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Abstract

Purpose: This project aimed to test an IoT and AI based system that monitor students from home to schools, during class hours and from school to home and notify parents and school administrators about the irregularity observed to their respective children.

Methodology: In this project, secondary data was used and was retrieved from the school's record of Wisdom School Musanze located in Musanze District. The main data to consider were sex whether male or female. Another important data was orphanage,whether pupil is orphan or not orphan, and school fees payment by checking whether student paid school fees or had not paid. These mentioned data were taken randomly from senior one (S1) to senior six (S6) in academic year 2020-2021.

Findings: The system is equipped of a finger print sensor to register and verify students and staff attendance, a Passive Infrared (PIR) sensor to detect the presence of human to wake-up the device, a real time clock to synchronize each generated report with the local time. A web application is developed to allow students real-time monitoring for parents and school administrators and the system is be able to generate a daily, monthly and annually report.

Unique contribution to theory, practice and policy: Classification machine learning with decision-tree algorithm is used to analyze data and generate a model to evaluate the impact of monitoring attendance on preventing students to dropout. The generated model with accuracy of 91.4% shows that keeping students' attendance at high percentage would reduce significantly the dropout rate in secondary schools of Rwanda.

Keywords: *Biometric, internet of things, sensor, fingerprint, regression and decision-tree.*

INTRODUCTION

Personal identification is an important aspect in recognizing the identity of a particular individual. A person's identity is validated through the traditional or biometric methods; biometric technology associated with Internet-of-things (IoT) provides a framework for integrated computing devices capable of managing efficiently the students' attendance.

According to Jain et al. (2000), there are two types of traditional methods which are token-based and knowledge based identifications. Examples of the token-based method include possession of a passport, driving license, and different types of cards such as identity (ID) card and credit card. Although it is convenient to carry these identity documents, these documents can be reproduced, stolen, or lost. On the other hand, the knowledge-based method is related to a password or personal identification number (PIN) created by each individual for authentication. Nonetheless, it tends to be forgotten easily, especially if the person has several passwords or PINs for different applications. Another alternative method is through biometric adoption, which considers the physical or behavioral characteristics distinctive to an individual. Physical characteristics refer to inherent features of the human body part. These include the face, fingerprints, and iris. On the contrary, behavioral characteristics deal with features observed from human action. Examples of human action are gait, voice, and signature (Dinca, & Hancke, 2017).

According to German and Barber (2017) application of biometrics in different domains. Biometric-based attendance recording or tracking system is part of the low percentage of biometric applications in the education sector, Attendance marking is considered as one of the crucial parts of a class. This is to ensure students participate in the class activities and learn from their educators. Student academic attendance is very crucial on account that it's going to have an effect on students from gaining knowledge, skills and their grades.

Currently in Rwanda, most of the school attendances are marked using the conventional methods such as calling out names or signing off attendance on paper. Unfortunately, these methods are not suitable for a large class. It is a waste of time for the educator to call out all the students' name to mark their attendance whereby the time can be utilized more efficiently for the teaching and learning processes. Another method is by signing off attendance. Distraction happens because the student needs to sign the attendance list and pass on to the other student during class.

Moreover, it can be compromised by a student who signs on behalf of their friend who does not attend the class. Therefore, biometric systems have been developed as an alternative way to mark attendance in class. One of the advantages is that the student cannot manipulate the attendance as each individual has different biometric characteristics. In addition, it also helps in improving efficiency and reduces the educator's burden as the attendance is marked automatically. This project is about taking the student fingerprint templates and matching them to fingerprint stored in database to confirm their attendance. The predominant purpose of carrying out this project is to design and implement an IoT-based student attendance system where the data are collected from a remote fingerprint device and sent to a web-based application for analysis and reports are automatically generated to concerned educational partners.

Problem Statement

The Government of Rwanda set policies to improve school progression and completion rate to reduce the numbers of students dropping out in secondary school but the dropout rate is still very high especially in non-boarding schools. The students leave their home early morning and

go to school and return back in evening, through the whole day there is no student's monitoring system for parents and school managers to ensure that students really attended classes. For some students, instead of attending classes they go in illegal practices. It is in this background that this research is contributing to reduce the dropout by developing a real time IoT and AI based student's attendance monitoring system that allow communication between parents and school managers, through SMS or Email notification.

Rwanda Education Statistics Related to Dropout

Rwanda has established a 12 years' basic education that include 6 years of primary school and 6 years of secondary school; most of these secondary schools are non-boarding school.

Table 1: Lower secondary school student's drop out from 2013 to 2019

	2013/14	2014/15	2015/16	2016/17	2017/18	2018/2019
Promotion rate	73.6%	74.%	81.9%	86.4%	86.9%	85.9%
Repetition Rate	11.6%	11.6%	11.6%	7.3%	6.%	5.%
Dropout Rate	14.7%	14.4%	6.5%	6.3%	7.1%	9.1%

Source: (MINEDUC, 2020)

Table 2: Upper secondary school student's drop out from 2013 to 2019

	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Promotion rate	92.2%	90.1%	90.1%	91.5%	94.40%	95.5%	92.60%
Repetition Rate	1.7%	3.8%	4.0%	6.0%	3.10%	5.0%	2.30%
Dropout Rate	6.0%	6.2%	5.9%	2.5%	2.50%	1.7%	5.10%

Source: (MINEDUC, 2020)

LITERATURE REVIEW

Research was carried out to identify the requirements of any biometric system, and specifically of a fingerprint system for use within the education environment, before comparing fingerprint suitability with that of other biometric techniques. A choice of fingerprint device had to be considered, and consideration given to the role of identification or verification, so that the best method of operation could be applied. Some biometrics attendance in different regions and show their drawbacks in education especially in case of Rwanda.

Tiwari et al. (2015) In designing a biometric based application seven characteristics have been identified for consideration in any system, which uses biometrics for authentication of individuals and the comparison of fingerprint techniques with the other biometrics methods is given here. This comparison is completely based on the scientific literature but examples are given in an attempt to elucidate the findings. The new school surveillance technology doesn't turn off when the school day is over: anything students' type in official school email accounts, chats or documents is monitored 24 hours a day, whether students are in their classrooms or their bedrooms. Tech companies are also working with schools to monitor students' web searches and internet usage, and, in some cases, to track what they are writing on public social media accounts.

In (Freebrowsinglink, 2021) Chinese schools are using 'smart uniforms' to track their students' locations. The reason of tracking the children is to encourage better attendance rates. For

tracking, each of student uniform has two inbuilt chips in the shoulders. This enables the appropriate management by knowing when a child exists/leaves the school premises. Face Identification is built right inside the uniforms and there is a small quantity of facial recognition software at the entrances to make sure that the right student is wearing the right outfit. There is Alarm system to keep the school premises in order, where by when student try to leave during school hours, an alarm goes on and there is change if he/she is allowed to go or not. The chips can apparently detect when a student has fallen asleep in class, and allow students to make payments (using additional facial or fingerprint recognition to confirm the purchase).

Despite having those little technologies built right inside those clothing, students can also wash, and rewash their uniforms without any hindrances. The developers on this smart uniforms are Guizhou Guanyu Technology Company, confirmed that each outfit can endure up to 150 degrees Celsius (302 degrees Fahrenheit) and 500 times of washes. Luminositylab (2021) Guardian Drones is an autonomous drone system designed by Luminosity researchers to increase university campus safety by augmenting existing emergency response teams with autonomous agents. Using a proprietary mobile application, students can request to be escorted through campus by an autonomous drone. The drone fleet provides illumination and establishes a live video link for ASU's Police Department to monitor activity. To ensure the success of the system, the drones were designed with multiple functional safety features, such as deployable parachutes and encryption protected software. The drone fleet is capable of responding to a student's request and arriving at their location on campus within a minute. The system was designed to be self-sufficient, in addition to the development of the drones, Luminosity students developed and submitted an invention disclosure for a base station that is capable of automatically docking and charging drones through a contact driven system.

Narzullaev and Narzullaev (2021) proposed a new AI-based system that can automatically detect the student's presence or absence in a classroom using the Wi-Fi signal information collected from student's smartphone. The proposed system does not require any additional investment in hardware or infrastructure and achieves up to 94% accuracy by implementing the Logistic regression-based machine learning classification algorithm. This system is not applicable in Rwanda because the rule of ministry of education (MINEDUC, 2020) doesn't permit the use of smartphones in secondary schools.

Shoewu et al. (2011) proposed an embedded computer-based lecture attendance management system where a single-chip computer based subsystems (an improvised electronic card and the card reader) were interfaced serially to the serial port of the digital computer. The electronic card is a model of a smart card containing the student identity (ID Name, Matriculation Number and five pin encrypted code). The student ID is authenticated by the card reader which compares the entrance code with the encrypted code on the card swiped through the card reader. The student is granted and or denies specific lecture attendance based on the result of the comparison by the backend software system running on the PC to which the card reader is serially interfaced. The system though provided a simplified, low cost embedded computer based system solution to the management of lecture attendance problem in developing countries but does not eliminate the risk of impersonation. The system is devise-based in which students have to carry RFID cards and also the RFID detectors are needed to be installed.

Shehu and Dika (2010) proposed a real time computer vision algorithms in automatic attendance management systems using Computer vision and face recognition algorithms and integrating both into the process of attendance management. The system eliminates classical student identification such as calling student names, or checking respective identification cards, but still lacks the ability to identify each student present in class thereby providing a lower

recognition rate because facial images are subject to change between the time of enrolment and time of verification and also poses a bigger financial burden during installation and does not offer any privacy protection. Jomon and Zacharia (2013) proposed a face recognition based attendance system based on Eigen face recognition. Images are converted into Eigen faces, Recognition is performed by comparing Eigen face got from the input image and Eigen faces in the database. The problem with this approach is that this method is very sensitive to face background, head orientations and it doesn't recognize the face of a person if the person is wearing glasses or a grown beard, etc.

There are also papers involving using biometrics for attendance (Shoewu & Idowu, 2012) fingerprint is used for marking the attendance of students. There is a biometric sensor which takes the fingerprint, feature extraction done on that data. If it is for enrolment, then that data is stored in the database else if it is for authentication then that data is started matching with the data in the database. The problem with this method is that for attendance students should go to the place where this hardware device is located or pass the hardware device around the students during class which can be a distraction to the students. (Chaniago & Junaidi,2016) presenting a student attendance application based on the SMS Gateway application that was made to ensure that students attend classes, with the following steps: students must submit an identity card to the teacher in charge, then the teacher scans the barcode printed on the card, and finally the data is stored in the database automatically. This application provides services for parents to find information on a weekly and monthly basis. This application can also be taken into consideration in making decisions for principals by downloading student attendance data in the Microsoft Excel file format. The implementation of SMS gateway-based applications for student attendance in schools is expected to be the solution to students' absenteeism problems.

RESEARCH METHODOLOGY

Methodology refers to the procedures or techniques used to collect data and analyse them. They are many techniques and this project used data collection, data analysis to generate a model then prediction model whose outcome is tp predict dropout and future use of information extracted from provided data.

Data Collection

In this project, we collected primary data from the school by installing a device and then students and staff need to enroll to the system at the beginning and then their attendance is taken and stored in database and data captured sent on cloud platform. With the time limitation, we decided to use secondary data taken manually by teachers and school's administrators, the used data are obtained from the school's record of Wisdom school Musanze located in Musanze district. These are from six classes taken randomly from senior one (S1) to senior six (S6) in academic year 2020-2021.

After interview with school staff, parents, students and education partners, it is realized that there is no available record of student's implication in drug abuse or teenage pregnancy but found that dropping out from the school keeps existing, This project helped much since it monitor and provide data and predict the dropout and this can help to mitigate the right solution to solve it by basing to the data and facts. A field of data was included in this research related to the students punished for escaping school during class hours because they are suspected to go in illegal activities such as drug consummation and adultery.

According to the literature some researchers shown that student's dropout might be influenced by parent poverty, being orphan or age, the database includes such data related to payment

historic, which is in charge of a student and their age. Finally, we included a field of data related to attendance (in percentage) because I assuming that by daily monitoring attendance I can reduce the case of drug abuse and teenage pregnancy, hence reduce the dropout. In total 240 students' data were gathered from S1 to S6. The data base contains the following: students 'ID, class, age, orphan, pay school fees, attendance and dropout.

Data Analysis

This is taken as a tool used to extract useful information from raw data collected and stored in database to help to make decisions. Collected data are accessed by a cloud platform that generates insight information to education partners. Multiple algorithm of machine learning were applied to the data to generate a model with high accuracy which shows the contribution of different variable to the school dropout.

Data Interpretation/Reporting Plan

Information gathered are shared to the end users like parents, school managers and education decision makers.

SYSTEM DESIGN ANALYSIS AND RESULTS

System Design

The student's attendance monitoring system consists of three main parts. The first is IoT hardware component that build the entire circuit. This part involves sensing components, data processing component and actuators components. The second part consists of programming to make system hardware operational. The last part is data processing and analytics, which is done using Python programming and regression as machine leaning technique and it is visualized on graph.

System Design Block and Circuit Diagram

The system is equipped of a finger print sensor to register and verify students and staff attendance, a PIR sensor to detect the presence of human to wake-up the device, a real time clock to synchronize each generated report with the local time.

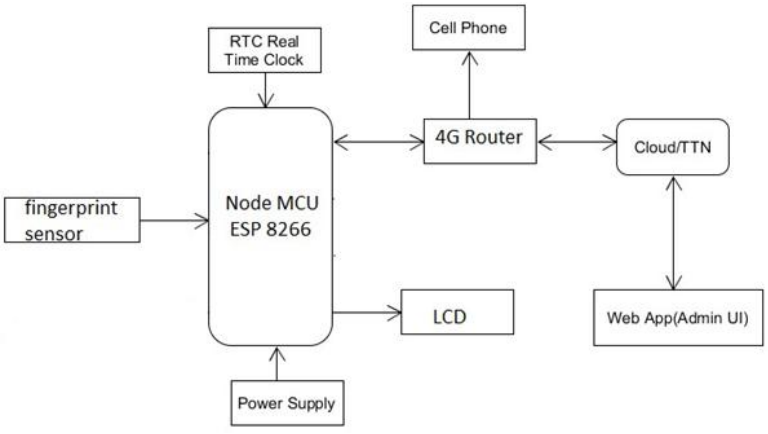

Figure 2: Block diagram of the attendance monitoring system

Solar energy harvesting is used to charge the device's internal battery, the system requires a router to connect to the internet and a web application is developed to analyse data and generate insight information. A web application also allows students real-time monitoring for parents and school administrators and the system is be able to generate a daily, monthly and annually report to education decision makers.

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Circuit Description

The first thing is to do in the program is to include all the required libraries. Here in my case, I have included "**Adafruit_Fingerprint.h**" for using R305 fingerprint sensor and

"**ESP8266WiFi.h**" for using ESP8266 NodeMCU Wi-Fi module. To use the I2C interface of an LCD display I used **LiquidCrystal_I2C.h** library. Then we configured the serial port in which fingerprint scanner is connected. In my case, I declared D5 as RX Pin and D6 as TX pin.

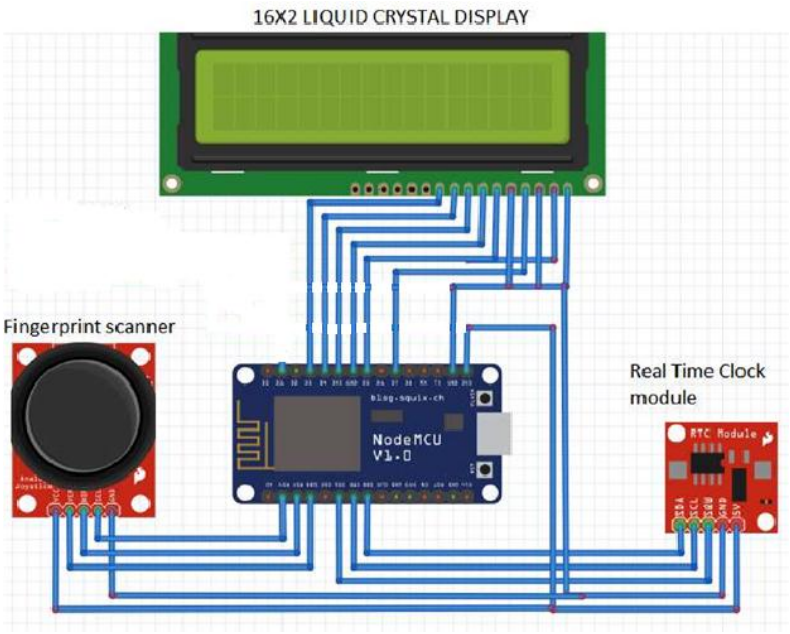

Figure 3: Project's circuit diagram

Next, I set my Wi-Fi router credentials in the program. Replace your network SSID name in place of "xyz" and password in place of "123456789". As we are going to use Pushing box API for sending the data to Google sheet, then I have to check for fingerprint sensor connectivity. This confirmed us regarding the fingerprint sensor's successful pairing with the NodeMCU. If the connection to the server is successfully established, then a complete URL is created using the device ID which is got in pushing box API. If the client doesn't respond for more than 5 seconds, it shows client timeout. Otherwise, it sends the data to Google sheet using the URL via pushing box API.

System Design Flowchart

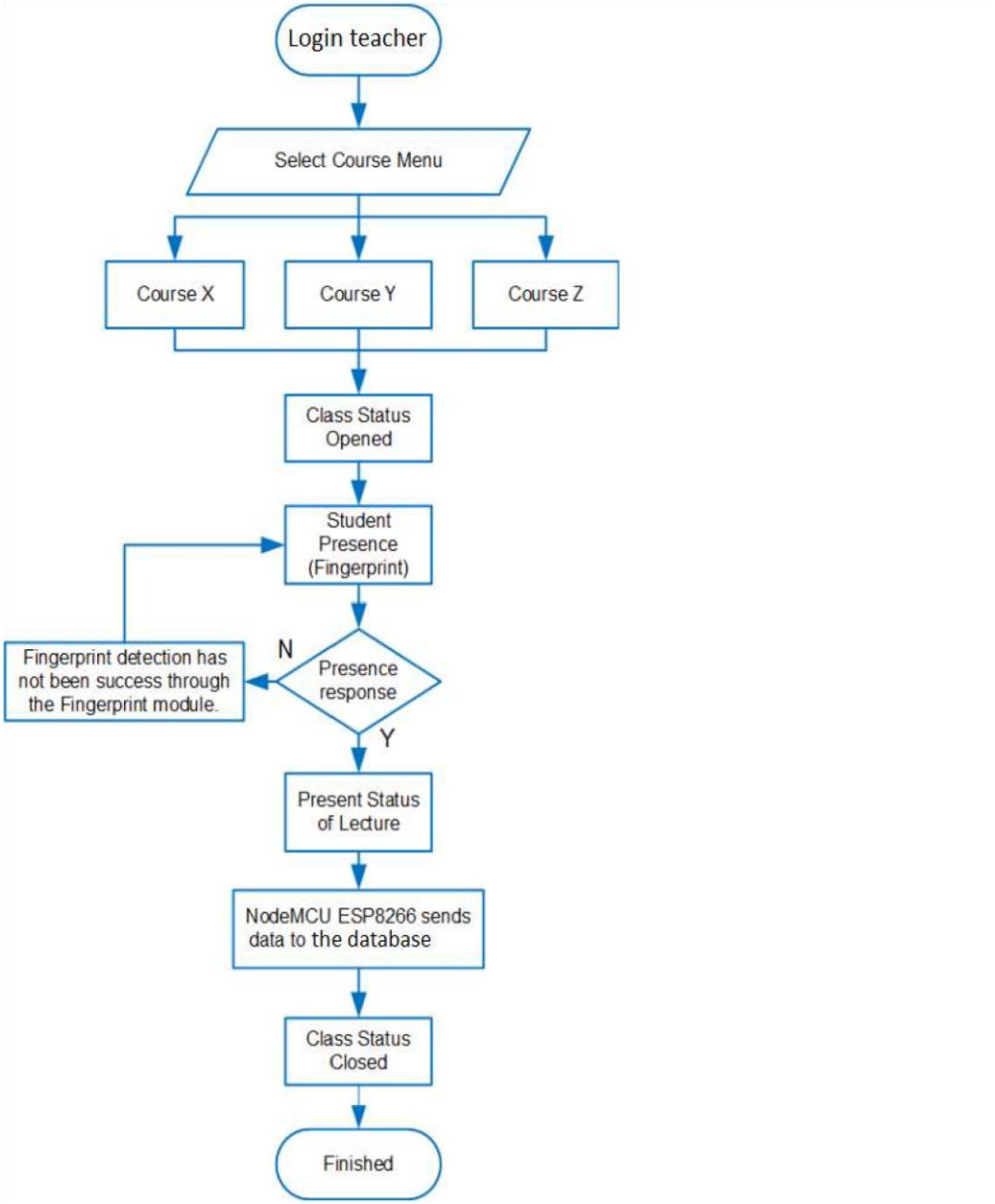

Figure 4: Flowchart of the attendance system

A flowchart is a graphical or symbolic representation of a process so that the process is more likely understood and applied correctly and consistently and it is easy to communicate it to other people. The above flowchart shows the steps of process undertaken by the attendance monitoring system when a teacher has to get the students 'attendance in his respective course.

System High-level Design

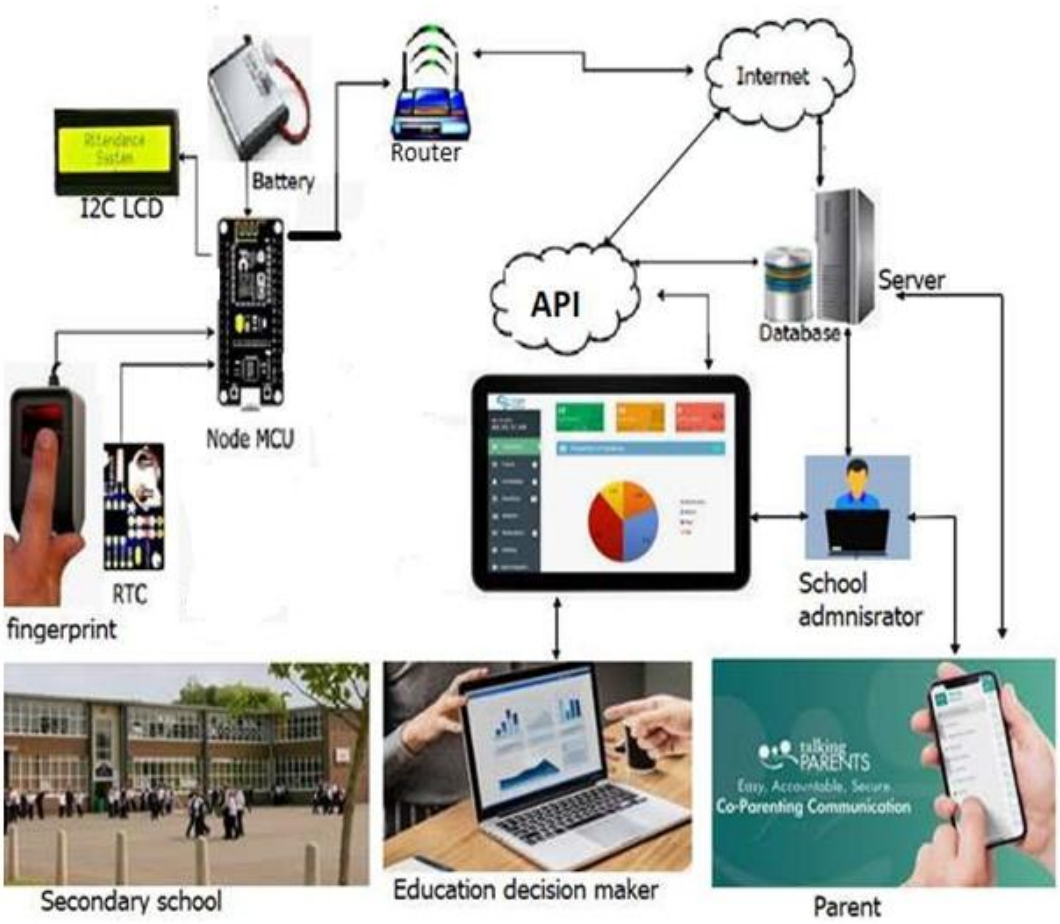

Figure 5: System high-level design

System Analysis

Algorithm to use

An algorithm is said to be a procedure or formula used to solve a problem.so we used codes to perform manipulations to achieve the results. More explanations and flow chart are given in as we proceed. Due to the type of output to predict which is categorical instead of numerical values, we found that classification algorithm is best fitting among others. Classification is the type of supervised machine learning which is mostly fitting in a predictive modeling problem where class or labels are categorical instead of numerical values. I chose classification among others because we were predicting labels like dropout or no dropout.

Machine learning is a method of data analysis that automates analytical model building based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention. Supervised learning is one of the most basic types of machine learning among others like unsupervised learning and reinforcement learning; here we focused on supervised learning because of the nature of the data and predicted output. The dataset obtained from the attendance system are saved in excel sheet and was used to train model.

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Table 4: Attendance monitoring system dataset

	classe	Age	sex	olphan	pay sc fees	punished for escaping classes	ATTENDANCE	School dropout
0	1	13	F	N	Y	N	86	N
1	1	13	F	N	Y	N	90	N
2	1	14	F	N	Y	N	78	N
3	1	13	G	N	N	N	91	N
4	1	13	G	Y	Y	N	88	N
...	...	...	...	...	...	...	...	...
235	6	19	F	Y	N	Y	42	N
236	6	19	F	N	Y	Y	39	Y
237	6	18	G	N	Y	Y	67	N
238	6	18	G	N	N	Y	77	N
239	6	17	F	N	Y	N	66	N

240 rows × 8 columns

The dataset shows that there are 240 students in 6 classes and among them at least 40 students were dropped out from school.

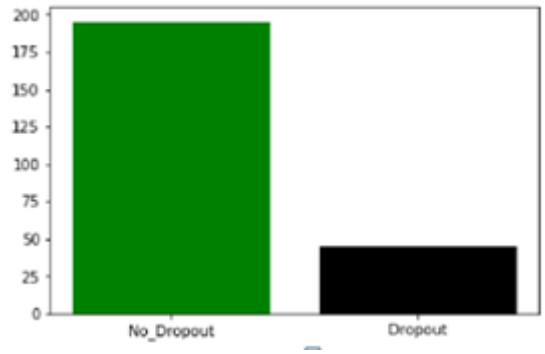

Figure 6: Non-dropout vs dropout

There is a problem of class imbalance between dropout and No_ dropout; hence it is needed to perform oversampling to fix this problem.

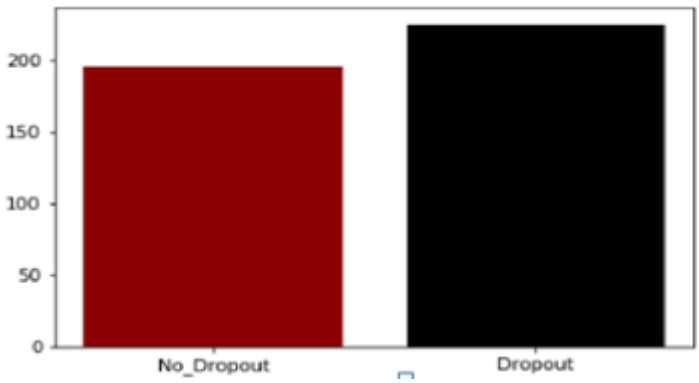

Figure 7: fix the problem of class imbalance

Some variables need to be pre-processed to be analyzed

Class input variable: In order to reduce the number of coefficient I decided to use lower secondary (0) and upper secondary (1)

Sex input variable has two fields, female (F) and male (G)

Orphan input variable: has two fields, orphan (Y) and not orphan (N)

Pay school fees: two fields pay school fees (Y) and not pay school fees (N)

Punished for escaping class during class ours: two field punished (Y) and not punished (N)

Table 5: Pre-processed dataset

	F	G	N	Y	N	Y	N	Y	Age	ATTENDANCE	School dropout
0	1	0	1	0	0	1	1	0	13	86	N
1	1	0	1	0	0	1	1	0	13	90	N
2	1	0	1	0	0	1	1	0	14	78	N
3	0	1	1	0	1	0	1	0	13	91	N
4	0	1	0	1	0	1	1	0	13	88	N

Three models of classification machine learning; Logistic Regression, K-Nearest neighbors and Decision Tree have been applied to the data to see which one is more accurate. Here are the results. For Logistic regression an accuracy of 81.9 % was obtained as shown in table 6.

Table 6: Logistic regression result

```
                precision    recall  f1-score   support

             N       0.82      0.80      0.81        51
             Y       0.82      0.83      0.83        54

avg / total          0.82      0.82      0.82       105

[[41 10]
 [ 9 45]]
accuracy is 0.819047619047619
```

For K-Nearest Neighbors an accuracy of 81.9 % was obtained as detailed in table 7.

Table 7: KNN result

```
==========Model 2 KNN==============
             precision    recall  f1-score   support

          N       0.76      0.76      0.76        51
          Y       0.78      0.78      0.78        54

avg / total       0.77      0.77      0.77       105

[[39 12]
 [12 42]]
accuracy is 0.819047619047619
```

Finally, for Decision Tree an accuracy of 91.4 % was obtained.

Table 8: Decision three result

```
==========Model 3 Decision Tree Classifier==============
             precision    recall  f1-score   support

          N       0.85      0.78      0.82        51
          Y       0.81      0.87      0.84        54

avg / total       0.83      0.83      0.83       105

[[40 11]
 [ 7 47]]
accuracy is 0.9142857142857143
```

RESULTS DISCUSSION

Impact of sex on dropout

The analyzed data shows that the number of girls (F) is almost equals to the number of boys (G), but more than 25% of girls are dropping out while on boys' dropout rate is about 18%, this is due to the fact that every student who get pregnant end up by dropping out.

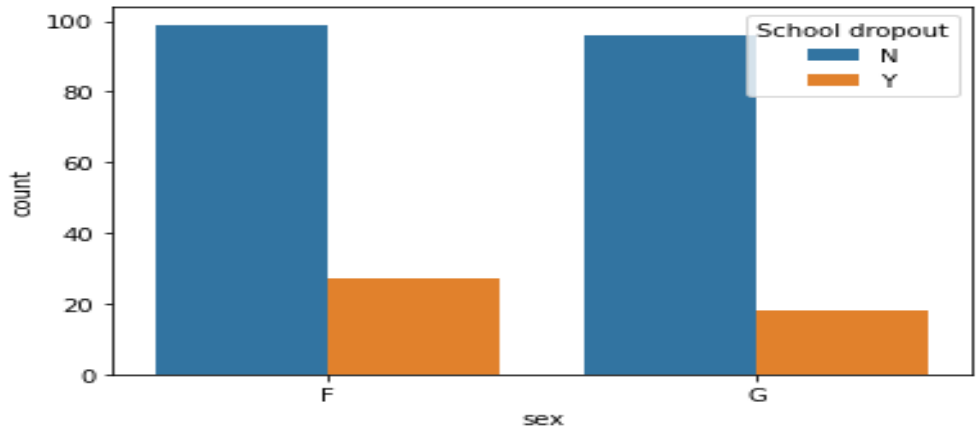

Figure 8: Impact of sex on dropout

Students' dropout vs secondary school levels

The data shows that the dropout rate is high in lower secondary school and it is reduced as the students' progress toward upper secondary school. There are about 9 dropouts over 43 students in senior one (187%) and this rate becomes 5 over 30 students with a percentage of 16.6%.

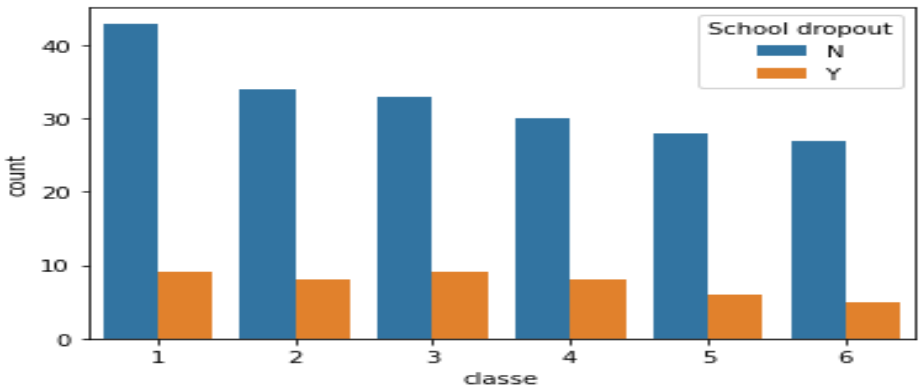

Figure 9: Students' dropout vs levels

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Students' dropout vs parent's poverty

The parents' poverty which was indicated by means of school fees payment either early or very late. In a total of 240 students, 155 of them got school fees on time(at the time of starting school) and 20 students dropout (12.9%), while 95 paid school fees with difficult among them 20 students dropout (20%). This showed that the parents' poverty is one of the factors that influence the dropout.

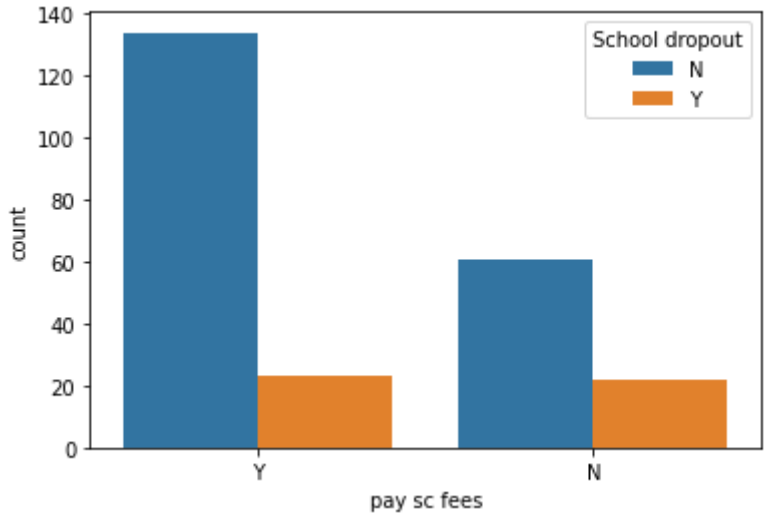

Figure 10: Students' dropout vs parents' poverty

Students' dropout vs student's punishment

Among 145 students who do not punished for escaping class during class hours, only 10 dropped out (6.9%) while among 95 students who were punished due to escaping classes 30 30 of them dropout which is 31.5%. This indicated that punishments due to class escape contribute to student's dropout.

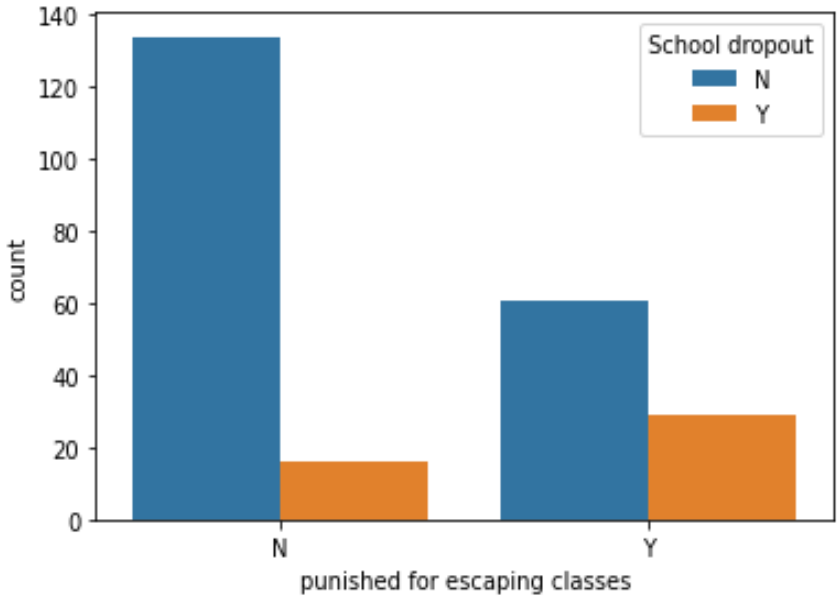

Figure 11: Students' dropout vs students' punishment

Students' dropout vs students' age and attendance

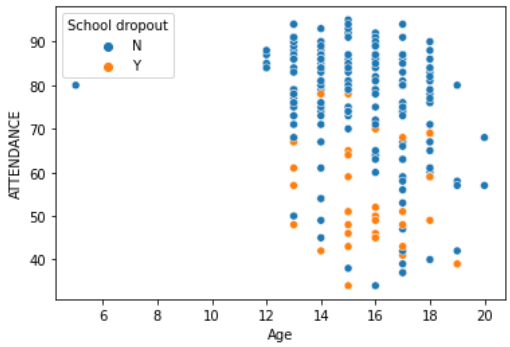

Figure 12: Students' dropout vs students' age and attendance

The dataset analyzed shows that students in secondary school belong to the range from 12 years to 20 years old, the figure 12 indicate that the age does not contribute to the dropout as the dropout cases are distributed to the whole range of age. In opposite, the attendance contributes a lot to the dropout as the students with greater than 70% of attendance do not dropout. So, to monitor the students' attendance would reduce significantly the dropout rate in secondary schools.

Results discussion from the model

In this analysis 75% of the dataset have been used for model training and 25% were used for model testing, the algorithms are used to train data and generate prediction results using three different models' algorithm and the results are obtained with different accuracies: Decision Tree had an accuracy of 91.4 %, K-nearest neighbors had an accuracy of 81.9 % and logistic regression we have an accuracy of 81.9 %. It is clear that classification with decision tree is generating a model which mostly feet to the collected data to predict the dropout in secondary school.

Table 9: Results comparison from three models

SN	Prediction model	Dropout	Precision	Recall	f1-score	Support	Accuracy
1	Logistic Regression	yes	0.82	0.8	0.81	51	81.90%
		non	0.82	0.83	0.83	54	
		macro avg	0.82	0.82	0.82	105	
		weighted avg	0.82	0.82	0.82	105	
2	K-Nearest Neighbors	yes	0.76	0.76	0.76	51	81.90%
		non	0.78	0.78	0.78	54	
		macro avg	0.77	0.77	0.77	105	
		weighted avg	0.77	0.77	0.77	105	
3	Decision Tree	yes	0.85	0.78	0.82	51	91.40%
		non	0.81	0.87	0.84	54	
		macro avg	0.82	0.83	0.83	105	
		weighted avg	0.82	0.83	0.83	105	

It is true that some other factors contribute to dropout like being orphan and social economic situation of the students' family but those factors can't be controlled, the attendance on contrary when monitored students were somehow forced to attend even if in some situation they could not without such mechanism. It is clear that decision Tree provide a model with high accuracy and the dropout is given by:

Dropout = 0.623Female_sex + 0.447Male_sex + 0.909No_orphan + 0.161Orphan +

0.861No_fees + 0.209Fees + 0.207Not_punished+ 0.863 Punished, + 0.099 Age -

0.078Attendance +1.113Lower_secondary -0.042Upper_secondary + 1.07

As the attendance has a negative coefficient (-0.078) this shows that attendance is indirectly proportional to the students' dropout and when the attendance increases the dropout decreases considerably so monitoring the attendance to keep it to high percentage reduces the dropout rate.

CONCLUSION

This project achieved its main purpose which was to design and implement an IoT based attendance monitoring system that monitor non-boarding secondary school's students from home to schools, during class hours and from school to home and notify parents and school administrators about the irregularity observed to their respective children in order to reduce the student's dropout rate. A fingerprint-based device is implemented for students and staff identification, authentication and evaluation while making attendance. The system is generating a real time report to parents and education decision maker and provides an efficient co-parenting communication regarding student's behaviors during class hours.

In this project a model that shows the impact of monitored attendance on preventing students' drop out in secondary schools is generated with an accuracy of 91.4% and it confirm the hypothesis because shows that keeping the attendance at high percentage would reduce significantly the students' dropout rate, but the model is not deployed to the system.

RECOMMENDATION

During the implementation of the project it was realized that students of Embedded Computing System were missing a lot of knowledge of programming especially on web application & database development and data analysis algorithm development.it is recommended to the center to find how to include such modules to fill the gap.

The system uses a single biometric technology (fingerprint) which has some drawbacks when there is skin degradation, so it is recommended to the future researcher to combine more than one technology to implement a more efficient recognition system.

The data set used in this project was taken from a single school and a small sample of 240 students data of a single academic year were analyzed; this might not output excellent results of students' dropout. Hence, it is recommended to the future researcher to expand sample to different schools of different districts and analyses data of more than one academic year.

The study recommend that further studies may be applied to this project where a model will be deployed to the system and shows the student's dropout probability based on system's database information.

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