APPLYING ARTIFICIAL INTELLIGENCE TECHNIQUES TO
MENTAL HEALTH DIAGNOSTIC EXPERT SYSTEM

Rozita Yati Masri, Hajar Mat Jani, Alicia Tang Yee Chong
Systems and Networking, College of Information Technology, Universiti Tenaga Nasional
KM 7, Jalan Kajang-Puchong, 43009 Kajang, Selangor
rozitay@uniten.edu.my, hajar@uniten.edu.my, aliciat@uniten.edu.my

ABSTRACT
Approximately one out of five Malaysians developed some kind of mental disorder, and similar scenario also applies to other countries. One-fifth of the population is a large quantity and there are not enough psychotherapists in Malaysia to attend to even half of these sufferers. Mental Health Diagnostic Expert System is proposed to facilitate the inexperienced psychotherapists in Malaysia to treat their patients with accurate diagnoses. Since the proposed expert system (ES) is to cater for the Malaysians, interviews with several psychotherapists have been conducted to observe the commonness, severity levels, and treatments of stress-related, psychotic, and neurological disorders among Malaysian mental patients. The proposed ES will use two Artificial Intelligence (AI) techniques, which are rule-based reasoning and fuzzy logic, as an approach in diagnosing the mental disorders and their severity levels. Another AI technique, Branch-and-Bound algorithm, is used for heuristic search to find the optimal path in diagnosing the disorder. A prototype of the proposed Mental Health Diagnostic Expert System is developed, and sample diagnoses are performed based on several common examples of mental disorders.

Keywords: Mental Health, Expert System, Diagnosis, Artificial Intelligence Techniques, Mental Disorders

1 INTRODUCTION
In the past, an estimation of 450 millions people around the world faced psychological disorders [1]. In Malaysia, approximately one out of five people developed some kind of mental disorder [2]. Although the majority is in denial of such condition, and only very few people are seeking help professionally, nonetheless, one-fifth of the population is a large quantity and there are not enough psychotherapists in Malaysia to attend even half of these people with mental health problems. Mental Health Diagnostic Expert System is proposed to facilitate the inexperienced psychotherapists in Malaysia to build up their expertise in diagnosing and treating their patients, and as a result, granting them the experience, trusts and confidence, so that they too can immediately attend these mental patients. Since the proposed Expert System (ES) will be used to cater for the Malaysian public, a survey for the general public has been conducted to observe the norms and awareness of the public in Malaysia regarding mental health and mental disorders. Interviews with several psychotherapists have also been conducted to observe the commonness, severity, and treatments of stress-related, psychotic, and neurological disorders among Malaysian mental patients.

The proposed ES will be used to assist the psychotherapists as if they are under supervision of a real expert. As more psychotherapists use the proposed ES, the diagnoses and treatments will eventually become standardized and indirectly will increase the accuracy of the diagnoses. Potential increase in new psychiatric centers throughout the nation is possible as more new psychotherapists are available to serve the mental patients. This will also help the public to become more aware of psychological problems and knowing where to look for help.

This paper focuses on the use of Artificial Intelligence (AI) rule-based reasoning technique and fuzzy logic as an approach to diagnose the conditions of people with mental disorders and to determine the degree of severity. The Branch-and-Bound algorithm is used for heuristic search in diagnosing the conditions, and decision tree is used to determine the types of treatment(s) to practice on the patient, depending on the type of disorders and the degree of severity.

2 RELATED WORK
Xpert4Health: Web Based Medical Protocol & Collaboration System is a health diagnostic ES. It is a web-based ES, which automates the decision making process, provides education and reinforcement for
staffs, and allows performance monitoring anywhere within the domain [3]. One of the advantages of this ES is that it facilitates collaboration with other experts, where the patient record is viewable online by the experts. The initial focus is in liver disease and in particular Hepatitis-C. The system uses a series of assessments consisting of questionnaires and results of medical tests. The system allows the physicians to create a hierarchy of assessments. Each outcome contains a diagnosis and commentary, as well as suggested treatments. The ES approach includes Boolean Algebra, specific medical constructs, decision tree logic, and is automated on the web [3].

The proposed Mental Health Diagnostic Expert System will have some similar features to Xpert4Health. The proposed ES will help assist the psychotherapists to perform assessments, and come up with the diagnosis, commentary and suggested treatments.

3 OBJECTIVES

Mental health professionals look mainly at personality characteristics, personal discomfort or experience of inner-suffering, and life functioning or capability of meeting society’s expectations for performance [4]. A mental disorder exists when the person’s behavior is either maladaptive for life functioning or when it causes serious personal discomfort or both [4].

Although Diagnostic and Statistical Manual of mental disorders (DSM-IV) has already been developed and used internationally among psychotherapists all over the world, not everything in the DSM-IV can be relied on 100%. Some of the contents of the DSM-IV are less reliable when diagnosing a patient from a country like Malaysia, where there exist many cultural traditions and customs. As the service is to cater for the public of Malaysia, it is important to analyze where they stand with regard to these issues, as the norms and preferences among Malaysians may differ from the people of another country. For example, in the United States, it is illegal for an adult to date a teenager, regardless of the age gap between the two individuals. However, based on the research conducted among the Malaysian public, approximately 75% of the respondents think it is acceptable and only 6% of them put the condition on the age gap. In Malaysia, a relationship of an adult and a teenager does not indicate that the people involved are suffering from any disorders. But had this study been conducted in the United States, these respondents would have been categorized as people who suffer from sexual disorders. But keep in mind that Malaysia has many different cultures and customs, and therefore, the norms in Malaysia differ from the norms in the United States, which makes this study critical in developing the proposed system, and lowering the chances of misdiagnoses to patients.

The objective here is to come up with computerized diagnoses using rule-based reasoning and fuzzy logic derived from the collected information in diagnosing patients manually.

4 RESEARCH METHODOLOGY

An exploratory research was conducted in observing the norms and abnormalities among the Malaysian public and the awareness of the public on the issues relating to mental health and mental disorders. In many social science circles, this method is used to find out how people have the same opinion of a certain subject, what meanings they give to their actions, and what issues concern them. The goal is to learn 'what is going on here?' [5].

The research was carried out through a survey. The questionnaires were divided into four categories:

i. General Questions on Mental Health
   - To determine how aware the respondents are toward mental health and mental disorders in general

ii. Symptoms of Mental Disorders
   - To determine how much knowledge the respondents have on mental disorders and their symptoms

iii. Mental Disorders among Malaysians
   - To verify how serious certain disorders are among mental patients based to the respondents' point of view.

iv. Personal Opinions
   - To verify the norms and abnormalities, preferences, and other personal opinions related to mental health and mental disorders.

The questionnaires consist of 22 main questions and 20 sub-questions. Only one out of the 42 questions is an open-ended question where it asks for the respondents’ opinions and suggestions in improving public awareness on issues related to mental health and mental disorders. The rest are all close-ended questions varied from multiple choices, true or false, and scaling.

The survey was conducted at Universiti Tenaga Nasional, Universiti Malaya, Universiti Kebangsaan Malaysia, and random people around Kajang area, targeting local citizens at the age of 13 and older. A total of 175 data were collected.
The data were analyzed in quantity measure, counting the number of respondents out of a total number of respondents (175) for each possible selectable option.

Interviews were conducted to five different psychotherapists in Malaysia to learn about the commonness, severity, and treatments of stress-related, psychotic, and neurological disorders among Malaysian mental patients.

There were 16 questions with three sub-questions for the interview. Only two questions were open-ended questions. The first open-ended question asks the psychotherapists to explain how they would determine if a patient suffered or psychotic or neurological disorders. The second open-ended question asks for the psychotherapists' opinions and suggestions in improving public awareness on issues related to mental health and mental disorders. The rest of the interview questions are all close-ended.

The interview questions were divided into five categories:

i. **General Questions**
   Basic questions on psychotherapies, drug prescriptions, and determining the type of disorders the patients suffer from

ii. **Commonness of Stress-Related, Psychotic, and Neurological Disorders**
   Questions on how common stress-related, psychotic, and neurological disorders are among Malaysian patients

iii. **Stress-Related Disorders**
   Questions on the factors and how severity of stress-related disorders is determined

iv. **Psychotic Disorders**
   Questions on the most common types and how severity of psychotic disorders is determined

v. **Neurological Disorders**
   Questions on the most common types, how the severity is determined, and how the present of neurological disorders is determined

5 SURVEY AND INTERVIEWS: RESULTS AND ANALYSIS

After analyzing the data as shown in Figure 1 and Figure 2, it can be concluded that roughly half of the survey respondents are somewhat aware about mental health and mental disorders. And based on the interviews conducted to five psychotherapists in Malaysia, the degree of severity of mental disorders can be determined by:

i. The number of physical and/or psychological symptoms
ii. Patient's behavior and answers to certain questions
iii. Performance on rating scales and tests (psychological and/or physical) such as manic test, anxiety test, Beck Depression Inventory, and computer tomography

5.1 Mental Health and Mental Disorders

Mental health concerns both emotional and psychological well-being. It involves how an individual thinks, feels, and acts toward life’s situation. However, only 81 out of 175 respondents agreed that Option1 (emotional well-being) is part of mental health; 97 out of 175 agreed on Option2 (psychological well-being); and 82 out of 175 respondents agreed on Option4 (how individual thinks, feels, and acts toward life’s situation). 13 people thought that (physical well-being), Option3, is part of mental health as well, which is not technically wrong, but it plays a role indirectly rather than directly like both emotional and psychological well-being. Option5 (not sure) indicated that six respondents are not sure what mental health is.

Figure 1. Illustrates the responses for descriptions of mental health

Mental disorders are “characterized by impairment of an individual's normal cognitive, emotional, or behavioral functioning” [6].

Figure 2 shows that only 60 out of 175 respondents agreed on Option1 (a sickness involving the brain); 79 out of 175 agreed on Option2, (a sickness involving a person’s behavior); and 82 out
of 175 agreed on Option4 (Abnormal condition or behavior that needs to be treated). A total of nine out of 175 agreed on Option3 (a sickness involving a person’s physical). Again, Option3 is not technically wrong, but it plays a role indirectly rather than directly as Option1 and Option2. Option5 indicated that 11 respondents are not sure what mental disorders are.

5.2 Stress-Related Disorders
Stress refers to the response to any environmental demand or pressures that creates a state of tension or threat [4]. Stress affects the interactions between individuals and their environment, and is perceived as straining or exceeding the individuals’ adaptive capacities and threatening their well-being [7]. When stress is not taken care of, it can lead to both physical problems, such as heart disease and weaker immune system, and psychological disorders, such as depression, anxiety, eating disorders, and substance abuse.

Based on the interviews, the degree of severity of stress-related disorder can be determined by the following:

i. Based on the number of physical and psychological symptoms the patient has
ii. By observing patient’s behavior and answers to certain questions
iii. Depression test/Beck Depression Inventory
iv. Anxiety test
v. Other rating scales

5.3 Psychotic Disorders
Psychosis is a mental state described as losing touch with reality. It is a severe mental state that causes abnormal thinking and perceptions. Although the exact cause of psychotic disorders is still unknown, many researchers believe that it involves many factors such as heredity, drug abuse, and imbalance of certain chemicals in the brain that lead to hallucinations and delusions.

From the results of the interviews, the most common psychotic disorders are schizophrenia, schizophreniform, schizoaffective, delusional, psychotic due to another medical problem, substance-induced psychotic, and bipolar disorder.

Based on the interviews, the degree of severity of psychotic disorders can be determined by the following:

i. Based on the number of physical and psychological symptoms the patient has
ii. By observing patient’s behavior and answers to certain questions
iii. Manic test
iv. Positive and Negative Syndrome Scale
v. Brief Psychiatric Rating Scale

5.4 Neurological Disorders
Neurological disorders are disorders that deal with the nervous system. They affect the central
(brain and spinal cord), the peripheral (somatic and sensory system), and the autonomic (control system) nervous system. The disorders are developed from damage to the nervous system, depending on the location and function. Damage in certain location of the nervous system may defect the control movement, communication, vision, hearing, or even cognition.

From the interview’s results, the most common types of neurological disorders are Alzheimer’s disease, Parkinson’s disease, attention deficit-hyperactivity disorder, dementia, stroke, and epilepsy.

The types of tests used to determine if a person has developed a neurological disorder include:

i. Psychological tests
ii. Laboratory screening test
iii. Computer tomography scan
iv. Magnetic resonance imaging scan
v. Genetic testing

Based on the interview, the degree of severity of psychotic disorders can be determined by the following:

i. Based on the number of symptoms the patient has
ii. By observing patient’s behavior and answers to certain questions
iii. Neurological examination such as CT scan
iv. Based on physical examination
v. Psychological tests

6 RULE-BASED REASONING AND FUZZY LOGIC

The results derived from the collected data are useful in developing the ES. Since there may be multiple possible solutions that can be derived from diagnosing a patient, the use of AI in developing the ES is very suitable. And unlike the conventional systems, problem solving is accomplished by applying specific knowledge instead of specific technique or algorithm. It reflects the belief that human experts have different knowledge rather than processing their knowledge differently from others.

Rule-based reasoning technique is useful in contributing to the success of diagnosing mental disorders. A set of production rules is made up of many inference rules that are entered as separate rules and are used together to draw the conclusion. One advantage of inference rules is that it uses reasoning that closely resembles human reasoning process. The ES uses the knowledge in a similar form to how a psychotherapist would actually perform the diagnosis and come up with a conclusion.

A linear approximation technique limits the control of performance in real life problems; therefore, fuzzy logic is a better alternative because it provides a non-linear control which is closer to the real world situations [8]. Fuzzy is used to represent and process linguistic information, with mechanisms to deal with uncertainty and imprecision. Questions such as how many times an episode or an incident occurs to the patients within a certain period of time may pop up during a diagnosis. The patient might not be able to tell the exact number of time the episode or incident has occurred over a period of time, but he/she might be able to provide the frequency (always, often, seldom, rarely, never) of the occurrence of the episode or incident. Here, fuzzy logic plays a role in diagnosing and determining the severity of the disorders.

Several rules can be derived from the results of the interview to develop the knowledge base. An example of rules is as followed:

**Diagnosing Depression**

if X has two to four symptoms of depression
AND X experiences the symptoms for a couple of weeks or more
then X suffers from minor depression (less severe)

if X has five or more symptoms of depression
AND X experiences the symptoms for a couple weeks or more
then X suffers from major depression (more severe)

if X if X has at least two symptoms of depression
AND X experiences symptoms for a couple of years or more
then X suffers from dysthymia (most severe)

Below is an example of how fuzzy logic is applied in determining the severity of minor depression, a less severe type of depression:

**Determining severity**

if X has two to four symptoms of depression
AND X experiences the symptoms for a couple of weeks
then X suffers from mild minor depression

if X has two to four symptoms of depression
AND X experiences the symptoms for a few or several weeks
then X suffers from moderate minor depression

if X has two to four symptoms of depression
AND X experiences the symptoms for many weeks
then X suffers from severe minor depression

The combination of rule-based reasoning and fuzzy logic approach of developing the ES is beneficial in assisting inexperienced psychotherapists in performing their job not only because the approach resembles human reasoning, but also because of the heuristic programming, which enables the ES to process the data fairly fast and more systematic. A state space representation is a search tree consisting of a collection of points, where each point represents a state of a problem. The state space will eventually grow bigger as more new rules of new-gained experience are added into the knowledge base; however, the searching time for a conclusion is almost unaffected. The conclusion given after a short period of search is just as acceptable and can be justified by tracing the searching route to reach the conclusion.

Search is a significant aspect of problem solving in AI. It explores alternatives in tree and finds sequence of steps in a planning case. Branch-and-Bound algorithm finds the optimal paths with less work. It keeps track of all partial paths for further consideration. Rather than terminating when a path is found, it terminates when the shortest partial path is longer than the shortest complete path. The algorithm is as follows:

i. Form a one-element queue consisting of zero length path (only root node)
ii. Remove the first path from the queue, create new paths by extending the first path to all the neighbors of the terminal node
iii. Reject all paths with loops
iv. Add the remaining new paths to the queue
v. Sort the entire queue by path length with most-likely paths in front
vi. Repeat step ii to v until the first path in the queue terminated at the goal node or when the queue is empty

Figure 3 demonstrates how the algorithm works. Assume that (S) is the set of symptoms that the patient has. The system would match the patient’s symptoms with the symptoms which have been classified into groups (G1 and G2). From there, the system would determine which disorder (D1, D2 or D3) the patient has. New disorders can easily be added into the system by defining new facts and rules consisting of the disorders’ properties such as the symptoms without affecting the already existed rules.

With the use of the proposed ES, the diagnoses and treatments will eventually become standardized and indirectly will increase the accuracy of the diagnoses.

Figure 3. Example of Branch-and-Bound Algorithm

7 THE PROTOTYPE

The prototype of the proposed Mental Health Diagnostic Expert System consists of two types of diagnoses of mental disorders: depression and eating disorders. Based on diagnoses of depression in Figure 4, the user will determine the number of symptoms of depression the patient has, whether it is less than two symptoms, two to four symptoms, or five or more symptoms. After determining the number of symptoms, the user will then confirm with the user the frequency of the symptoms, whether the

Figure 4. Tree diagram of diagnosis of depression
patient has experienced the symptoms for less than two weeks, at least two weeks, or at least two years. The type of depression and the severity level of the depression can only be determined after the number of symptoms and the length of time a person has been experiencing the symptoms are confirmed. An example of the rule-based reasoning and fuzzy logic in diagnosing and determining the disorder’s severity level is provided in section 6.

The diagnosis of eating disorders, as shown in Figure 5, however, starts by determining where the patient falls under the given weight categories: under weight, normal weight, or over weight. The system will then declare a statement reasoning why the patient fall under such category. The user will have to state whether the statement is true or false. Based on the answer of the statement, the expert system will determine which type of eating disorders (anorexia, bulimia, and binge-eating) the patient is most likely suffering from. The system will collect the number of symptoms the patient has to confirm, and will determine whether the patient really does suffer from such disorder and how serious the disorder is (severity).

![Figure 5. Tree diagram of diagnosis of eating disorders](image)

There is no doubt that certain symptoms may lead to certain disorders. However, some disorders may also share the same symptoms. For example, a patient may have lost a lot of weight. However, weight loss is a symptom that is shared by both depression and anorexia. To determine which of the two disorders the patient actually has, other symptoms that the patient may have will also be taken into account, which determines the probability of which disorder is best-fit with the symptoms. The length of time a person has been experiencing the stated symptoms is very crucial in determining the disorders. If a person is experiencing the depression symptoms only for a few days, that does not necessarily mean that the person suffers from a depression. The person might have experienced an upsetting event which caused him or her to be sort of depressed. This situation is considered as normal, and this is inline with the current practice within the mental health and disorders field.

To make sure that our proposed Mental Health Diagnostic Expert System is making diagnoses based on how a psychotherapist actually diagnoses a patient, we work closely with an appointed consultant, who happens to be a well-known psychotherapist in Malaysia. He advises us on the rules (symptoms and other characteristics or conditions that are applicable and needed in diagnosing a patient for mental disorders) that we need to apply in the diagnosing process.

8 CONCLUSION

Mental Health Diagnostic Expert System is proposed to facilitate the inexperienced psychotherapists in Malaysia to treat their patients with accurate diagnoses. AI techniques are used to implement the proposed expert system (ES). Rule-based reasoning and fuzzy logic are useful in representing the process of the expert’s knowledge in diagnosing the patients and determining the degree of severity. And Branch-and-Bound algorithm is used for the heuristic search to improve the time in searching. With the proposed ES, the diagnoses and treatments would eventually be standardized and thus would increase the accuracy of the diagnoses. Aside from the interviews conducted to several domain experts as mentioned earlier, a main expert who is a paid consultant will clarify, justify, and verify the system to ensure the validity and accuracy of the diagnoses.

REFERENCES


