3D Facial Features in Neuro Fuzzy Model for Predictive Grading Of Childhood Autism

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Abstract: Autism Spectrum Disorder (ASD) is a clinically heterogeneous neurological developmental disorder. It is called a spectrum disorder because of its range of symptoms. Early diagnosis and proper intervention is required for the effective treatment of autism. Diagnosis is based on the quantitative and qualitative analysis made by the clinician. The expertise of the clinician is so important in the proper diagnosis and classification of autism. This paper proposes an Expert system that act as a support system to the clinician. Major clinical attributes of autism along with facial features are used as input to the expert system. The main highlight is the use of feautures from 3D facial imagery for autism classification. The expert system operates in two modes, diagnosis mode and grading mode. Naïve Bayes classifier is initially used for diagnosis mode where as overall system is implemented using a Neuro-Fuzzy approach. In the diagnosis mode 100% accuracy and in classification mode 98.8% accuracy is obtained.

Keyword: Autism, ASD, 3D Face, Neuro-Fuzzy System, Neural networks, Fuzzy logic, Expert system.

Introduction: Autism spectrum disorder (ASD) is a clinically heterogeneous condition with a wide range of factors. A satisfactory diagnosis measure for ASD is currently unavailable. Autism is a neurological handicap in children, which is usually diagnosed in early child hood. There is lack of definitive biomarkers for autism diagnosis. The diagnosis mostly depends on a range of factors. People with autism show different clinical features and symptoms. There is lot of scope for quantitative research on ASD in developing countries like India. Satisfactory and accurate data for research in autism is unavailable in India. The frequency of ASD diagnosis is increasing. Many Factors like increased awareness,improved detection mainly contribute to this. The publication in DSM-5 on May 2013 adds major revisions needed to remove the confusing labels associated with ASD. The earliest symptom is the absence of normal behavior. All children should be screened using a standardized Autism screening tool at 18 and 24 months of age [1].

Symptoms of ASD must be present in the earlier developmental period mostly by the second year of life (after 12 months). But least severe type of ASD may be diagnosed by 4 to 6 years or later. Intervention should begin as early as possible. In intervention consider the core distinctive features of autism and it should be specific and proof based. More over it should be well structured and appropriate to the developmental need of the child.

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Even though there are inter individual difference in the clinical levels of children with ASD, they share some common characteristics like deficit in social interaction/communication and behavioral abnormalities.

Studies shows that children who deficit to recognize face in childhood shows severe autistic features at teenage. Researches shows that human recognize a person by their body if someone is coming from far away or the face is obscured. So for identifying a person, brain uses facial characteristics and also other physical cues.

Researchers at the University of Missouri have identified facial features measurements in children with autism and developed a screening tool for young children. The sample consists of children from 8 to 12 years of age. Judith Miles, Professor Emeritus of child health-genetics in the MU Thompson Center for Autism and Neuro Developmental Disorders point out that a portion of those children diagnosed with autism tend to look alike with similar facial characteristics [2].

In this research we are developing an expert system that use core clinical features with its attributes, facial characteristics and parental status as input.

Autism: Clinical features and Diagnosis

Autism detection can be done by using quantitative tests and qualitative analysis. In DSM IV ASD diagnosis is based on Language delays, Social Communication Problem and Repetitive behavior. Where as in DSM V ASD diagnosis is having two criteria domains namely Social interaction domain and Repetitive or restricted behavior domain. The Core Clinical features of autism can be brought under the following heads with attributes.

1. Behavioral problem
   a) Poor eye contact
   b) Lack of responsiveness to others
   c) Difficulty in building social relationship
   d) Repetitive acts
   e) Self harm
   f) Compulsive behavior
   g) Hyper Activity
   h) Poor joint attention
   i) Solo play
   j) Excessive fear
   k) Poor emotional response

2. Language Disorder
   a) Muteness
   b) Echolalia
   c) Sound making

3. Intellectual retardation
   a) General intellectual retardation
   b) Brain Seizures

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4. Facial Features
   a) Open Eyes
   b) Wide Mouth
   c) Large region between mouth and nose.
   d) Expression less face
   e) Open mouthed Appearance
   f) Prominent Forehead

5. Parents Status
   a) Not Autistic
   b) Autistic

The earliest symptom is the absence of normal behavior. Normally when a parent or a healthcare provider notices any delay or abnormal behavior in the child at, or prior to the age of three they are prompted to consult a developmental pediatrician. The child is analyzed carefully and any abnormality is observed in the core functional areas, the developmental pediatrician recommends the child for assessment test using any of the standard autism testing tools. These tools are normally a checklist or questionnaire containing autism features. The clinician fills the data using his observation and a structured discussion with the parent of the child under scrutiny. After filling the details a final score is generated. Comparing the obtained score with the threshold value, the clinician initially classifies the child as either not autistic or autistic. The next step is to identify which Autistic class or grade the child belongs to. Based on the total score compared against a threshold the child is diagnosed as mild, moderate and severe. Consider the total score(S) adds up to 60 and the threshold is 30, the grade and remarks is as shown in table 1.

Score	Class/ Grade	Remarks
Score <30	Normal	Typical
Score 30 to 34	Mild	Requiring support
Score 34 to 38	Moderate	Requiring Substantial support
Score >38	Severe	Requiring very substantial support

Table 1: Score with Grade

The expertise and dedication of the clinician is an important factor while analyzing the grade or class of autism. Expert clinician can easily spot the grade of autism. Some clinician fully depends on the diagnosis tool and there are possibilities of wrong classification. More over the fuzziness in the Score may also lead to misclassification. Studies say that a proper initial diagnosis and follow up is required for autism. If we are using an expert system as a support system for clinicians the misclassification and problems in initial diagnosis of autism can be avoided up to an extent. In this research we are developing an expert system to assist clinicians in their diagnosis procedure.

Related work:

Silberberg et al.[3] focus on the prevalence of neuro-developmental disorder among children aged 2 to 9 years in the different areas of India. They also analyzed the risk factors associated with neuro-developmental disorders along with the development of screening and diagnosing methodology.

An investigation related to the epidemiology of ASD in India was reported by Mukerji et al.[4]

Myers et al.[5] suggests that the primary goal of treatment for ASD is to maximize the child's ultimate functional independence and quality of life by minimizing the core features of ASD.

Robins et al.[6] objective is to validate the modified checklist for Autism in toddlers.

Yasmin H. Nuggers[7] studied the prevalence, risk factors and diagnosis of ASD in developing countries. In his brief reviews controversies regarding the increase in estimate of prevalence, implications of changes in ASD definitions are also discussed.

Vijay Sagar KJ[8] focus on the study of developmental disorders in India. He concludes his article by saying that there is a need of proper diagnosis and screening tools for Autism in India.

Hammond et al.[9] proposes the use of dense face models in 3D Analysis of facial morphology. The model provide a detailed visualization of 3D face shape variation with capability to training the Physicians to recognize the core components of particular syndromes. Ten fold cross validation testing is done on the sample faces using different pattern recognition algorithm.

Vezzetti et al.[10] highlights 3D human face descriptions, land marks measures and geometrical features. Analysis of facial morphology is very important in the study of facial abnormalities.

Gupta et al.[11] worked on the assumption that different facial expressions can be considered as isometric deformation of facial surfaces .Even though deformation occurs, the intrinsic property of the surface remain the same.

Aldridge et al.[12] investigation focus mainly on the correlation between brain development and face. Brain develops in concert and coordination between the developing facial tissues. ASD is due to alteration in embryological brain, suggests that there are differences in the facial structures of ASD children and normally developing one. Finally the authors concludes that there are significant differences in the facial morphology of boys with a ASD compared normally developing one.

Weigelt et al.[13] reports the face identity recognition is deficit in ASD. The deficit is both process specific and domain specific. They suggest that Autism is a domain specific disorder.

Ruggeri et al.[14] objectives is to find the similarity and difference between the terms biomarker and endophenotype. There study includes the established biomarkers and endophenotype in autism research along with the discovery of new biomarkers.

Dataset: The background study and data collection for this work is done at Block Resource Centre Cherthala, Kerala, India. BRC is a Government agency working along with Sarva Shiksha Abhiyan. The dataset consists of 47 children, which includes both boys and girls. The ratio of boys and girls is 12: 1. The age is from 2 years to 12 years. While studying and analyzing the dataset we are making use of the expert opinion from Pediatric Neurologist, Developmental Pediatricians, Speech Therapist, Remedial Educators, Clinical Psychologist and Parents.

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Proposed system with objectives:

Objective: Our research focus on developing an expert system for the initial diagnosis and grading of childhood autism. This system can be used as a support system for the clinicians while diagnosing autism. The proposed system is having two modes of operation, Diagnosis mode and Grading mode as shown in figure 1. Initially in the diagnosis mode expert system predicts whether the child is non-autistic or autistic. Once the output of the diagnosis mode is autistic then the next phase is activated. In this phase a detailed analysis is done and the possible outcome is the class or grade of autism.

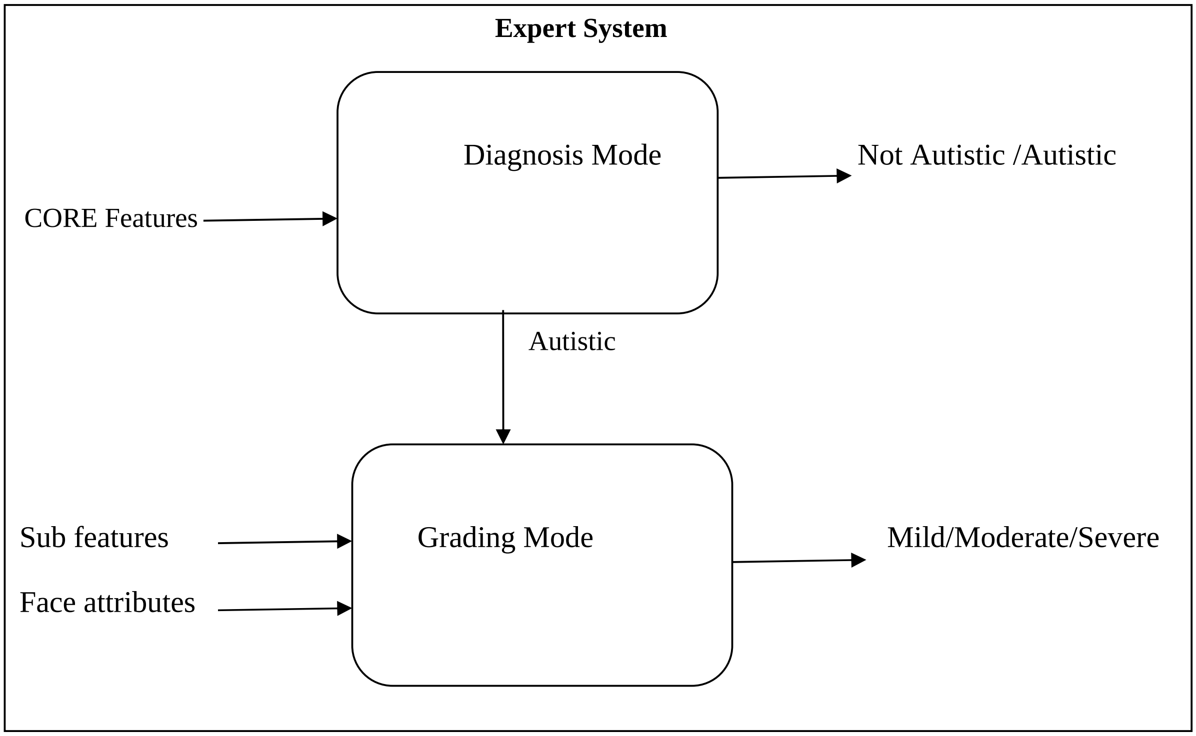

Figure 1: Flow chart of the expert system.

Scale	Output	Remarks
0	Normal	Non autistic
1	Mild	Requiring support
2	Moderate	Requiring Substantial support
3	Severe	Requiring very substantial support

Table 2: Grading

The core feature of autism is analyzed initially during the diagnosis mode. Core features includes Behavioral problem, Language disorder and General mental retardation. Based on the core features the diagnosis mode output is not autistic or autistic.

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If the output is autistic then the second phase is activated, the sub features of each of the core features are analyzed. Facial features along with status of parents are along given importance. The most important characteristic of this expert system is the integration of facial features. The face image of the child under diagnosis is captured; it is modeled to 3D or captures the image using a 3D imaging system. In 3D imaging the geometric depth information is having more importance. Facial features include mouth, eyes and the region between mouth and nose. A portion of Autistic children's have wider mouth, open eyes and large region between the mouth and nose as shown in figure 4. Other common facial characteristics are expression less face, open mouthed appearance and prominent forehead region. Using 3D Geodesic distance as the measure identifies the variance of the features from normally developing kids. Our aim is to extract the exact geometrical information from the face under scrutiny and compare it with a template and used this information for training. By using these facial attributes our focus is to study the contribution of each feature to grading of autism.

Our analysis, point out the fact that Children below the age of 8 with other clinical features of Autism mostly lack the facial features mentioned above. But children from the age of 8 and 12 have shown the above mentioned facial features along with other clinical features of Autism. Our expert system is designed in such a way that the weightage of facial features is varied by considering the age of the child under diagnosis. If the age is below 8 the weightage of the features in percentage is as 75(core features) : 15(facial features) : 10 (Parents status). Whereas age range from 8 to 12 the weightage of the features in percentage is as 65(core features) : 25(facial features) : 10 (Parents status).Parent status is also considered, this feature include whether the parents are autistic or not and age of the parents during conception is also given weightage.

In the grading phase three sets of features namely attributes from core features, facial attributes and parent's status is considered. The weightage of the features varies depending on the age of the child. Initially we consider the two phases as two separate classification problem. In phase 1 the number of inputs are limited so a Naïve Bayes classifier is applied and it suites our problem and it gives the result autistic or non autistic as shown in figure 2. The input to the classifier is the core features such as Behavior problem, Language Disorder and General Mental retardation.

Figure 2: Diagnosis Mode

In the second phase more inputs belonging to different features are considered which include attributes from the core features, facial region and parental status. Naïve Bayes classifier is applied and result is analyzed but there exists some fuzziness after a certain threshold. We need to integrate the two phases and a neuro- fuzzy approach is applied. Soft computing approach like neural network and fuzzy logic can play a vital role in the design of such an expert system. Fuzzy logic is used to interpret expert knowledge directly using rules with linguistic base. In this system we are qualitatively collecting lot of information with structured discussion with parent and from clinician's observation.

Linguistic base can easily be framed into fuzzy rules. Neural network are good in recognizing patterns. So this hybrid approach yields better performance. The output of the grading phase is as shown in table 2.

Results:

To design the neuro-fuzzy system for diagnosis of autism we consider the attributes of core features, facial attributes and parental status. The hybrid architecture is as shown in figure 3.

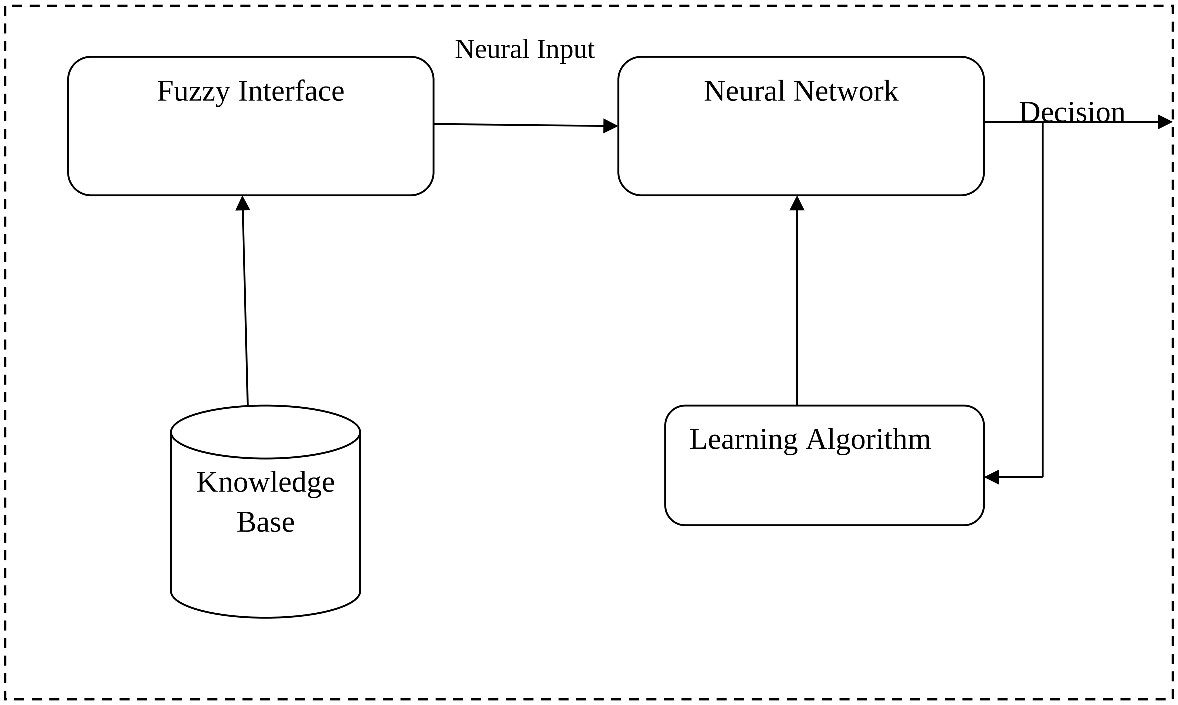


Figure3: Neuro-Fuzzy Expert System Architecture for predicting Autism

The knowledge base consists of twenty two fuzzy parameters. The neural network is trained to learn the parameters of the membership functions representing the linguistic terms in the rule. Sample fuzzy rules applied in the Knowledge base is as follows:

R1: If (Behavior Problem) && (Language Disorder) && (General Mental retardation) then belongs to class Autistic

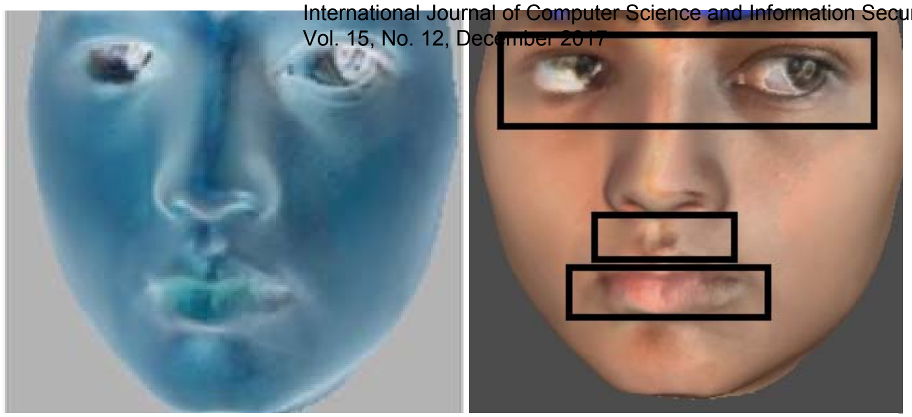
R2: If (Behavior problem Attributes (1 || 2 || …..n)) &&(Language Disorder Attributes (1 || 2 || …. n)) && (Mental retardation Attributes(1 || 2 || …..n)) then belongs to class Autistic .

Different soft computing model have been tested like Naïve Bayes, SVM, K-Means, FCM and Neuro Fuzzy with the same input attributes using Weka tool .The performance is evaluated and the most outstanding results are shown in table4. The operational procedure of the neuro fuzzy system for autism classification is shown in figure 5

The expert system is tested and evaluated by the different stakeholders, the accuracy and evaluation survey summary is shown in figure 6 and 7.

Technique	Sample size	Inputs	Outputs	Accuracy rate
Naïve Bayes	47	12	2	100
Neuro- Fuzzy	47	22	4	98.8

Table4: Performance of Classifier.



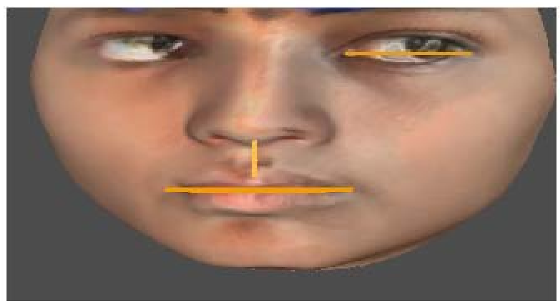


Figure 4: Facial Features

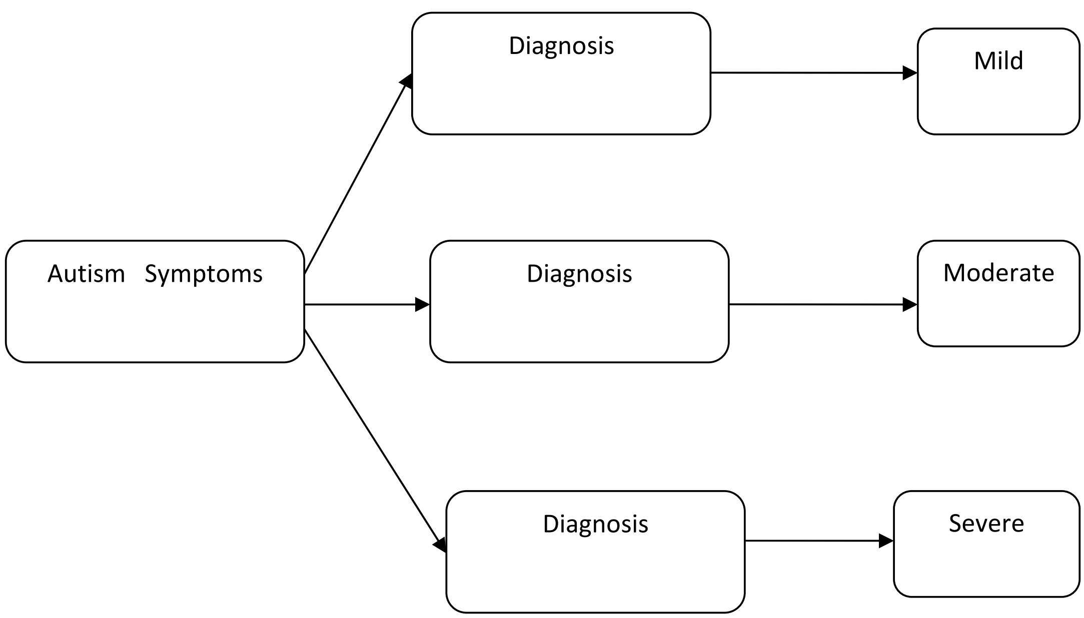


Figure 5: Operational Procedure of the Neuro-Fuzzy system for Autism classification

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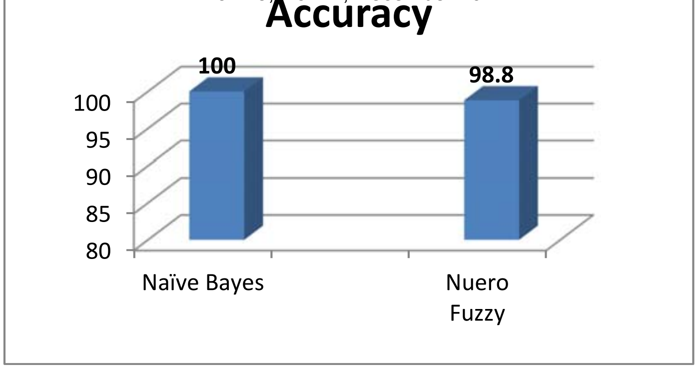

Figure: 6 Accuracy

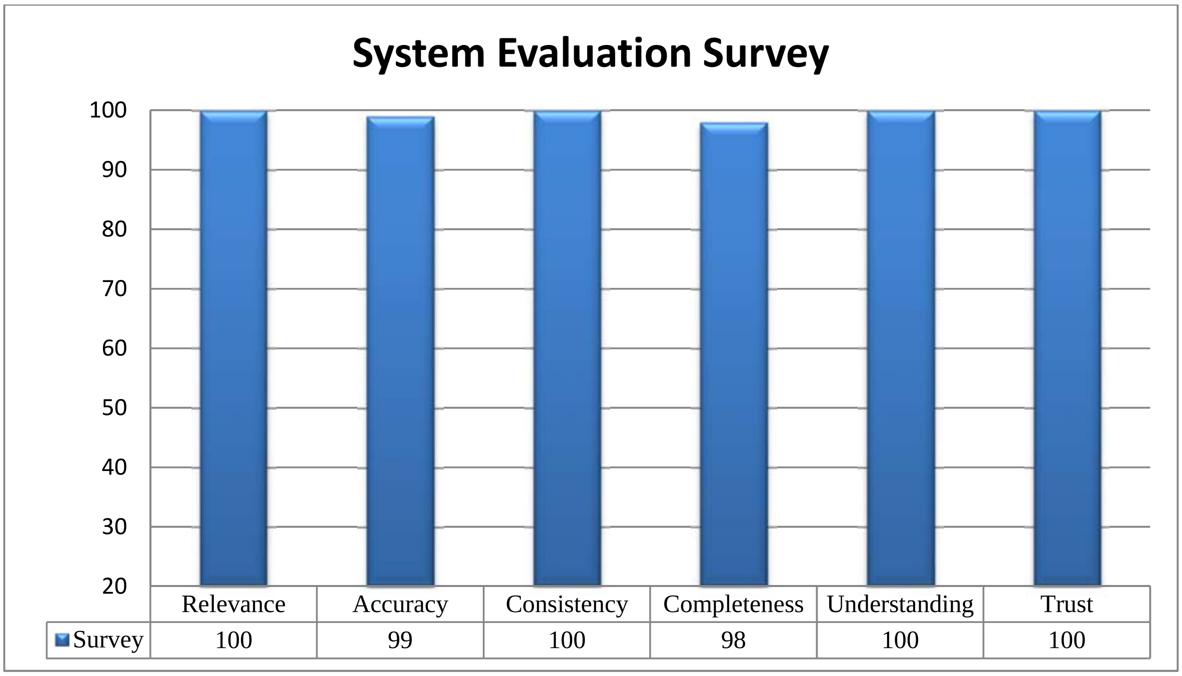

Figure 7: Expert system evaluation Survey

Conclusion: Studies related to the cause and symptoms of Autism spectrum disorder are going on around the world. Information Technology is finding lots of application in all fields. Due to the complexity and heterogeneous nature of this disorder, fewer works are reported which make use of IT in this area. Our expert system captures different inputs and produces an appropriate output. This system can be used by clinicians as a support system. The expert system is used and evaluated by 20 potential users and they all provide positive responses relating to input, output and quality of the system. Integrating 3D facial features as input to the system add a new dimension in Autism research.

https://sites.google.com/site/ijcsis/
ISSN 1947-5500

References:

[1] Myers SM, Johnson CP. Management of children with autism spectrum disorders. Pediatrics.2007;120:1162-82.

[2] Tayo Obafemi-Ajayi, Judith H. Miles, T. Nicole Takahashi, Wenchuan Qi, Kristina Aldridge, Minqi Zhang, Shi-Qing Xin, Ying He, Ye Duan. **Facial Structure Analysis Separates Autism Spectrum Disorders into Meaningful Clinical Subgroups**. *Journal of Autism and Developmental Disorders*, January 2015 DOI: 10.1007/s10803-014-2290-8

[3]. Silberberg D, Arora N, Bhutani V, Durkin M, Gulati S, Nair M, *et al.* Neuro-Developmental Disorders in India-From Epidemiology to Public Policy. Neurology. 2014; 82:P7-P324.

[4]. Mukerji S. A large scale, two phase study to estimate prevalence, and raise awareness, about autism spectrum disorders in India. Action for Autism, Jan 2009. New Delhi, India.

[5]. Myers SM, Johnson CP. Management of children with autism spectrum disorders. Pediatrics.2007;120:1162-82.

[6]. Robins DL, Casagrande K, Barton M, Chen CMA, Dumont-Mathieu T, Fein D. Validation of the modified checklist for autism in toddlers, revised with follow-up (M-CHATR/F). Pediatrics.. 2014;133;37-45.

[7]. Yasmin H. Neggers, Department of Human Nutrition, University of Alabama, Tuscaloosa AL, USA, Autism spectrum disorders: Increasing prevalence and changes in diagnostic criteria.

[8]. Vijay Sagar KJ. Research on autism spectrum disorders in India. AP J Psychol Med 2011;12 (1): 69–72.

[9]. Peter Hammond, Tim J. Hutton,1 Judith E. Allanson,Linda E. Campbell, Raoul C.M. Hennekam,Sean Holden, Michael A. Patton, Adam Shaw,I. Karen Temple, Matthew Trotter,Kieran C. Murphy, and Robin M. Winter, American Journal of Medical Genetics 126A:339–348 (2004)

[10]. Vezzetti E.; Marcolin F. (2012). 3D human face description: landmarks measures and geometrical features. In: IMAGE AND VISION COMPUTING. - ISSN 0262-8856

[11]. Gupta, S., Markey, M. K. , Bovic, A. C. (2010) “Anthropometric 3D Face Recognition”, *International Journal of Computer Vision*, Vol. 90, No. 3: 331-349.

[12]. Aldridge, K., George, I. D., Cole, K. K., Austin, J. R., Takahashi, T. N., Duan, Y., & Miles, J. H. (2011). Facial phenotypes in subgroups of prepubertal boys with autism spectrum disorders are correlated with clinical phenotypes. *Molecular Autism*, *2*, 15. http://doi.org/10.1186/2040-2392-2-15

[13]. Weigelt S, Koldewyn K, Kanwisher N (2013) Face Recognition Deficits in Autism Spectrum Disorders Are Both Domain Specific and Process Specific. PLoS ONE 8(9): e74541. doi:10.1371/journal.pone.0074541

[14]. Barbara Ruggeri ,Ugis Sarkans , Gunter Schumann ,Antonio M. Persico, Biomarkers in autism spectrum disorder: the old and the new, Springer-Verlag Berlin Heidelberg 2013