the user. This history can indicate the effectiveness of the system. The expected result would be more than 80% of user have improvement in 1 month, which is the designed testing period of our system as stated in our schedule.

In order to examine the depression severity improvement, users are required to login for more than one time. In the beginning of the therapy prediction, users are required to go through the PHQ-9 questionnaire again to diagnose the depression severity. By comparing with the history of the corresponding user, we can change the value in the row “improved” to “1”, which means that the users have mental health improvement. Also, as the therapy is useful to the patient or user, it will be used as a training data in next neural network training.

Table 3 have illustrated the statistic of severity improvement according to the MySQL database. There are 43 out of 48 users (~ 90%) have recorded depression severity improvement after using the system. This can indicate that the mindfulness therapy system is useful and in some extend that it can rescue the mental health disorder in an effective manner.

Depression Severity Improvement	Yes	No	NA
Number of Data	43	5	0

Table 4. Number of Data with Depression Severity Improvement

5. Potential Risks, Challenges, and Mitigation

Potential risks and challenges appear in every project, big and small. In this part, we will discuss the three limitations and risks found in my proposed online therapy system due to the nature and the complexity of online therapy. One of them is about the insufficient acceptancy of online therapy due to it low prevalence. The remaining two is due to the complexity of development and can be improved in further research and future work.

5.1 Limitation of Training Data

There are three possible risks and challenges in the project. Firstly, there is limited training data. We have employed neural network in the project. In order to improve the system, some practical data is needed to train the weighting between inputs and the best therapy. Practical data means that the data is really provided by a depression user. However, as mindfulness therapies usually last between few days to a week, there may not have sufficient practical data to train the system before submission. To mitigate this challenges, we are going to implement real time training. In order words, the system will train itself in a constant period of time and provide an improving result as the number of user increase.

5.2 Insufficient Public Acceptancy of Online Therapy

Secondly, online therapy is still hard to be accepted by the public. As online therapy combining psychotherapy with online therapy, many psychologist and therapist are still debating on the effectiveness in delivering the therapy online. As a result, people may still resist to use online therapy as their depression treatment despite of the better accuracy of depression detection. However, as this system aims to promote online therapy and give a

helping hands to the students in Hong Kong suffering depression, people can treat this as an inexpensive, immediate, and convenient solution if they feel depressed sometimes.

5.3 Limitation of Flexibility of the System

Thirdly, the system limited the types of mental disorder and types of therapies in order to reduce the complexity. As there are many different mental health disorder in Hong Kong, this system may not be flexible enough to diagnose any other disorder except depression. Also, there are many therapies to deal with different mental disorder, the system cannot provide a comprehensive comparison between different therapies and provide the best therapy available. This can be mitigated by developing a more flexible model on top of this system in the future research.

6. Project Schedule and Milestones

For the current stage, we have already finished the third deliverable including final report and finalized tested implementation of the system. The development process is completed and can meet all the stages in the schedule (see Table 5). The system can deliver the best therapy to user with automatic neural network training with machine learning. This meet with our project plan and also provide extra features such as feedback system and automatic training of neural network. A final presentation and poster presentation will be finished in early May. After some training, our system can deliver the best therapy to user with around 93% accuracy. In the future, we hope that the system can be improved with flexible therapies and support a broader mental health disorder.

Stages	Expected Start Date	Expected End Date	Status
1st Phase Deliverables - Detailed project plan - Project web page	1 Oct 2017	14 Oct 2017	Finished
Preparation of 2nd Phase Deliverables	22 Dec 2017	10 Jan 2018	Finished
2nd Phase Deliverables - First presentation - Detailed intermediate report	10 Jan 2018	10 Jan 2018	Finished

- Preliminary development (Neural network)			
System Development - From: Big Five Inventory (Traits) and PHQ-9 (Depression Severity) - To: The best therapy (Mindfulness therapies)	1 Jan 2018	15 Mar 2018	Finished
System Training and Testing	15 Mar 2018	14 Apr 2018	Finished
Preparation of 3rd Phase Deliverables Preparation of Final Presentation	1 Apr 2018	14 Apr 2018	Finished
3rd Phase Deliverables - Finalized tested implementation - Final report	15 Apr 2018	15 Apr 2018	Finished
Final Presentation	16 Apr 2018	20 Apr 2018	
Project Exhibition	21 Apr 2018	2 May 2018	

Table 5. Final Year Project Working Schedule

7. Future Studies

In this section, we will discuss about the further improvement of the project so as to improve the functionalities and performance of the neural network system.

7.1. Resumption of Training Process

Resuming training process is useful to improve the efficiency and accuracy of the system. To resume the training process, Tensorflow have offer different function and features in the library, including "tf.train.Saver()" and "import_meta_graph('xxx.meta')" [29]. After training the neural network in the first time, we can save all the variables and network graph to a checkpoint file by the Saver function so that all weights and biases is preserved. In the next training session, we can retrieve the parameter by calling "import_meta_graph('xxx.meta')" function. After that, we can get the variables and assign it to corresponding weights and biases and resume the training session. By resuming the training process, the CPU consumption during the training process will be lower and the training time of the system will be much shorter as the system is only required to train with the updated dataset. Moreover, as the training time is shortened, training session can be created more frequently. Therefore, more updated

trained neural network can be delivered to the user and improve the accuracy of the therapy prediction.

7.2. Improving Therapy Implementation and Delivery

In this project, we have direct the user to the therapy guide video on YouTube after the prediction. This may harm the consistency of the system as user need to travel to another platform to receive the therapy. In order to provide a more seamless experience to the user, in-site therapy implementation and delivery should be developed. For instance, we can use scripts, video, or make use of video frame to display the therapy guild to the user. As a result, user can have a more seamless experience throughout the process.

7.3. Including Tensorflow GPU Device Support

In this project, the neural network is training only on the CPU kernel. CPU is highly occupied by the python training programme during the training session. In order to improve the efficiency and reduce the consumption of CPU kernel, Tensorflow allows both CPU and GPU device types support [30]. In other words, the programme can run on both CPU and/ or GPU depends on the program configurations. This suggestion can be a possible solution for high CPU consumption server or local server with at least on GPU devices.

7.4. Dynamic input and output of the system

In order to reduce the complexity, this project only focus on depression and mindfulness therapies. However, there are more than one mental health disorders in Hong Kong. Therefore, the system can be further improved by supporting dynamic mental illness indicator inputs and therapy output. For instance, the system can offer a input and output configuration panel so that different company can use the system to train their own data and deliver the best therapy to their patients. This can be done by making the dimension of the tensors in Tensorflow more dynamic, so that the system is capable for different numbers of input and output. Further development can focus on this suggestion and to improve the usability of the system.

8. Conclusion

The online mental health therapy with machine learning aims to improve the prevalence and accuracy of mental health diagnosis and to provide the best therapy to depression severity matching. Online therapy become more common in this century, people can look for therapist or having therapy online. However, most of the online therapy website do not contain dynamic feature which the therapy may not suitable for users. By employing a machine learning algorithm - neural network to decide the relationship between depression severity, traits and best therapy, user can have a better experience in the treatment process. The platform uses PHQ-9 questionnaire, a standardized online depression screening and diagnosis tools, as an input. It also employed the Big Five Inventory, a questionnaire describing personality in five primary factors. The score of the PHQ-9 and Big Five Inventory will be further analysed by a neural network. The output of the neural network is the best matching of the 10 mindfulness therapies suggested by Courtney [25]. User feedback and depression severity improvement will be used to train the system in order to provide a more accurate prediction for users.

The development of the neural network system is already finished and can be deployed to the public. Regarding the experiments and the results, the system have satisfied all the expected result set in the beginning of the project with an outstanding accuracy (~93%). All functionalities have been tested with different test cases. Also, user acceptance testing shows that users are very satisfied with the online therapy (~80% of users rated 4 or 5 out of 5) with no one rated 1 score from the feedback. This illustrated that the concern of shifting the therapy online may scarify the user is not significant. Non face-to-face therapy can also deliver a satisfying therapy to the users. In the depression severity improvement testing, the result shows that around 90% of users have some extends of improvement after receiving the therapy. This shows that online therapy can somehow deliver a satisfying and accurate therapy which can rescue the health health disorder in an efficient manner. In general, the system can provide an accurate and satisfying mindfulness therapy to the users and perhaps can outperform the diagnosis of traditional face-to-face mental health therapist.

In conclusion, this project is contributing to the online therapy in the way to improve the prevalence and accuracy of online mental health diagnosis with the best therapy suggestion.

In the future, the system should offer a flexible type of mental health disorders and comprehensive therapies so that more people can be benefitted from the system and reduce the cost of mental health diagnosis

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Appendices

Appendix A
PHQ-9 Depression Scale

PHQ-9

Over the last 2 weeks, how often have you been bothered by any of the following problems? *(Use "✔" to indicate your answer)*	**Not at all**	**Several days**	**More than half the days**	**Nearly every day**
1. Little interest or pleasure in doing things.....	0	1	2	3
2. Feeling down, depressed, or hopeless.....	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much.....	0	1	2	3
4. Feeling tired or having little energy.....	0	1	2	3
5. Poor appetite or overeating.....	0	1	2	3
6. Feeling bad about yourself — or that you are a failure or have let yourself or your family down.....	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television.....	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite — being so fidgety or restless that you have been moving .around a lot more than usual.....	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way.....	0	1	2	3

(For office coding: Total Score _____ = ___ + ___ + ___)

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all	**Somewhat difficult**	**Very difficult**	**Extremely difficult**
☐	☐	☐	☐

Appendix B
Big Five Inventory (BFI)

Scale:

The Big Five Inventory (BFI)

Here are a number of characteristics that may or may not apply to you. For example, do you agree that you are someone who likes to spend time with others? Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement.

Disagree strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree Strongly
1	2	3	4	5

I see Myself as Someone Who...

____1. Is talkative

____2. Tends to find fault with others

____3. Does a thorough job

____4. Is depressed, blue

____5. Is original, comes up with new ideas

____6. Is reserved

____7. Is helpful and unselfish with others

____8. Can be somewhat careless

____9. Is relaxed, handles stress well

____10. Is curious about many different things

____11. Is full of energy

____12. Starts quarrels with others

____13. Is a reliable worker

____14. Can be tense

____15. Is ingenious, a deep thinker

____16. Generates a lot of enthusiasm

____17. Has a forgiving nature

____18. Tends to be disorganized

____19. Worries a lot

____23. Tends to be lazy

____24. Is emotionally stable, not easily upset

____25. Is inventive

____26. Has an assertive personality

____27. Can be cold and aloof

____28. Perseveres until the task is finished

____29. Can be moody

____30. Values artistic, aesthetic experiences

____31. Is sometimes shy, inhibited

____32. Is considerate and kind to almost everyone

____33. Does things efficiently

____34. Remains calm in tense situations

____35. Prefers work that is routine

____36. Is outgoing, sociable

____37. Is sometimes rude to others

____38. Makes plans and follows through with them

____39. Gets nervous easily

____40. Likes to reflect, play with ideas

____41. Has few artistic interests

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____20. Has an active imagination

____21. Tends to be quiet

____22. Is generally trusting

____42. Likes to cooperate with others

____43. Is easily distracted

____44. Is sophisticated in art, music, or literature

Scoring:

BFI scale scoring ("R" denotes reverse-scored items):

Extraversion: 1, 6R, 11, 16, 21R, 26, 31R, 36
Agreeableness: 2R, 7, 12R, 17, 22, 27R, 32, 37R, 42
Conscientiousness: 3, 8R, 13, 18R, 23R, 28, 33, 38, 43R
Neuroticism: 4, 9R, 14, 19, 24R, 29, 34R, 39
Openness: 5, 10, 15, 20, 25, 30, 35R, 40, 41R, 44

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Appendix C
User's Depression Severity and Big Five Input Records

id	Username	Depress Severity	Openness	Conscientiousness	Extraversion	Agreeableness	Neuroticism
117	Ng Andrew	2	4	5	3	1	3
118	HUANG CHAO_HSUAN	2	4	3	2	5	3
119	CHIU CHING WAI KERRIE	1	1	4	3	5	3
120	Lee Chak Wang	1	4	2	1	2	4
121	Chan Chak Yan	2	4	1	2	5	3
122	CHAN Chau Wong	1	3	3	3	5	2
123	Liu Cherry	2	5	1	2	1	3
124	Ho Cheuk Hang	1	4	3	3	2	3
125	Hai Cheuk Man	3	7	6	7	6	5
126	YIP Cheuk Yin Bryan	3	8	6	6	8	6
127	HO Chi Fung	3	8	7	5	10	6
128	Choi Chi Hin	5	10	6	6	10	5
129	Wong Chi Ho	3	8	9	6	7	6
130	LI Chi Leung	3	6	10	5	7	8
131	SHEUNG Chi Sum	7	13	14	9	15	9
132	Lau Chi Yeung	6	14	13	9	13	11
133	Ngau Chi Yuen	7	13	14	10	12	11
134	Low Chien Tat	7	11	14	9	15	10
135	Leung Chin Hei Leonardo	6	13	14	9	11	9
136	Wan Ching Ho	7	11	11	11	11	12
137	Lo Ching Kwan	9	17	18	15	18	15
138	HO Ching Man	10	18	16	16	17	13
139	Ho Ching Sum	8	17	18	15	17	16
140	CHAN Ching Sze Caesar	9	19	19	14	16	14
141	Kwok Ching Yin	11	24	24	19	23	19
142	Chan Ching Yin	11	23	25	17	22	20

143	CHAN Chiu Tung	11	22	21	19	21	20
144	Wong Choi Yiu	11	24	25	18	21	18
145	LEUNG Chui Shan	11	23	21	18	21	20
146	LAI Chun Ning Lawrence	15	26	26	23	28	23
147	Wong Chun Ning Nigel	15	29	29	22	26	21
148	Hon Chun Pong	18	31	32	25	32	27
149	LIANG Chun Pui	18	33	32	28	30	27
150	Chan Chin Ting Daniel	17	34	31	27	30	26
151	Lee Chun Yiu	17	34	31	25	32	28
152	YUA Chung Hin Harris	19	36	36	31	36	30
153	Cheung Chunho Billy	21	36	37	30	35	29
154	Tsang Churn	20	36	34	29	37	32
155	Monceret Diane	21	39	34	29	34	32
156	Sy Fion Hoi Ki	19	40	37	31	37	30
157	Yeung Geoffrey	21	40	37	30	36	31
158	Yeung Harriet	23	43	41	35	41	34
159	Mak Hau Man	22	44	38	34	40	35
160	Chan Hau Tung	22	41	38	36	38	34
161	TSANG Hin Hung	26	47	43	38	42	40
162	Lok Hin Nam	26	47	44	38	42	39
163	Cho Hing Ting Frankie	26	46	45	39	45	38
164	Kwong Hin Wai	25	50	43	38	45	37

Appendix D

Hardware and Software Configuration

Operation System:	macOS Sierra
Laptop Model:	Macbook Pro (Retina, 13-inch, Late 2012)
Processor:	2.5 GHz Intel Core i5
Memory:	8GB 1600 MHz DDR3
Graphics:	Intel HD Graphics 4000 1536 MB
Python:	Python 3.6.5