Autism Diagnosis/Screening Systems and Applications Survey

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Summary
Autism is a neurodevelopmental disorder affecting individuals from childhood up to adulthood. Most of the individuals on the autism spectrum disorder (ASD) are said to have certain behaviors and disabilities. In most cases, the lack of specialists and tools to examine children for ASD makes its diagnosis very difficult and untimely. This has led to late intervention, resulting to significant decrease in quality of life of the patient. As at today, several computer applications have been implemented to aid diagnosis of ASD. This paper presents the survey of such applications including: Expert systems, mobile applications, chat bots etc. used for the screening/diagnosis of Autism. Several databases relating to Autism diagnosis systems or applications were searched and studied. In particular, most of the applications were either developed based on DSM 4 or DSM 5 criteria or machine learning implemented based on already existing Autism diagnosis tools such as the MCHAT, Q-CHAT 10, ATEC, etc. Almost all the systems reviewed have shown promising result and can be implemented to be used in real life clinical diagnosis/screening. This paper is aimed at providing a review of the Tools used for Autism Diagnosis and Screening.

Keywords:
Autism, Diagnosis, Screening, Applications, Expert systems

1. Introduction

This study is an extended study of [1], a literature review of tools used for Diagnosis and screening. Autism Spectrum disorder (ASD) is a neurodevelopmental disorder associated with so many multiple developmental challenges and behaviors according to the Diagnostic and Statistical Manual of Mental Disorders in its fifth edition (DSM-V) [2]. According to science, women with ASD may exhibit less behaviors than men, there is no laboratory test yet to assist health care personnel to diagnose the condition and no pharmacological treatment yet for ASD [3]. Mobile and system applications have proven to be supportive tools for the therapy of children and adult on the spectrum [4]. Approximately 1.5% of the world's population suffers from ASD and is still misdiagnosed by both child and Adult psychiatrists and sometimes even confused for other Neurodevelopment conditions which have similar characteristics[5].

Factors which affects disparities in Autism diagnoses according to some [6] researchers include ethnicity, race, severity of the symptoms present and co-occurring conditions. According to the researchers white raced children are mostly diagnosed earlier, they have access and privilege to interventions and services. According to the American Academy of Pediatrics [7] ASD can be diagnoses as early as 18 months of age but the result of a study conducted in the US suggest a reliable detection and diagnosis of ASD at 14months of age because most children may have overcome their developmental challenges at that age.

But according to a recent research conducted by Leader G. et al [8] the average age of ASD diagnosis is 5years and 5 months which depends on some factors such as a child having other psychological conditions, some challenging behaviors or any other Autism comorbid condition. The authors suggested for awareness to parents, to raise concerns if they notice any challenging behaviors in a child. Therefore, there is need for simple assessment tools to be available to parents for screening children as early as possible and also frequently in order not to miss the early intervention period.

In a study conducted by Guthrie w. et al[9], Modified Checklist for autism in Toddlers with Follow-up (M-CHAT/F) was used for screening 23,634 children of ages 16 to 26months, all the children received a follow up check at the age of 4years. The researchers screened 91% of the children who were qualified for the check up based on some conditions, out of which 9.5% screened positive at first administration and 6.2% at second screening. Therefore, the researchers concluded the inaccuracy of M-CHAT/F in screening ASD than previously assumed by the health care providers based on their records, that M-CHAT/F only identified 38.8% of children who were later diagnosed with ASD. As earlier mentioned, this study is an extended version of [1] a conference paper we presented. Only 13 articles were reviewed, while we reviewed 22 articles in this Study by expanding our search criteria and data bases. Several article databases were consulted for this study which includes IEEE Xplore, Research gate, Google scholar and Multidisplinary Digital Publishing Institute (MDPI). The following criteria were used for choosing article in this study:

- Articles published between 1992 – 2021
- Articles published in English Language
- Studies which are for ASD
- Studies which used technologies like expert system, mobile based applications, robots, chat-bot, Augmented reality, video conferencing and telehealth systems to screen, detect and diagnose ASD

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This paper has reviewed tools used for Autism Diagnosis and screening and the various technologies use in developing them. This study is organized into 3 main sections: section A is for the Expert systems, section B is for the mobile based applications and the last section is for others which include Augment reality, robot and chat bot.

2. Related Work

This section provides the review of works that are related and similar to this research. The first paper we reviewed is our research paper [1] recently published which we are currently extending. We reviewed 13 expert systems and mobile applications that are being used for Autism diagnosis/screening. We find out that most of the expert systems developed are rule based, DSM 5 was mostly the diagnosis criteria used and machine learning methods were used in most of the research. Based on our findings we also concluded that most of the tools developed fall either on Automating an existing screening tools or augmented reality, so also the sources of data are based on legacy screening tools.

In another paper we presented [4], we reviewed 6 software applications that are used for the therapy of children on the spectrum, only articles published in English were included and the ones which are used only for ASD. The articles were analyzed based on the therapy they provide and the technique being used for developing the application. We found out at technology has been advancing in terms of developing such applications from pictures and cards, to human computer interaction, augmented reality and cloud computing as well. Our conclusion was that the applications do really help in the therapy of such individuals and parents have seen noticeable improvements while using them on their kids.

In a similar review [10] 28 articles were reviewed which are mostly screening tools for detecting Autism for the general population in children up to six years of age. The authors concluded that the use of technology for screening Autism is very needful and there is need for more sophisticated tools that can use eye trackers to be developed for screening in place for the traditional tools we have. In another review paper by Song et al [11] 13 papers were reviewed after going to the search and exclusion criteria, the authors found out very few papers have been published on using Artificial Intelligence (AI) technology for diagnosis of Autism unlike other fields despite the spike of growth of its occurrence in the whole world. The Authors also found out that implementing AI into general health care system still faces numerous challenges because of the data collection and cleaning that is being required for an accurate machine learning algorithm result. They concluded that AI can really help professionals in screening, diagnosis and treatment process if it can be in cooperated into the system.

Another paper reviewed is [12] which used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, 22 articles met the criteria for the review. They found out that Autism Diagnostic Interview-Revised (ADI-R) and Autism Diagnostic Observation Schedule-Generic (ADOS-G) were the most commonly screening tools utilized and concluded that though so many machine learning methods have been used and shown promising result, none has given the readiness of it to be used in real-life clinical practice. Tatarisco et al [13] used 5 different machine learning algorithms on the 4 Quantitative Checklist for Autism in Toddlers (Q-CHAT) set which they concluded that machine learning can be used to develop shorter, faster and more accurate Autism screening tools which can be used in our primary health care centers.

Dahiya and Mcdonnell [14] also did a systematic review on video and mobile applications used for remote telehealth assessments for screening early signs of ASD, articles searched where limited to studies that examined participants of birth to 1month, 2-23months and 2-5yrs.out of 551 articles, only 7 met the criteria for selection using the PRISMA system. And out of the 7 articles, four articles used video conferencing or video analysis to do the assessment while 3 used mobile or web-based Application as a screening tool. Their findings from the 7 articles reviewed suggest that more studies are needed for the research area though the studies did really reveal effectiveness of the Telehealth assessment tools in remote area and future studies should continue to build these novel approaches that can be used for a wider range of areas because we all know the high cost of comprehensive assessment which are less available and the need for early diagnosis of ASD is very important.

Another systematic review conducted by Dahiya et al [15] reviewed 16 articles which the authors extended to focus on articles whose participant are 0-12years an extension of the article reviewed above [14]. Out of the 16, 10 articles are on technology-based screening tools for ASD while the other 6 are tools used for ASD diagnostic assessments. The studies identified new methods of technology-based assessments which include live video observations, delayed video observations, web and mobile tools and phone screening interviews. These methods have proven to be promising, though telehealth is just starting to be used but due to Covid-19 pandemic there is need for further research in this area so as to reduce person to person contact. The authors suggested that more research is

needed for technologies for use in screening and diagnosing older children and the need to further investigate whether remote devices or tools can actually and accurately be used for ASD assessment.

Bartolome N. A. and Zapirian B. G. also conducted a systematic review [16] on Technology based tools used as support tools for persons with ASD which is similar to a research paper we presented in a conference [4] titled "A Survey of Software Applications used in Therapy for Autistic Children". The Authors targeted on research articles based on certain criteria mentioned which were search on some database. They concluded that technology is really a support tool for persons on the spectrum and for also the parents and professionals who do therapy for them.

Thabtah F. and Peebles D. conducted a study [17] on the Early Autism screening tools that are used for ASD. In their study, a total of 37 different screening tools were reviewed which were critically analyzed in terms of their performance, evaluation, target audience, scoring methods, other available versions and administration. The authors concluded that none of the screening tools is said to be performing good enough in terms of the afore mentioned parameters, very few of the tools comply with the DSM-5 screening criteria, many of them can only be administered by a well-trained professional, many are not freely available for users and only three are available on mobile phone. This study has given enough reason for researchers to develop tools that will overcome these limitations mentioned.

Hyde et al also did a review [18] on applications of Supervised Machine Learning in ASD, 45 articles were reviewed and some of the findings are: firstly, Support Vector Machine (SVM) and Alternating decision tree (ADtree) are the most commonly machine learning algorithms used, secondly that the use of machine learning in ASD research is of great value in practical applications and early intervention has proven to show a great improvement. Abu-nasser B. et al [19] reviewed 33 medical expert systems used in medical practice. Google scholar was the main source of the articles for this study and the authors concluded expert system will continue to play an important role in the medical field for diagnoses and recommending a treatment.

3. Literature review of Autism Diagnosis /Screening Systems and Applications

A. Expert Systems: This section gives the review of expert systems, how they were developed, the DSM criteria used and how the system is being used for Autism diagnosis/ screening.

1. A knowledge-based system for diagnosing autism: A case study on the application of artificial intelligence to psychology [20]: DAI is a knowledge based expert system developed in the year 1992 one of the first expert system developed to specifically diagnose Psychological conditions. Prototyping method was used in the development where 3 versions were developed before the final version. Dai was said to diagnosed 12 neurodevelopmental conditions including Autism and was evaluated to perform well in all the diagnoses that was tested. The knowledge base was developed by series of interview session with an expert in the field and the testing was also done by 4 experts including the expert that provides the knowledge base. The system is surely based on DSM 4 since it's an old system and obviously no machine learning was used in the development. Some of the limitations and issues identified from the system are: need to improve the user interface, need to carry out broader evaluation on the system, adding more facilities like explanation and report generation to the system and lastly making the systems diagnose many other developmental conditions.
2. Development of a Diagnostic Expert System for Autism Disorder [21]: Pakistan Childhood Autism Diagnostic Expert System (PCADEX) is an interview based expert system develop for Autism diagnosis to be used in Pakistan only. The system was developed using the 77 questions from the Autism Treatment Evaluation Checklist (ATEC) questionnaire which were reduced to 54 questions. A child having Autism answers more questions than those that don't have, similar to how a human expert does. Prolog was used for designing the Knowledge base of the systems. The system classifies a child as normal, borderline, mild or severe Autistic after answering the questions. And lastly the system was said to perform accurately after testing and served the purpose for which it was developed for.
3. Development and Evaluation of an Expert System for the Diagnosis of Child Autism [22]: This is a pilot study conducted to see the possibility of using an expert system in medical practice for Autism Diagnosis and the researchers confirmed that Expert system can really help in diagnosis and also Therapy. The expert system was developed in two stages; the first stage was implemented using the Parents Evaluation of Developmental (PEDS) and the second based on Childhood Autism Rating Scale (CARS). The system was developed using PROLOG. The

evaluation of the system was conducted by 12 nurses who worked in pediatric hospitals using 3 Autistic individual as case study. The system was measured based on its usability, usefulness and diagnostic value. The authors concluded that the study should stimulate researchers develop expert system based on machine learning algorithms that will help clinicians professionally.

4. Developing Autism Screening Expert System [23]: The development of Autism screening Expert System (ASES) was done using machine learning algorithm in 2 stages. At the first stage, machine learning algorithm was used to reduce the number of questions to 68 from a set of data gathered using 238 questions completed by 170 parents. The questionnaire was completed by 85 parents of children with Autism, 65 parents of normal children and 20 parents of children with down's syndrome. In the second stage, Support vector machine and random forest were trained using the data for classification. This system was measured and said to have high accuracy when compared to similar tools and validity in a very good range. The researchers conclude that the expert system can be implemented to help professionals to screen autism at an early stage because of its well-constructed knowledge base.
5. Autism Severity Level Detection using Fuzzy Expert System [24]: AUTISYS is an autism diagnosis expert system developed using fuzzy logic to diagnose autism and also gives the level of Autism present on the person. The knowledge for building and testing the system was gathered using a questionnaire (36 questionnaire) completed by parents and teachers of children on the spectrum and interview with a psychologist. Rules were then generated for building the system using the questionnaire and weight as assign to them. A person having <= 4 was said to have mild (level 1) Autism, > 4.0 & < 8.0 is Moderate (level 2) Autism and > 8.0 is Severe (level 3) Autism. The system was tested with 30% of the data gathered and was 60% accuracy when compared to the expert's diagnosis.
6. A Belief Rule Based Expert System to Assess Autism under Uncertainty [25]: BRBES is a Autism diagnosis expert system for diagnosing autism under uncertainty, the expert system knowledge base is an extension of the traditional if then statement. The system was developed to assess the level of Autism present in individuals and also to asses it overtime. The system was tested on 100 school students in Bangladesh where teachers were measuring the level of Autism based on some certain factors. The system was said to perform better than similar fuzzy logic developed with matlab and expert's opinion.
7. The Development and Acceptance of Autism Advisory Expert System [26]: This is an Autism diagnosis expert system developed to be used by parents and care takers not only for diagnosis but also for giving advice and providing awareness about the condition. The system also classifies the diagnosis based on the level of Autism detected that either Level 1, level 2 or level 3. The knowledge base of the system was gathered from literature as well as from experts as we have seen from other studies. The system was tested and evaluated by 25 users and each feedback was recorded. The system was evaluated based on its ease of use, accuracy, consistency, completeness and relevancy. 94%of the users concluded the relevancy of the system and also 92%concluded the accuracy of the system.
8. Expert System For Autism Prediction in Children With Web- Based Forward Chaining Method [27]: This is a web based autism diagnosis expert system based on the DSM 5 diagnosis criteria. The system was developed in Malaysian language. Data collection for the knowledge base was done through existing literature and then rules generated using forward chaining method for the assessment. The system was tested with 64 data set and accuracy of 87.5% was obtained.

The summary of the expert systems reviewed is summarized in Table 1 below. The table gives the sources of data, details of technologies used in the development of Expert systems and how the expert system was evaluated. It also gives the year the expert system was developed.

Table 1: Expert System

Article	Year	Technologies used	Data Sources	System Evaluation
[20]	1992	Rule based Expert System	Single human	Evaluated by experts from Different areas
[21]	2011	N/A	ATEC	
[22]	2012	Predicate Logic	PEDS &CARS	Evaluated by 12 nurses
[23]	2012	N/A	170 parents	Machine learning Methods

[24]	2014	Fuzzy Logic	Interviews and 36 Questionnaires	30% of the data Collected
[25]	2015	Rule Bases Inference Methodology using the Evidential Reasoning (RIMER)	FEW	Compared with Expert Opinion and Fuzzy based System
[26]	2016	N/A	Literature and one on one interview with an Expert	Evaluated by 25 Participants
[28]	2019	N/A	Literature	Compared with 64 instances of expert Opinion

B. Mobile Based Applications: This section gives a review of the Mobile based applications, how they were developed, the DSM criteria used and how the system can be used for Autism diagnosis/ Screening by a user.

9. The Design, Development, and Deployment of RoboParrot for Screening Autistic Children [29]: RoboParrot is a system developed for Autism diagnosis using a parrot robot remotely controlled by an expert via a computer interface. A camera is also attached to the cage of the robot to record the movements of the person in its front. The parrot also has speaker, micro phone and sensors attached to it. The software applications used are the graphical user interface and a voice morphing platform in other to make the controllers voice similar to a parrot's voice to be more realistic. The diagnosis done by the system is based on DSM 4 criteria. The system was tested using 52 participants of which 36 are Autistic children and 16 are normal kids where evaluation was done both individually and in group. Machine learning was used for the classification where lack of attention and unstable posture were the main features that are said to differentiate normal kids from Autistic kids, this was conducted using the WEKA platform.

10. A Novel System for Supporting Autism Diagnosis Using Home Videos: Iterative Development and Evaluation of System Design[30]: NODA is a remote Autism diagnosis system structured in two parts, the first part is the Smart capture is a mobile based application used by parents to record videos of their children and the second part NODA connect is a web based portal used by professionals to assess the videos uploaded by parents and do diagnosis by tagging behaviors to the DSM criteria for Diagnosis. The system was developed using iterative method of software development while collaborating with a diagnostician who has a 20years expertise in Autism diagnosis. The Knowledge base was gathered by interviews with families of Autistic children and the clinicians, so also the evaluation was conducted. But before the development, interviews and a pilot testing was conducted with few families and clinicians to assess the possibility of using it for a real life diagnosis.

Table 2: Mobile Application

Article	Year	Machine Learning used or not	Data Sources
[29]	2015	Yes	52 Participants
[30]	2016	No	Literature, 11 Clinicians and 6 parents of children with autism
[31]	2016	Yes	32 Participants
[32]	2016	No	Nil
[33]	2018	Yes	162 Videos
[34]	2019	Yes	Over 1400 instances
[35]	2020	Yes	228 Instances
[36]	2020	No	Nil
[37]	2016	No	Nil
[38]	2020	Yes	6075 Instances

11. A Quantitative Screening Approach to Autism Spectrum Disorders[31]: Gaze-Wasserstein is an Autism Screening system based on the DSM 5 criteria. The system consists of 2 main components, the first is the data collection device usually a computer system, mobile device or a wearable eye tracker referred to as the local access. The second is the remote access device used by the physicians to administer diagnosis using the gaze pattern –based measurements. It is said that the gaze distributions of individuals on the spectrum is fewer than that of the typical children. The evaluations of the system were done with 32 participants using k-Nearest Neighbors (KNN) Classification and leave-one – out validation and the system recorded a good result.

12. A smart device based automated autism screening tool for Bangladesh [32]: Autism Barta is a mobile based Autism screening application implemented using the M-CHAT screening tool algorithm. The user will register his details before using the application and every detail including the assessment if the user is said to have Autism is stored in an online data base which is assessable later on. The system automatically refers the user to the nearest community health center based on the address provided for confirmation and future intervention plans. The system was developed to be used in Bangladesh only and was developed in Bengali language.
13. Mobile detection of autism through machine learning on home video[33]: This is a system developed for screening Autism based on machine learning algorithm on home videos. First, 8 machine learning algorithms were trained and validated using real data sets from medical records generated using ADOS or Autism Diagnostic Interview-Revised (ADI-R) screening tools. Then a mobile application was developed for parents to upload home videos of children with ASD, participants were advised to use the platform and videos were uploaded and selected based on some certain criteria's. And then 9 video raters were trained, tested and asked to tag the videos uploaded. Machine learning algorithms were also used on the videos for tagging features related to Autism. The authors concluded that mobile home videos and machine learning algorithms can be used for Classifying individuals by feature tagging without physically seeing the individual. This could fasten and save cost and resources on the processes also.
14. An accessible and efficient autism screening method for behavioral data and predictive analyses [34]: ASD test app is a mobile application designed to screening Autism for all ages. The application is implemented using the Autism Spectrum Quotient (AQ10) and Q-Chat screening tools. The user selects the language he wants to use and age criteria he wants to screen for, and each of the four modules contain 10 questions to be answered by the user. All data inputted by users were store in a database which can later on be used data analysis and future research. Results can be emailed from the application also.
15. A predictive model for pediatric autism screening [35]: This study developed a mobile application for screening Autism using Pictorial Autism Assessment Schedule (PAAS) questions and embedded with a trained machine learning classification model. The data for training and evaluating the model was also collected from PAAS responses completed for 228 children. Each of the diagnosis found from the data used was confirmed by clinical Observation for both Autism and neurotypical child. A number of classification algorithms was trained, tested, compared and evaluated using the WEKA plat form where Random Forest was evaluated to be the best algorithm to be used for Autism predication for the mobile application. The user answers 21 PAAS questions using the mobile app and the resulted will be provided upon complete, then his/her will be advised whether to go for further investigation in a healthcare center or not.
16. A Smart Phone Based Mobile Application to Detect Autism of Children in Bangladesh [36]: Prottoy is another Autism screening mobile application developed in Bengali language to be used in Bangladesh. The application is implanted using the Childhood Autism Spectrum Test (CAST). The user does registration and answers questions on the application, if Autism is found to be true, the user is referred to the nearest Hospital for confirmation and therapy. It uses a cloud based data repository for storing user's information and assessments. In addition, it contains a 3D pictorial representation and scenarios to help its users understand their questions.
17. A mobile, interactive and integrated framework for screening and confirmation of autism [37]: Smart Autism is a mobile application frame work design to screen, assess and confirm autism in individuals of ages 0-17 years. The application is cloud based, meaning that information/data gathered are store on the cloud. Three layers of assessment makes up the application working process. The first is the screening process where a user answers question based on ages, 16 months to 36 months are given the M-CHAT R questionnaire, 3-11years are given the CAST questionnaire and 12-17 years are given the Autism Spectrum Screening Questionnaire (ASSQ). If autism is suspected, the systems sends a video to the user and the mobile application record the child as the video is being played, the recording is the being sent to an expert for a virtual assessment. If after the second stage autism is still suspected, the user is referred to an Autism Resource center (ARC) for confirmation by performing an Actual assessment which is the third process.

18. A New Autism Screening System Based on Artificial Intelligence[38]: Autism AI is a mobile based autism Screening application integrated with a deep learning algorithm known as Convolutional Neural Network (CNN) via a web service. The user is given Q-CHAT 10 questionnaire to answers based on the ages he registers with for the screening. Once the user completes the questionnaire, responses are validated and sent to the CNN algorithm to predict whether the users have autism or not based on the data store in cloud. The result is given to the user and a data usage consent form is also sent to the user. It also asks users if they have formal diagnoses which are also being stored in the data base including the prediction. A comparative study was conducted with other algorithms and CNN was said to perform best in terms of accuracy, specificity and sensitivity.

Table 2 above gives more details of the mobile applications reviewed in terms of the data sources, whether machine learning was used or not and the year the application was developed.

C. Human robot interaction and Others: In this section, other applications were reviewed such as Chatbot, System based and web services.

19. A Diagnostic Chat-bot for Achluophobia and Autism [39]: AquaBot is a Chat-bot use for Autism diagnosis using natural language processing and decision tree. The chat bot interacts with the user by allowing the user to mention his complains in it language and diagnosis is provide based on the decision reached on the decision tree. The user uses the chat window to type in the complaint in text and the chat bot also replies via the same window. Sentences are separated into keywords and then compared for similarities with the symptoms saved on the system until all symptoms are save when the session is completed. Then the depth first search is used to make the diagnosis. The system was tested and 88% accuracy was obtained. The system can also be used for Diagnosis of Achluophobia using the same procedure.
20. Grading Autism Children Using Machine Learning Techniques [40]: this study was conducted using clinical data set obtained from CARS and some classification algorithms used on the data set to classify them into the different level of Autism. 100 instances of the data set were used out of which 30 were severe, 20 moderate, 29 instances and 21 instances have Autism. In this study, decision true was found to be the model with greatest accuracy with both training data and test data for doing the classification. Therefore, machine learning algorithms can help pediatricians to detect and classify Autism.
21. Augmented Reality and Novel Virtual Sample Generation Algorithm Based Autism Diagnosis System [41]: this a system developed for screening Autism from the movements of child's upper limb. The system uses Augmented reality and machine learning algorithms to be able to classify children as having Autism or not. The data for training and testing was said to be gathered from different sources. The Augmented reality was used to create virtual objects so as to make the children move their hands and recording the movement was done by Microsoft Kinect. The system was designed in 3 main parts, the AR task, tracking movement part and lastly data collected analysis part.
22. A robotic approach to autism screening in toddlers [43]: Q- CHAT NOA is an early autism detection system using some of the questions of the Q- CHAT 10 questionnaire that do not require answers from the mother and the NOA robot is placed in front of the child to assist in performing the observation . The system was evaluated using toddlers' data set obtained from a research as mentioned.

Table 3 below give more details of these applications in terms of the data sources used for the development of the application and other technologies embedded in the application.

4. Discussion

In this study, we reviewed 8 expert systems in section A, 10 mobile based applications in section B, a chat-bot and 3 others using different methods in section C all used in Autism diagnosis/screening in both toddlers and adults. From our review, we found out that some mobile applications and Expert systems were developed for certain countries which are mostly the Low Medium income Countries (LMIC) as shown in Table 4 below.

This is due to the lack of Qualified specialist that can do the diagnosis and screening in such areas. As seen in the table Bangladesh has the highest number of applications developed, and these applications were developed in their Bengali Language.

Table 3: Chat-bot, Robot and Others

Article	Type of Application	Data Sources	Other Technology used	Machine learning used
[39]	Chat-bot	Literature	Natural Language processing	Yes
[40]	System Based	100 Instances	Nill	Yes
[41]	N/A	30 Instances	Augmented Reality and Human Computer interacttion	Yes
[42]	Web Service	1054 data sets	Robot	Yes

In the study, we also found out that most of the applications and expert system were either electronic version of the legacy screening tools used in Autism diagnosis and screening or used some of the questions from the legacy tools as shown on Table 5 below. And some applications used data obtained using the legacy tools either for screening or Diagnosis to develop a model or algorithm for screening Autism. As seen in Table 5, most of the mobile applications developed are based on existing screening tools that have shown some promising result. And also, most of the data sources used are very small as shown in the Tables 1, 2 and 3. The highest number of data sets used is 6075 in a mobile application development shown in Table 2.

Table 4: Systems/Applications made for Specific Countries

S/No	Name of Application	Type of Application	Country developed for
1	PCADEX [21]	Expert System	Pakistan
2	ASES[23]	Expert System	Iran
3	BRBES [25]	Expert System	Bangladesh
4	Autism Barta [32]	Mobile Application	Bangladesh
5	A predictive model for Peadiatric Autism screening [35]	Mobile Application	Sri Lanka
6	Prottoy [36]	Mobile Application	Bangladesh

Table 5: System/Applications Based on Legacy Screening Tools

S/No	Name	Type	Legacy Screening Tool
1	PCADEX [21]	Expert System	ATEC
2	Development and Evaluation of an Expert system for the diagnosis of Child Autism[22]	Expert System	PEDS & CARS
3	Gaze-Wasserstein [31]	Mobile Application	ADOS
4	Smart Autism [37]	Mobile Application	M-Chat R, CAST & ASSQ
5	Autism Barta [32]	Mobile Application	MCHAT
6	Grading Autism Children Using Machine Learning Techniques[40]	System Based Application	CARS
7	An accessible and efficient autism screening method for behavioral data and predictive analyses [34]	Mobile Application	AQ10
8	Autism AI [38]	Mobile Application	Q-CHAT 10
9	A Predictive Model for Pediatric Autism Screening[35]	Mobile Application	PAAS
10	Prottoy [36]	Mobile Application	CAST
11	Q-CHAT NOA	Web Service Provided	Q-CHAT

In this study, we also found out the age categories that these systems/applications can diagnose/screen. In Table 6. below, the age categories of the systems/applications is indicated for the ones provided in each paper.

As seen in the table, most applications were developed for screening of Children from ages 0-12 years, very few can screen/diagnose individuals older than 13 years of age. Though most attention is given to toddlers in Autism diagnosis, but there is still need for the older ones who are on the spectrum or even the normal ones who are not on the spectrum to be able to screen and diagnose themselves.

Table 6: System/ Applications age range for Diagnosis

Article Reference	0-4 years	5-12 years	13-18years	19 Above
[20]	✓	✓	×	×
[21]	×	✓	×	×
[22]	✓	✓	×	×
[23]	✓	✓	×	×
[30]	✓	✓	×	×
[31]	✓	✓	×	×
[37]	✓	✓	✓	×

[32]	✓	×	×	×
[39]	✓	✓	×	×
[33]	✓	✓	×	×
[34]	✓	✓	✓	✓
[28]	✓	✓	✓	✓
[38]	✓	✓	✓	✓
[41]	✓	✓	×	×
[36]	✓	✓	×	×
[42]	✓	×	×	×

5. Conclusion

In this study, we have reviewed 22 articles on the development of Expert systems, Mobile applications, Web services, chatbot and others used in Autism screening and diagnosis. We have found out that these systems and applications can be used where there is no enough expert to perform the screening /diagnosis and also most of the systems have been evaluated based on performance, simplicity and accuracy which they have shown good percentages.

Therefore, we can conclude that these systems can be implemented in real life clinical practice and countries where they lack theses experts especially the LMIC and specifically in Africa. There is also need to have these systems to diagnose individuals of all ages because we have seen that very few reviewed can do so.

And lastly there is serious need of data in this field of study, most of the earlier applications developed rely on literature and human expert for data. We need more applications from different regions and locations to provide data so that more research can be done in this field of study.

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