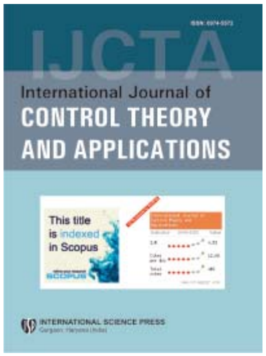

International Journal of Control Theory and Applications

ISSN : 0974–5572

Volume 10 • Number 23 • 2017

Prediction of Mental Health Problems Among Children using Fuzzy Clustered Bayesian Model

Sumathi M.R.[a] and Poorna B.[b]

[a]*Research Scholar, Department of Computer Science, Bharathiar University, Coimbatore, India.*

E-mail: sumathikuben@yahoo.co.in

[b]*Principal, Shri Shankarlal Sundarbai Shasun Jain College for Women, Chennai, India.*

E-mail: poornasundar@yahoo.com

Abstract : According to World Health Organization, 10-20% of children and adolescents all over the world are experiencing mental disorders. These disorders have become the leading cause of disability in young people. However, correct diagnosis of mental disorders at an early stage improves the quality of life of children and avoids complicated problems at later stage. Various expert systems have already been developed for diagnosing mental disorders like Schizophrenia, Depression, Dementia, etc. This study focuses on predicting basic mental health problems, like Attention and Academic problem, Anxiety Symptoms, Developmental delay, Attention Deficit Hyperactivity Disorder, Pervasive Developmental Disorder using machine learning techniques, Bayesian Networks and Fuzzy clustering. The Bayesian Network structure learning from data is a challenging task and hence a new model has been proposed. The proposed model uses Fuzzy logic, Clustering and Bayesian techniques. The model has been experimented with prediction of basic mental health problems among children and with the UCI dataset for predicting Breast cancer. The performance of the Bayesian network constructed with the proposed model was compared with the general Bayesian Network Structure Learning algorithms and the experimental results have shown that the proposed model performs better than the earlier algorithms.

Keywords: *Fuzzy Clustering, Bayesian Network, Structure Learning, Prediction.*

1. INTRODUCTION

Mental Health Problems (MHP) has become one of the main causes of the burden of disease worldwide and it often starts at an early age and may destroy lives, with an impact on families, colleagues and communities. Depressive disorders will become the second leading cause of the global disease burden by 2020 [1]. There are strong links between physical and mental health problems. If untreated, these problems severely affect children's development, their educational attainments and their potential to live fulfilling and productive lives. The best way to deal with a crisis is to prevent it from happening in the first place. Hence, in this study an expert system is developed to help the psychologists in predicting the basic MHP that has affected the children and treat them at an early stage.

Expert system (ES) is a branch of Artificial Intelligence that works within a particular domain. These are designed to provide expert quality performance on domain specific problems. Mental Health Diagnostic Expert Systems mimic the role of a psychologist with a view to diagnose the MHP. Various Machine Learning techniques are available to develop expert systems. Bayesian Networks is a popular machine learning technique which is widely used in expert systems for predicting diseases.

Bayesian networks (BN), a graphical model representing probabilistic relationship among random variables, have been successfully applied in many domains like medical diagnosis, hardware troubleshooting, etc. The BN model was considered as it is well suited for representing uncertainty and causality. It consists of two components, a network structure in the form of a Directed Acyclic Graph (DAG) and a set of Conditional Probability Distributions (CPD), one for each variable characterising the dependencies between the variables. BNs have been used in predicting various mental disorders like schizophrenia, depression, psychosis, etc. This study concentrates on predicting the basic mental health problems that affect children, viz. Attention problem, Academic Problem, Anxiety Problem, Attention Deficit Hyperactivity Disorder and Pervasive Developmental Disorder. Fig.1 shows a simple Bayesian Network. If there is a directed edge in a DAG from node Y to node Z, Y is said to be a parent of Z and Z is called a child of Y. The presence of an edge connecting two nodes implies that these two variables are dependent. The absence of an edge between any two nodes implies that these two variables are independent given the values of any intermediate nodes.

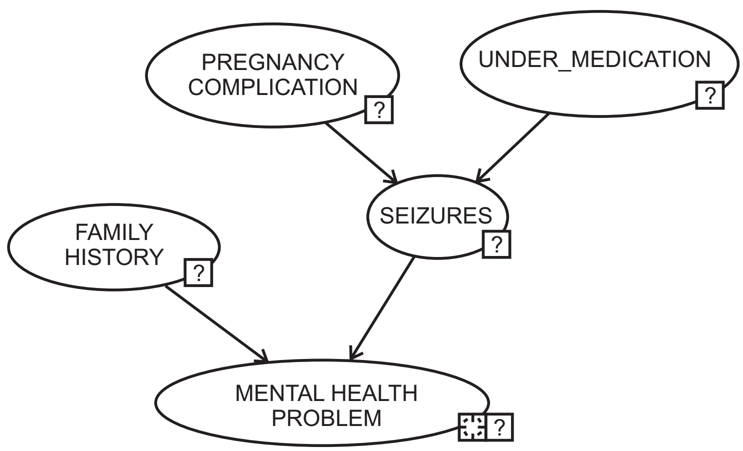

Figure 1: Simple Bayesian Network

A simple Bayesian Network is shown in Figure 1 with 5 nodes and 4 arcs. The nodes *Pregnancy_ Complication* and *Under_Medication* are parents of node *Seizures*. The arcs show that there is a direct relationship between Pregnancy_Complication and Seizures, while there is an indirect relationship between Pregnancy_complication and Mental_Health_Problem. Learning a BN refers to data based inference of either the conditional probability parameters for a given structure or the underlying graphical structure itself. We focus here on the process of structural learning, to discover the relations between various variables and predict the mental health problem.BN structures are being learnt using the score-based and the constraint-based methods. The score-based methods along with a search strategy find a structure with optimal score. More importance is given for the search strategy and the scoring function. Various scores *viz*., Log-likelihood, Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Bayesian Dirichlet Score (BDE), etc. are available for Bayesian Networks. The constraint-based methods infer structures through conditional independency tests. The constraint-based methods are generally faster than the score-based methods and give a trustworthy result when sufficient data are provided. In this paper, we propose a model that considers the advantages of both the methods.

Clustering involves assigning data points to clusters such that the items in the same cluster are as similar as possible, while items belonging to different clusters are as dissimilar as possible. Broadly, clustering can be divided into two namely, Non-Fuzzy clustering and Fuzzy clustering. Non-fuzzy clustering divides data into distinct clusters and each data point can only belong to exactly one cluster. Fuzzy clustering is a form of clustering in which each data point can belong to more than one cluster. Fuzzy clustering algorithm attempts to partition a finite collection of '*n*' elements of X = $\{x_1, x_2, \ldots\ldots x_n\}$ into a collection of '*c*' fuzzy clusters with respect to some given criterion. The algorithm returns a partition matrix W = $w_{i,j}$ belongs to [0,1], I = 1, 2, …., *n*, and *j* = 1, 2, …. *c*, where each element $w_{i,j}$, tells the degree to which element x_i, belongs to cluster c_j. Fuzzy *c*-means algorithm, proposed by Dunn (1973) and later improved by Bezdek (1981), is an extension of K-means where each data point can be a member of multiple clusters with a membership value.

In this paper, an attempt has been made to develop a Fuzzy Clustered Bayesian model that predicts basic MHPs which affect children. Fuzzy clustering has been used to cluster the random variables based on mutual information between them. The clustered variables are then combined to learn smaller BNs. After generating BNs for all clusters, they are combined to form a complete network for prediction. This paper differs from other papers as the fuzzy clustering has been performed on the mutual information among the variables rather than on the dataset. The main focus of the research is to construct the model and compare its performance with the conventional models. It also analyses whether the model constructed shows the causal effect relationship as shown in the expert knowledge based Bayesian Network.

This model reduces the search space as a few variables are involved in each cluster. We conducted an experiment with the proposed method on UCI Dataset to predict Breast Cancer. Then, we conducted an experiment with the proposed model to predict the basic mental health problems among children and compared with predictive accuracies of other algorithms. The empirical results show that the Fuzzy Clustered Bayesian model achieves good performance in prediction.

The paper has been organized as follows. Section 2 details on the related work in predicting MHPs using BNs. Section 3 discusses on the dataset and the methodology of the study. The proposed model has been detailed in Section 4. Section 5 presents a brief on the results and evaluation. Section 6 concludes and suggests on future work that can be done on the study.

2. RELATED WORK

The research on applying machine learning techniques in mental health diagnosis has started in nineteen eighties. A number of expert systems and decision support systems have been developed for diagnosing mental disorders. A literature review on diagnosis of mental disorders and techniques used in diagnosis have been given in table 1.

Table 1
Literature Review on Mental Disorder diagnosis using Artificial Intelligence Techniques

Ref. No.	*Diagnosis*	*Techniques used*
[2]	DSM-IV Axis-I Disorders	Decision Tree
[3]	DSM-IV Axis-II Personality Disorders	Structured clinical Interview
[4]	Mental Disorders	Constraint Based Reasoning
[5]	Depression	Feature Selection Algorithms (OneR, SVM, Information Gain, ReliefF)
[7]	Diagnosis and suggestion of t reatment plans	Rule based Reasoning, Fuzzy Logic, Fuzzy Genetic Algorithm

Ref. No.	*Diagnosis*	*Techniques used*
[8]	Analytic Review of Artificial Intelligence in Psychological practice	Artificial Intelligence Techniques
[9]	Schizophrenia	Graphical Approach
[10]	Adult Depression	Neuro-Fuzzy Techniques
[11]	Schizophrenia	Production Rules and Probabilities
[12]	Depression or Dementia	Depth First Search using Backward Strategy
[14]	Parkinson's Disease	Artificial Neural Network, Support Vector Machine
[15]	Mental Disorder Classification	Attribute Extension Approach
[16]	Dementia, Alzheimer and Mild Cognitive Impairment	Bayesian Networks
[17]	Parkinson's Disease	MultiLayer Perceptron with Back Propagation Learning
[18]	Genome-wide Classification of Mental Disorders	Bayesian Networks, Support Vector Machines, Logistic Regression, Random Forest, Radial Basis Framework, Polygenic Scoring Approach
[19]	Anxiety, Behavioral Disorders, Depression, Post Traumatic Stress Disorders	Neural Networks
[20]	Parkinson's and Primary Tumour Diseases	Artificial neural Network, Decision Tree and Naïve Bayes

The literature review shows that, a number of research works are going on in computerizing the diagnosis of mental health disorders and efforts are also taken to diagnose the mental health problems using different machine learning techniques in an efficient way. Various combinations of machine learning techniques (Hybrid techniques) are being employed to improve the accuracy of diagnosis with reduced set of features from profiles of patients. This research is to propose a Fuzzy Clustered Bayesian model for predicting the possibility of primary mental health problems like Attention Problems, Anxiety Symptoms, Autism symptoms, Developmental Delay, Attention Deficit Hyperactivity Disorder and Pervasive Developmental Disorder. Early diagnosis of these types of problems among children allows early treatment and improves their quality of life.

3. MATERIALS AND METHODS

The dataset for the research was collected from a clinical psychologist. It consists of 110 children profiles in the form of word documents. From the documents, 25 attributes relevant for the research were identified and values of those attributes were stored. The attributes identified from the dataset are listed in Table 2. Pre-processing like identifying missing values and converting numeric values into nominal values, etc. were performed on the dataset. After pre-processing, 77 instances were obtained for training. Feature selection was performed using Best First Search technique to identify more relevant attributes and eliminate irrelevant and redundant attributes. The attributes selected after applying feature selection algorithm are shown in bold in Table 2. On discussion with the psychologist and based on expert knowledge, a Bayesian Network was constructed using GeNie tool and the parameters were learnt from the dataset. The model was validated with 2-fold cross-validation. This network is called the Expert Knowledge-based Bayesian Network (EKBN). The BN generated is shown in Figure 2(*a*). Using GeNie tool, a BN was generated automatically from data (DBN) (*i.e.*) without expert knowledge, and the generated network is shown in Figure 2(*b*). The predictive accuracies of EKBN and DBN are 48% and 58% respectively.

Table 2
Attributes identified from the documents

No.	*Attribute*	*Meaning*	*Values*
1.	Age_Group	Age group of the child, Infant / Early Childhood / Middle Childhood / Adolescent	{I, E, M, A}
2.	Family_History	Presence / Absence of psychological disorder in the family	{Y, N}
3.	Pregnancy_Complication	Presence / Absence of Complication during pregnancy	{Y, N}
4.	Delayed_Speech	Presence / Absence of delay in development of speech	{Y, N}
5.	Under_Medication	Whether the child is under any type of medicinal control	{Y, N}
6.	Academic_Performance	Whether the performance of the child is adequate/ inadequate in academics	{A, I}
7.	Relationship_Formation	Whether the child has adequate ability to socialize with peers, relatives and teachers	{A, I}
8.	Behavioral_Problem	Whether the child has any problem in behavior, Ex. Cheating, telling lies	{Y, N}
9.	Concentration	Whether the child has adequate ability to focus his attention on a particular object or activity	{A, I}
10.	Restless	Whether the child is able to relax or involving in constant activity	{Y, N}
11.	Seizures	Whether the child has a sudden surge of electrical activity in the brain which may cause unconsciousness, rigidness, muscle stiffness, uncontrollable movements, etc.	{Y, N}
12.	Learning_Difficulty	Whether the child has any difficulty in acquiring age appropriate knowledge and skills	{Y, N}
13.	Attention_Aroused	Whether the child is psychologically alert, awake and attentive	{Y, N}
14.	Attention_Sustained	Whether the child is able to direct and focus cognitive activity on specific stimuli	{Y, N}
15.	CBCL_Score	A checklist filled by teacher/parent/self-report to identify problem behavior in children	{BC, EC, AC}
16.	IQ_Test_Score	A standardized test to assess the intelligence level of the child. The level may be Below Average, Average, Above Average	{BA, A, AA}
17.	ADHD_Positive	Screening test score for Attention-Deficit/Hyperactivity Disorder	{Y, N}
18.	ODD_Positive	Screening test score for Oppositional Defiant Disorder to measure argumentative and defiant behavior of the child	{Y, N}
19.	Mani_ Episode_Test_Score	Screening test score for manic episode to check extreme elation or irritability in the mood of the child	{Y, N}
20.	General_Anxiety_Disorder	Screening test score to measure the anxious level of the child	{Y, N}
21.	Major_Depressive_ Episode	Screening test score to measure the major depression level of the child	{Y, N}
22.	CDI_Score	Screening test score to measure the depressive symptoms of the child	{AC, EC, BC}
23.	PDD_Score	Screening test score to measure the level of pervasive developmental disorder of the child	{MODERATE, NO, MILD}
24.	Autism_Score	Screening test score to identify whether the child has difficulty in communicating and forming relationships with other people and in using language and abstract concepts	{MODERATE, NO, MILD}
25.	Mental_Health_Problem	The classes attribute specifying the mental health problem of the child.	{ATT, ANX_ SYM, PDD, DEV_DELAY, AUT_SYMP, ADHD}

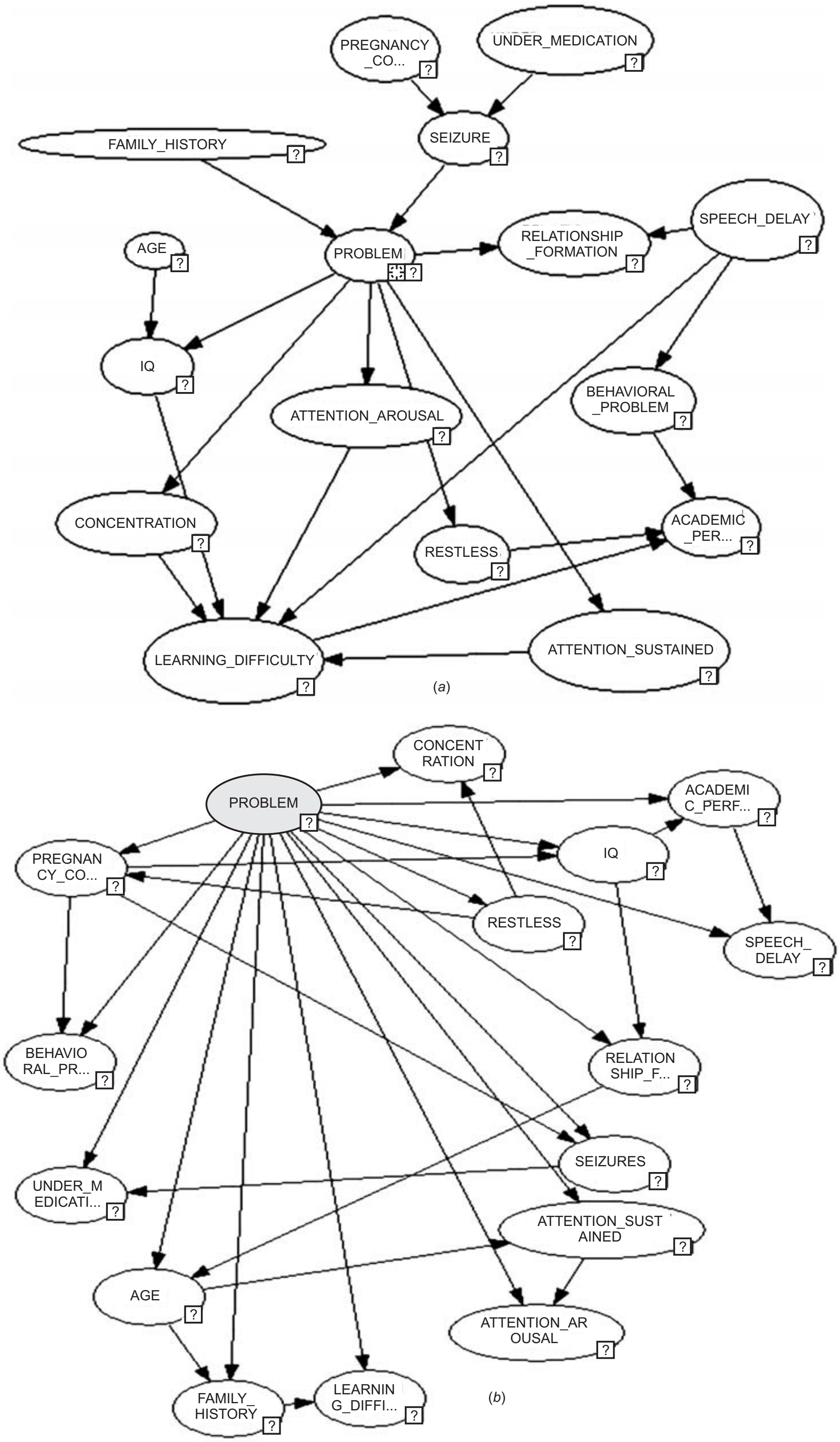

Figure 2: (*a*) Expert Knowledge based BN - EKBN (*b*) Data based BN - DBN

To improve the predictive accuracy of the BNs, Fuzzy Clustered Bayesian model is proposed. The model is detailed in Section 4. This model assists the professionals to diagnose the mental health problem effectively at an early stage, if the known evidences of the patient are given as input.

4. RESULTS AND DISCUSSION

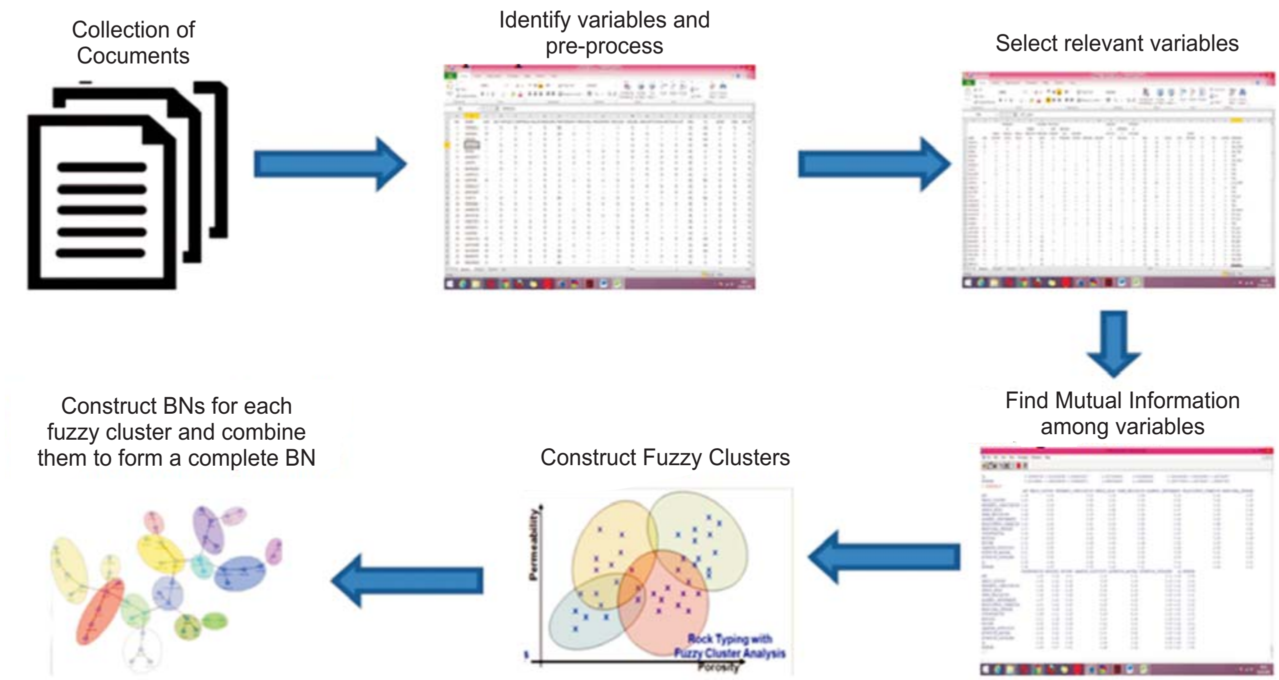

Figure 3: Fuzzy Clustered Bayesian Model

The proposed model was executed in six steps. As the first step, the required documents were collected from a clinical psychologist. Next, the documents have been pre-processed *i.e.* incomplete documents were removed, missing values were filled, numeric values have been categorized and stored in MS-EXCEL. Then, feature selection was performed on the dataset and the relevant features and their values were extracted. As the fourth step, find mutual information among variables using R tool and membership degree matrix is constructed for the attributes to the clusters. The more the attribute is near to the cluster centre, the better is its membership towards the particular cluster. Next, based on membership values, the attributes are assigned to various clusters. If the membership values of an attribute is equal in various clusters, then fuzzy clusters are generated. The cluster centres and membership values of the data points are updated through some iteration. Depending upon the fuzziness of the attributes, the clusters were combined and a complete BN was generated. Three Fuzzy Clustering methods, Fuzzy K-Means, Fuzzy K-Medoids, Fuzzy K-Means with Entropy Regularization were applied on the dataset and the results were compared. Two popular search techniques namely, Tabu search and Hill Climbing search and three score types namely, Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and Bayesian Dirichlet Score (BDE) were considered to generate the best BN. Different number of clusters were generated and their predictive accuracies are shown in Table 3.

The table 3 shows that the Fuzzy K-Means and Fuzzy K-Means with Entropy Regularization performed better than Fuzzy K-Medoids when Hill Climbing search was employed with BDE Score.

Table 3: Experimental Results of the Fuzzy Clustered Bayesian Model for Mental Health Problem dataset on various scores

Clustering Method	*Search Type*	*Score Type*	*Number of Clusters* 2	4	6
Fuzzy K-Means	Tabu	AIC	68	62	60
		BIC	65	61	56
		BDE	68	61	61
	Hill Climbing	AIC	57	66	61
		BIC	66	53	49
		BDE	**69**	48	58
Fuzzy K-Medoids	Tabu	AIC	56	45	66
		BIC	48	45	65
		BDE	58	45	65
	Hill Climbing	AIC	45	60	66
		BIC	53	66	65
		BDE	53	52	65
Fuzzy K-Means with Entropy Regularization	Tabu	AIC	68	61	66
		BIC	65	57	64
		BDE	68	60	62
	Hill Climbing	AIC	57	61	64
		BIC	66	64	61
		BDE	**69**	60	64

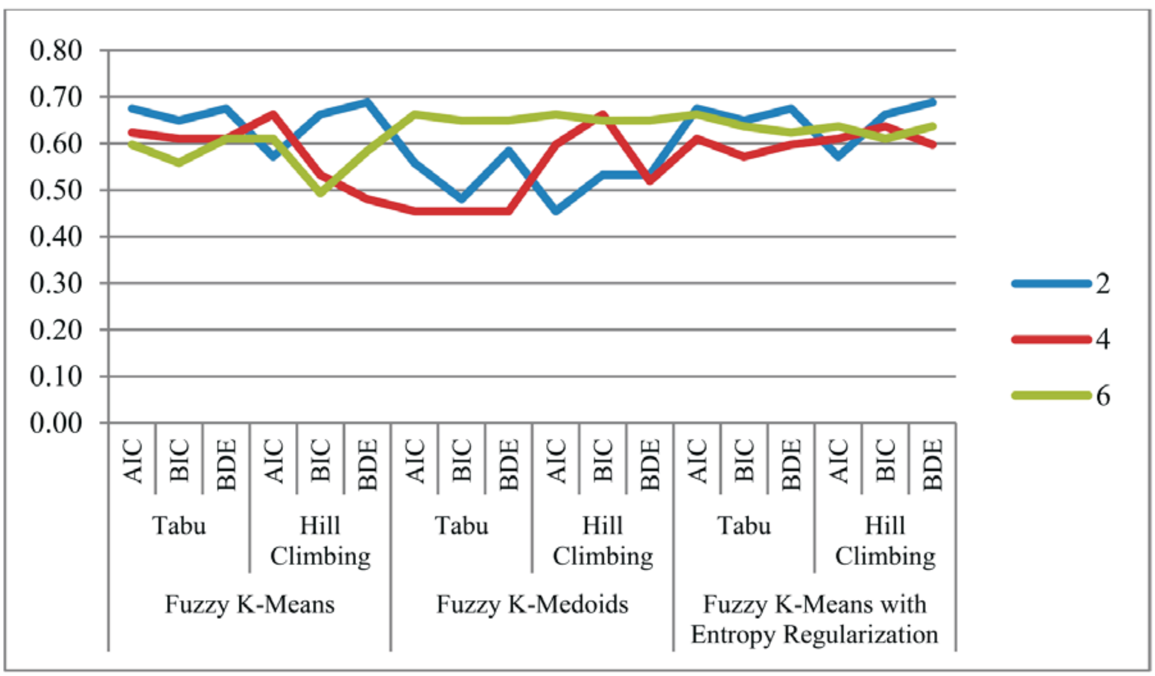

Figure 4: Comparison of Predictive Accuracy of Fuzzy Clustered Bayesian Model for predicting Mental Health Problems among Children

The pictorial comparison of the predictive accuracies of the three algorithms with two different strategies and three BN scores is shown in Figure 4. The graph shows that, when the number of clusters is less, the accuracy is more. And the Fuzzy K-Means and Fuzzy K-Means with Entropy Regularization algorithm performed better than the Fuzzy K-Medoids algorithm. Hill climbing algorithm performed well in searching the Bayesian Networks with BDE Score.

The comparisons of predictive accuracies of EKBN, DBN and Fuzzy Clustered Bayesian model based BNs shows that the latter one is more accurate than the others. Table 4 and Figure 5 show the high predictive accuracies of Fuzzy Clustered Bayesian model for predicting Breast Cancer using UCI dataset.

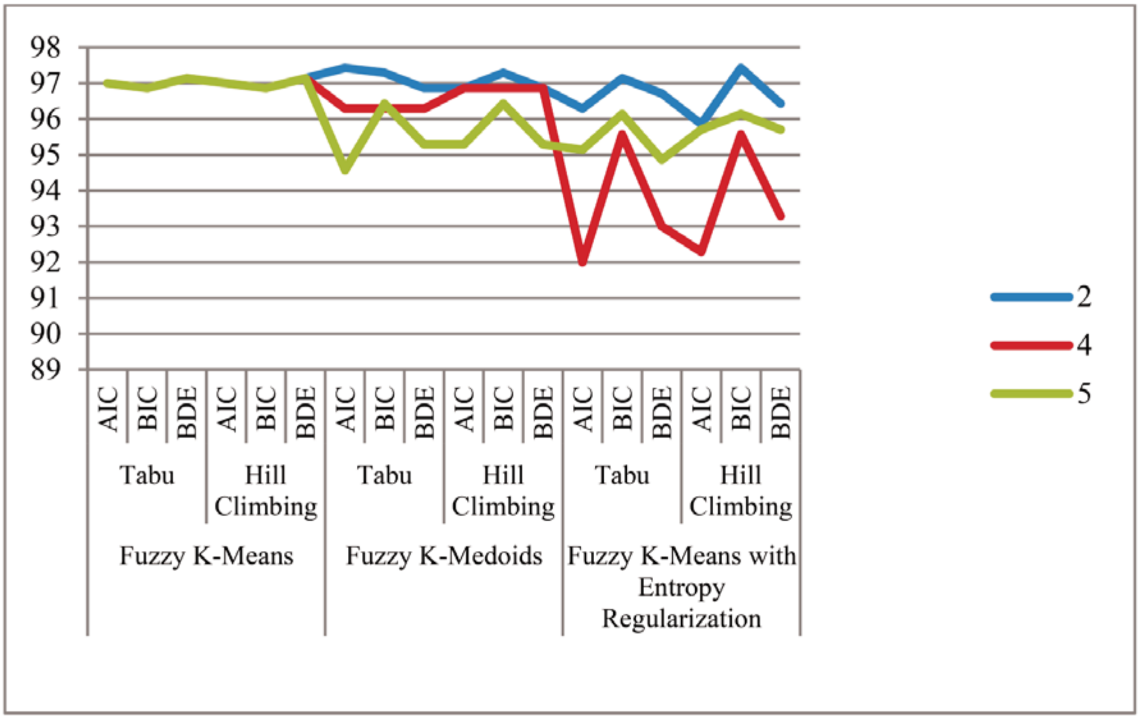

Figure 5: Comparison of Predictive Accuracy of Fuzzy Clustered Bayesian Model for predicting Breast Cancer

Table 4
Experimental Results of the Fuzzy Clustered Bayesian Model for Breast Cancer dataset on various scores

Clustering Method	*Search Type*	*Score Type*	*Number of Clusters* 2	4	5
Fuzzy K-Means	Tabu	AIC	97	97	97
		BIC	96.86	96.86	96.86
		BDE	97.14	97.14	97.14
	Hill Climbing	AIC	97	97	97
		BIC	96.86	96.86	96.86
		BDE	97.14	97.14	97.14

Clustering Method	*Search Type*	*Score Type*	*Number of Clusters*		
			2	*4*	*5*
Fuzzy K-Medoids	Tabu	AIC	**97.43**	96.29	94.57
		BIC	97.29	96.29	96.43
		BDE	96.86	96.29	95.29
	Hill Climbing	AIC	96.86	96.86	95.29
		BIC	97.29	96.86	96.43
		BDE	96.86	96.86	95.29
Fuzzy K-Means with Entropy Regularization	Tabu	AIC	96.29	92	95.14
		BIC	97.14	95.57	96.14
		BDE	96.71	93	94.86
	Hill Climbing	AIC	95.86	92.29	95.71
		BIC	**97.43**	95.57	96.14
		BDE	96.43	93.29	95.71

5. CONCLUSION

This study proposed a Fuzzy Clustered Bayesian Model to diagnose the basic mental health problems of children effectively. Fuzzy clustering has been used to cluster the random variables based on mutual information between them. The clustered variables are then combined to learn smaller BNs. After generating BNs for all clusters, they are combined to form a complete network for prediction. An experimental analysis was performed over three algorithms, namely, Fuzzy K-Means, Fuzzy K-Medoids and Fuzzy K-Means with Entropy Regularization. Tabu Search and Hill Climbing Search techniques were employed to search the BNs on various scores like Akaike Information criterion, Bayesian Information Critierion and Bayesian Dirichlet Score. Fuzzy K-Means and Fuzzy K-means with Entropy Regularization with Hill Climbing and BDE Score performed well and the predictive accuracy are higher than others. The model was applied on the UCI dataset to predict Breast Cancer. The accuracy was high with all clustering methods, search types and various scores. In future, this model can be modified and the predictive accuracy can be improved by altering the parameters of the algorithms. The number of parameters can also be increased to increase predictive accuracy in diagnosing the basic mental health problems among children. Thus, the constructed Fuzzy Clustered Bayesian Model could be used to assist the mental health professionals for diagnosing the basic mental health problems among children at an early stage and helps them to live fulfilling and productive lives.

REFERENCES

[1] http://blogs.fortishealthcare.com/mental-health-india-wake-up-call/

[2] Buchanan BG, Shortliffe EH. Rule-based Expert Systems: The MYCIN Experiments of the Stanford Heuristic Programming Project. Addison-Wesley, Reading, MA, 1984.

[3] Miller AM, Pople HE, Myers JD. "INTERNIST-I, an experimental computer-based diagnostic consultant for general internal medicine", New England Journal of Medicine, 1982:307:468-476.

[4] Yap, R. H., & Clarke, D. M. (1996). An expert system for psychiatric diagnosis using the DSM-III-R, DSM-IV and ICD-10 classifications. Proceedings of the AMIA Annual Fall Symposium, 229–233.

[5] Kipli, Kuryati, Abbas Z. Kouzani, and Isredza Rahmi A. Hamid. “Investigating machine learning techniques for detection of depression using structural MRI volumetric features.” International journal of bioscience, biochemistry and bioinformatics 3.5 (2013): 444-448.

[6] Wolpert DH, Macready WG, David H, William G. No Free Lunch Theorems for Search. Technical Report SFI-TR-95-02-010 (Santa Fe Institute)1995[Reflist]

[7] Masri, R.Y.; Jani, H.M., “Employing artificial intelligence techniques in Mental Health Diagnostic Expert System,” in *Computer & Information Science (ICCIS), 2012 International Conference on* , vol.1, no., pp.495-499,12-14 June 2012 doi:1 1109/ICCISci.2012.6297296

[8] Luxton, David D. “Artificial intelligence in psychological practice: Current and future applications and implications.” *Professional Psychology: Research and Practice* 45.5 (2014): 332.

[9] Razzouk, D., Mari, J.J., Shirakawa, I., Wainer, J., & Sigulem, D.. (2006). Decision support system for the diagnosis of schizophrenia disorders. *Brazilian Journal of Medical and Biological Research*, *39*(1), 119-128.

[10] Chattopadhyay, S., Kaur, P., Rabhi, F., Acharya, U.R., 2011. An automated system to diagnose the severity of adult depression. In: Jana, D., Pal, P. (Ed.), Proceedings of Second International Conference on Emerging Applications of Information Technology (CSI EAIT-2011), IEEE Computer Society and Conference Publishing Services, Kolkata, India, pp. 121–124.

[11] Luciano Comin Nunes, Plácido Rogério Pinheiro, Tarcísio Pequeno Cavalcante, and Mirian Calíope Dantas Pinheiro, “Handling Diagnosis of Schizophrenia by a Hybrid Method,” Computational and Mathematical Methods in Medicine, vol. 2015, Article ID 987298, 13 pages, 2015. doi:1 1155/2015/987298

[12] Basavappa SR; Rao SL; Harish B; Shantala R Basavappa ; Shobini L Rao Department of Electronics & Communication, Manipal Institute of Technology, Manipal, India. Expert system for dementia / depression diagnosis. NIMHANS Journal. 1996 Apr; 14(2): 99-106

[13] Rahman, Rashedur M., and Farhana Afroz. “Comparison of various classification techniques using different data mining tools for diabetes diagnosis.” *Journal of Software Engineering and Applications* 6.03 (2013): 85.

[14] Gil, David, and M. A. G. N. U. S. Johnson. “Diagnosing parkinson by using artificial neural networks and support vector machines.” Global Journal of Computer Science and Technology 9.4 (2009): 63-71.

[15] Gomuła, Jerzy, Krzysztof Pancerz, and Jarosław Szkoła. “Classification of MMPI profiles of patients with mental disorders–experiments with attribute reduction and extension.” Rough Set and Knowledge Technology. Springer Berlin Heidelberg, 201 411-418.

[16] Seixas, Flávio Luiz, et al., “A Bayesian network decision model for supporting the diagnosis of dementia, Alzheimer′ s disease and mild cognitive impairment.” *Computers in biology and medicine* 51 (2014): 140-158.

[17] Khemphila, Anchana, and Veera Boonjing. “Parkinsons disease classification using neural network and feature selection.” *World Academy of Science, Engineering and Technology* 64 (2012): 15-18.

[18] Pirooznia, Mehdi, et al.. “Data mining approaches for genome-wide association of mood disorders.” *Psychiatric genetics* 22.2 (2012): 55.

[19] Dabek, Filip, and Jesus J. Caban. “A Neural Network Based Model for Predicting Psychological Conditions.” *Brain Informatics and Health*. Springer International Publishing, 2015. 252-261.

[20] Tawseef Ayoub Shaikh.,”A Prototype of Parkinson’s and primary tumor disease prediction using data mining techniques”, International Journal of Engineering Science Invention, vol 3,Issue:4.