HANDWRITING AND VOICE RECOGNITION APPLICATION FOR STUDENTS WHO NEED SPECIAL EDUCATION

Umut Zeki[1], Tolgay Karanfiller[2], Kamil Yurtkan[3]

[1,3]Department of Computer Engineering, Cyprus International University, Haspolat, Nicosia, Cyprus

[2] Computer and Instructional Technology Teacher Education, Cyprus International University, Haspolat, Nicosia, Cyprus

[1]umut_zeki@hotmail.com, [2]tkaranfiller@ciu.edu.tr, [3]kyurtkan@ciu.edu.tr

Abstract: The students who need special education can learn relatively slower than the usual students. To assist and enhance the learning activities for these kinds of students, we have proposed a mobile application in our previous studies. In this study, we have developed two modules that will make it possible to implement all the features of the stepwise learning method. The additional modules are those that can recognize the handwriting of the students and also recognize the voice of the students. In stepwise teaching method, "write" and "say" are fundamental steps. Therefore, with the addition of these modules, the system will be able to recognize the voice and handwriting as well. The main contribution of this study is that the sayings of mentally impaired students are different than the usual students. So, the learning system will include a training system that is dedicated to each student. Furthermore, the handwritings of these students may include many translations and transformations of the images. The learning system will be employed to cover all possible translations and transformations on the images of mentally impaired students. We aim to recognize the voice and handwriting of mentally impaired students with an acceptable rate of accuracy. The system will be tested on real students in the learning process of the digits. This study will be used to enhance the teaching modules for other assistive teaching methods that are currently available.

Keywords: special education, mobile application, stepwise method, rule-based system, voice recognition, handwriting recognition.

Introduction

Because of having portability, Internet, games and social media, mobile devices have become an indispensable part of our lives. For this reason, new applications for mobile devices are being developed every day. Although there are many applications in almost every area, there is not enough study in some areas such as Special Education. Students who need special education may learn slower than other students and consequently may face with learning difficulties. Based on this problem, we proposed an intelligent mobile application that supports the teaching of digits(0-9) in mathematics. This article will explain the two modules of the application: handwriting recognition and voice recognition. Students with mental disabilities may learn slower and need more repetition to reinforce what they have learned. If this kind of applications increases, the students will be able to consolidate what they have learned at school without the limit of time and space alone or under the supervision of teachers. The algorithm of this application designed based on the Stepwise Method; because it is a very effective method to teach mathematics concepts to the students who need special education. In addition, all steps of the Stepwise Method can be applied by using this algorithm.

In the application development process, the handwriting recognition module which will be used in the 'write' step and the voice recognition module which will be used in the 'say' step is not yet completed. The 'do' and 'show' steps are completed. At the same time, the student's responses will be collected in a database and will be designed to provide detailed analysis and reports about the student by using Rule-Based System. Although the language of the application is in Turkish, it can be adapted to other languages in the future. Implementation of all the steps of the Stepwise Method, voice recognition and handwriting recognition modules and the ability to make analyses about the student through the Rule-Based System are the novelties of this study. In application, as in the Stepwise Method, there are four stages to teach a concept; "do, show, say and write". The 16 steps, which are the combination of these, consist of sessions such as do-do, do-show, say-write; where the teacher first teaches the concept and then expects the student to apply it. The part where the teacher explains the concept is adapted with the help of animation and sound in the application. All of the parts that the student "do" and "show" is completed and explained in the previous study.

Methodology

Since this study is about developing a smart application for children in need of special education, the literature review has been done by selecting keywords special education, mobile application, stepwise method, rule-based system, voice recognition, and handwriting recognition. However, since there are not many studies that are similar to the ongoing study and include all keywords, the studies that are included in the literature and partially contain the keywords have been added to the article from the side of our interest. Demands for mobile applications have increased in parallel with the increasing use of smart devices.

Developments Related to Smart and Educational Mobile Applications

The "Intelligent Mobile Learning Interaction System (IMLIS)" provides an environment of mobile learning for people who need special education [8].

"Fingu" is designed for children aged 4 to 8 to develop their arithmetic skills that use a multi-touch feature for iPad devices.

Erkalan, Calp, Şahin, designed an expert system; "Designing and Realizing an Expert System to be Used to Profession Choosing by Utilizing Multiple Intelligences Theory".

Fórtiz, Almendros, and Martínez developed a mobile learning application on IOS devices for students who need special education.

"My Voice" is another application designed for special education. Users can input vocabulary words and the application link these words with pictures.

"A Prototype Mobile Expert System for Nutritional Diagnosis" analyses the eating habits and body characteristics, it makes a proper eating plan for the person.

"A Mobile Application Design for Students Who Need Special Education" aims to teach the students the concepts like short-long, more-less and order the objects.

"Design and Development of a Mobile Learning System For Computer Science Education in Nige¬rian Science Education Context" is a mobile learning system to support teaching and learning of com¬puter science courses.

"1x1 Trainer with Handwriting Recognition" is a mathematical learning application which facilitates the learning and studying of simple multiplications by using handwriting recognition.

"Handwritten Text Recognition: With Deep Learning and Android" offers a new solution to traditional handwriting recognition techniques using concepts of Deep learning and computer vision.

"Mobile Learning Application for Children: Belajar Bersama Dino" proposed the design and development process of Mobile Learning Application which is Belajar Bersama Dino that mainly suitable for children who aged four to six years old including voice recognition capability.

Handwritten Recognition

Handwriting recognition is the recognition of handwritten letters, numbers, and symbols by computer systems. Although this process is quite easy for people, it is a very difficult problem for computers to automatically recognize lines and curves on the ground as letters and numbers, and later on as meaningful words. Today, many documents are still on paper only. It is very important to digitize these documents and transfer the information to the computer. In recent years, great progress has been made in the studies on the recognition of text, so that programs that automatically recognize printed texts on a clean and readable surface have started to enter our lives. On the other hand, the current technology is still limited to handwriting recognition. The difficulty in recognizing handwriting arises from the fact that there are many different types of writing characters and differences from person to person, as well as the letters being interconnected. When handwriting recognition methods become operational, this also saves us from using the keyboard and allows us to type and draw in a much more natural way. Examples of such systems are the electronic agenda (PDA) and other tablet computers.

Methods

Handwriting recognition methods can be divided into two groups: Interactive (online) and non-interactive (offline) methods. Interactive systems are specially designed systems that recognize handwriting at the time of writing. In general, electromagnetic or electrostatic tablets are used. The touches of the pen and the continuity of the movements are considered. Electronic agendas (PDA) is a very common method today. Non-interactive systems are generally the process of trying to recognize the information previously written on paper by digitizing. While interactive systems need to be very fast to keep up with the writing speed, in non-interactive systems, there is no time limitation for the recognition of writing. The advantage of interactive systems is that the shape characteristics of the letters can be observed as well as the movements during writing. Furthermore, one of the greatest benefits of interaction with the user is that errors can be corrected immediately. Non-interactive systems are easier to mislead, as there is no information about the movements during writing, and especially because old documents will not be clean and legible enough.

Non-interactive (Offline) methods

Non-interactive methods are used to recognize the print on paper. First, the document needs to be digitized. Document analysis is the first important step. The document must first be divided into paragraphs and sentences, then into words.

Interactive (Online) methods

Interactive systems are generally systems that automatically detect handwriting or drawings by obtaining coordinates of pen movements by electronic tablets. Although it is faster to use a keyboard to migrate an existing document to a computer, the use of pen and paper is more preferred for creativity and reorganization of documents. Therefore, such systems that interactively recognize handwriting are very important. Two different features are important for correct recognition of letters: static and dynamic properties. Static properties are also used by non-interactive systems, the different sizes of upper and lower case letters, 'g', 'y', 'j' as they lie below the reference line, 'l', 'k', 'b' than other letters long, some letters are dotted. They are important for separating the letters. Dynamic features, which are unique to interactive systems, are similar to where the pen's first touch is when writing a letter, then how the pen follows the movement, and how many times the hand is raised and lowered during a single letter. Interactive systems use both features to recognize handwriting. One of the major advantages of interactive systems is that the user can adapt to the system day by day because it is constant interaction with the user and start writing his writing in a way that it is easier to recognize and also correct errors immediately.

Voice Recognition

Speech recognition is a software or hardware that the ability to translate the human voice to a form that computer can understand. This kind of recognition is frequently used to control a device, do tasks, or write without using a keyboard, mouse, or press any buttons. Nowadays, it is accomplished on a computer by using Automatic Speech Recognition(ASR) software programs. A lot of programs that have ASR capability need the user to "train" the ASR program to recognize their voice. By doing that, it can more accurately transform the speech to text. There are two types of speech recognition. One is called speaker-dependent and the other is speaker-independent.

Speaker Dependent Voice Recognition System

Speaker–dependent software is commonly used for dictation software, while speaker–independent software is more commonly found in telephone applications. Speaker–dependent software works by learning the unique characteristics of a single person's voice, in a way similar to voice recognition. New users must first "train" the software by speaking to it, so the computer can analyze how the person talks. This often means users have to read a few pages of text to the computer before they can use the speech recognition software.

Speaker Independent Voice Recognition System

Speaker–independent software is designed to recognize anyone's voice, so no training is involved. This means it is the only real option for applications such as interactive voice response systems. The downside is that speaker–independent software is generally less accurate than the speaker–dependent software.

Stepwise Method

The Stepwise Method, is developed by Cawley, which is a teaching method for learning mathematical concepts that are mostly applied to the students who have special education needs. There are 16 steps in this teaching method, which is the dual combination of the steps of “do, say, show and write”. During the implementation of the method, the teacher first explains a concept and then asks the student that concept. For example, in step do-do, the teacher does and asks the student to do it; or the teacher says and then asks the student to write (say-write). There are 4 sets of tools in each step and these sets are implemented one after the other. If the student responds correctly to the three of the 4 sets of sessions, the criteria are met and proceeds to the next step. To be able to apply

this method, students should have some abilities: touch, rhythmic counting, readiness to distinguish between concepts less; also should understand and apply such instructions like saying, receiving, giving, showing, etc. However, the names of symbols in the toolsets to be used to teach the numbers must also be well known by the student.

All steps of the Stepwise Method are shown in Table 1.

Table 1: Teacher / Student interaction in Stepwise Method.

Teacher/Student	DO	SHOW	SAY	WRITE
DO	*DO-DO*	*DO-SHOW*	*DO-SAY*	*DO-WRITE*
SHOW	*SHOW-DO*	*SHOW-SHOW*	*SHOW-SAY*	*SHOW-WRITE*
SAY	*SAY-DO*	*SAY-SHOW*	*SAY-SAY*	*SAY-WRITE*
WRITE	*WRITE-DO*	*WRITE-SHOW*	*WRITE-SAY*	*WRITE-WRITE*

Methodology

Our motivation is to develop an application to teach numbers to the students with mild mental retardation who have only a few studies in the literature. In this context, we deemed it appropriate to adopt the Stepwise Method, which is a very successful and frequently used method to teach mathematical concepts to the children who need special education. The "write" session in which the student will respond by writing, will be performed by using handwriting recognition and the "voice" session which the student will respond by talking, will perform by using voice recognition. Using this application with mobile devices allows the student to repeat a concept as many times as he/she needs anywhere. This will speed up learning.

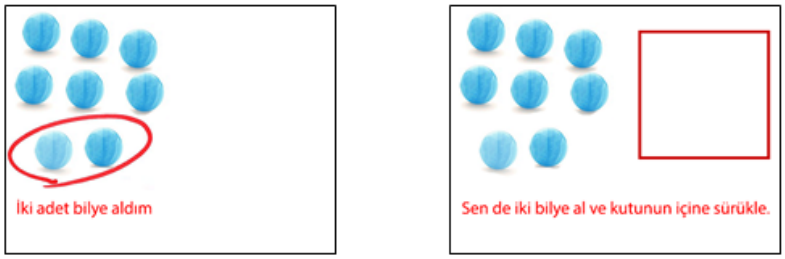
Adaptation of Stepwise Method to the Mobile Application

In the mobile application, this method will be applied as follows: First of all, while setting research subjects, students will be selected to have a well understanding of less-than-concept and to be able to demonstrate prerequisite behaviour of rhythmic counting from 1 to 10. It is also expected that subjects will have basic self-care skills (toilet, eating, and dressing), matching skills in terms of concepts and recipient language skills. The two-word directions should be understood and their fulfillment is important in terms of using this practice.

Before the training, the student is asked whether knows the material to be used in this session (eg. do-do steps/marbles). If the student answers correctly, the training begins. Otherwise, the program quits to the main menu. This question is repeated if the student does not respond to a question asked(10s), or if the question is answered incorrectly. If the student does not answer the question or gives wrong answers three times, the program gives a clue to the student. The same question is asked again after the clue is given. If the student remains unresponsive or gives a wrong answer 3 times, the application will move to the next step and the student will be considered unsuccessful in this session. At the end of a step, if the student knows at least 3 out of 4 (75%) of the questions asked in 4 sets, the criterion is deemed valid and the next step is taken. There are 16 steps in the teaching of each concept. They are applied by the teacher-student interaction, therefore, an iterative algorithm will be applied by changing the steps.

Teaching the Concept of Numbers

Figures 2 through 5, the sample animations are shown. On the left, the animations are shown instead of the teacher in real life. The Figures on the right are the realization of what the students do in real life by saying, touching, dragging or writing in the program.

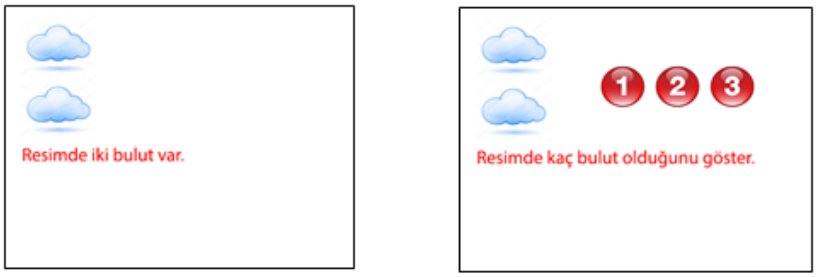


(a) (b)

Figure 2. *Do-Do (Yap-Yap in Turkish) Step: (a) the application shows how to take two marbles. (b) The student is asked to drag two marbles into the box.*

(a) (b)

Figure 3. *Show - Say(Göster - Söyle in Turkish)*: Step *(a) the application shows two stars. (b) the student is asked to say the number of stars.*



(a) (b)

Figure 4. *Show – Show (Göster-Göster in Turkish) Step: (a) the application shows two clouds. (b) the student is asked to show the number of clouds.*

(a) (b)

Figure 5. *Do - Write (Yap - Yaz in Turkish) Step:(a) the application shows two stars. (b) the student is asked to write the number of stars.*

As already stated, the instructions and tips given by the teacher are provided as animations in the application. When the student's response is expected, various tools will be used to respond to by doing, showing, saying and writing according to the application stage. In the do step, the drag and drop feature will be used to drag the desired amount of the items to the desired area. In the show phase, the touch feature will be used, so that the student can

show the item at the desired amount. In the say phase, when the student says the number of items, voice recognition will be used so that the application can identify this voice. In the write phase, handwriting recognition will be used, so that the application can verify whether the written digit to the desired region is correct or not.

The Interface

The application "Rakamları Öğreniyorum" – 'I am Learning Digits' aims to teach digits(0-9) with mild mental disabilities. The application is being developed by using the Java Programming Language on the Android Studio platform.

The Figure 6 shows the authentication screen of the program. If user has already registered, he/she can login by pressing the orange button(GİRİŞ) otherwise, user has to press the pink button(KAYIT OL) to go to the register screen(Figure 7). When user login successfully, opening screen appears as shown in Figure 8.

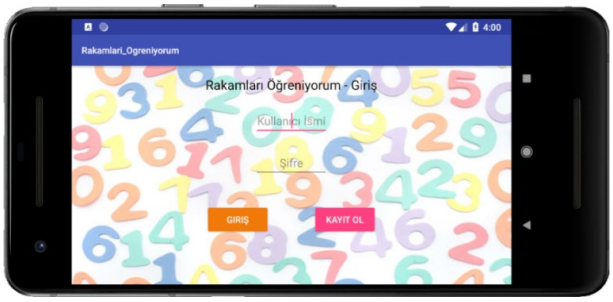


Figure 6. *Login screen.*

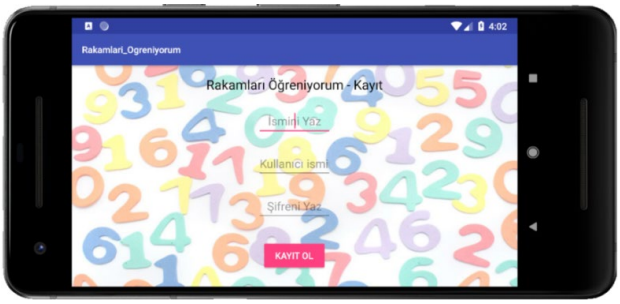


Figure 7. *Register screen..*

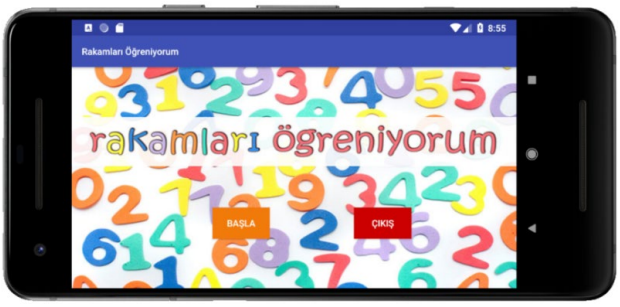


Figure 8. *Opening screen of the program(After successful login).*

In real life Stepwise Method is accomplished with the teacher. The owl was used as a tutor because it represented wisdom here, shown in Figure 9.

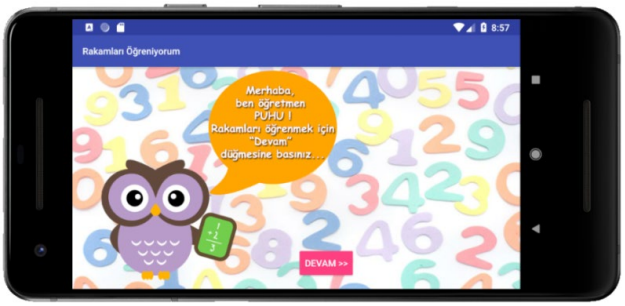


Figure 9. *Teacher Puhu.*

The application starts with do-do step and applies all steps in sequence. However, before the training, it is checked whether the materials to be used in that step are known to the student. An example is provided in Figure 10.

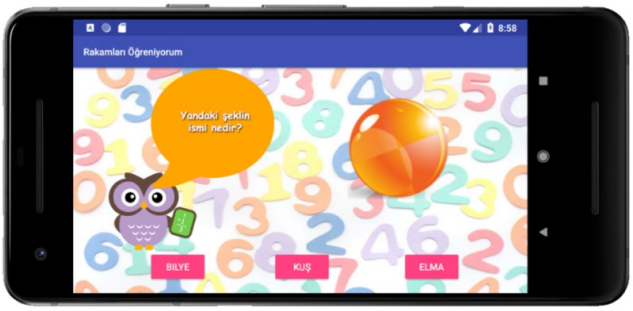


Figure 10. *The block diagram of the application (numbers in the diagram indicates the order of processing).*

In the first structure of the do-do step, the student is given information about the concept with the help of an animation; In the second build step, the student is expected to perform the required application by giving a directive, as shown in Figure 11.

Figure 11. *Student is informing about the concept.*

For example, when applying the do-do step of concept 2, the student is expected to use the drag-and-drop feature to move the ball from left to right as desired. If the student does it correctly, the application moves to the next stage. If the student does wrong, the application asks the same question again. It gives a hint when it doesn't know 3 times. If it does not know 6 times in total, the program moves to the next stage. Figures 12 and 13 show related screen shots.

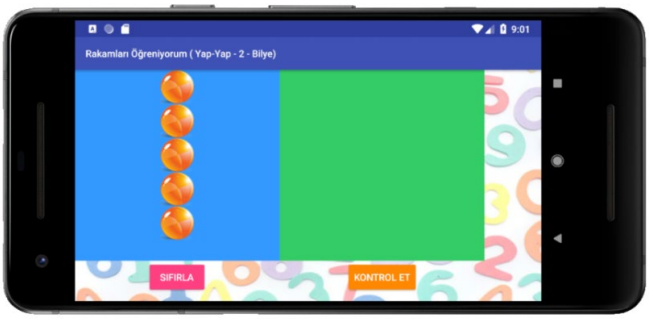


Figure 12. *Student is expected to drag and drop 2 marbles.*

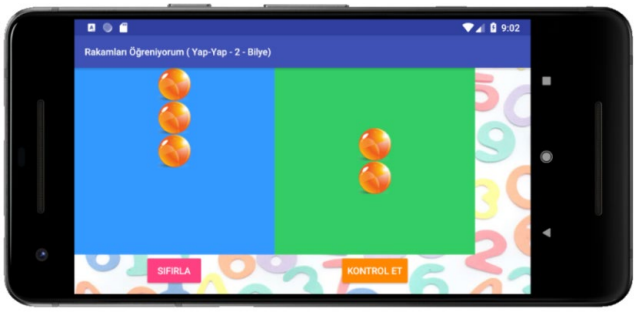


Figure 13. *Two marbles are dragged. Program will pass to next stage if student presses "kontrol et(check)" button.*

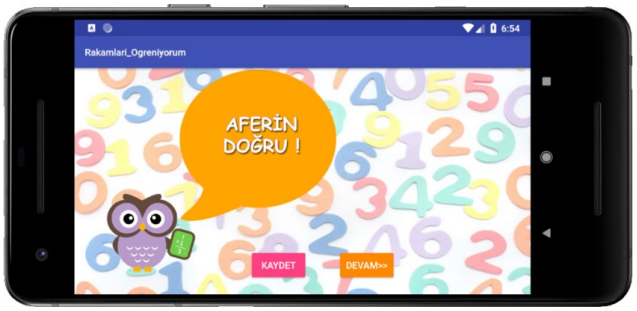


Figure 14. *If the student answers correctly, this screen appears.*

Implementation of Handwritten Recognition System to the Mobile Application

Handwritten Recognition is a method used to read a handwriting, recognize and transfer it to computer as optical characters. By adapting the handwriting recognition method to the application, the "write" session will be held by the student using the Stepwise Method. Studies related to this module are in progress. Mentally disabled individuals may experience difficulties while writing; for example, writing slower than normal peers, the letter or number is skewed, unable to write without raising his hand. For this reason, these are taken into account when developing the handwriting diagnostic system.

In the handwriting recognition module, the student is expected to write down the result in the blank box next to the symbols shown in the Figure 15.

Figure 15.*Student has to draw a number into the grid.*

The module is developing using TensorFlow software in Android Studio. Tensor flow is an open source deep learning library. Convolutional Neural Network will be used as Handwriting Recognition Algorithm. CNN have been widely employed for image recognition applications because of their high accuracy, which they achieve by emulating how our own brain recognizes objects.

Machine learning only works more accurately with a lot of data. So it is needed handwritten number samples to get started. MNIST data set of handwritten numbers will be used as samples.

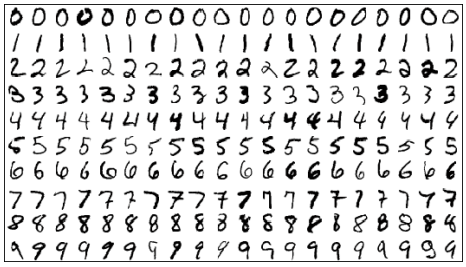


Figure 16. *Some numbers from the MINST data set.*

The next step is to use a neural network to take numbers as input. Neural networks are a set of algorithms, modeled loosely after the human brain, that are designed to recognize patterns According to a computer, an image is really just a grid of numbers that represent how dark each pixel is:

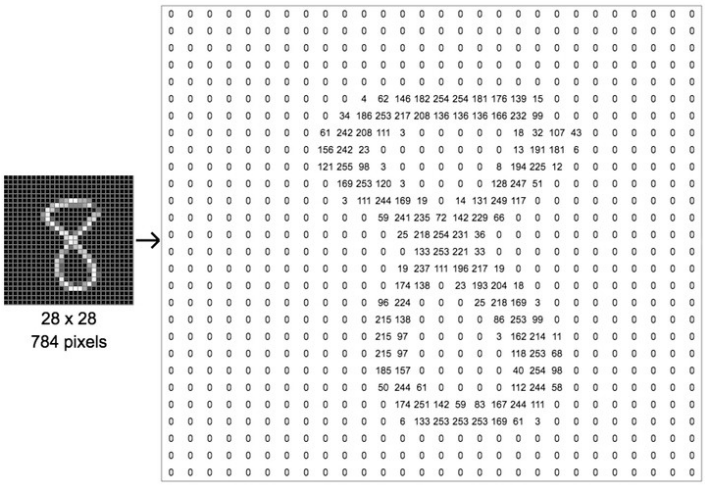


Figure 17. *To a computer, an image is really just a grid of numbers that represent how dark each pixel is.*

In this process, it will not be difficult to define a number that is properly written to the centre. The main problem is the numbers written on the edges that are not in the centre. These will not give proper results in a poorly designed handwriting identification system and will result in low accuracy of the system. There are several ways to solve

this problem: One of them to use the Brute Force Algorithm to scan a grid frame by frame, the other one is using Brute Force Algorithm to store an image file in the system for every possible position. But, the most effective method is to use Convolutional Neural Networks. The idea is to divide the image to several pieces by sliding window search and save each result as a seperate image tiles. The next thing is to fed a single image into a neural network to see if it was an "8". The same implementation will be done for each individual image tile by keeping the same neural network weights in the same original image.

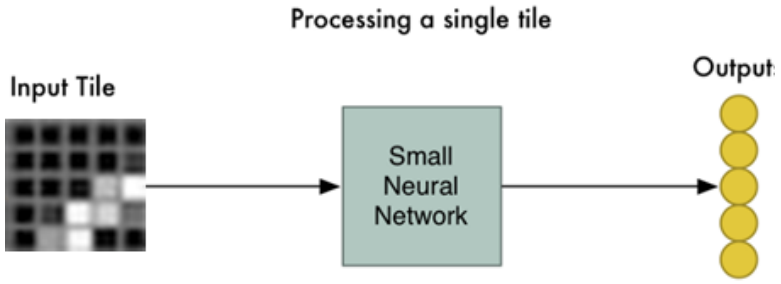


Figure 18.*Feed each image tile into a small neural network.*

Then the results from each processed tile will be saved into a new array. The next step is to make downsampling because the array is still big.

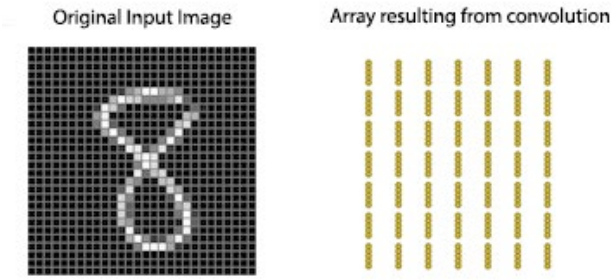


Figure 19. *To reduce the size of the array, we downsample it using an algorithm called max pooling.*

To reduce the size of the array, max pooling algorithm will be used. The algorithm checks each 2x2 square of the array and keep the biggest number. Eventually, the image is down to a small array. It is more suitable to use that array as inputs of another neural network.

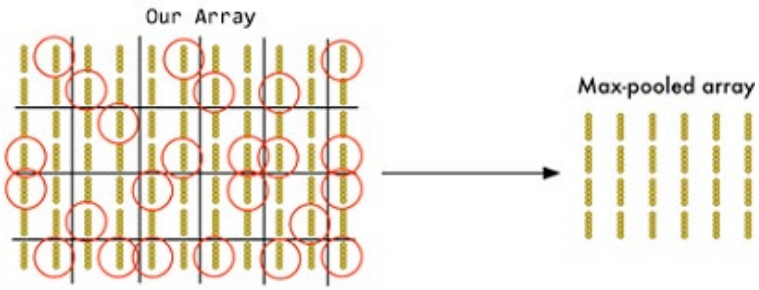


Figure 20. *Algorithm checks each 2x2 square of the array and takes the biggest number.*

This final neural network will decide if the image is or isn't a match. To differentiate it from the convolution step, it is called as "fully connected" network which it is shown in Figure 21.

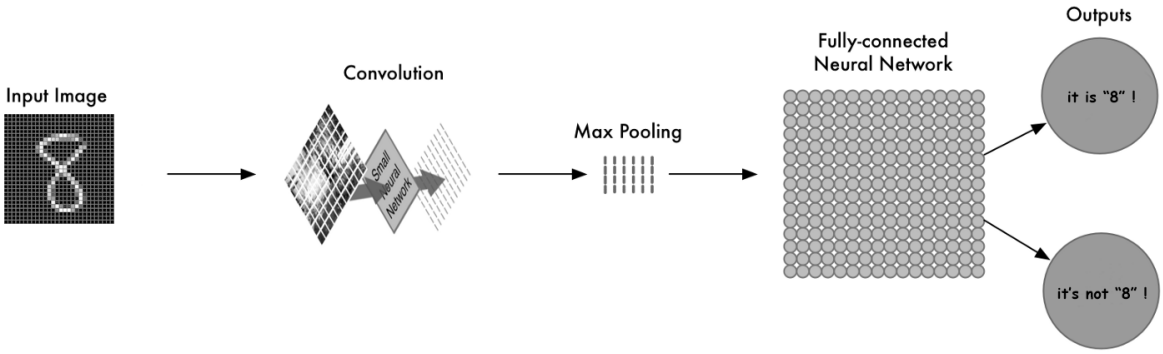


Figure 21. *Fully connected network.*

The use of convolutional neural networks is a conventional method. The main challenge is that the students who need special education, have very different and unique style of writing. Instead of the conventional training phase including training set images, we are planning to propose a subject based training algorithm. Where, each student's writing style will be trained as a seperate classifier.

Implementation of Speech-to-Text Recognition System to the Mobile Application

In the speech-to-text recognition module, the student is expected to say the result by pressing the microphone. Speech-to-text recognition is a tool that has the ability to process the human voice and decode it as text. By adapting the speech-to-text recognition method to the application, the student's "say" session of The Stepwise Method will be held.

Figure 22. *Student has to talk by pressing the microphone button.*

For children with special educational needs, acquisition of the mother tongue is one of the areas that may be problematic. Children affected by various degrees of mental disabilities may experience problems in both receptive and expressive language development (slower speaking, stuttering, swallowing some words). Therefore, taking speech samples of normal individuals and trying to understand what a mentally disabled child is saying during the voice recognition process may result in low accuracy. For this reason, the voice samples of each student will be taken before they come to the saying part of the program. The program will do this itself during the flow process of the program. To overcome this challenge, a subject-based training algorithm will be developed to achieve accurate speech recognition.

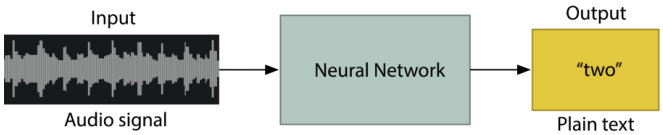


Figure 23. *Neural machine translation*

In the implementation, each student's voice will be trained to the system with the help of the teacher using the program. After the student's voice has been trained, the given answer will be recorded as a one-dimensional sound wave. After acquiring the audio input, it will be fed into a deep neural network. The input to the neural network will be sufficient audio chunks. For each little audio slice, it will try to figure out the letter that corresponds to the sound currently being spoken.

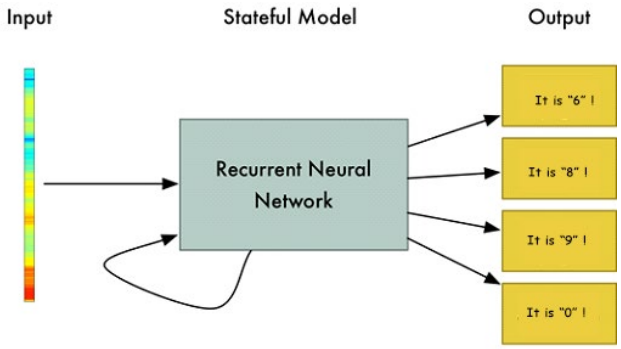


Figure 24. *The model's current state influences the next calculation.*

Recurrent neural network will be used for estimations because it is a neural network that has a memory to influence the future predictions. By having that memory of previous predictions helps the neural network make more accurate predictions going forward.

Block Diagram of The Application

The overall process consists of three main blocks shown in Figure 12. Each block contains teacher guidance. In the beginning of the presentation, application checks whether the student knows the object of the educational set to be used. If the answer is true, education begins, otherwise application returns to main menu. Student will count as successful, if the student answered correctly among 3 of the 4 material sets presentations.

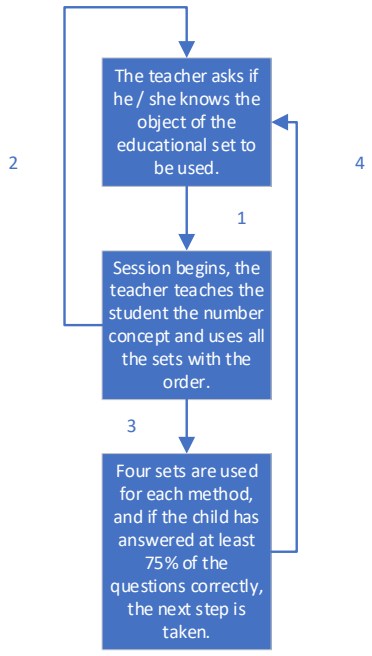


Figure 25. The block diagram of the application
(numbers in the diagram indicates the order of processing).

The Flowchart of the Overall Process

This flowchart given in Figure 13 shows the teaching process of the digit 2. The same algorithm will be applied to all numbers. In the flowchart; item_set[ ] is an array for item set pictures to demonstrate the teaching part and set_no is the index of item sets. Pictures will be taken from image database. The objects of item sets are shown below:

item_set[0]=beads
item_set[1]=buttons
item_set[2]=erasers
item_set[3]=lids

There will be 16 steps in this algorithm and in each step, the four item set will be shown to the student in an orderly manner. During the teaching process, if necessary, a hint picture will be shown to the student.

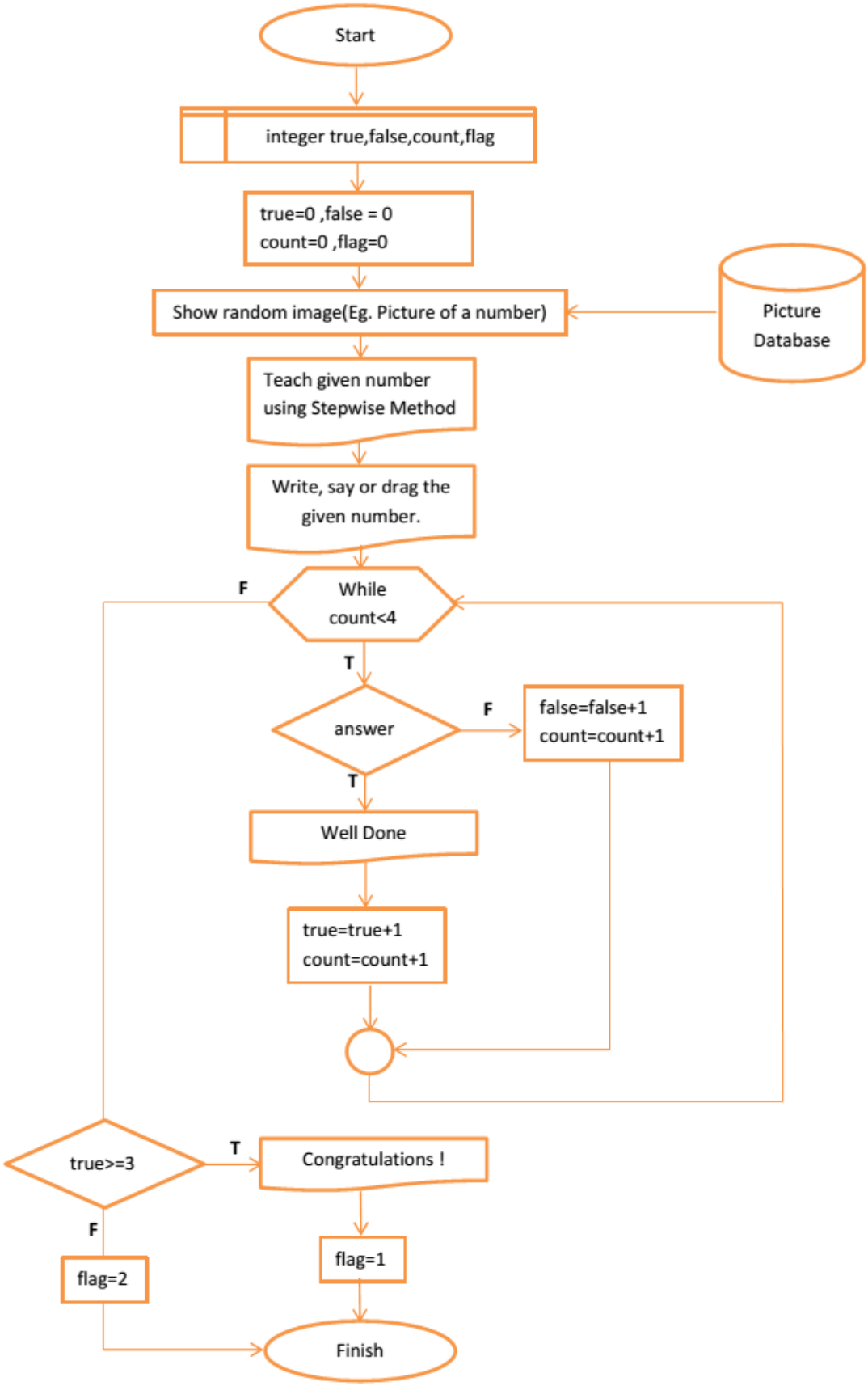


Figure 26. The generic flowchart of the teaching module.

Application Platform

The application is developed in Android Studio platform, based on Java Programming Language. In order for users to be able to run this application, the operating system installed on their smart phones or tablets must be at least Android 4.0 (Ice Cream Sandwich).

Android Studio has been chosen as a program development environment; because, Android-powered devices are much more common than the others, currently in the marketplace. According to the Netmarketshare.com, year 2018 market share of operating systems for mobile devices are: IOS (29.29%), Android Studio (68.93%) and other (1.65%). Also, Android-powered devices are cheaper and more accessible than other competitors [14].

Conclusion

This article contains information about two modules of an application written to assist teaching numbers to children who need special educational. The application aims to use the Stepwise Method, which is a very effective method used to teach mathematics to children in need of special education, in all aspects. The proposed application is aimed to assist the teacher during education. In brief, this system consists of several sessions where the teacher first informs the child about the desired concept and then expects the child to respond to the same concept. The sessions are a total of 16 and can be exemplified by the combination of do, say, show, and write. For example, the do-show step consists of sessions that the teacher does through the training and asks the student to show. I bought two marbles from the stack, and you show me which card have two marbles. The teacher side in the application is designed with animation. In the sections that the student will apply, the stages of make and show were explained in the previous article. What is described here is how to integrate the write and say steps into the application. At the write level, the student is expected to write the answer to the question asked where the application applies handwriting recognition methodology. In the say step, the student is expected to answer the question by speaking. Then the application applies enhanced speech recognition methodology. Both modules will be designed using Deep Learning. The novelty in this part is that the neural networks will employ subject based training phase. The unique feature of this work is that the system is designed to implement all the steps of the Stepwise Method.

References

Zeki, U. & Karanfiller, T & Yurtkan, K. (2019). An Intelligent Mobile Application Design Based On Stepwise Method Supporting Special Education. *International Symposium on Engineering, Artificial Intelligence & Applications.*

Zeki, U. & Karanfiller, T & Yurtkan, K. (2018). An Extended Mobile Application Design For Special Education To Teach Numbers. *International Conference On Perspectives In Future Education*.

Karanfiller, T., Göksu, H., & Yurtkan, K. (2017). A Mobile Application Design for Students Who Need Special *Education. Education & Science/Egitim ve Bilim, 42(192).*

Cawley, J. F., & Vitello, S. J. (1972). Model for arithmetical programing for handicapped children. *Exceptional Children*, *39*(2), 101-110.

Balçık, B. (2015). Zihinsel yetersizliği bulunan öğrencilere etkileşim ünitesi yöntemiyle toplama becerisinin öğretimi. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi*.

Oyelere, S. S., Suhonen, J., Wajiga, G. M., & Sutinen, E. (2018). Design, development, and evaluation of a mobile learning application for computing education. *Education and Information Technologies*, *23*(1), 467-495.

FernáNdez-LóPez, Á., RodríGuez-FóRtiz, M. J., RodríGuez-Almendros, M. L., & MartíNez-Segura, M. J. (2013). Mobile learning technology based on iOS devices to support students with special education needs. *Computers & Education*, *61*, 77-90.

Barendregt, W., Lindström, B., Rietz-Leppänen, E., Holgersson, I., & Ottosson, T. (2012, June). Development and evaluation of Fingu: A mathematics iPad game using multi-touch interaction. In *Proceedings of the 11th international conference on interaction design and children* (pp. 204-207). ACM.

Zare, S. Intelligent Mobile Learning Interaction System (IMLIS). *A Personalized Learning System for People with mental Disabilities Department of Mathematics and Informatics, University of Bremen*.

Campigotto, R., Mcewen, R., & Epp, C. D. (2013). Especially social: Exploring the use of an iOS application in special needs classrooms. *Computers & Education*, *60*(1), 74-86.

Netmarketshare (2019), Available: http://www.netmarketshare.com.

Rabko, M., & Ebner, M. (2018). 1x1 Trainer with Handwriting Recognition. *International Journal of Interactive Mobile Technologies (iJIM), 12(2), 69-79.*

Yahaya, N. S., & Salam, S. N. A. (2014). Mobile Learning Application for Children: Belajar Bersama Dino. *Procedia-Social and Behavioral Sciences*, *155*, 398-404.

