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Care4Student: An Embedded Warning System for Preventing Abuse of Primary School Students

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Abstract: Child abuse is a social and medical problem that has negative effects on the individual development of the child and can lead to mental disorders such as depression and post-traumatic stress disorder in both short and long-term mental health. Therefore, any abuse that the child may encounter should be immediately intervened. This paper presents the design of an integrated embedded warning system that includes an embedded system module, a server-based module, and a mobile-based module as a solution to concerns of ensuring the safety of students in places where there are fewer safety measures. Our solution aims to ensure that the school management team is quickly informed about the adverse situation that primary school students may encounter and able to respond to them. In this context, this system activates the warning status when it correctly detects the phrases 'help me' and 'give it up'. Thus, any negativity that may be encountered in a closed environment is prevented. The embedded warning system detected correctly the phrase "help me" with 80%, and the phrase "give it up" with 75%.

Index Terms: Child abuse, embedded system, sound recognition, school safety.

1. Introduction

Child maltreatment or child abuse is a well-known social and medical problem that is as old as human history [1]. Child abuse and neglect are a traumatic experience that can affect the child throughout life and can lead to mental disorders in both short and long term such as depression and post-traumatic stress [2, 3]. Pala et al. emphasizes that the main aim of prevention of child abuse is to stop the abuse before it starts [4]. According to the World Health Organization (WHO) [5], child abuse is defined as deliberate or non-deliberate behaviours by an adult, society or country that adversely affects the child's health, physical and social development". WHO reported that one in four adults was sexually abused during childhood, and also 12% of children were sexually abused in 2015.

Immediate intervention should be made to the negative situations that primary school students may face. Otherwise, the character or personality development of the student will be affected adversely. The study by Koçtürk stated that school environment can be a protective factor for child abuse and neglect as well as a risk factor [6]. School administrators and teachers are of critical importance in preventing, identifying and responding to child abuse. The school management should present a safe environment in order to prevent child abuse and neglect in the school by taking safety precautions [7].

Embedded systems and the internet of things play a role in many fields today. For example, Kumar and Akashe proposed a GSM-based security system with internet of things applications [8]. Singla et al. proposed a system to monitor and control gas concentration in real time. The personal computer based system they developed for gas sensor modules, embedded control, monitoring and control has successfully operated under different gas concentrations and environments [9]. Kun et al. designed an embedded video surveillance system based on MicroBlaze. The authors carried out real-time conversion and processing of multichannel video data with this system [10].

The subject of this study is computer-assisted measures that can be taken to prevent child abuse. For this problem,

there are patent studies relation with apparatus attached to the child's arm or wrist. However, a study based on central embedded system design that will work especially in closed areas has not been encountered in the literature. The main focus of the study is to ensure the safety of students in school areas where there are less security measures. With the proposed system, the school management personnel are aware of the adverse situations that primary school students may encounter in order to intervene quickly. In this context, an embedded warning system, hereafter Care4Student, was developed to prevent the negative situations that students may face in closed-places such as toilets. Therefore, it is thought that this system will contribute to school safety measures.

The remainder of this paper is organized as: Section 2 is related works; Section 3 shows an overview of the proposed system. Section 4 presents the experimental results conducted on the 'help me' and 'give it up' phrases. Section 5 addresses the limitations of the proposed study. Section 6 draws conclusions and suggests for future work.

2. Related Work

The focus on risk factors and the results of this problem in the studies of the child abuse problem have been observed. For example, Koçtürk discussed and evaluated the things to do in the school environment considering the prevention of child abuse and neglect problem in terms of school employees (school administrators, teachers and school counselor). According to this study, the educational and legal regulations will improve the child protection system in Turkey, create a safe school environment, and increase the effectiveness of education activities for the children under risk [6]. Kaytez et al. presented a study including the child abuse, types, prevalence, legal dimension, effects on children and prevention works [11]. Çeçen reviewed the literature on the prevalence of sexual abuse towards the children, its devastating effects on the children, prevention studies in developed countries, and emphasized the importance of implementing school-based prevention programs in the fight against child abuse in Turkey [12]. Zeanah ve Humphreys suggested that the clinical methods will help maltreated children to minimize their suffering [13]. Wismayanti et al. reviewed current knowledge about child sexual abuse in Indonesia, in the context of existing laws and policies that influence child sexual abuse prevention and intervention [14]. Chou et al. examined the Child Protection Act on child maltreatment in Taiwan. This study examined the secular trends in incidence rate of physical abuse of children, and in-hospital death proportion in terms of before Act and after Act in 2003 [15]. Dubowitz et al. examined the relation between types of childhood maltreatment at the age of 14, 16 and 18 and alcohol and marijuana use problems and disorders in young adulthood [16]. Reza et al. used a questionnaire dataset to investigate emotional abuse experiences and their responses to abuse within the school system on 450 primary school students in Bangladesh. The authors found in their research that poverty is an important factor in emotional abuse [17]. Boisjoli and Hebert aimed to compare the level of alexithymia between a comparison group of school-age victims of child sexual abuse and non-victim children. The authors found in their studies that victims of child sexual abuse presented significantly higher levels of alexithymia compared to their non-abused peers. In addition, the authors discussed the role of alexithymia in the relationship between child sexual abuse and both internalized and external behavioral problems [18]. Bengwasan and Bancual examined the development in different areas of abused children. In their studies, the authors studied 206 abused and neglected children from a local psychotherapeutic center in the northern Philippines. The authors examined differences in the developmental level of these children by age, gender, and type of abuse [19]. Javed and Islam proposed a system that continuously monitors the child's movements and gives a warning [20]. Moreover, there are patent studies to prevent child abuse. In some of these studies, a dangerous situation signal is sent to the parents with an electronic card apparatus attached to the children's arms, so that the parents can follow their children. As can be seen in the literature review, although there are different studies on child abuse, there is no study conducted with an embedded warning system that has a central role in preventing child abuse. This has been the starting point of our main motivation. The embedded system proposed in this study is set up in a closed environment independent of the students and constantly listens to the environment.

3. An Overview of Designed System

Our approach is focused on the detection of malevolent persons in closed places, and warning teachers. An overview of this system is demonstrated in Figure 1. The proposed system is composed of: i) embedded system module with presence of a microphone, ii) mobile application, iii) a web server with the management system and alert processing.

The proposed system based on TCP client/server architecture manages the communication between the embedded system module and the server system. Socket programming was employed to perform the interprocess communications of the client and the server. The server starts and waits for the signal coming from embedded system. The client then sends a connection request to the server on the same port. The connection is established, and the embedded system sends a signal if the banned words captured. The server receives this message and sends a message "Be careful! teacher" to mobile phone, and so the warning and alarm is activated. Note that both the server and the mobile phone could open or close the embedded system for new requests on port 37001. In this context, the server waits for requests from the embedded system and, based on these requests, generates some steps. The following steps describe the communication

between the embedded system and the server system:

a) Server starts and waits for a signal from Raspberry Pi 3 B+.
b) Embedded system sends a message to the server.
c) Server returns an “alarm activated” message so that the client can know that the message was received with success by the server;
d) Server sends a message to the mobile phone, so it displays “Be careful teacher”.
e) After the environment is checked by teachers, the system listens to the environment again.

Thus, a communication is construct between the embedded system module and the server system that will send the warning messages to the teachers. Embedded system is a Raspberry Pi 3 B+ with a microphone.

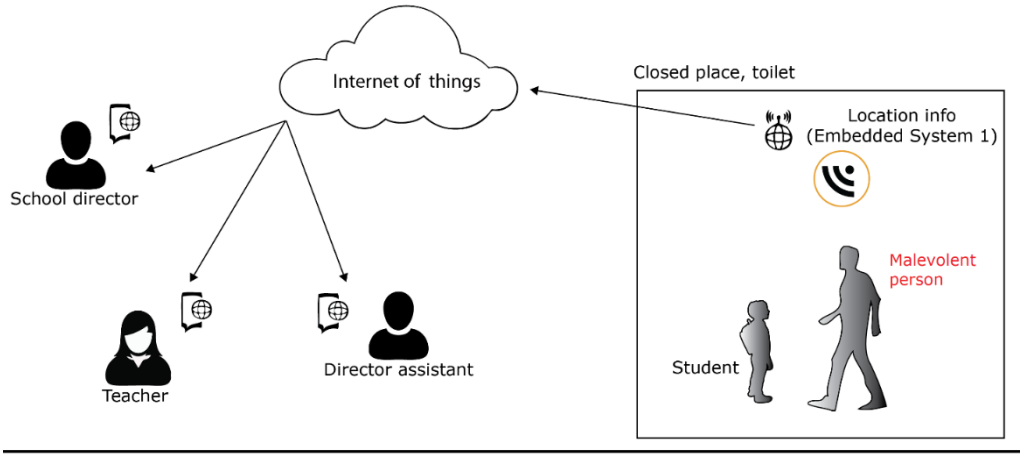

Fig.1. An overview of the proposed system.

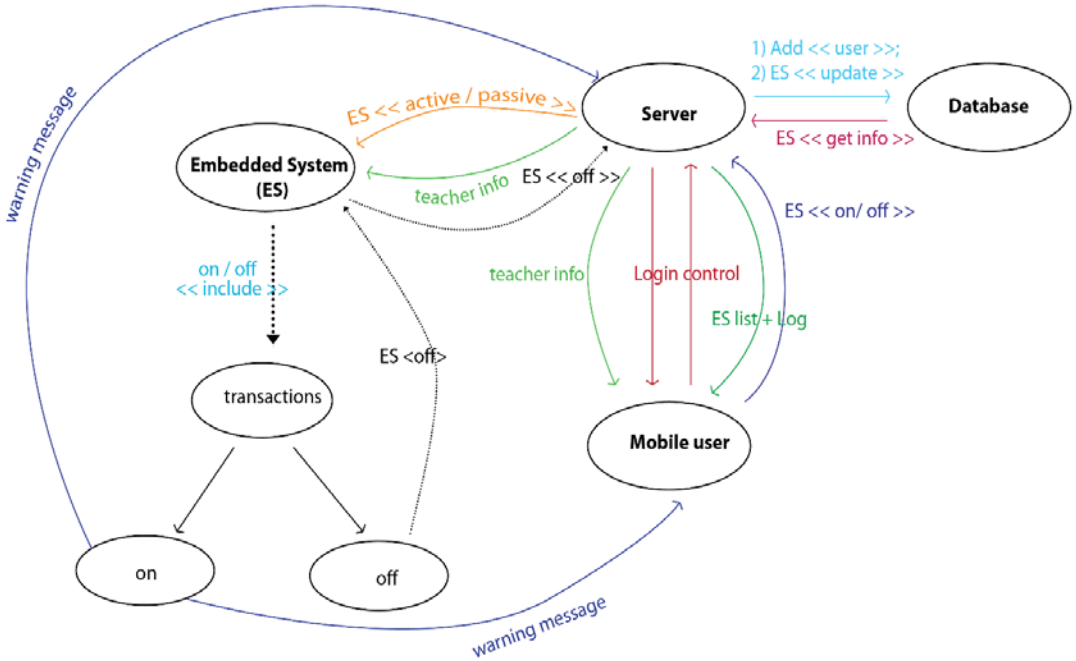

Fig.2. Care4Student Use Case Diagram

The use case diagram of the Care4Student is demonstrated in Figure 2. The developed system basically consists of three parts: mobile side (1), server side (2) and embedded system side (3). The embedded system, with microphone component, captures the banned words and then sends the alert to the server. If a child with a risk of abuse in the school is detected, a message will be sent to the server. The server will then process this message and sends a warning message to the teachers. Main steps of the proposed system are as follows:

a) The embedded system continuously listens to the environment through a microphone. The sound received from the microphone is translated into text using the Google and Sphinx voice recognition libraries. The text is

split into the words, and the words that matches with banned words defined in the system are detected. Care4Student then sends an alert message to school administrator via email and mobile notification. The phrases “give it up” and “help me” which are quite widely used in spoken language are chosen for experiments.

b) The authorized person checks the closed place.
c) The administrator has the right to turn on/off this system via the mobile application. The system reboots by the administrator and continues to listen to the environment.

The hardware and software components used in the Care4Student system are listed in Table 1 and described below, respectively.

Table 1. The items used in this study

Hardware/Software Item	Implementation Technology
Server System (Web API + Web Page)	C#
Embedded System	Raspberry Pi 3 B+ and Microphone
Mobile Application	React Native

This section provides information about the modules of the proposed system. Each of the main steps is described in the following subsections in detail.

3.1. Server Side Design

This section describes the implementation of the Client/Server application. The system sends the message “Be careful! There is a problem in the closed place.” to the teachers. For the development of the client/server application of this work, C# and Visual Code IDE were used.

The server system responds to the requests of the embedded system and also processes the information coming from mobile application users. A Web API was written in C# programming language. The features of this API are:

a) Sends the data to the embedded system and mobile.
b) Checks user information from database and gives the answer.
c) Presents a list of active / passive embedded systems and log information to mobile users.
d) Sends the on / off command to the embedded system, immediately. The embedded system does not listen to the environment when it receives the “off command, it listens to the environment after it receiving the “on” command.
e) Sends teacher information to the embedded system.
f) Writes alarm active information into the database system. This information is used by the mobile application to alert.

The server-side operations listed below are performed with a web interface developed based on the Dot Net Core 2.2 MVC architecture, in the Care4Student system.

a) Performs the process of adding the new embedded system to the database, and updates the status of any embedded system according to the warning message.
b) Updates the status of any embedded system in the database as on/off if needed.
c) Adds new user information, and edits, and deletes user.
d) Identifies users who can access to the mobile and web interface. Thus, the system administrator or school principal can access to the data or reports in detail.

All data were stored in the SQL Server system installed on the server machine. Additionally, Entity Framework Core architecture was used for database connection.

3.2. Embedded System Design

Raspberry Pi 3 B+ was used as the main component in the embedded system. Raspberry Pi 3 B+ is a Linux-based, low-size, low-cost device that can be used as a personal computer [21]. This device uses the microphone to communicate with system and teachers. Communication between the Raspberry Pi 3 B+ and the microphone was carried out via the USB port. The tasks performed by using Python language on Raspberry Pi 3 B+ embedded system is given below.

a) The embedded system retrieves its own status from the server via the Web API. If the status is passive, it does not listen to the environment. When it is active, it performs the following steps, respectively.
b) Continuously listens to the environment by using the microphone.

c) Converts the sound received from the microphone to text.
d) Obtains the words by splitting the text according to the space character.
e) If heard of the phrases the ‘help me’ or ‘give it up', in other words, during the abuse time, the alarm active information is sent to the database through the web API.
f) With Web API, the list of teachers is retrieved.
g) Continuously checks the alarm status by web API. Listens to the environment again by administrator’s restarting the system.

These steps are also shown in the flow chart in Figure 3.

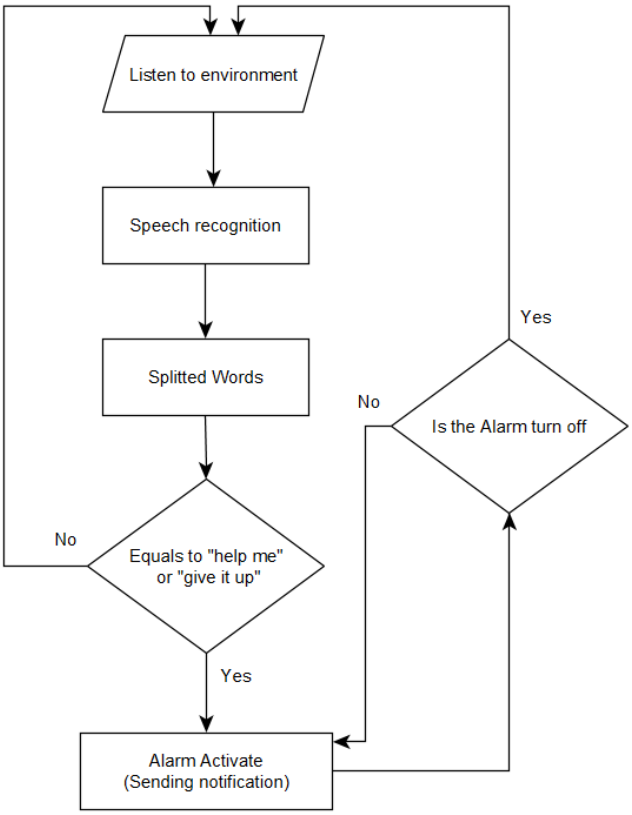

Fig.3. Sound detection steps

3.3. Mobile Side Design

A user-friendly application interface was designed to enable the mobile application of this system to be operated by the school management team. All software development phases of the mobile application were employed with React Native. In this application, there are four screens, which are ‘Connect’, ‘Login’, ‘School’ and ‘Log’, explained below briefly.

Connect: IP and port information required to connect to the server is received through this screen.
Login: User name and password information is controlled via the web API, and so the access to the mobile application is provided.
School: This is the list of embedded systems. The current status of the embedded systems getting with the Web API is displayed, the on/off operations of the embedded system and active / passive operations of the warning system could be conducted.
Log: This is the screen where the logs of embedded systems are displayed. On-off, date/time information of the embedded system taken from the server with Web API is listed.

4. Experiments

Google Speech recognition (Google SR) and Sphinx Speech recognition (Sphinx SR) libraries were compared in experiments. As seen in Pseudo code below, accurate detected letters were find out using the ratio of characters correctly detected to all characters by the speech recognition libraries such as Google SR and Sphinx, in other words, by calculating the number of overlapping characters between referenced word or phrase and captured word phrase. In this

context, experiments were carried out for both phrases 20 times with Google and Sphinx voice recognition algorithms. The results obtained from the tests performed are presented in Table 2. If the N character of the word or phrase that is caught by the system is equal to 'help me' or 'give it up' phrases, the warning system is activated. For the phrase 'help me', Google SR detected it correctly in 16 of 20, while Sphinx SR detected it correctly in 15 of them. For the phrase 'give it up', both Google SR and Sphinx SR correctly detected 15 out of 20 experiments.

Pseudo-code 1. The calculation of the ratio of characters correctly detected.

```
N=0          (N indicates accurate letter number. N value is set to 0 for start)
i=0
while (i <= character_length(processed_word))
    if i < character_length(referenced_word)
        if processed_word[i]==referenced_word[i]
            N = N + 1
        else
            break
        i=i+1
        end if
    end if
end while
```

Table 2. Results for the ‘help me’ and ‘give it up’ phrases

Phrase	Speech recognition	True detected	False detected	Accurate detection ratio %
‘help me’	Google SR	16	4	80
	Sphinx	15	5	75
‘give it up’	Google SR	15	5	75
	Sphinx	15	5	75

Occasionally, a noise may occur due to student mobility in closed spaces in schools, and this is inevitable. For this reason, we tested the Care4Student performance by using synthetic noises to evaluate the capability and performance of the proposed study. In this context, Weibull and Uniform synthetic noises were added to the correctly determined phrases 'help me' and 'give it up' one-off, and the results obtained here were included in the experimental study. The reason for adding noise is to also examine the effect of noise on the stable operation of the system.

Synthetic noises were used by uniform and Weibull distributions randomly. Uniform distribution is widely used, especially when the parameter space is finite but the value and distribution are not known. It has a simple structure compared with other distributions. $\sigma^2 \epsilon\, (\Delta_{min}, \Delta_{max})$, assuming that σ2 is evenly distributed over a given range, uniform distribution is defined as in Equation 1 [22].

$$\delta(\sigma^2) = \frac{1}{\Delta_{max} - \Delta_{min}} \tag{1}$$

Weibull Distribution proposed by Waloddi Weibull in 1936 is a very powerful tool representing distributions of different scales and shapes. It is extremely important to characterize the probabilistic behaviour of many real-life natural phenomena [23]. This distribution is given in Equation 2.

$$F(x) = 1 - exp\left[-\left(\frac{x - x_0}{\eta}\right)^{\beta}\right] \tag{2}$$

where $\beta > 0$ is the shape parameter, $\eta > 0$ is the scale parameter, $x_0 \geq 0$ is the position parameters and $x \geq x_0$ is the stochastic variable with the same scale η unit.

The sounds with coefficient initial value of 0.01 and 5 different noise levels with 0.01 increments by each noise, were obtained. Thus, the effects of noises obtained with different threshold values on the Care4Student system were examined. In this context, Google Speech recognition (Google SR) and Sphinx SR libraries were compared. The signals containing noised sounds having the minimum and maximum coefficients are demonstrated as an image in Figure 4. Accordingly, row 1 and 2 show synthetic audio signals obtained by minimum and maximum coefficients of Noise #1. Similarly, line 3 and 4 show synthetic audio signals obtained by minimum and maximum coefficients of Noise #2.

Noise #1 and Noise #2 were added to the ‘help me’ and ‘give it up’ sounds beginning with a coefficient value of 0.01 and increased with 0.01 intervals. The effects of noises for correctly detected phrases 'help me' and 'give it up' were demonstrated in Figure 5. Both Google SR and Sphinx libraries detected correctly the ‘help me’ phrase in all of the noise values. In addition, while the Google SR library detected correctly the ‘give it up’ phrase for all noisy sounds, the Sphinx library detected correctly 'give it up' phrase in some noise levels.

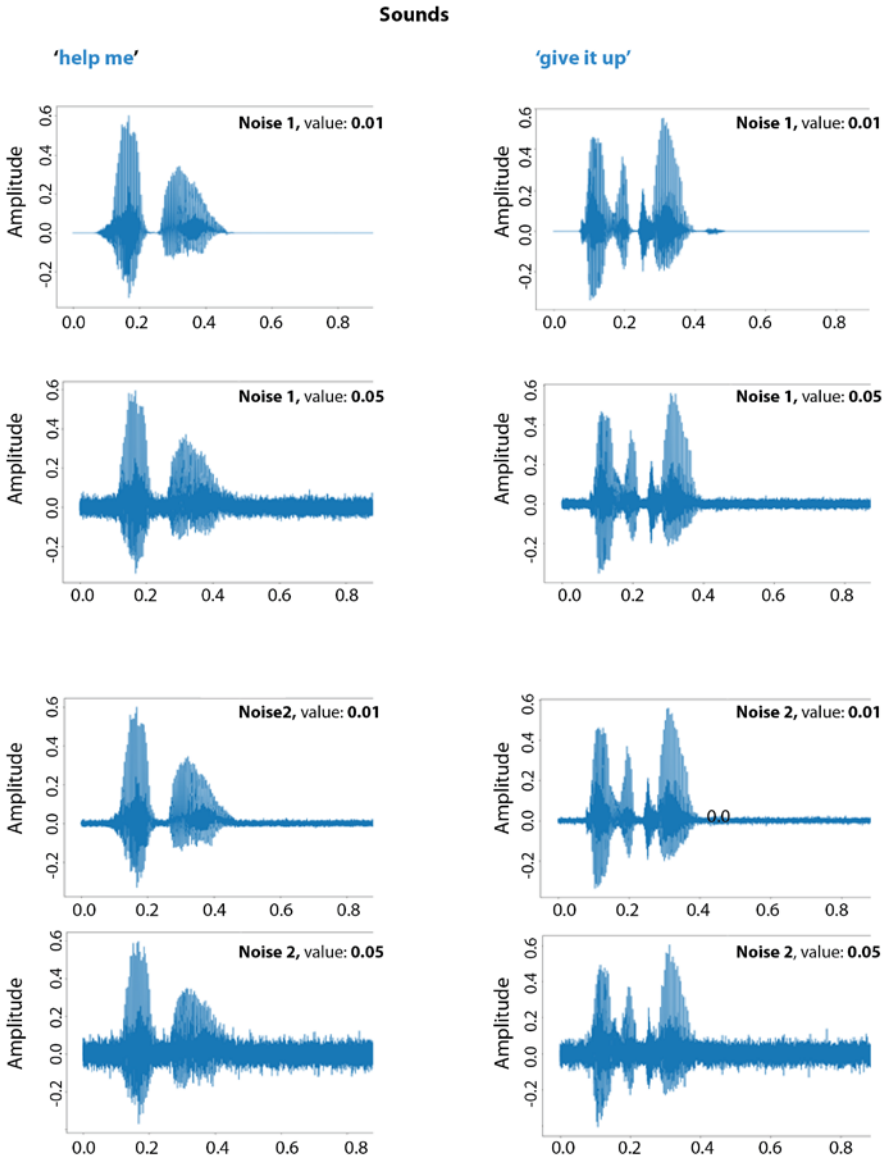

Fig.4. Sounds having synthetic noises

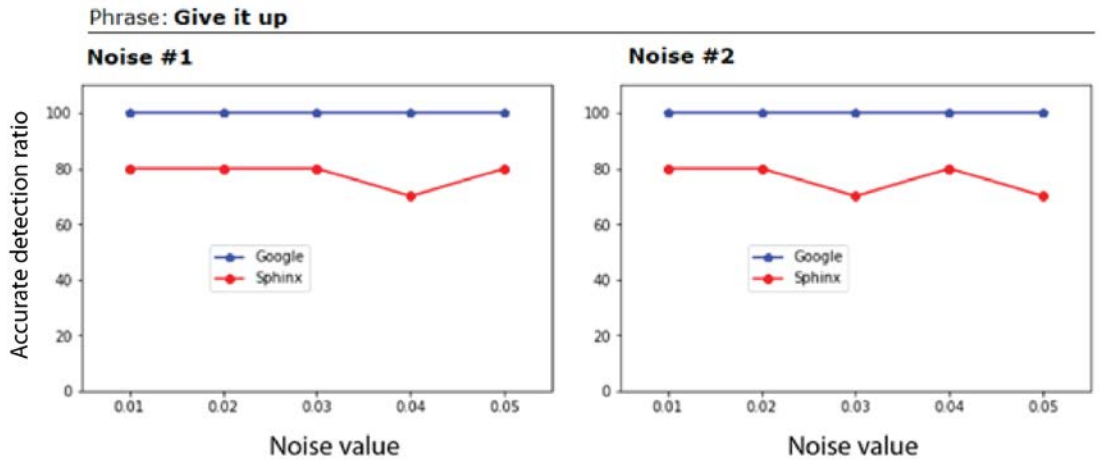

Fig.5. Experiments on the phrases having synthetic noises.

5. Limitations

This study has several limitations. The embedded and server modules were implemented in a laboratory environment. All experiments were conducted in this environment. The microphone, which transmits the sound directly to the embedded system, is an important component in this study. The awareness of school management of the dangerous situation depends on the accomplishment of speech recognition of the embedded system in the environment. But, the properties of the microphone used in this study are not very sufficient in receiving the sound from the real environment. Therefore, more efficient and competent microphones should be used.

6. Conclusion and Future Works

This paper presents a system specifically designed to track the negative situations that primary school students may encounter. We can say that Care4Student is useful for preventing the abuse events. We designed three main modules in the workflow system: (a) the server, which is for the mobile application access to the embedded system, to activate or deactivate the embedded system and etc., (b) the mobile application, which is used to notify the administrator and teachers for incoming messages from the embedded system and is also used to activate and deactivate this alert system (c) the Raspberry Pi 3 B+ embedded system, which is the core beneficiary. The embedded system captures prohibited words in its environment, and activates the warning system to notify the teacher and school principal in adverse situations in real-time. The school personnel check the school environment against negative situations and so a safe environment is presented by preventing a child abuse. When the administrator reactivates this system, the system continues to run in real-time.

Care4Student system specifically presents a quickly aware of the negative situation, and possibility intervene to it in the areas where security measures are inadequate, and violence or abuse is very common. In experimental studies, 20 experimental studies were conducted for each of the phrases 'help me' and 'give it up'. The Care4Student system is a valuable system which presents 80% and 75% detection ratios by Google SR for ‘help me’ and ‘give it up’ sounds, respectively. Thus, the proposed system has the ability to notify the teachers in real-time in a healthy way as soon as it catches the searched word. In the proposed study, the students do not need to have any materials with them. An embedded system has been designed that all students can benefit from. The system is installed once in suitable locations in closed environments and listens continuously. The proposed system will be a very useful and sustainable system when the microphone limitation problem is overcome. If desired, different words or words in different languages that correspond to the help me and give it up phrases can be easily included in the system. For example, a prototype of this study was tested in Turkish words such as ‘yardım’ and ‘bırak’ too, and it was seen that the system was working effectively.

According to the experiments in this study, the microphone in this system may operate unstable from time to time. We think that the proposed system will work more stable with a higher-performing microphone.

As future improvement, we intend to develop new functionalities and to adapt the application to new requirements which are more appropriate for primary school students. Also, in future, it is aimed to incorporate our own developed speech recognition model based on machine learning to this system.

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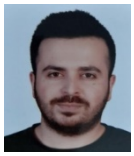

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