

Meta Heuristic based Fuzzy Cognitive Map Approach to Support towards Early Prediction of Cognitive Disorders among Children (MEHECOM)

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Abstract

Background: The main objective of this paper is to focus on the early prediction of occurrence of cognitive disorders such as Autism, Dyslexia and Delirium among children. The common primary attributes are related to learning, social interaction, behaviour, understanding of objects and so on. Detecting this disorder at an early age is challenge lying among health care specialists, and researchers. **Methodology:** The proposed prediction method involves the modelling approach such as Meta Heuristic and Fuzzy Cognitive Map named as MEHECOM. **Findings:** The primary aim of MEHECOM model is to identify the disorders among children as an early measure and support towards early mechanism to alleviate from these disorders. The performance shows that MEHECOM predicts chances of dyslexia and autism disorders at an average of 65.22% compared to 48.7% of FEAST which adopts fuzzy cognitive map and 35.92% of decision tree approach. **Applications:** This MEHECOM model can be applied for the earlier prediction of all other cognitive disorders like amnesia, dementia etc.

Keywords: Cognitive Disorders, Early Prediction, Fuzzy Cognitive Map, Meta Heuristic Approach

1. Introduction

Autism and dyslexia are considered as pervasive developmental disorder of brain¹ whose symptoms can be expected to appear during the first three years of childhood. Though Delirium is considered as major brain disorder prevailing among elder citizens, currently survey reveals that this disorders is also found among children. Survey¹ shows that these disorders occur in approximately 15 out of every 100 births and it is five times prevalent in male child than compared to female child. Both autism and dyslexia do affect the processing power

of children alone with spatial integration, and organizing of information hence it significantly impacts the verbal communication, social interaction in open groups as well disables the functional skills.

Detailed research study shows that early predictions of cognitive disorders are primarily linked only with behavioural aspects of children, while their clinical reports or consecutive analytical test approaches are not much taken into consideration. Hence in order to design a deterministic approach for predicting learning dis-order among children affected with dyslexia and autism, the behavioural aspects of children, analytical/logical attitude,

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level of understanding, regular clinical data, and their regular behaviour in society are considered. MEHECOM research work focuses on two major objectives:

- To understand and identify the challenges behind cognitive disorders among children between 2 to 15 years.
- To predict chance of occurrence of cognitive disorders based on behavioural attitudes and ASD tests and support using learning mechanisms to treat children.

MEHECOM is designed as a risk analysis and prediction mapping methodologies being developed and validated using dataset obtained from standard organizations. The study reports on outbreaks, surveillance activities carried out by health aware organizations. These approaches are essential to enhance accuracy and sensitivity of early warning activities.

2. Background

Major research works towards prediction of cognitive disorder is related towards biological phenomenon, but later research works demand the need for machine learning support and intelligence approach. Theoretical and empirical contributions from clinical, genetic, neuroscientific, and animal studies have the potential to not only elucidate the causes of ASD, but also to identify mechanisms for early diagnosis and individualized interventions.

Researchers have sought rapid categorical assessments of ASD¹ although usually at the value of reduced sensitivity/specificity, or population sampling biased towards additionally severely impacted individuals¹⁰. Machine learning looks a viable possibility for accelerating these diagnostic efforts by identifying essential nosological components, eliminating redundancy but maintaining accuracy. Research studies have demonstrated the abnormalities in structure and function of dyslexic brains. This brain dysfunction manifests also by eye movements abnormally³ which is based on processing of the Videoculography (VOG) eye movement signals. High correlation between the neuronal activity and eye response, as well as linear dependence of eye movement on stimulus velocity, has been clearly documented by numerous studies⁴ and prior studies⁵ have together provided highly descriptive, clinically valid characterizations of the narrative difficulties encountered by individuals with ASD across language contexts.

2.1 Factors Affecting Cognitive Disorders

MEHECOM proposes an optimized model of analytical Meta heuristic with fuzzy cognitive map approach for prediction which involves the challenges lying behind learning aspects behind children affected with autism or dyslexia. Though the major factors which affect cognitive disorders is not well researched, the survey suggests that environmental aspects, hereditary issues and missing parental care are considered as major challenges.

2.2.1 Autism

Autism characterized by qualitative impairment in reciprocal social communication, further by repetitive, restricted, and stereotyped behaviours. Previously considered rare, ASD are now recognized to occur in more than 1% of children, causing immense suffering to individuals and their families. The complexity and heterogeneity of ASD make it necessary to obtain large-scale samples which are difficult to attain in any individual lab.

2.2.2 Dyslexia

Dyslexia shows the difficulty in developing reading skills primarily elementary school children. The difficulties rise due to reduced visual symbols and verbal sounds being associated with cognitive disorder. While motivational factors must also be reviewed in assessing poor performance, dyslexia is considered to be present from birth. Most scientific criteria for dyslexia exclude cases that can be explained as arising from environmental factors such as lack of education or sensory deficits.

Children with dyslexia articulate their inability to read, write or spell at an in age based inappropriate level. They will generally have average or above average intelligence, yet may have poor academic achievement. They may have smart and good oral language abilities but will perform much more poorly on similar written-language tests¹². Children having this issue are commonly called as lazy, dumb, careless, immature, or bad behaviour attitude.

2.2.3 Delirium

Delirium is considered as an acutely disturbed state of mind related cognitive disorders which are characterized by illusions, restlessness, incoherence, occurrence of intoxication, fever and other disorders¹¹. This disorders is found 74.32% among elder people as well 25-21% among just born infants. The complexity of the disorders is primarily attributed to slow or missing growth of brain

cells⁶ hence the complexity of predicting the disorders is higher than compared to other cognitive disorders such as autism or dyslexia.

3. MEHECOM Approach

Autism and dyslexia cognitive learning factors¹ are interconnected with factors concerning the causal relationships amongst characteristics and components which constitute the system. Every interconnection between components and related event, A_i and A_j , possess a weight, W_{ij} (Figure 1.), which represents the strength of the causal relationships between components or related events A_i and A_j . W_{ij} indicates whether the component A_i causes the event A_j or reciprocate each another.

The directional flow indicates the component causing the event or event happened due to component. The weight assigned over the link is related to the components A_i or events related A_j . The assignment of weight over links at a period of time indicates the causality of an event happening.

$$\text{Hence, } \begin{cases} W_{ij} > 0 & \text{positive causality} \\ W_{ij} < 0 & \text{negative causality} \\ W_{ij} = 0 & \text{no existing relation} \end{cases} \quad \text{-----(1)}$$

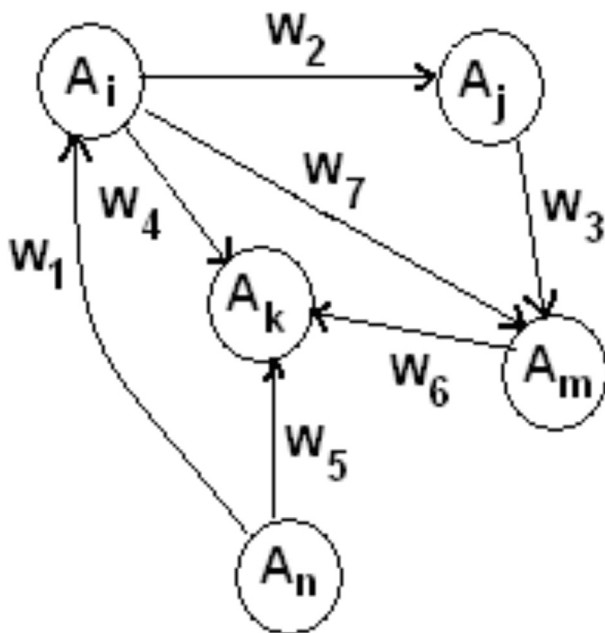


Figure 1. Mapping of components, events over variable weight.

When the weight W_{ij} of any link is assigned a value, its relation to another component or event is positive value, negative or NULL in its bondage. Such bondages are the primary intuition to any relation existence. Numerous components of concepts and the initial weights of the FCM are determined by human knowledge and experience. Values A_i of each component is a transformation of the fuzzy values assigned by the members of the experts. The FCM converges to a steady state (limit cycle) according to the scheme proposed in¹.

$$S_i = f \left(A_i(k) + \sum_{j=1}^N W_{ij} \cdot A_j(k) \right) \quad \text{----- (2)}$$

In this equation,

A_i is the member in use

S_i is the component index

k is the interaction index and $f(\cdot)$ is the sigmoid function

$$W(i, j) = \frac{1}{1 + e^{-\tau x}} \quad \text{----- (3)}$$

Equation (3) determines and guarantees the weight between components, where $A_i \in [0, 1]$ $\tau > 0$ is a parameter, whose steepness in the area depends upon its related components and intensity, here $\tau = 1$.

S_i determines the intensity component of number of members which attribute to predict the disorder. Maximal the relationship maintained between the components lead to improved and early prediction. This index leads to an improvement over dynamic weight metric and hence higher accuracy in prediction.

The meta heuristic variables which does not contribute to aid in prediction will receive least reference and hence least weight in prediction. Figure 2 shows the cluster $C_1 \dots C_m$ which has multiple members $A_1, B_1 \dots Z_1$, where $I = 1, 2, \dots, m$. The members are clustered based on k-means clustering approach []. Clusters can work together based on the causality metrics and assigned weight W_{ij} , as $W_a, \dots, W_r$ to propose the predictive outcome. Weights can be defined as value as in Section 3.1 as such values determine the usage or intensity of positive, negative or null which determines the prediction rate.

3.1 MEHECOM Algorithm

// Define meta heuristic members

- C_i , where $i = 1, 2, \dots, m$ and A_j , where $I = 1, 2, \dots, n$ // Cluster
- $\forall A_i \subset C_i, \exists$ a relation 'k', defined as a relation // Member

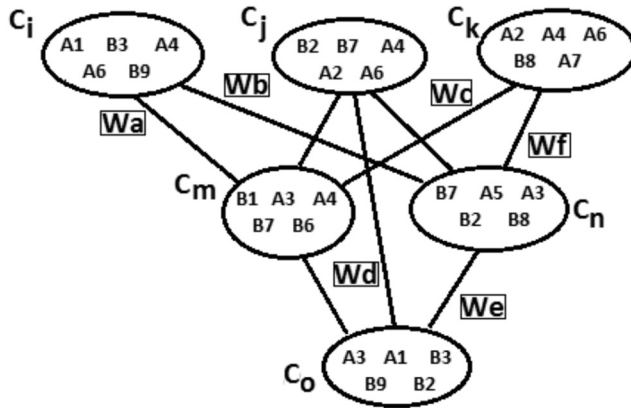


Figure 2. Cluster of components and causality establishment.

/* Where,

W_{ij} is defined as a bondage between A_i and A_j

K is defined as a relational value of an attribute,

which configures the Cluster C_i

f being the sigmoid function

*/

- c. $A_i \times C_i = \Pi_{ai}(A_i \times C_i)$ // set of relation that exists between members of A and

C to define heuristic sets.

// Generate classification based on disorders

symptoms,

clinical test procedures, standard tests values

- d. While (not C_i)

Begin

- e. If $(C_i \notin C_j)$ or $(C_i \in A_i)$, $W_{ij} > 0$ then // positive value

$$K = \sum_{i=1}^n [f(x) \cdot W_{ij}]$$

$C_i = C_i + 1$ // create cluster C_i

- f. If $(C_i \notin C_j)$ or $(C_i \in A_j)$, $W_{ij} < 0$ then // negative value

$$K = \sum_{i=1}^n [f(x) \cdot \sum_{i=n}^m W_{ij}]$$

$C_j = C_j + 1$ // create cluster C_j

- g. If $(C_i \notin C_j)$ or $(C_i \in A_k)$, $W_{ij} = 0$ then // NULL value

$K = 1$ // no change in heuristic update

$C_k = C_k + 1$ // create cluster C_k

End

- h. if $((\forall \text{ member } A_i \subset C_i) \text{ and } (A_i, B_i, \dots, Z_i \in C_i \dots C_n))$
if $(\forall \text{ member } A_i \sim \text{member } B_i)$ then

$$\text{Assign } W_{ij} = \sum_{i=1}^n \left(\frac{C_i}{S_i} \right)$$

MEHECOM works on defined clusters which are associated with components or members over dynamic weights (Step-b). Assignment of weight depends on causality of member which attributes to prediction of cognitive dis-

order. MEHECOM algorithm adopts clustering based on K-means approach, where each member is related to intensity of members in cluster (Step c), hence if a cluster C_i has more members then the association of members is associated with a weight W_{ij} (Step d). Assignment of weight value is dependent on set of Meta heuristic attributes. (Step a) (Step e) (Step f) (Step g). This optimizes the chances to detect cognitive disorder early in minimal time as well supports working on large dataset.

Figure 3 shows various defined members of cognitive disorder such as symptoms, clinical lab results, test values which attribute to chance of disorder. The change in weights indicated as positive value or negative value or no change suggests the need for any variable or component to play a role in prediction of disorder. MEHECOM algorithm adopts selection of Meta heuristic members over which weighted fuzzy cognitive map is applied.

Figure 4 describes the relation existing between Meta heuristic variables and dynamic weight. Figure 4a relates the bondage existing between causal members and their weights. Higher the weight value, higher is the linkage. Figure 4b indicates the relationship existing among the members in a cluster.

The linkage between dynamic weights W_{16} , W_{15} , W_{12} , $W_{13} \dots W_{21}$ shows the high density among members while other weights are low density weights to be neglected over prediction.

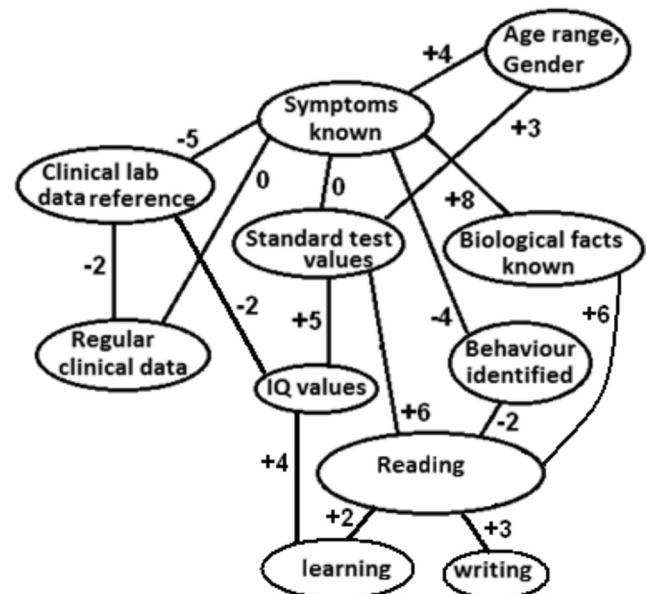


Figure 3. MEHECOM framework over cognitive disorders.

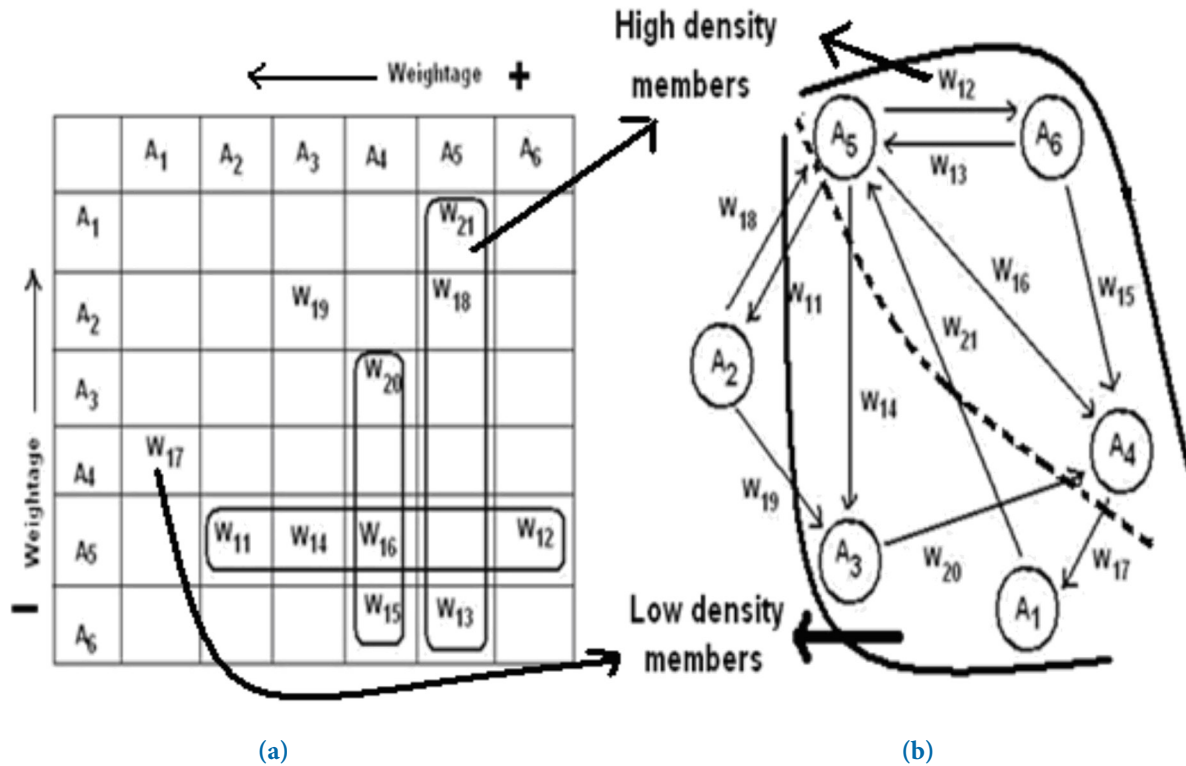


Figure 4. (a) Mapping of dynamic weight over meta heuristic variables and member density. (b) Linkages between the high/low density members and their weight.

4. Metrics and Performance Analysis

To analyze the performance of MEHECOM, an early prediction method for cognitive disorder, R Studio has been incorporated as a tool. The analysis of MEHECOM involves three different datasets obtained for cognitive disorders such as Autism, Dyslexia and Delirium, where the focus is towards early prediction of cognitive disorders identified among children varying between 2 years to 15 years. The dataset required for conduct of research work is obtained from experts, health care specialists, parents, teachers through questionnaires/interviews based on observations on cognitive disorder among children. Data is also collected from various standard repositories⁷ for reference and comparison as well for analysis.

4.1 Dataset

The study and conduct of research in this paper focus on children of variable age groups between 2 to 15 years, which are classified into two groups. The non-dyslexic

children belong to category of girls' and boys' inspite of age being the factor. Data obtained from Confusion Assessment Method (CAM) from the Intensive Care Unit is considered as the most specific bedside tool for the assessment of delirium in critically ill patients. Medline⁸ and Embase databases⁹ were searched for studies on delirium in critically ill patients.

Autism data is gathered through Autism Diagnostic Observational Schedule⁹ and diagnosed according to DSM-IV criteria (American Psychiatric Association 1994), ADOS and ADI algorithm scores were considered.

The prediction accuracy measured over three approaches FEAST, Fuzzy Cognitive Map, Weighted Decision Tree over the proposed approach MEHECOM as critically shown in Figure 5, Figure 6 and Figure 7. The test which was executed for 150 respondents who are varying in age group from 2 years to 15 years shows variation in metrics based on prediction accuracy, prediction time for analysis and a case study on analytical skills.

Figure 5 shows more than 82.59% of prediction accuracy over MEHECOM, which are 21.20% higher than

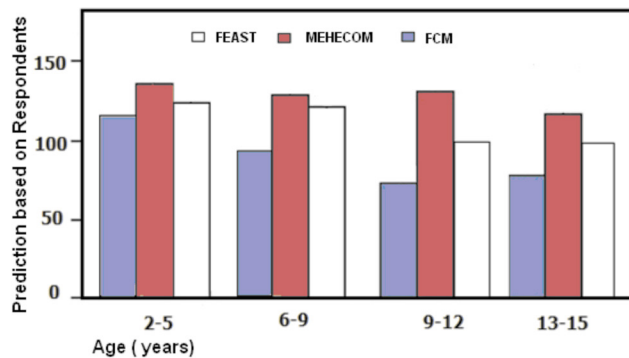


Figure 5. Prediction of cognitive disorders from active respondents.

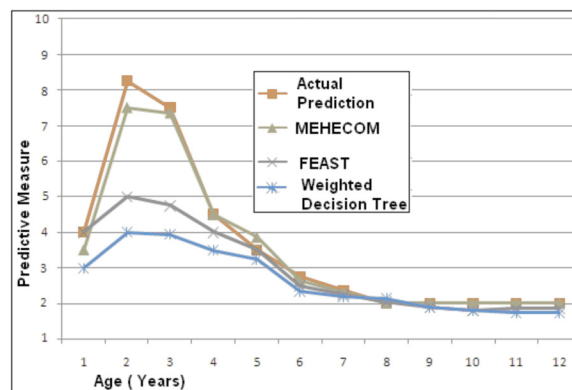


Figure 6. Predictive measure of delirium over observed measure.

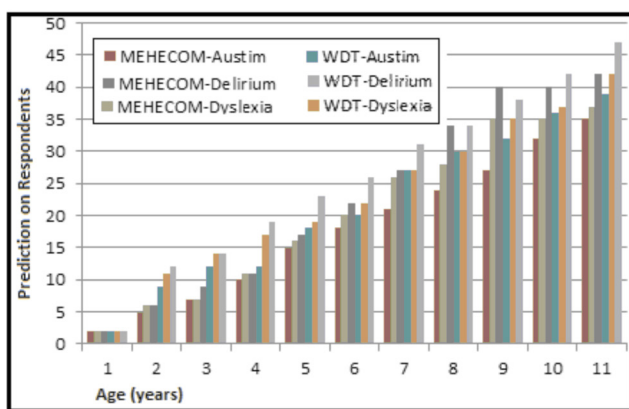


Figure 7. IQ test based predictive measure of MEHECOM.

FCM approach and 15.93% higher than FEAST approach. Out of 150 respondents' data, MEHECOM was able to predict around 120 to 135 records accurately, while FCM was able to predict between 70 to 110 records on an average. FEAST demonstrates 100 to 125 records accurately for different age groups. Since the objective of proposed model MEHECOM focuses on early prediction of cognitive disorder, between the age groups of 2 years to 5 years and 6 years to 9 years.

The early prediction of delirium using MEHECOM approach is compared over actual prediction and with existing approaches such as FEAST, Weighted Decision Tree approaches. Performance of MEHECOM is measured and found to be similar to observed actual prediction in a dataset of 150 respondents whose age groups differ between 2 years to 12 years. It was found that MEHECOM suggests an early prediction with an aver-

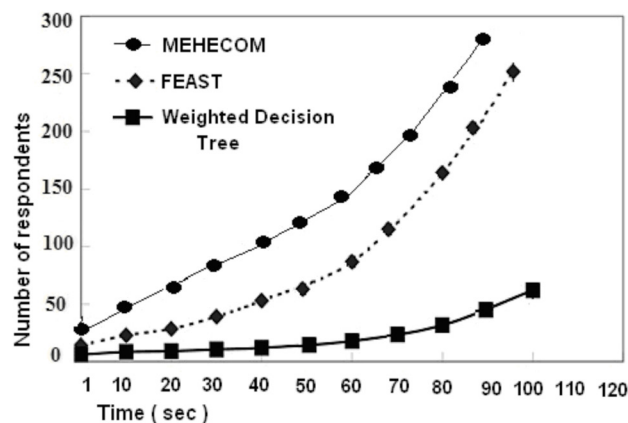


Figure 8. Prediction approaches MEHECOM, WDT for cognitive disorders.

age of 4.52% of prediction compared to 4.98% of actual prediction.

IQ tests are primarily conducted over children to predict their sense of understanding a concept. MEHECOM primarily supports dyslexia and delirium disorders which uses IQ test to predict children lagging in behavioural and conceptual facts. MEHECOM predicts larger group of respondents over short period of time, where it supports on an average of 270 participants in 87 seconds, whereas FEAST detects around 243 participants in 90 seconds and WDT detects only 50 participants in 100 seconds as shown in Figure 7.

Figure 8 explains prediction of autism, dyslexia and delirium over MEHECOM approach and WDT approach. MEHECOM approach shows minimal time to predict disorder among 50 respondents compared to existing approaches.

5. Conclusion

This paper looks into both cognition and behaviour of child affected due to dyslexia, delirium and autism using a cooperative predictive approach of meta heuristics and fuzzy cognitive map over dynamic weighted relation among members or components involved. This approach does not use any biological phenomenon but uses multiple disorder metrics such as symptoms, behaviour to categorize the members. MEHECOM approach adopts Meta heuristic variables as the algorithm optimizes to a controlled mechanism to predict the disorder at an early stage, so that steps can be taken to cure/rectify. MEHECOM approach is tested using R Studio, compared with existing schemes such as FEAST, WDT and FCM approaches. Performance of MEHECOM towards prediction of cognitive disorder was accurate compared to other approaches. The work can be extended towards incorporating swarm intelligence models to optimize the search constraints and improve prediction of cognitive disorders.

6. References

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