An Expert System to Assist with Early Detection of Schizophrenia

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Abstract. Schizophrenia is one of neurobiological disorders whose symptoms appear in young age. Psychiatrists use client-centered therapy to recognize five symptoms of schizophrenia. They comprise: delusions, hallucinations, negative symptoms, grossly disorganized or abnormal motor behavior, and disorganized thinking and speech. Patients experiencing their acute psychotic episode must be quarantined to prevent their unsocial behavior. An early detection of the schizophrenia symptoms is necessary to avoid acute psychotic episodes. An expert system to aid in diagnosing early schizophrenia symptoms is presented in the paper. The system represents psychiatrist knowledge in the form of rules, facts and events and uses them to assess whether a patient suffers from schizophrenia. The knowledge-base is displayed in the form of questions to the patient. The expert system uses forward chaining while gathering the answers from patient. All answers are transformed into facts and processed using Boolean reasoning to generate the diagnosis. The diagnosis states whether the patient has schizophrenia, and if so, it indicates also the type of schizophrenia.which

Keywords: Schizophrenia · Symptoms · Expert system · Boolean reasoning

1 Introduction

Schizophrenia is one of mental health disorders whose symptoms appear in young age. Psychiatrist, as an assessor, recognizes if a patient suffers from schizophrenia trying to diagnose its five symptoms: delusions, hallucinations, negative symptoms, grossly disorganized or abnormal motor behavior, and disorganized thinking and speech [1, 2], as shown in Fig. 1. Delusion is a firm belief in something untrue or not based on reality; patients misinterpret events and their significance. Hallucination is a false perception of five senses: vision, hearing, smell, taste, or touch; patients hear voices that no one else can hear or see, smell or feel things that others do not. Negative symptom is a condition in which patients experience a decrease in quality of life. Sadner [3] lists three negative

symptoms: affective flattening, alogia and avolition. Grossly disorganized or abnormal motor behavior including catatonia is characterized by childish behavior or emotional outbursts. Disorganized thinking or speech is a condition when patients have trouble in concentrating and organizing their thoughts logically making effective communication impaired. When patients experience acute psychotic episodes they must be quarantined to prevent their unsocial behavior. The community often stigmatizes persons with schizophrenia labelling them as the demented. According to Depkes RI (Departemen Kesehatan Republik Indonesia) 1.7 per thousand of Indonesia population experience schizophrenia. Assistance of psychiatrists is needed to support the patients and educate them how to cope with their illness [4].
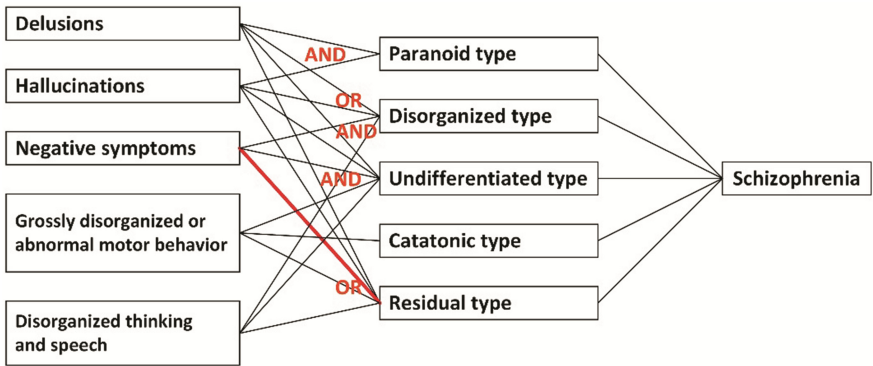

Fig. 1. Schizophrenia symptoms and types (*source* [1, 2])

Psychiatrists apply client-centered therapy to assess whether a patient suffers from schizophrenia [5, 6]. The client-centered therapy uses a question and answer approach to respond statements according to a number of keywords [7]. This therapy is conducted by face-to-face sessions and all the answers are written down. Each schizophrenia symptom has its own set of keywords [7]. For example, delusions have ten keywords and each of them has its own standard questions to indicate whether the patient exhibits symptoms of delusions. These standard questions are used during the client-centered therapy as the basic questions to be answered by the patient. The psychiatrist analyzes the answers and evaluates the patient for a mental disorder. Client-centered therapy is used to assess delusions, hallucinations and disorganized thinking and speech. During the session the psychiatrist evaluates the patient for grossly disorganized or abnormal motor behavior, including catatonia, by analyzing his/her face and body gestures. The psychiatrist also interprets changes in emotions or unbridled emotions to identify the negative symptoms [1, 2]. At the end of a session the psychiatrist gives a diagnosis whether a person has schizophrenia and determines the type of the illness. There are five types of schizophrenia as recognized by the DSM-5 (Diagnostic & Statistical Manual of Mental Disorders) [1] and shown in Fig. 1. The first one is paranoid schizophrenia, if the person experiences delusions and hallucinations. Disorganized schizophrenia occurs if the patient manifests negative symptoms and disorganized thinking and speaking and also shows delusion or hallucination. Undifferentiated schizophrenia

arises when the person reveals general symptoms of schizophrenia without any dominant symptom. The catatonic type of schizophrenia takes place when the patient displays grossly disorganized or abnormal motor behavior including catatonia. And the last type is residual schizophrenia which occurs when the patient suffers from all symptoms with a negative symptom as the dominant one. Acute psychotic episodes can be prevented provided the symptoms are detected early and psychiatrist administers treatment according to symptoms.

The psychiatrist can be assisted during the therapeutic session by a computer program like ELIZA and PARRY [8–10]. Both ELIZA and PARRY simulated the conversation between the psychiatrist and patient. ELIZA was developed by Joseph Weizenbaum using pattern matching techniques and played as a psychiatrist to response the patient. In turn, PARRY, created by Kenneth Colby, attempted to simulate a person exhibiting paranoid schizophrenia. Both of ELIZA and PARRY could simulate a client-centered therapy, where computer acted as a psychiatrist to gather the patient data during a therapeutic session. However, they were early natural language processing computer programs and their usefulness was limited.

Nowadays, expert systems (ES) are the class of software capable of helping psychiatrists in diagnosing mental disorders [11–13]. Some ES are designed specifically to support detecting schizophrenia symptoms [14–16]. Much attention has been also paid to clinical decision support in diagnosing schizophrenia based on the analysis of EEG signals of schizophrenic patients [17–19]. The other computer-aided diagnosis methods for schizophrenia encompass the analysis of abnormalities in brain activation patterns using functional magnetic resonance imaging (fMRI) [20–22].

An expert system designed to assist the psychiatrist with diagnosing early schizophrenia symptoms is presented in the paper. The system represents psychiatrist's knowledge in the form of rules, facts and events. The system holds a dialogue with a patient and while gathering the answers from the patient it uses the forward chaining method to evaluate the rules. Next, all answers are transformed into facts and processed using Boolean reasoning to generate the diagnosis.
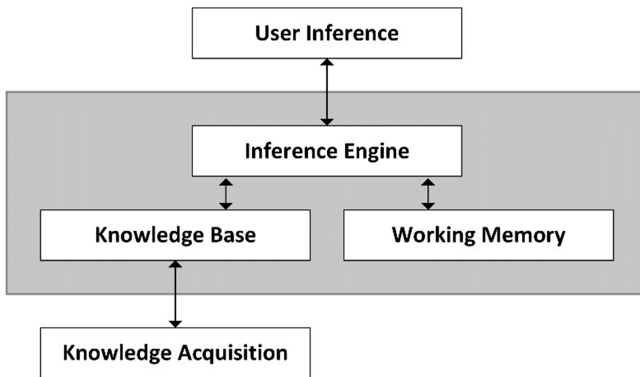

Fig. 2. General architecture of the proposed expert system

2   Structure of the Proposed Expert System

Expert systems (ES) are part artificial intelligence and constitute a class of computer programs which simulate human reasoning to resolve complicated decision-making problems [23, 24]. ES performs reasoning over a representation of human knowledge rather than through conventional procedural code. The aim of ES is to replace or aid a human expert in accomplishing complex tasks, such as diagnosing diseases or equipment faults, making financial or weather forecasts, and scheduling vehicle routes or robotic actions.

General architecture of proposed ES to aid in schizophrenia diagnosis is depicted in Fig. 2. The system comprises five main components: knowledge acquisition, knowledge base, user interface, working memory, and inference engine. The knowledge acquisition consists in acquiring information on schizophrenia symptoms, diagnosis and therapy from medical books and journals as well as the psychiatrist expertise and transforming it into rules which are stored in the knowledge base. The knowledge base is composed of 48 rules which are converted into questions presented to the user during a session. The user interface controls the dialog between ES and the user. It displays a series of questions and reads the user's responses into the working memory. The working memory is utilized as a storage of data entered by the user and results provided by the inference engine. The inference engine imitates human reasoning and based on the user's responses and knowledge base generates the conclusion whether the patient suffers from schizophrenia. Moreover, it determines the type of schizophrenia if this is the case. The engine employs the forward chaining technique to deduce its diagnosis [15]. Boolean reasoning is used while mapping rules and facts. The inference engine divides rules into five main categories as shown in Fig. 1, namely delusion, hallucination, negative symptoms, disorganized thinking and speech, and grossly disorganized or abnormal motor behavior. Next, the engine checks the patient's symptoms to generate the type of schizophrenia. There are five types of schizophrenia, namely paranoid, disorganized, undifferentiated, catatonic, and residual schizophrenia, as illustrated in Fig. 1. ES generates and displays its diagnosis to the end user through the user interface after all rules are examined.

ES applies the client-centered therapy in the form of a question-answer session. There are no dominant rules in this research. Inference engine employs a nominal scale for each patient's answer, i.e. each YES answer is denoted by 1 and NO answer is marked by 0. ES concludes that the patient suffers from a given symptom of schizophrenia if he/she answers at least one YES for symptom's questions. But according to schizophrenia diagnostic criteria the patient has one or all schizophrenia symptoms if he/she exhibits signs of schizophrenia for at least six months and this happens frequently. Therefore, ES asks also five supportive questions for each rule. The questions are as follows:

1. How long does he/she experience the symptom?
2. When did the symptom start?
3. When did the symptom last appear?
4. How often does the symptom occur?
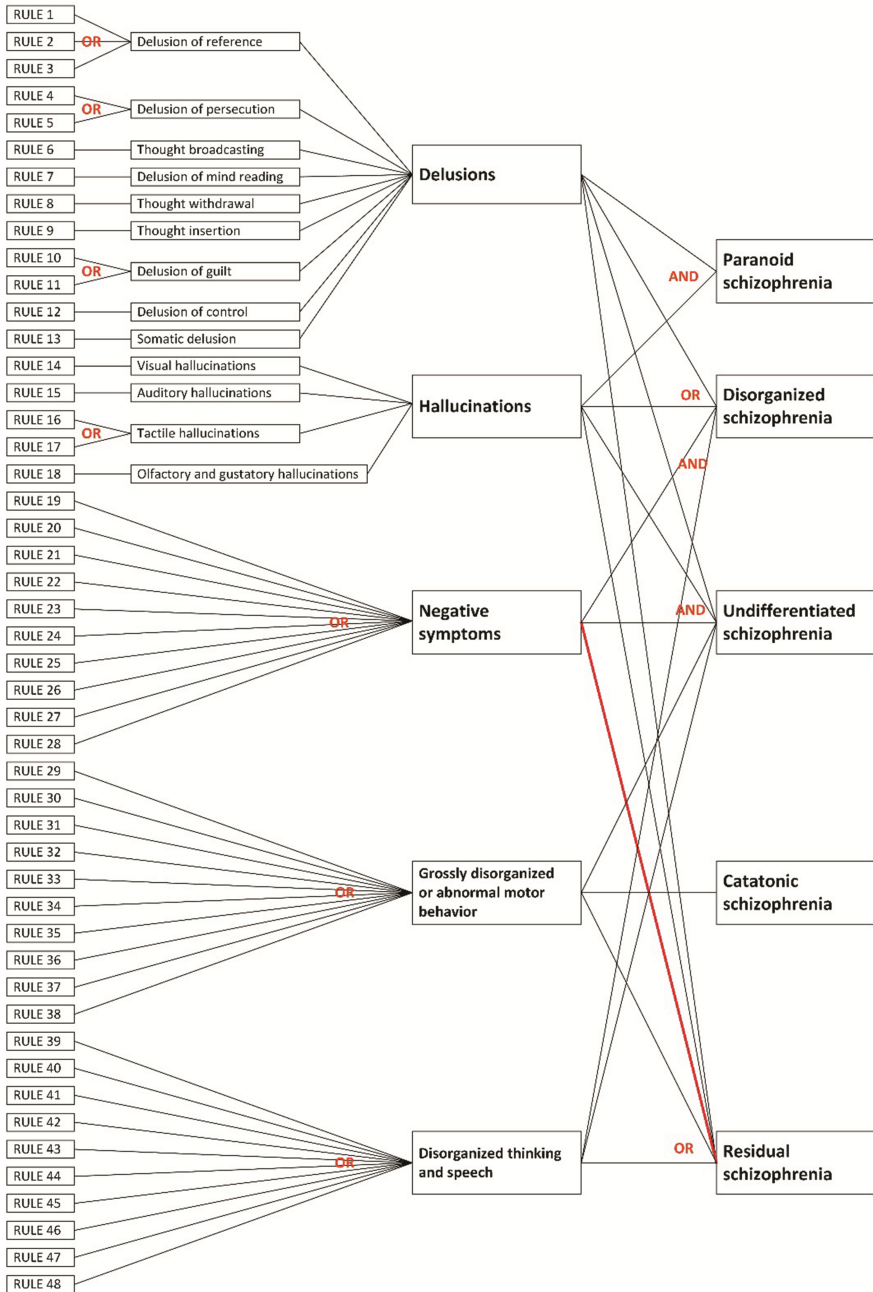5. How and what does he/she feel while exhibiting the symptoms?

Fig. 3. Map of expert system rules

The ES rules are divided into five categories corresponding to the five main symptoms of schizophrenia, as shown in Fig. 3. The first category, delusion, has nine subcategories. Each subcategory of delusion is evaluated as depicted in Fig. 4. Delusion of reference contains three rules: RULE 1, RULE 2, and RULE 3. If at least one of the three rules is fired then the signs of delusion of reference are proved. Delusion of persecution comprises two rules: RULE 4 and RULE 5. At least one of the two rules should be satisfied to prove the symptoms of delusion of persecution. Thought broadcasting, delusion of mind reading, thought withdrawal, and thought insertion consist of RULE 6, RULE 7, RULE 8, and RULE 9, respectively. In turn, delusion of guilt embraces two rules: RULE 10 and RULE 11. At least one of the two rules should be fired to prove the symptoms of delusion of guilt. And finally, delusion of control and somatic delusion include RULE 12 and RULE 13, respectively. A patient suffers from delusion, if he/she satisfies at least one of the aforementioned rules.
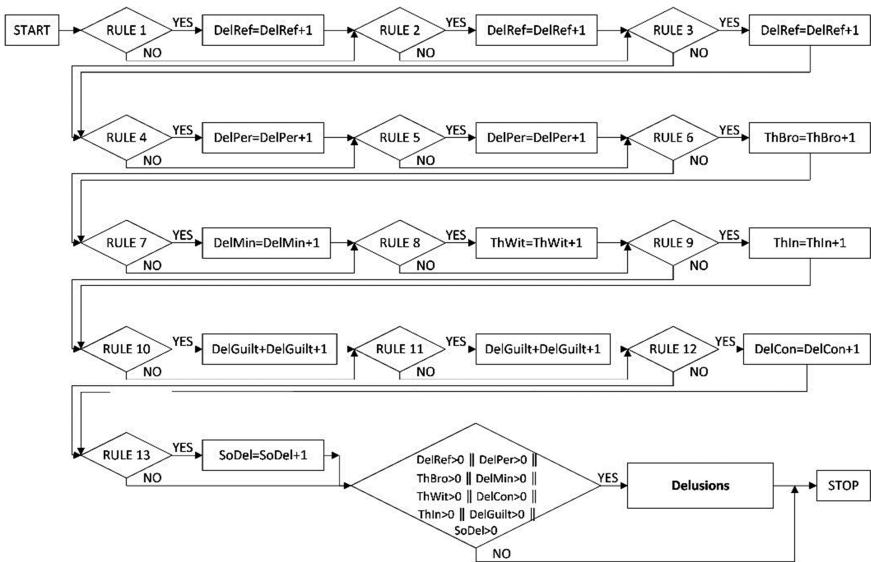

Fig. 4. Evaluation of the delusion symptoms

The evaluation of the second category, hallucination symptoms, is illustrated in Fig. 5. This category has five main rules and four subcategories. Visual hallucinations and auditory hallucinations contain RULE 14 and RULE 15, respectively. In turn, tactile hallucinations comprise two rules: RULE 16 and RULE 17. If at least one of the two rules is fired then the signs of tactile hallucinations are proved. And finally, olfactory and gustatory hallucinations consist of RULE 18. Appraisal of this hallucination symptoms is almost the same as in the case of delusion. A patient suffers from hallucination, if he/she satisfies at least one of the aforementioned rules.
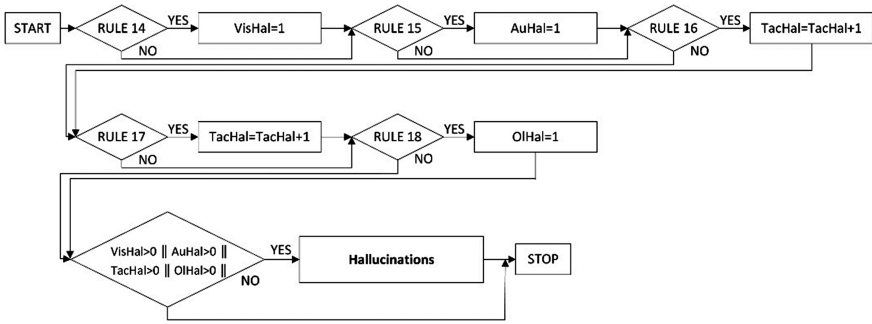
Fig. 5. Evaluation of the hallucination symptoms

The assessment of the third category, grossly disorganized or abnormal motor behavior including catatonia, is presented in Fig. 6. This category comprises ten rules that need to be verified together with the five supportive questions. If all the rules and supportive questions are satisfied, the patient is identified to exhibit grossly disorganized or abnormal motor behavior.
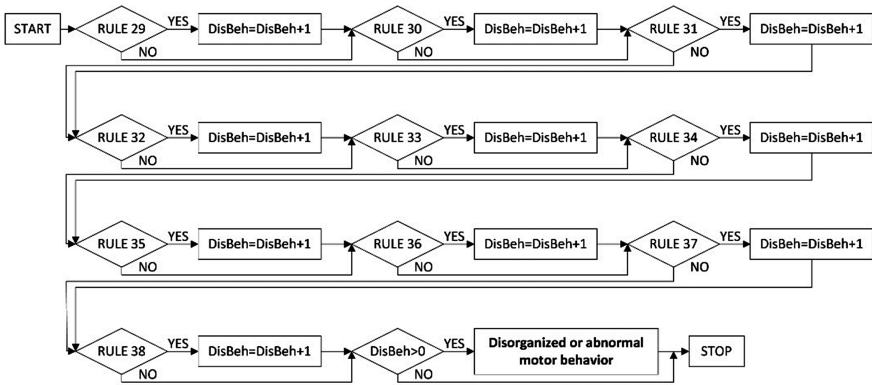

Fig. 6. Evaluation of the grossly disorganized or abnormal motor behavior

The fourth category, disorganized thinking and speech, embraces ten rules. Its evaluation procedure is shown in Fig. 7. Similarly to the three preceding symptoms, this category also contains supportive questions for each rule to verify whether the patient shows the symptom. The last category, negative symptoms, also has ten rules. Evaluation of this category is almost the same as in the case of the other symptoms (see Fig. 8).
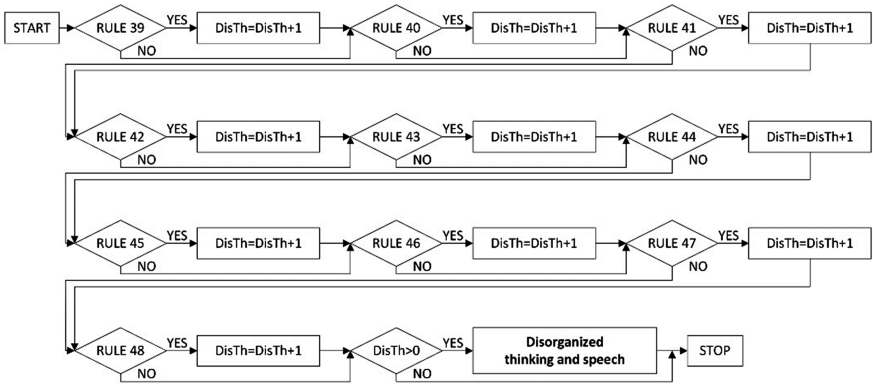
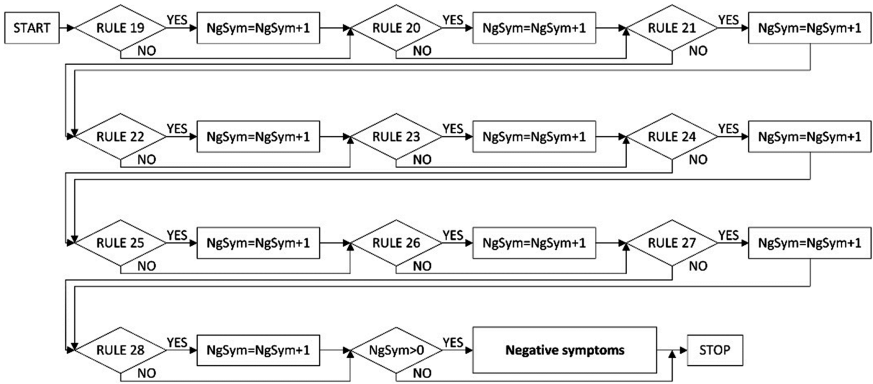**Fig. 7.** Evaluation of disorganized thinking and speech

Fig. 8. Evaluation of negative symptoms

3   Results and Discussion

All rules embedded in the knowledge base have equal weights. Boolean reasoning was used to generate the result during this research. Each question connected with a given rule must be answered either YES or NO. Five additional questions about the symptoms have to be answered to support each rule with YES response. These questions ask how long a given symptom recurs, how often the symptom occurs, when it starts, when the symptom last appeared, and how he/she feels when the symptoms appears. The questions strengthen the diagnosis because the patient is recognized to suffer from schizophrenia if he/she has the symptoms at least six months and the symptoms appear frequently during this period. If the patient satisfies a given rule and the criteria expressed by supportive questions are met, then ES adds to the conclusions that he/she exhibits the rule's symptom. ES generates the result through following steps:

1. A rule with YES answer is saved in the working memory.
2. Check whether the answer for supportive questions meets the criteria.
3. Determine a sub symptom according to (1) and (2).
4. Determine the symptom according to (3).
5. Determine the schizophrenia type according to (4).

ES shows the type of schizophrenia with supported facts in conclusion. The first one is the paranoid type of schizophrenia. This type is diagnosed when at least one symptom of delusions or hallucinations is recognized. The second type, disorganized schizophrenia, is determined if at least one sign of disorganized thinking and speech and negative symptoms is distinguished, but also if at least one of delusion or hallucination rules is satisfied. The third type, catatonic schizophrenia, is indicated if at least one rule of disorganized or abnormal motor behavior is fulfilled. The forth type, undifferentiated schizophrenia, is diagnosed if at least one rule for each symptom is met, but there is no dominant symptom. The last type, residual schizophrenia, is identified if at least one negative symptom is dominant and at least one positive sign (of delusions or hallucinations) is exhibited.

ES diagnoses whether a patient suffers from schizophrenia if he/she meets criteria depicted in Figs. 3, 4, 5, 6, 7 and 8, where each symptom has at least six month episode's period. ES processes the patient's answers and maps them into five schizophrenia types (Figs. 1 and 3). For example:

1. Patient answered YES to the questions connected with the 6th and 15th rules.
2. ES analyzed the answers to supportive questions.
3. ES determined that the patient exhibits the delusion of percussion and auditory hallucination sub symptoms.
4. From these sub symptoms ES concludes that the patient has delusion and hallucination symptoms.
5. ES performs mapping as in Figs. 3, 4 and 5 and formulated the diagnosis that the patient suffers from the paranoid type of schizophrenia.

Due to limitations of this ES it is necessary that the parents or guardians also answer a number of questions. They should answer all questions connected with disorganized behavior and negative symptoms. They should answer to a number of questions to verify some patient's responses particularly those related with the period of an episode, date of the last episode and frequency pattern.

ES shows only the diagnosis if the patient suffers from schizophrenia and what type of schizophrenia he/she has. The system does not handle the action to be taken, the psychiatrist may use results provided by ES as hints about therapy. According to [1, 2, 26] there are several actions to be taken. Antipsychotic medications are used for positive symptoms, antidepressant are applied for depression symptoms, glycine supplements are administered for negative symptoms, omega-3 fatty acids help to reduce negative and positive symptoms, as well as antioxidants. Patients in severe conditions need to be quarantined to prevent their unwanted actions. Psychotherapy can be used to educate patients how they can deal with their conditions and socialize.

4   Conclusions and Future Work

The expert system presented in the paper can diagnose schizophrenia according to the medical diagnostic criteria and the psychiatrist's expertise. The expert system helps the psychiatrist in early detection of schizophrenia. The system generates the diagnosis based on the patient's responses to a series of questions representing the knowledge-base. It shows supported facts but does not propose the action to be done. The psychiatrist should administer the treatment according to the result provided by the expert system.

Future research is needed to introduce dominant rules and evaluate them to optimize the diagnosis process. The user interface should be designed based on Human Computer Interaction (HCI) principles adapted especially to schizophrenia needs. The new interface could optimize the process of gathering data from patients as well as improve the usability of the system and increase user's satisfaction. Voice recognition is also needed to automate the client-centered therapy especially in voice analysis. The noise emitted by the patient while mumbling or talking to himself cannot be heard by humans. According to psychiatrist expertise such a noise might be the symptom of delusion or hallucination. The psychiatrists also suggest to implement gesture recognition to analyze mood, true answers, and disorganized behavior during the client-centered therapy. The user interface can be also equipped with natural language processing to analyze the answers to the five supportive questions. Machine learning methods could be also employed to evaluate the stage of schizophrenia to help the psychiatrist to take the right treatment.

References

1. Diagnostic and Statistical Manual of Mental Disorders: DSM-5 (5th edn.). American Psychiatric Association, Arlington (2013)
2. Sue, D., Sue, D.W., Sue, D.M., Sue, S.: Understanding Abnormal Behavior, 11th edn. Wadsworth Publishing, Belmont (2015)
3. Sadner, G.: Schizophrenia: a cognitive science viewpoint. In: Almann, K.V. (ed.) Schizophrenia Research Trends, pp. 55–93. Nova Science Publishers, New York (2008)
4. Depkes RI. Lighting the Hope for Schizoprenia Warnai Peringatan Hari Kesehatan Jiwa tahun 2014. http://www.depkes.go.id/article/view/201410270010/lighting-the-hope-forschizoprenia-warnai-peringatan-hari-kesehatan-jiwa-tahun-2014.html. Accessed 28 Oct 2016
5. Gendlin, E.T.: Client-centered developments and work with schizophrenics. J. Couns. Psychol. **9**(3), 205–212 (1962)
6. van Blarikom, J.: A person-centered approach to schizophrenia. Person-Centered and Experiential Psychotherapies **5**(4), 155–173 (2006)
7. Rogers, C.R.: Significant aspects of client-centered therapy. Am. Psychol. **1**(10), 415–422 (1946)
8. Weizenbaum, J.: ELIZA - a computer program for the study of natural language communication between man and machine. Commun. ACM **9**(1), 36–45 (1966)
9. Shah, H., Warwick, K., Vallverdú, J., Wu, D.: Can machines talk? Comparison of Eliza with modern dialogue systems. Comput. Hum. Behav. **58**, 278–295 (2016)

10. Güzeldere, G., Franchi, S.: Dialogues with colorful personalities of early AI. Stanford Humanities Review, SEHR 4:2, Constructions of the Mind (1995) http://web.stanford.edu/group/SHR/4–2/text/dialogues.html
11. Yap, R.H., Clarke, D.M.: An expert system for psychiatric diagnosis using the DSM-III-R, DSM-IV and ICD-10 classifications. In: Proceedings of the AMIA Annual Fall Symposium, pp. 229–233 (1996)
12. Yankovskaya, A., Kitler, S.: Mental disorder diagnostic system based on logical-combinatorial methods of pattern recognition. Comput. Sci. J. Moldova **21**(3), 391–400 (2013)
13. Singh, S.: A fuzzy rule based expert system to diagnostic the mental illness (MIDExS). Int. J. Innovative Res. Comput. Commun. Eng. **3**(9), 8759–8764 (2015)
14. Razzouk, D., Mari, J.J., Shirakawa, I., Wainer, J., Sigulem, D.: Decision support system for the diagnosis of schizophrenia disorders. Braz. J. Med. Biol. Res. **39**(1), 119–128 (2006)
15. Singh, P.K., Sarkar, R.: A simple and effective expert system for schizophrenia detection. Int. J. Intell. Syst. Technol. Appl. **14**(1), 27–49 (2015)
16. Nunes, L.C., Pinheiro, P.R., Cavalcante, T.P., Pinheiro, M.C.D.: Handling diagnosis of schizophrenia by a hybrid method. Comput. Math. Methods Med. Article Id 987298 (2015) http://doi.org/10.1155/2015/987298
17. Sabeti, M., Katebi, S.D., Boostani, R., Price, G.W.: A new approach for EEG signal classification of schizophrenic and control participants. Expert Syst. Appl. **38**(3), 2063–2071 (2011)
18. Hiesh, M.H., et al.: Classification of schizophrenia using genetic algorithm-support vector machine (ga-svm). In: 5th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC). IEEE, pp. 6047–6050 (2013). doi:10.1109/EMBC.2013.6610931
19. Elgohary, M.I., Alzohairy, T.A., Eissa, A.M., Eldeghaidy, S., Hussein, M.: An intelligent system for diagnosing schizophrenia and bipolar disorder based on MLNN and RBF. Int. J. Sci. Res. Sci. Eng. Technol. **2**(4), 117–123 (2016)
20. Rashid, B., Damaraju, E., Pearlson, G.D., Calhoun, V.D.: Dynamic connectivity states estimated from resting fMRI identify differences among schizophrenia, bipolar disorder, and healthy control subjects. Front. Human Neurosci. **8**, 897 (2014). doi:10.3389/fnhum.2014.00897
21. Juneja, A., Rana, B., Agrawal, R.K.: A combination of singular value decomposition and multivariate feature selection method for diagnosis of schizophrenia using fMRI. Biomed. Signal Process. Control **27**, 122–133 (2016)
22. Varshney, A., Prakash, C., Mittal, N., Singh, P.: A multimodel approach for schizophrenia diagnosis using fMRI and sMRI dataset. Intelligent Systems Technologies and Applications 2016. AISC, vol. 530, pp. 869–877. Springer, Heidelberg (2016). doi:10.1007/978-3-319-47952-1_69
23. Lucas, P., Van Der Gaag, L.: Principles of Expert Systems (International Computer Science Series). Addison-Wesley, Boston (1991)
24. Giarratano, J.C., Riley, G.D.: Expert Systems: Principles and Programming, 4th edn. Course Technology, Boston (2004)
25. Gupta, S., Singhal, R.: Fundamentals and characteristics of an expert system. Int. J. Recent Innov. Trends Comput. Commun. **1**(3), 110–113 (2013)
26. Lehman, A.F., et al.: Practice guideline for the treatment of patients with schizophrenia. Am. J. Psychiatry **161**, 1–56 (2004). Second edition