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Implementation of FEM RBF Method on Male and Female ADHD Brain

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Abstract

Attention Deficit Hyperactivity Disorder (ADHD) is a pervasive neuro-biological disorder that begins during childhood and even persists in adolscence. Most of the male and female ADHD persons are affected differently. But only few studies have pointed out that differences. In this proposed paper, the differences between male and female patients with ADHD are discussed by studying and analyzing the important brain regions. Here the Fuzzy, EM and RBF methods are combined to find the differences. Changes in brain circuitry differentially impact on the male and female ADHD patients. The result showed that the males brain have much more gray matter and less white matter when compared with female brain.

Key Words: Attention deficit hyperactivity disorder, behavioural differences, brain structure, brain differences.

1. Introduction

Attention Deficit Hyper Activity Disorder (ADHD) is a neuropsychological disorder that starts from childhood and can even persist in adolescence also. A person with ADHD finds more difficulty to focus on something without getting distracted, more impulsive and restless. Nowadays, Attention Deficit Disorder, Attention Deficit Hyperactivity Disorder, Hyperkinetic Disorder, Hyperactive words are used frequently. Usually, ADHD was observed and diagnosed based on the behavior of the person under various circumstances from various relevant sources. But many young children are inattentive and restless without necessarily being affected by ADHD. To avoid the misperception and better accurate diagnosis, it is done clinically with the assistance of the science and technology. ADHD in children is completely different from normal childhood anxiety, excited and boisterous behavior. Many children, especially very young ones, are inattentive and restless without necessarily being affected by ADHD.

2. ADHD Brain Structure

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurological disorder and it creates development delay. It approximately affects 8% of children in the universe. The ADHD brain is 4% to 6% smaller than the normal brain. Cerebellum, frontal lobes, white matter, caudate nucleus, temporal gray matter, cerebral cortex, cortexes, limbic system, reticular activating system, etc are the most important brain regions connected with memory power, focus, concentration, attentiveness, impulsation control, inhibition, and carrying out various motor activities. The following figure shows the differences in normal brain and ADHD brain fig(1)[1].

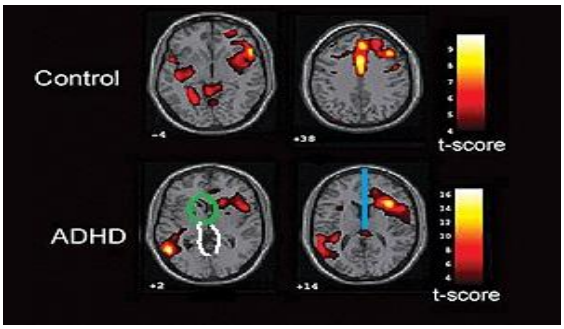

Fig. 1: Showing the normal and ADHD Brain Differences[1]

3. Behavioural Differences in Male and Female

Generally, Men and Women don't think or act in the same way. There are some differences in their behavior. Men are better at mathematical work and spatial location which is concerned with the abstract thinking. They often have a tendency of being more independent, dominant and aggressive. But on the other

hand, women are superior in language. They have artistic and aesthetic talents. They are capable of a greater emotional and empathic capacity. There are some tangible evidences to prove that men and women process information, control emotions and use language very differently. There are differences in size of the whole brain in terms of certain regions or in terms of neurons. But the fundamental difference is due to relative functionality. This can be studied in terms of changes in connectivity in brain architecture and not by the size of the brain. Because the differences in brain size disappear while correcting factors taken such as difference in body size[21].

3.1. Brain Differences in Male and Female

As a fundamental approach, a study in the differences of the brain in male and female in the terms of Gray Matter (GM) and White Matter (WM) is done. Gray Matter and White Matter are the most important parts in cerebral ultra structure. They are discussed below.

Gray Matter and White Matter

The Central Nervous System (CNS) has two kinds of tissue called gray matter and white matter. Gray matter has a pinkish-gray color and contains cell bodies, dendrites and axon terminals of neurons. White matter is full of axons connecting various parts of gray matter to each other. Gray matter develops quickly during childhood, but slows during adolescent. Gray matter volume peaks at the age of 11 in girls and at the age of 13 in boys. Then, the volume of gray matter begins to decline. Gray matter is located on the surface of the cerebral cortex and also includes deep brain structures such as the thalamus and basal ganglia. White matter is located beneath the gray matter of the cerebral cortex and comprises long neural pathways which are responsible for transferring information between gray matter regions where the processing of information occurs[22]. The following figure shows the differences in male and female brain in terms of White matter (WM) and Gray matter (GM)fig (2)[2].

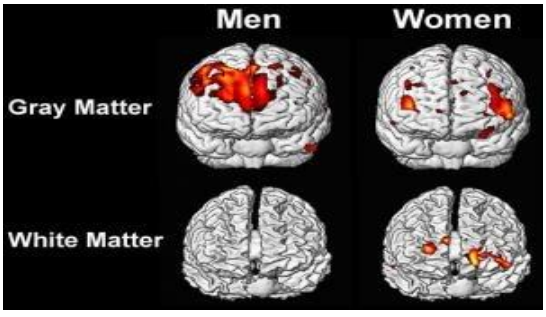

Fig. 2: Showing Different Cerebral Ultrastructure of Men and Women[2]

From the above picture it is clear that men have more gray matter which consists of body neurons and woman have more white matter which consists of nerve fibers. Brocca and Wernicke are the regions of the brain which are related to language comprehension and processing. These regions are bulky in female brain and they use both hemispheres simultaneously. But men can only use the

dominant hemisphere at a time. The corpus callosum architecture is greater in women which helps them in greater interhemispheric communication.

3.2. Behavioural Differences in Boys and Girls with ADHD

Boys and Girls who are affected with ADHD shows different symptoms. Following are some points that mention the difference in ADHD symptoms in them.

No:	Boys	Girls
1	Obvious and external behaviour	Often withdrawn attitude
2	Impulsivity i.e., acting out	Low self-esteem and anxiety
3	Hyperactivity such as running, kicking, beating and hitting	Poor in academic achievement due to intellectual impairment
4	Inattentiveness	In attentively or usually day-dreaming
5	Aggressive nature physically	Verbal aggression by teasing, name calling, etc.
6	Lack of Focus	Less Obvious and more internal

3.3 Brain Differences in Male and Female with ADHD

Attention Deficit Hyperactivity Disorder (ADHD) is a neurobiological brain disorder which is greatly influenced by Genes. The normal brain and the ADHD brain structure differs and has been stated earlier. Male and female behaviours are also different. It is analyzed that these differences are caused due to the differences in their brain structure. The brain differences in a normal male and female has also been discussed earlier. Like that, the brain of Male ADHD and Female ADHD also differs. So ADHD must be diagnosed and treated considering the gender also.

4. Literature Review

Bo-yong Park and Hyunjin Park et. al, proposed " Connectivity differences between adult male and female patients with attention deficit hyperactivity disorder according to resting–state fuctional MRI"- under this group-wise differences are studied using degree centrality for different brain areas. They use graph theory, thresholding techniques and correlation analysis. Changes in brain circuitry is analyzed here by using resting state MRI. The important limitations of this study are the usage of band –pass filter ranging from 0.009 to 0.08 Hz to the time-series data. Some researchers argue that they didn't employ multi-modal approaches. They didn't consider onset age and duration of disease[3].

Andrew C.Peterson, Sheng Zhang, Sien Hu, Herta H.Chao and Chiang-shan R. Li et.al, proposed "The effects of Age,from Young to Middle Adulthood, and Gender on Resting State Functional Connectivity of the Dopaminergic Midbrain". Under this method, an attempt is made to understand the underlying neural mechanism which causes the disorders it varies by sex and age. They use the blood oxygenation level dependent (BOLD) signals to correlate the time course of VTA (Ventral Tegmental Area) and SNc(Substantia Nigra Pars Compacta). They also used thresholding techniques and paired *t*-test for

analysis.

The important limitations of this study are unable to assess the functional implications of the current connectivity. Young and middle age data are only taken for this study. So it is limited to age range findings. Problems regarding site-specific variables such as different gender ratios. Here distinct patterns of cerebral functional connectivity of the VTA and SNc are taken for analyzing gender differences. But there are also some more important differences in the rsFC of the midbrain nuclei. Age related changes in the rsFC is more prominent in men when compared to the women[4].

Chao Zhang, Nathan D. Cahill, Mohammad R. Arbabshirani, Tonya White, Stefi A. Baum and Andrew M. Michael et.al, proposed "Sex and Age Effects of Functional Connectivity in Early Aduthood".In this paper, the regression and graph theoretical analyses is used to find and explore the effects of sex and age on functional connectivity by using the AAL atlas parcellation. Bonferroni correction method is also used here. Functional connectivity remained significant after controlling the cognitive measures. FC in females exhibited a faster cross-sectional decline with age.Male brains were more locally clustered in all lobes but the cerebellum; female brains had a higher clustering co-efficient at the whole-brain level., male brains were more segregated and female brains were more integrated.

Each method has its own merits and demerits. The AAL atlas parcellation is a powerful tool to determine the significant sex and age effects on functional connectivity. But some researchers argued that the functional in homogeneity for anatomical parcellation may induce and lead to biases for constructing network and graphical analyses[5].

Jace B.King, Deborah Yurgelun-Todd, Amanda Stoeckel, Jennifer M.DiMuzio and Melissa P.Lopez-Larson et. al, proposed "Sex differences in white matter integrity in youths with attention-deficit/hyperactivity disorder: a pilot study". The study is about the disparities in white matter (wm) microstructure and organization found in persons with attention deficit/hyperactivity disorder (ADHD) on the basis of the gender differences. They have taken diffusion tensor imaging (DTI) to investigate and the examine the impact of sex on measures of fractional anisotropy (FA).64-Direction DTI scan on a 3 Tesla Siemens scanner. FSL'S TBSS methods are used for further evaluation univariate analysis is done on mean FA which is extracted by WM tractigraphy atlas. The important limitation of this study is that being the modesty samples, the two different groups showed similarity on important variables such as FSIQ,etc. Consistent findings is obtained while using the two different data analyses methods[6].

Robyn L.Miller, Erik B.Erhardt, Oktay Agcaoglu, Elena A.Allen, Andrew M. Michael, Jessica A.Turner, Juan Bustillo, Judith M.Ford, Daniel H.Mathalon, Theo G.M.Van Erp,Steven Potkin et. al, proposed "Multidimensional frequency

domain analysis of full-volume Fmri reveals significant effects of age, gender, and mental illness on the spatiotemporal organization of resting-state brain activity" A new canonical, transparent technique for characterizing the role in overall brain activation in terms of spatially scaled periodic patterns with the given temporal recurrence rates is introduced. The foremost important feature of this technique is the spatiotemporal spectral profile (STSP). 4D spectral analysis of rs-fMRI is done with gender and age. The main limitation to this study is that for accurate results further research and development is needed. The techniques must be modified according to the needs and to get the desired result[7].

Yeu-Sheng Tyana, Jan-Ray Liaod, Chao-Yu Shena, Yu-Chieh Lina, Jun-Cheng Wenga et.al, proposed "Gender differences in the structural connectome of the teenage brain revealed by generalized q-sampling MRI". Under this, they introduced a new method called Generalized q-sampling imaging (GQI). This method characterize complicated fiber patterns and distinguish fiber orientations, giving an opportunity for more accurate, higher-order descriptions through the water diffusion process. The structural connectome was obtained by graph theoretical and network-based statistical (NBS) analyses. The first and foremost limitation of this study is that the age-matched cross-sectional design is not studied considering the longitudinal aspects. Puberty status are not taken into consideration[8].

E.Mark Mahone, Marin E.Ratna, Deana Crocetti, Jessica O' Brien, Walter E.Kaufmann, Martha B. Denckla and Stewart H. Mostofsky et.al; proposed "Comprehensive Examination of Frontal Regions in Boys and Girls with Attention-Deficit/Hyperactivity Disorder". Under this, a new comprehensive frontal parcellation method is proposed. This method provide important data about the anatomy of functionally relevant regions in comparison with the past methods. The first and foremost limitation is that the medication details are not taken into consideration and MANOVA table has to be computed for larger variables[9].

Benjamin Dirlikov, Keeri Shiels Rosch, Deana Crocetti, Martha B. Denckla, E.Mark Mahone, Stewart H. Mostofsky et. al; proposed "Distinct Frontal lobe morphology in girls and boys with ADHD ". Under this, a fully automated frontal lobe atlas is introduced. By applying this, they generated functionally distinct frontal subdivisions. Surface area (SA) and Cortical thickness (CT) was assessed in each region. The overall differences within boys and girls in the perspective view of diagnosis and the effect of diagnosis were analyzed. Only few studies were done in finding the distinction in frontal lobe of boys and girls. Nowadays ongoing researches were found. So a lot of future work has to be done in this field[10].

Lisa A.Jacobson, Daniel J.Peterson , Ken S. REosch, Deana Crocetti, Susumu Mori, Stewart H. Mostofsky et. al; proposed" Sex-Based Dissociation of white matter Microstructure in children with Attention-Deficit/Hyperactivity Disorder". They analyzed the estimated differences in WM microstructure on

the basis of age, IQ and handedness. The effects of diagnosis and sex on fractional anisotropy (FA) were assessed in terms of motor, premotor and prefrontal areas. The group differences in FA and associations with response control such as [CVRT] reaction time variability and commission error rate were analyzed and examined separately within sex[11].

L izhou Chen, Xiaoqi Huang, Du Lei, Ning He, Xinyu Hu, Ying Chen, Yuanyunan Li, Jinbo Zhou, Lanting Guo, Graham J.Kemp, Qiyony Gong et. al; proposed "Micro Structural abnormalities of the brain white matter in attention-deficit/hyperactivity disorder". They assessed both the children and adolscents with ADHA and healthy controls by conducting psychiatric interviews. They focused and analyzed the behavioural problems by using the revised Conners' Parent Rating Scale. Executive functions were measured and analyzed by using the Stroop Colour-Word Test and the Wisconsin Card Sorting test. They also used the diffusion tensor images for analysis. The limitation of this study is that, it is limited to cross-sectional design and small sample size. The cluster size of the significant result was also small[12].

Martin J.Batty, Elizabeth B.Liddle, Alain Pitiot, Roberto Toro, Madeleine J. Groom, Gaia Scerif, Mario Liotti, Peter F.Liddle, Tomas Paus and Chris Hollis et.al; proposed "Cortical Gray Matter in Attention-Deficit/Hyperactivity Disorder:A Structural Magnetic Resonance Imaging Study". A fully automated method on the estimates of regional volumes of gray and white matter were used. They processed the structural images by applying a volumetric pipeline method. They further analyzed the measurement of each lobe in the cortial and areas of frontal lobe by using FreeSurfer. The main limitation of this method is that it is not suitable to explore multiple a priori areas and in detecting the small effects post hoc. The groups are not matched in the terms of IQ[13].

Winke Francx, Alberto Llera, Maarten Mennes, Marcel P.Zwiers, Stephen V. Faraone, Jaap Oosterlaan, Dirk Heslenfeld, Pieter J. Hoekstra, Catharina A. Hartman, Barbara Franke, Jan Buitelaar and Christian F. Beckmann et. al; proposed "Integrated analysis of gray and white matter alterations in attention-deficit/hyperactivity disorder". A multimodal analysis of structural MRI modalities in ADHD is proposed by them. Persons with and without ADHD underwent a linked independent and component analysis. This is a data driven analysis which is able to decompose the data into multimodal independent components. It reflects the common inter-subject variation across imaging modalities. Further improvements and modifications should be done to find accurate variations and reliable results[14].

Daniel Kessler, Michael Angstact, Robert C.Welsh and Chandra Sripada et. al; proposed "Modality-Spanning Deficits in Attention-Deficit/Hyperactivity Disorder in Functional Networks, Gray Matter, and White Matter". A new method to unite the structural and functional modalities in a common model is proposed. For this, a joint independent component analysis, a multivariate, multimodal method which is capable of identifying cohesive components that

span modalities was used by them. The default mode network (DMN) and task-positive networks (TPNs) were analyzed by them. The multimodal method used is a good one. But overlapping betterments must be done. Improvisation and modifications could bring accurate results[15].

Sudipta Roy, Debayan Ganguly, Kingshuk Chatterjee, Samir Kumar Bandyopadhyay et. al; proposed "Computerized White Matter and Gray Matter Extraction from MRI of Brain Image". An automated segmentation for WM and GM extraction from brain MRI is proposed by them. They used the concepts of binarization, wavelet decomposition, and covexhull for visual inspection and quantification. They tested this method on three different types of MRI brain images such as Transvers, Sagittal,Coronal. This method can be used mainly for preprocessing step and need modifications and improvements [16].

Joseph A. Helpern, Vitria Adisetivo, Maria F. Falangola, Caixia Hu, Adriana Di Martino, Kathleen Williams, Francisco X Castellanos, Jens H. Jensen et. al; proposed "Preliminary Evidence of Altered Gray and White Matter Microstructural Development in the Frontal Lobe of Adolescents with Attention-Deficit Hyperactivity Disorder:A Diffusional Kurtosis Imaging Study". An investigation is made about the non-Gaussian water diffusional kurtosis imaging(DKI) for finding out the age effects on GM and WM. For this they conducted the study of microstructural changes in the prefrontal cortex of persons with ADHD and TDC. They performed regression analysis of the PFC ROI on MPRAGE and DKI images. The major drawback of this study is that it lacks the typical age-related change that occurs in both the axial and radial directions. Moreover, a longitudinal study with larger sample sizes is needed to characterize the potential developmental abnormalities in ADHD[17].

Ming-guo Qiu, Zhang Ye ,Qi-yu Li,Guang-jiu Liu,Bing Xie,Jian Wand et.al; proposed "Changes of Brain Structure and Function in ADHD Children". A detailed analysis is done on the brain structure and function of ADHD children by using MRI and DTI. They have been classified age wise. This study doesn't provides clear pictorial information[18].

Uma Maheswary.K and S.Manju Priya et.al; proposed" Multimodal Brain Imaging Technique: A review of the applications in ADHD diagnosis". In this paper, a detailed study is conducted about the various multimodal techniques used nowadays. These powerful techniques are used to detect the abnormalities which leads to the chronic condition are discussed[19].

Sidong Liu, Weidong Cai, Siqi Liu, Fan Zhang, Michael Fulham, Dagan Feng, Sonia Pujol, Ron Kikinis et.al; proposed "Multilodal neuro imaging computing: a review of the applications in neuropsychiatric disorders". In this paper, a brief explanation about the applications of multimodal techniques in neuro disorders is given[20].

5. Proposed Work

Different people used various approaches and methods in finding the differences in Male ADHD and Female ADHD brain. But there is a need for some improvisation to get accurate results. So a new method named FEM RBF is proposed. It is the combination of Fuzzy, Em and Radial Basis Neural Network to get better results. Fuzzy C-means (FCM) is a method of clustering which allows one piece of data to belong to two or more clusters. This method is frequently used in pattern recognition. It is based on minimization of the objective function.

$$J_m = \sum_{i=1}^{N}\sum_{j=1}^{C} u_{ij}^{m}\left\|x_i - c_j\right\|^2, \quad 1 \le m < \infty \text{ [23]}$$

where m is any real number greater than 1, u_{ij} is the degree of membership of x_i in the cluster j, x_i is the ith of d-dimensional measured data, c_j is the d-dimension center of the cluster, and ||*|| is any norm expressing the similarity between any measured data and the center. Fuzzy partitioning is carried out through an iterative optimization of the objective function shown above, with the update of membership u_{ij} and the cluster centers c_j by:

$$u_{ij} = \frac{1}{\sum_{k=1}^{C}\left(\frac{\left\|x_i - c_j\right\|}{\left\|x_i - c_k\right\|}\right)^{\frac{2}{m-1}}}, \qquad c_j = \frac{\sum_{i=1}^{N} u_{ij}^{m} \cdot x_i}{\sum_{i=1}^{N} u_{ij}^{m}} \text{ [23]}$$

This iteration will stop when $\max_{ij}\left\{\left|u_{ij}^{(k+1)} - u_{ij}^{(k)}\right|\right\} < \varepsilon$, where ε is a termination criterion between 0 and 1, whereas k are the iteration steps. This procedure converges to a local minimum or a saddle point of J_m. C–means clustering algorithm and it is a starting point for the fuzzy extensions. These algorithms are based on objective functions J, which are mathematical criterial that quantify the goodness of cluster models that comprise prototypes and data partition. Objective functions serves as cost functions that have to be minimized to obtain optimal cluster solutions. Thus, for each of the following cluster models the respective objective function expresses desired properties of what should be regarded as the ‘‘best’’ results of the cluster algorithm. The main advantage of fuzzy c-means clustering, it allows gradual memberships of data points to clusters measured as degrees in [0,1].

Fuzzy c-means alone is unable to provide good results for certain parts. The resulting regions are not spatially continuous, due to the fact that only grey level uniformity is checked. So EM is combined with this. Expectation Maximization is iterative method for parameter estimation where there are missing data. It consists of two steps: Expectation and Maximization. This method is applicable to wide range of problems. But EM method is subjected to much investigation.

So it is necessary to combine RBF with that. RBF or Radial Basis Neural Network is becoming an increasingly popular neural network with diverse applications and is probably the main rival to the multi-layered perception**.** The basic architecture for a RBF is a 3-layer network. The input layer is simply a fan-out layer and does no processing. The second layer or hidden layer performs a non-linear mapping from the input space into a higher dimensional space in which the patterns become linearly separable.RBF trains faster than a MLP. Another advantage is that the hidden layer is easier to interpret than the hidden layer in an MLP.

6. Results & Discussion

This proposed method could be seen in MATLAB 8.6 R2015b. MATLAB (Matrix Laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. A proprietory programming language developed by Mathworks. Matlab 8.6 has many advantages. It possess new Matlab execution engine (a.k.a-LXE); graph and digraph classes to work with graphs and networks; MinGw-W64 as supported compiler on windows. This is the last version with 32-bit support.

This proposed technique is implemented using Brain MRI images. The resolution range is 750-1080. Within this range images can give accurate results. But by using Image resize option, it can process any range of images. It is also made an option for conversion of 3D images to 2D. The images are preprocessed with average filter for noise removal. Mean filtering is a simple, intuitive and easy to implement method of smoothing images, i.e., reducing the amount of intensity variation between one pixel and the next. Mean filter is commonly known as smoothing, averaging, box filtering. The idea of mean filtering is simply to replace each pixel value in an image with the average value of its neighbours, including itself. This has the effect of eliminating pixel values which are unrepresentative of their surroundings. Mean filtering is usually thought of a convolution filter. Separate values were given to identify male and female image by fixing pixel value. The result obtained by using mean filter is as follow:

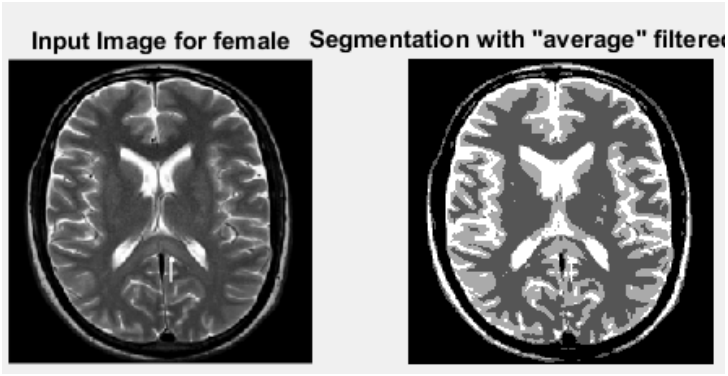

Fig. 3: Showing the Original Image and Filtered Image of Female

As stated earlier, the segmentation of Gray Matter (GM) and White Matter (WM) has to be done in proper way to diagnose ADHD. The combination of fuzzy, em and RBF techniques for automated segmentation were implemented. The following figures show the results for female and male separately.

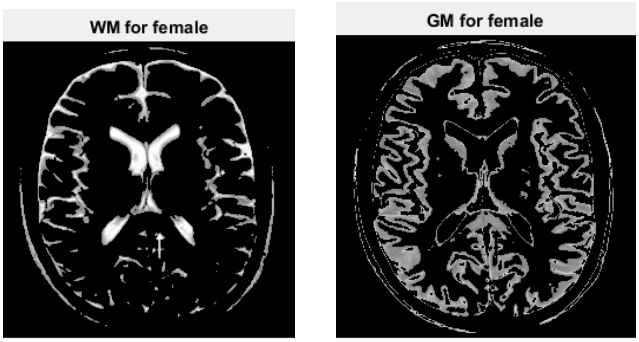

Fig. 4: Showing the Segmentation of White Matter (WM) and Gray Matter (GM) in Female BRAIN MRI

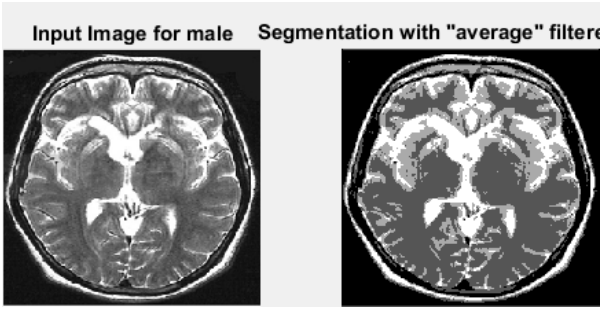

Fig. 5: Showing the Original Image and Filtered Image of Male

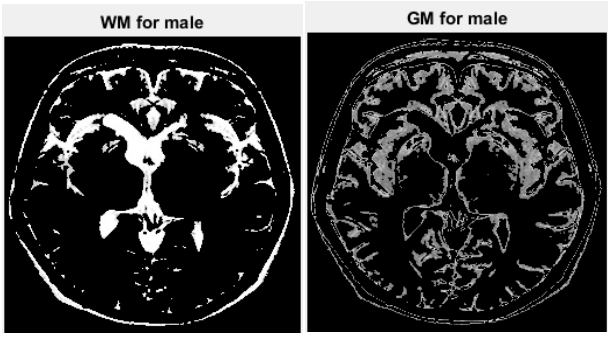

Fig. 6: Showing the Segmentation of White Matter (WM) and Gray Matter (GM) in male Brain MRI

7. Limitations and Future Work

Due to the accuracy level of the result obtained from the single method, The combination of different methods were used. But this method yield only satisfactory results. Lot of improvisation and modifications should be done with this and the best techniques and methods should be done. So far to get a clear

cut image, the study be in depth and innovative new methods should be incorporated. So future study should be done by innovating powerful method which is capable of differentiating male and female ADHD brain clearly.

8. Conclusion

Thus, this paper provides information connected with ADHD (Attention Deficit Hyper Activity Disorder) which is a neuropsychological, neuro biological disorder. As the behaviour of the male and female vary due to the difference in their brain structures and functions, the behaviour of the male ADHD and female ADHD also vary. For finding the differences in their brain structure and functionality, many techniques are widely used now. In this paper, a discussion about the different techniques proposed by different authors are mentioned. A novel method called FEM RBF, by combining different techniques is also proposed. The results are accurate and reliable. There are many ongoing researches that are present in this field. Suitable techniques should be used to get accurate results. According to the result obtained, it helps to provide different types of proper and needy treatment to the people. Separate ways of treatment should be given to the male and female to get the desired results. Then ADHD can be made as a gift for both.

References

[1] www.bluelight.org.

[2] http://images.sciencedaily.com

[3] Park B.Y., Park H., Connectivity differences between adult male and female patients with attention deficit hyperactivity disorder according to resting-state functional MRI, Neural regeneration research 11(1) (2016), 119-125.

[4] Peterson A.C., Zhang S., Hu S., Chao H.H., Li C.S.R., The Effects of Age, from Young to Middle Adulthood, and Gender on Resting State Functional Connectivity of the Dopaminergic Midbrain, Frontiers in human neuroscience 11 (2017).

[5] Zhang C., Cahill N.D., Arbabshirani M.R., White T., Baum S.A., Michael A.M., Sex and age effects of functional connectivity in early adulthood, Brain connectivity 6(9) (2016), 700-713.

[6] King J.B., Yurgelun-Todd D., Stoeckel A., DiMuzio J.M., Lopez-Larson M.P., Sex differences in white matter integrity in youths with attention-deficit/hyperactivity disorder: a pilot study, Frontiers in neuroscience 9 (2015).

[7] Miller R.L., Erhardt E.B., Agcaoglu O., Allen E.A., Michael A.M., Turner J.A., Bustillo J., Ford J.M., Mathalon D.H., Van Erp T.G., Potkin S., Multidimensional frequency domain analysis of full-

volume fMRI reveals significant effects of age, gender, and mental illness on the spatiotemporal organization of resting-state brain activity. Frontiers in neuroscience 9 (2015).

[8] Tyana Y.S., Liaod J.R., Shena C.Y., Lina Y.C., Wenga J.C., Gender differences in the structural connectome of the teenage brain revealed by generalized q-sampling MRI, Neuroimage: Clinical 15 (2017), 376-382.

[9] Mahone E.M., Ranta M.E., Crocetti D., O'Brien J., Kaufmann W.E., Denckla M.B., Mostofsky S.H., Comprehensive examination of frontal regions in boys and girls with attention-deficit/hyperactivity disorder, Journal of the International Neuropsychological Society 17(6) (2011), 1047-1057.

[10] Dirlikov B., Rosch K.S., Crocetti D., Denckla M.B., Mahone E.M., Mostofsky S.H., Distinct frontal lobe morphology in girls and boys with ADHD, Neuroimage: Clinical 7 (2015), 222-229.

[11] Jacobson L.A., Peterson D.J., Rosch K.S., Crocetti D., Mori S., Mostofsky S.H., Sex-based dissociation of white matter microstructure in children with attention-deficit/hyperactivity disorder, Journal of the American Academy of Child & Adolescent Psychiatry 54(11) (2015), 938-946.

[12] Chen L., Huang X., Lei D., He N., Hu X., Chen Y., Li Y., Zhou J., Guo L., Kemp G.J., Gong Q., Microstructural abnormalities of the brain white matter in attention-deficit/hyperactivity disorder, Journal of psychiatry & neuroscience: JPN 40(4) (2015), 280-287.

[13] Batty M.J., Liddle E.B., Pitiot A., Toro R., Groom M.J., Scerif G., Liotti M., Liddle P.F., Paus T., Hollis C., Cortical gray matter in attention-deficit/hyperactivity disorder: a structural magnetic resonance imaging study, Journal of the American Academy of Child & Adolescent Psychiatry 49(3) (2010), 229-238.

[14] Francx W., Llera A., Mennes M., Zwiers M.P., Faraone S.V., Oosterlaan J., Heslenfeld D., Hoekstra P.J., Hartman C.A., Franke B., Buitelaar J.K., Integrated analysis of gray and white matter alterations in attention-deficit/hyperactivity disorder, NeuroImage: Clinical 11 (2016), 357-367.

[15] Kessler D., Angstadt M., Welsh R.C., Sripada C., Modality-spanning deficits in attention-deficit/hyperactivity disorder in functional networks, gray matter, and white matter, Journal of Neuroscience 34(50) (2014), 16555-16566.

[16] Roy S., Ganguly D., Chatterjee K., Bandyopadhyay S.K., Computerized White Matter and Gray Matter Extraction from MRI

of Brain Image. Journal of Biomedical Science and Engineering 8(9) (2015), 582-589.

[17] Helpern J.A., Adisetiyo V., Falangola M.F., Hu C., Di Martino A., Williams K., Castellanos F.X., Jensen J.H., Preliminary evidence of altered gray and white matter microstructural development in the frontal lobe of adolescents with attention-deficit hyperactivity disorder: a diffusional kurtosis imaging study, Journal of Magnetic Resonance Imaging 33(1) (2011), 17-23.

[18] Qiu M.G., Ye Z., Li Q.Y., Liu G.J., Xie B., Wang J., Changes of brain structure and function in ADHD children, Brain topography 24(3-4) (2011), 243-252.

[19] Uma Maheswary K., Manju Priya S., Multimodal Brain Imaging Technique: A review of the applications in ADHD diagnosis, International Journal of Computer Trends and Technology 46(2) (2017), 34-39.

[20] Sidong Liu, Weidong Cai, Siqi Liu, Fan Zhang, Michael Fulham, Dagan Feng, Sonia Pujol, Ron Kikinis, Multilodal neuro imaging computing: a review of the applications in neuropsychiatric disorders, Brain Informatics 2(3) (2015), 167-180.

[21] http://www.ncbi.nlmnih.gov/

[22] www.frontiersin.org

[23] https://en.wikipedia.org/wiki/Fuzzy_clustering#Algorithm