Early Diagnosis of the Learning Disabilities in Kids Using a Computer Game-Based Solution

Rohan Samarasinghe1 Member IEEE and Gamini Abeyasinghe2
1 Department of ICT, Faculty of Technology, University of Colombo, Sri Lanka 2 Teaching Hospital Kuliyapitiya, Sri Lanka
1 rohan@ict.cmb.ac.lk, 2 gbabey@sltnet.lk

Abstract: This paper presents the extracted computational techniques and outcomes of software solution developed for learning disability evaluation in kids age from 3 years to 6 years. Learning disabilities are neurological disorders which affects brain functions. It is efficient to diagnose them in early stages. The developed application screens the learning disabilities by using gamification module. This game module contains tasks which are based on symptoms of these disabilities. By evaluating children's interactions to the tasks, this game module evaluates the child condition and provides the results to respective parties. Background problem of these disabilities, clinical diagnosing methods and criteria and methodology used for development of this solution is explicated by this paper. Ultimately, the proof testimonies of concepts are set forth by summarizing the outcomes obtained from standard statistical concepts.

1 Introduction

Learning disabilities are neurological disorders that affect the brain's ability to receive, process, store, respond to and communicate information. These are not the same as intellectual disabilities which are formerly known as mental retardation, sensory impairments, or autism spectrum disorders. Learning disorders are among the most frequent disorder in childhood accounting for 5-15% in children across different language and cultures (DMS5). People with learning disabilities are of average or above-average intelligence but still struggle to acquire skills that impact their performance in school, at home, in the community and in the workplace. Learning disabilities are lifelong disabilities and may not improve with time or with intervention. Learning disabilities are mainly four types. They are Dyslexia, Dyscalculia, Dysgraphia, and Dyspraxia. Each type is involved with different ability of brain [1].

Dyslexia is perhaps the best-known learning disability. It is a learning disorder that impedes one's ability to read and understand the text. It can manifest in various ways. Some people struggle with phonemic awareness which mean they fail to recognize the way wards break down according to the sound. Other related issues include fluency, spelling, and comprehension etc. It can affect spoken language, written language and language comprehension [2]. Hence, the Child can get one or combination of them. Dyslexia can simply describe as disability with language and reading. The second major learning disorder is the Dyscalculia where there is a problem with arithmetic and math concepts. It refers to a persistent difficulty in the learning or understanding of number concepts, counting principles, cardinality, or arithmetic. These difficulties are often called a mathematical disability [4]. They are poor in calculation, as well as concept like time, measurement, and estimation. Writing disability is known as Dysgraphia. Writing is a skill highly valued in our society, even in a time of computers and technology. In the past, handwriting was prized because it was a primary form of communication; people needed to get notes to others that were legible. Children are not able to keep up with written assignments, cannot put coherent thoughts together on paper, or write legibly in correct format [3]. Their writing may have obvious omission which affect the quality and readability of the text. Not only that they also struggle with sentences structure and grammar. Dyspraxia otherwise sensory integration disorder manifests itself in problems in adequately registering, interpreting, organizing, and integrating sensory information to produce an efficient response. Children with dyspraxia is often referred to as having "clumsy child syndrome" because of their tendency to bump into things and frequently have trouble with sports, e.g., catching balls.

Dyspraxia is characterized by difficulty in planning smooth coordinated movement. That is why it is also known as Developmental Co-ordination Disorder (DCD) [5]. People with LD face different kind of problems in every stage of life. Bullying in school is the difficult for children. Because effect of bullying is haunt them throughout the life. Difficulties in several areas listed in following table 1.

TABLE I COMMON PROBLEMS OF LEARNING DISABILITIES

Area	Difficulties
Social	Lack of ability to comprehend nonverbal communication
	Significant deficiencies in social judgment and social interaction
Academic	Problems in math, reading comprehension, handwriting
	Problems with organization, problem-solving, higher reasoning
	Strengths include strong verbal and auditory attention and memory
Visual-Spatial	Lack of image, poor visual recall
	Faulty spatial perception and spatial

	relations
Motor	Lack of coordination
	Severe balance problems
	Difficulties with fine motor skills
Emotional	Frequent tantrums, difficulties soothing, easily overwhelmed
	Fears of new places and changes in routines Prone to depression and anxiety as they get older

Source: http://www.waisman.wisc.edu/

Experts aren't exactly sure what causes learning disabilities. One of the possible causes is heredity. Often, learning disabilities run in the family, therefore it's not uncommon to find that people with learning disabilities have parents or other relatives with similar difficulties. It is assumed that Problems during pregnancy and birth also contributing. some of these Learning disabilities may be secondary to illness or injury happened during or before birth. It may also be due to low birth weight, premature or prolonged labor, lack of oxygen, drug and alcohol use during pregnancy. The factors postulate after birth includes Head injuries, nutritional deprivation, and exposure to toxic substances. (i.e., heavy metal like lead). Learning disabilities are not apparently related to economic discrepancy, environmental factors, or cultural differences. In fact, there is frequently no apparent cause for learning disabilities.

Evaluating these disabilities are different from country to country. With the amount of knowledge parents have on these disabilities; time to evaluate these conditions can vary. In countries like Sri Lanka, many parents are not aware of this medical condition and children with LD are labelled as idiots or lazy children. Also, in the school with the number of children in the class, teachers may not able to keep an eye on each child. Hence, children lag behind due to learning difficulties.

If the parents or teacher suspects that the child who is having learning disabilities, they may take the child to a trained consultant for assessment and opinion. Generally, most consultants use DSM V criteria to diagnose such events [6]. If parents, teachers, and other professionals discover the child learning disability in an early stage and provide the right kind of help, it can give the child a chance to develop skills required to lead a successful and productive life. In Sri Lanka, they use some paper base mechanisms which are very time consuming and unattractive. Unawareness of this condition could badly affect rest of their lives in terms of learning.

2 EXISTING SYSTEMS

In Sri Lanka there is no software-based method available to evaluate

these disabilities even though internationally, Yalu kind of game-based applications are difficult to find. There are several computer-based applications designed to test this issue, but most of them are based on questionnaires to be followed by parents, guardian, or child. For that they must be very keen in computer literacy. Computer-based application with localized languages is hardly found and fluency in English is also required because most applications are in English. These applications will not be able to use in most of the countries because of developing the applications in English and not suite for most of the countries. Although these applications give results based on answers provide to questions, not by the interactions of user or by observing the actions of user. Moreover, these applications address to more mature children in age above six. Basically, those existing solutions does not address all four types of learning disabilities and they are not interesting for children at all.

- **Dore dyslexia symptom check** [7] – Questionnaire based testing application. Child or parent can answer the questions and take the test results. User must have good computer literacy to perform this test. This is a free test, but in order to get results user has to give an email then the results will be sending to that email. This application can test only one category of learning disorder.

- **Adult Self-Assessment Tool by IDA** [8] – Questionnaire based testing method designed only for adults. Adult can answer the questions given in test and according to answers given to the questions, the user will be given a scores. The Websites has explained the evaluation criteria and says that if user has high score, he has high possibility of Learning Disabilities (DL). The user must have good computer literacy and those who have poor computer literacy knowledge they will not be able to interact with this system. Moreover, this system contains some applications to train dyslexic students.

- **Dyslexia Screener** [10] – This system has a major limitation that the age must be above 6 years to do testing with this system. Moreover, it's very costly because it contains different type of screening applications and if the parents want to other disabilities, they have to purchase them to test other disabilities. Hence, most of the middle-income families find some difficulties to use it because of the cost.

- **Lexercise** [11] – Complex dyslexia screening application. Child must have a good computer literacy to test with this application.

The main Problem with all these systems is, they have specially been developed to identify one kind of learning disability, but most of the time the children may have more than one learning disability which is very difficult to diagnose with those systems. All these systems are online or desktop mode applications and can be played by a person who has more computer literacy only. A summary of the existing system with the language, age, focused disability, and users are given in table II.

TABLE II: SUMMARY OF BACKGROUND CONTEXT

Name	Lang	Age	Disability	User	Attrac tivene ss
Lexercise	En	6+	Dyslexia	Parent	No
Dore	En	Adult	Dyslexia	Parent/ Child	No
IDA	En	Adult	Dyslexia	Parent	No
Screener	En	6 -14+	Dyscalculia	Child	No
Checklist	En	Adult	Dyspraxia	Parent/ Child	No
Yalu	En/ Sin	4-6	All LDs	Child/ Parents	Yes

As almost all the screening applications address only one type of Learning Disability users who are having multiple disabilities face problems to diagnose all the disabilities using a single application. Moreover, there wasn't any application to early diagnose of the Dysgraphia which is one of the main disabilities in children. Hence, having understood the weaknesses and limitations of the existing systems and the disability that hasn't been addressed by any of the existing systems the YALU Learning Disability Evaluation Kit was introduced to overcome the said weaknesses. YALU system is designed to identify all four types of learning disabilities including Dysgraphia. This product is designed in very interactive way so that the children can interact with games with high interest. The YALU Learning Disability Evaluation Kit is explained section II.

3 YALU LEARNING DISABILITY EVALUATION KIT

The YALU Learning Disability Evaluation Kit has been developed to diagnose the learning disabilities of the children aged between 4 to 6 years old in early stages, using a user-friendly computer-based gaming software solution. The YALU was designed to detect symptoms of learning disabilities in children and can generate a report based on the performance of the child on computer games and it will help to diagnose the learning disabilities of the children both by the parents and the doctors.

When a game software is designed for the kids to diagnose the disability it has to be considered age groups of the kids, kids knowledge levels in the age groups, abilities, and child psychology of respective age groups. Therefore, the YALU has been designed under the consultation of psychiatric specialists and a child psychologist. YALU is a story-based game series which includes attractive and user-friendly graphics and interesting stories which give instructions to go through the games. Ultimately YALU comes to children in a tablet computer which requires only ability to touch and a display screen with a Kinect device to detect

body gestures of the child.

The evaluation of the child based on the performance of the game is systematic and for each age group three level (preliminary, intermediate, and advanced) of games have been developed. Upon finishing one level of a of a game of certain age group, it will automatically switch to the next level of games. Therefore, YALU uses several techniques to fulfil above aspects by game changing mechanism, with parent/guardian questionnaires and with an effective result analyzing mechanism.

Parents can create a profile in the YALU web site with an account, then the result of each attempt of the computer games can be uploaded to the web site. Hence, this system is very convenient to the kids as well as the parents and doctors, when the parents have free time, they can get the game played by the kids and upload the result to the system. The components of the YALU Learning Disability Evaluation Kit is explained below.

A. *Overview of the YALU System:* The main functionalities of the "YALU" Learning Disability Evaluation Kit are Learning Disabilities symptom detecting game series, game changing mechanism using an AI algorithm in order to diagnose and to confirm user Learning Disability condition, analyzing the result using the experts' comments and threshold values and generate final conclusion report an upload to the web site. Figure-1 shows the High-level architecture of the YALU system to explain the above functionalities and system is mainly used the tablet computer game series, Kinect based game series and a website. The tablet computer game series has been developed to use with the Android mobile phone also.

Fig. 1. High-level architecture diagram of Yalu system

1) *Tablet/Mobile computer game series:* Android game series can be played in android tab devices and mobile phones. It identifies Dyslexia, Dysgraphia and Dyscalculia. These games can be played by the children in age groups from four to six. We developed five different android games for the different age groups starting from four years and the age is   increased by six months

with the different games. For instance, age groups are 4 years, 4.5 years, 5 years etc. Most of the games are based on stories known to children. The instructing language of the game can be localized and here in this game the use can select either Sinhala or English. Therefore, the child can listen the instruction of the game in his native language and do the game. One game level has multiple tasks and the highest level has more than eighteen tasks to complete the game with two sub- levels. The games do not indicate that the child response is right or wrong and no marks are given until the game is finished. Finally, the system analyzes the answers and based on the threshold values analyze the result and make a predictive analysis using the result about the learning disabilities.

2)   *Kinect based game series:* Kinect PC game series used to identify Dyspraxia and specially designed for the children who are in age six. Child must move hands and the body   to interact with game and each motion of the body is identified using Kinect device. Here, in this Kinect based game series, there are two games designed for the children to identify the Learning Disability. All these games are very attractive, colorful, user-friendly and easily to understand as the native language is being used. Each child will be given separate login to the system; hence, the parents/guardians can ensure that child has not played these games with previous practice. If the child had been played these games before the result and prediction wouldn't have been accurate.

3)   *Website:* The web site provides the facility to the parents to register in the system and they can create a profile in the website. Then it provides the facility to download the game to the user's device installs the games. Having been installed the game system to the user device the games can be played offline without connecting to the Internet. Having the offline facility to the system, the system could increase the availability of the system in any condition of the Internet and the children can play those games and view results of the games after finishing them. The Result will accurately predict whether child is having disabilities or not having any of these disabilities. The final result of the games can be uploaded to the system to the user's profile with the date and time stamp. Then the parents can consult a specialist with this result and confirm the real situation of the child. To analyze the history of these disabilities ant to give more accurate prediction, A questionnaire was introduced to the parents to fill about child and his background. This questionnaire will be helpful for the final conclusion made by the specialist doctor.

4 IMPLEMENTATION OF THE YALU

The YALU Learning Disability Evaluation Kit was developed using Open-Source software to minimize the development cost as well as to provide the service for all required parties. Eclipse as Java IDE to develop the games and Android 4.2 Jellybeans, mobile operating system for the tablet and mobile devises to run the games for the kids. For the Kinect based PC game series visual Studio latest version and XNA Gaming studio have been used for the development of the game software. The YALU web site needs the front end and backend as the system will be used for the commercial purposes and to maintain

the kids' profile in the system. Therefore, rather than using the Native PHP, this system has been used the Laravel framework for the back-end and Bootstrap for the front end. Front-end and Back-end was connected from AJAX. the YALU system is used the MySQL and SQLite as databases to store user profiles, results of the games and generated reports of the kids. The Restful API is used to handle the database this system.

Tablet/Mobile Game Series

These games have been designed based on the famous stories for the kids with attractive background story for each game and the children have to play the game to know the whole story. According to the playing instructions given by the game in background, the children need to interact with the game. For each age group there is one main game which contains two levels and each of which includes three sub games for identifying dyscalculia, dysgraphia and dyslexia with the following symptoms for each disability.

For dyscalculia,

- Can count, but difficult to count objects.
- Trouble recognizing printed numbers
- Trouble organizing things in logical way
- Difficulty discriminating large or smaller number.

For dysgraphia,

- Mix upper- and lower-case letters
- Inability to write or draw in line or margin
- Trouble forming letter shapes
- Trouble in writing given pace

For dyslexia,

- Recognize letters
- Difficult in matching letters/words to sounds
- Difficulty in learning the alphabet, numbers, days of week like similar common word sequence.
- Reading wrong order.

Each sub game contains six to eight tasks with three subtasks for each game. First level game is static whereas the second level of game is dynamic. According to answers given by the child for the first level, the system analyzes the result and changes to the second level automatically by confirming the results.

To provide the different types of interactions by the games, several types of tasks have been developed with these games to identify the potential disability symptoms of the children accurately. Preliminary types of the tasks are selections of the correct answer for the images from multiple set of answers. The second type of tasks are to drag and drop the correct answer to the pictures given in the game. Also, the child who plays the game can

change the selected answer if he feels that the selected answer is wrong. The child is given the facility to change the answer any time whenever he wants before finishing the game. Moreover, this type of tasks provides the facility to draw the lines and shapes accurately. The child must draw the lines on the given shapes carefully and application will check if the child has drawn on the given coordinates accurately. Next type of tasks is to draw images according to the given instructions to by the game and the system checks the accuracy of this level also. Third type of tasks are matching the objects using lines. The child needs to draw lines to the matching answers. Last type of tasks is to draw a given letter with a correct shape. The drawn letter will be checked the accuracy by using image processing techniques by the system.

The registration process must be done by the parent or guardian of the child when he uses at the first time by providing all the required information to the system. Basically, child full name, address, date of birth and contact tel. number are the mandatory information for the system and username and password also must be given to the system to create the login account. Then the set of games can be downloaded and installed in the device and setup the environment for the child to pay these games. When the child login to the system by giving the username and password, the system calculates the age of the child and select the right set of games that matches with the age and load it to the devise. If he finishes all the types of games of his age group successfully getting the required marks, he will be automatically switched to the next age group's set of games. Having this automatically switching method for next age groups, the doctors and easily diagnose the condition of the child accurately.

As the child can play the computer games related to these disabilities offline in his device and save the results of the games in the same device will help to save the communication cost and it provides the high availability of the system for the children. When the child finishes the games, the system checks the Internet connection and if it is available the progress of the child (result) will be uploaded to the user profile. Otherwise, the system looks up the Internet connection and when it is established the result will be uploaded.

When he uses the games in the next time, the system checks the age of the child and if the child is in the same age group, system checks if there are any new updates of the games available. Unless there are any updates of the games, it will switch to the game interface otherwise the updates will download and install before the game interface opens to the child.

Following figure-2 show some screenshots of the Tablet games developed for the kids.

Fig. 2: Screen shots of the tablet games

Moreover, the figure-3 shows a child is playing the Kinect game.

Fig. 3: Screen shots of the Kinect Game

Automatically Game Changing Methodology

As explained before, there are two game levels available for evaluation process i.e., first static level and second dynamic level. In first level of the games, the system checks and stores the child's interactions with the game tasks. Then after finishing of this level, internal evaluation is taken place with the given instructions and threshold values and generate a report based on the result. From the evaluation result, if the child has achieved required level successfully, he will be automatically switched to the next level of games or otherwise step down in one level and start with that age group. For instance, the child is given the level one game according to his age. Assume that the age of the child is five years and for this age group three types of android games have been designed for the kids. Moreover, each type consists of maximum of eight tasks (two tasks to identify each disability) to identify the main four learning disabilities. After completion of the level one games, the system calculates the marks for each disability and if child scores more than minimum of 4 marks in one disability, he will eligible to go for the next level from that disability check games. Otherwise, he will be automatically stepped
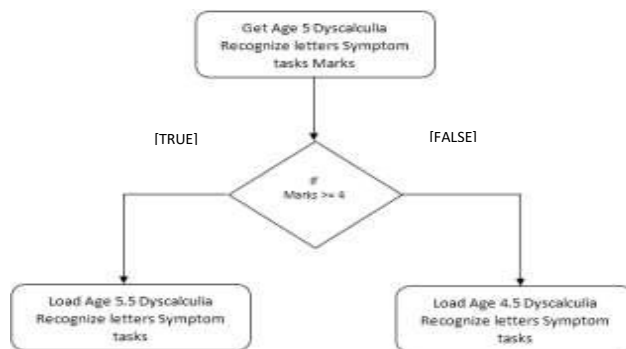
down to the previous games. The main advantage of this system is that it can be diagnosed the four learning

Fig. 4. Game changing algorithm

disabilities from one system with the level of the disability. The game changing algorithm of the YALY is given in Figure 4.

Analyzing the Result

Having been played all the games by a child in the chosen age group, the parents also must fill the feedback web form about the child. The game result and the feedback must push into the backend server of the system. Using the threshold values and experts' comments, the result will be analyzed

and generate a report about the child. This result will be uploaded to the child's profile and parents and doctors can refer it for the further treatments.

This report generation process is used an algorithm to analyze the child interaction with the games and feedback questionnaires filled by the parents. The algorithm is developed to process each interaction of the child with the game and connecting with symptoms given by the expert doctors and judge that the child is having the symptom of the said disabilities. Hence, it will help to diagnose learning disabilities of the children accurately in the early stages of the kids.

There are some characteristics that cannot be identified by the game itself. Hence, the feedback questionnaire is specially designed to get the child behavior and attitudes which cannot be checked by a computer game, but they have to be taken into consideration for the final report about the child is suffering from learning disabilities or not. The tablet game results are providing response of children on dyslexia, dysgraphia and dyscalculia symptoms while the Kinect games provide the dyspraxia symptoms' responses.

The algorithm checks the child condition step by step as given bellow.
- ✓ Get symptoms one by one of the tablets and Kinect games and give a mark to child's interaction.
- ✓ For the first level of the game will be weighted by 2 and the next level of game also will be weighted by 4 or 1 according to average marks of first level.
- ✓ If the child passes the level 1, he will be eligible for the next level which has the weight by 4. Or else if the child fails level 1 next game will be weighted by 1 in game category.
- ✓ This will continue until all the games of that level are finished and get the summation of the marks belongs to each learning disability and analyze.
- ✓ After getting the final mark of all the disabilities and considering the questionnaires, it will give red, yellow and green warning colors depending on the criticality of the symptoms of the disabilities of the child is having.
- ✓ Finally, system would generate a report using the result of the games and questionnaire and make a conclusion about child's symptoms with recommendations.

The conclusion report can be accessed only by the parent or guardian of the child. There for they have to login to the website to access. The report can view on the webpage or can be downloaded in PDF format to get a printout. Also, the report can be sent to the consulting doctor via an email.

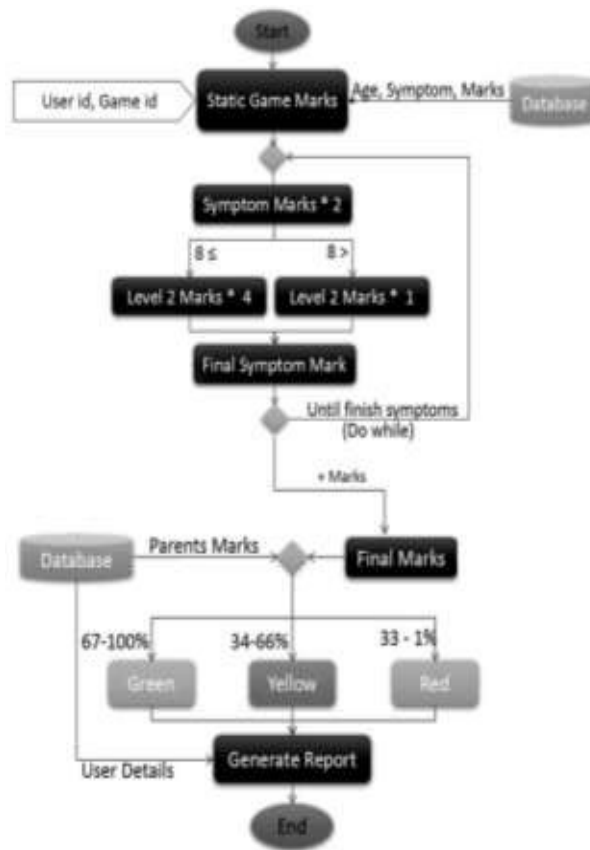The Figure 5 below shows the game analyzing algorithm that is used by the system.

Fig. 5. Diagram of game analyzing algorithm

FINDINGS / RESULTS AND EVIDENCE

YALU Learning Disability Evaluation Kit game software system has been tested in two ways. First is to ensure its functional features and their abilities and second test to ensure the medical accuracy of diagnosing the right disability of the kids. During the development phase, the unit testing and integrating testing of the system have been done and final system testing was done after the final integration of the whole games to the system. Here in this system, the predefined test cases which covered all these four disabilities were used to test fully functional and non-functional requirements of the system. All the tablet games   and Kinect games with the web application have been passed the system testing.

To ensure the medically correctness in the system, the result evaluation criteria, and threshold values of the disabilities that can tolerate to work as a normal human were decided by the expert of this area of consultant Child Psychiatry Professor. According to expert's idea it was more efficient to use five age groups (starting from 4 years, 4.5 years, 5 years, 5.5 years and 6

years) in games and develop tasks to each age group by introducing the basic, preliminary and Advanced games that match to the age groups for the kids. That concept is the basic system structure of this system.

To perform User Acceptance Testing (UAT) of this system, the two Preschools were selected. There 25 students have played the games and obtain the final concussion.

Each preschool teacher was given a document with criteria and the symptoms which are testing in each age groups. The teachers were given instructions to go through the criteria and mark each child for having these symptoms or not. Then those marked children play the YALU games and their parents were given a web form questionnaire to answer about their kids. Using both game result and the answers, conclusion for each child is given.

Preschool 1	
Tested children count	: 10
Criteria matched children	: 3
Evaluated as positive (criteria matched)	: 3
Evaluated as positive (criteria not matched)	: 1
Preschool 2	
Tested children count	: 15
Criteria matched children	: 4
Evaluated as positive (criteria matched)	: 3
Evaluated as positive (criteria not matched)	: 2
Total No of students	
Tested children count	: 25
Criteria matched children	: 7
Evaluated as positive (criteria matched)	: 6
Evaluated as positive (criteria not matched)	: 3

YALU system has been tested   using 50 students in age four to five in three different preschools. From those students 14 students has been marked as having learning disability symptoms by their teachers. And from our system 12 of them were identified as positive for having probability of being learning disability. Therefore, it can conclude that e 85% of accuracy can guarantee from our system. However, the accuracy could be increased with the accurate answers of the parents about their kids.

CONCLUSION

There are several applications designed to test the learning disabilities of the kids but most of these applications are based on questionnaires to be

followed by parents, guardian or child. Most of these applications want computer literacy knowledge and the English to use them. Therefore parents, guardian or children who have a poor English knowledge will not be able to use those applications. Moreover, the final reports of those application are based on of the questionnaire and the child interactions, actions, and behavior   do will not be taken into consideration and analyze for the result. Getting kid's interaction is the most important fact when diagnosing these Learning disabilities of the children. And also, most of the available applications are web-based and it will hardly be found the standalone applications for this scenario. Therefore, the system having all features and diagnosing all four types of disabilities couldn't find until we develop this YALU Learning Disability Evaluation Kit for the children. Also, most of the existing applications are basically address to more adult children (above 6 years old) and did not support for the kids. If we can detect these Learning Disabilities in early ages (less than age 8) the parents can get the prompt actions by consulting right doctor and treat to the children.

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Rohan Samarasinghe (Member IEEE) got the M.Sc. in 2000 from the Kyushu University Japan, Ph.D. in 2006 from the Kyushu Institute of Technology, Japan and MBA for Management of Technology in 2009 from the Kyushu Business School, Kyushu University Japan. During his Ph.D. Degree program his research interest was Data Mining and Knowledge Discovery from databases. Now his research interests, medical information systems, Data Science and Business Intelligence Data Visualization, and predictive and perspective data analytics. Currently he is working with Artificial Intelligence (AI) based Business Intelligence Framework for the cross industry and business to make prediction of the of the business and to make perspective analytic for the survival and enhance the business.

After the graduation in 2006, he has joined to the Faculty of System Engineering, Kyushu Institute of Technology as a researcher and served there for three years. Then he joined to Department of Information technology, Faculty of Computing, Sri Lanka Institute of Information Technology as a Senior lecturer and served there for 10 years. Currently he is working in Department of ICT, Faculty of Technology, University of Colombo Sri Lanka as a Senior Lecturer. During his academic carrier he has supervised large number of MSC and undergraduate research projects and published many international conference and journal papers. Currently, he is supervising three M.Phill. students who are researching the said framework. Also, he has been appointed as a technical evaluator of state banks in Sri Lanka and now he is a member of Expert and technical evaluation committee of Ministry of Higher Education in Sri Lanka.

Gamini Abeyasinghe got the MBBS in 1995 from faculty of medicine, university of peradeniya, Sri Lanka with an honour pass. The post graguate qualification was obtained from university of Colombo in 2003 after successful five year training program. Following that further training was obtained from Australia in years 2004 and 2005. In addition to the general surgical work he got special training in laperoscopic surgery in Australia. During his stay in Australia he got honour pass in pre-hospital care management. Furthermore he worked as a conjoined lecturer in the school of medicine-rural clinical division, south west Qeensland region.
After coming back to Sri Lanka in December 2005 he worked as consultant General Surgeon in various parts of the country. His teaching experience include nursing, training(Nursing school Colombo), training medical students(Faculty of Medicine University of Rajarata Sri Lanka) and post graguate surgical training(since 2010). He was an examiner for the final MBBS since 2005, post graguate institute since 2015 and examiner for the Examination of Registration to Practise Medicine(ERPM) which is conducted by Sri Lanka medical council since 2016.
He was a member of board of study of surgery in the post graguate institute of Sri Lanka from 2015 to 2018.
One of his special interests is in trauma care. He's the resource person for the National Trauma care Management Course(NTMC) since 2012. He is also a resource person for Health Emergency and Disaster management training center which is operated under supervision of Faculty of Medicine, University of Perdeniya and Ministry of Health Sri Lanka with the support of the World Health Organisation. He serve as a member of national disaster management team in Sri Lanka. He had worked as the vice president of the Association of General Surgeon of Sri Lanka in 2018/2019 and committee member in 2016/2017. In addition to clinical work and teaching involving research work.