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EyeKids: Real-Time Tracking and Monitoring System for Child Safety

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***Abstract*—EyeKids is a tracking and monitoring system that implements Global Positioning System (GPS) technology for obtaining location data, a General Packet Radio Service (GPRS) network for data transmission, and a cloud database for storing tracking data with the main purpose of allowing a parent to ensure their child safety remotely. Child safety is the number one priority of any parent. They are concerned about their child's well-being and wanted to keep an eye on their child's every movement. This project is meant to provide a solution to the concerned parents. This system includes three main components, a child tracking device, a parent-side application, and a cloud database. The tracking device is built using Arduino Uno Microcontroller Board, SIM808 GPS/GPRS/GSM module, and a push button. The tracking device sends its device ID, latitude, and longitude to the PHP server first using an HTTP request before it goes through the uploading process on the server to Firebase Database via HTTPS. Mobile EyeKids Parent-side application is based on Android where it is developed using the Flutter framework and implements Firebase Authentication for user authentication. The application consists of three main tracking functions, tracker, path tracking, and tracking analysis. The tracker function allows parents to track their child's location based on the coordinate obtained which is displayed on a map. Path tracking functions show paths taken by children throughout a selected day on the map. Parents also are able to view analysis of child movement based on tracking data stored in the cloud database. The integration of hardware and software components of the system is evaluated to assess the correctness of the system through white box testing, black box testing, and user acceptance testing. The project follows a Rational Unified Process development model that has been adjusted to suit the size of the project and its requirements. The project has successfully developed and tested to be able to track child movement when the device is turned on and provide child location reports on a monthly basis.**

***Keywords*—GPS, GPRS, tracking, cloud, mobile application**

I. INTRODUCTION

In today's world, with the rising trends of crime cases especially involving children, parent cannot help but worries that one day it might involve their child. They are eager to know every movement of their child to make sure of their safety and wellbeing. Consequently, it will affect their daily life and work performance. This project called EyeKids aims to locate and track a child's location with the main purpose of maintaining child safety. This project involves three components which are the child device, the parent's application, and a cloud server. The child device will use GPRS service combined with GPS to send the child coordinate in longitude and latitude to a cloud server database. The parent's side application can request the location data from the server and then provide a graphical view of the child's last updated location, the path they take, and analysis of their movement.

II. RELATED WORK

A. *Child Tracking Device Based on GPS and GSM*

The work by Al-Mazloum and his colleague [1], focused on providing a solution to track children using services that are offered on Android mobile phones which are the GPS and SMS services to allow parents to track their child's position in real-time. This system consists of two sides, parent side application and child side application, which serve as the master and slave respectively. Child side applications mostly work in the background as a listener considering that it is difficult for children to use a mobile application unguided. Therefore, the child side will listen to requests from the parent side via SMS and reply with location information. Location information is retrieved from GPS and network providers. Only one with the most accurate information will be sent to the parent side. This system also includes a geo-fencing feature where parents may set area boundaries to restrict their child's movement. A notification will be sent to the parent when the child goes beyond the area.

The system design offers several advantages. First, the application on the child side does not require any interaction upon location request by the parent as it works in the background to listen for any request before replying to the request automatically. It is useful considering that it is going to be used by children. Next, communication between applications is done using SMS services therefore internet connection is not required at all making it beneficial for a situation where an internet connection is not available. Thirdly, location can be determined even when the child is indoors since the system not only offers location determination using GPS but also using network provider service. Since GPS can only determine outdoor location, the network provider provides another alternative for location detection.

One of the notable limitations is that data transfer using SMS service is costly. Network providers put a charge for every SMS sent. Therefore, if parents want to consistently determine their child's location, they will need to spend a lot on the data transfer.

B. Mobile Monitoring and Alert System

This system is a work by Coelho and Paiva [2], where they provide a solution using SMS service to allow the parent to monitor their child remotely. The system offers three types of remote monitoring which are single positioning, frequency scheduler, and range. Single positioning allows the parent to request for child's position and it will reply with GPS coordinate visualize on a map. The next function is the frequency scheduler; it enables the parent to set a frequency for how many times they receive location updates. The last function is the range; it defines a secure range that will trigger an alert message if the child leaves the range area. The system consists of two applications, one for the child and another for the parent. Parents will need to configure their number at their child's side so that it will send information to them. The child application will run in their phone background, so they do not have to interact much with it. They used Fused Location Provider which is a location API for android to obtain child location information. It will choose whether to obtain location information from Wi-Fi, cell tower, or GPS according to their priority.

The use of Fused Location Provider provides an effective way of obtaining location information from different sources that work both indoors and outdoors. A system that only uses GPS will not be able to obtain location information when the child is indoors. The only concern about this system is that the child will have to carry a mobile phone for it to work. It might not suitable for tracking younger children.

C. Child Safety Monitoring System (ChildGuard)

Gao, Guo, Xie, and Luo [3] proposed a system to monitor the child in real-time that is low-cost and easy to use. They make use of a device such as smartphones and wearables to monitor location and child activities. The system includes three-part, a guardian application, a child application, and a server. Its main functions include path and region protection. The in-path safety function gathers child's location information and sends it to their guardian. It also will give voice alert to the child when they behave unusually such as when they are playing on the road or to remind them of the traffic light. It will also send an alert to their guardian. Meanwhile, the region safety function alerts the guardian when the child goes beyond a specified area and it will also alert the child. The communication between the guardian application and child application is done through a web server via the Internet. They use an instant messenger software development kit (iMSDK) to allow information transmission between the two applications without knowing both sides' IP addresses. The child's coordinate is obtained using GPS, Wi-Fi, and a base station before it is sent to the guardian application every three minutes. These coordinates are saved, and each coordinate is connected to form polylines that show the child's movement.

This system provides more than one option for obtaining location information which is by using GPS, Wi-Fi, and a base station. Therefore, it has better positioning than a system that only uses GPS. However, it needs an Internet connection to connect to the web server, if Wi-Fi is not available then data from the child application cannot be stored on the web server and the parent is unable to retrieve real-time information about their child's position. Other researchers on this subject could be found in [4] and [5] which include Wireless Sensor Network (WSN) and Machine Learning techniques.

Each one of the systems studied uses different technologies in obtaining the information. EyeKids obtains location information from two different sources which are from GPS and cell towers to provide better accuracy and availability. A system that uses only one source might not be able to obtain the location information whenever needed due to the availability of the source. GPS and SMS-based tracking system only use GPS for obtaining location coordinate, therefore it will not be able to get location information when the child is indoors as GPS need a clear view of the sky for it to work.

Two of the system uses GSM communication for data transmission while ChildGuard and EyeKids use 3G and GPRS respectively. In EyeKids, data need to be transmitted to a server via the Internet, hence, mobile data communication provided by GPRS is necessary. 3G also serve the same purpose but with higher speed and is suitable for larger data size. Since only location data need to be sent to the server, so GPRS capabilities are enough for the system to work.

In all fours system compared as in Table 1, only EyeKids uses a standalone device for its child side while the others utilize mobile devices. A standalone device is the most suitable to be used by children so that they will not have to carry a mobile device that cost a lot. The cost is also a lot less than having a mobile phone that has all the required specifications for the system to work.

TABLE 1. COMPARISON BETWEEN RELATED WORKS

	GPS & SMS-Based tracking using smartphone	**Mobile Monitoring and Alert SMS System**	**ChildGuard**	**Real-Time Tracking and Monitoring System (EyeKids)**
Functions:				
Positioning	✓	✓	✓	✓
Path tracking			✓	✓
Distress Alert				✓
Obtaining Location:				
GPS	✓	✓	✓	✓
Wi-Fi		✓	✓	
Cell Tower/ Base Station	✓	✓	✓	✓
Network	GSM	GSM	3G	GPRS
Parent-Side	Mobile apps	Mobile apps	Mobile apps	Mobile apps
Child-Side	Mobile apps	Mobile apps	Mobile apps	Standalone device

III. METHODOLOGY

The development methodology chosen for this project is Rational Unified Process (RUP). RUP is an adaptive and flexible development model which can be personalized according to the needs of the project, team, and organization. It is initially created by Rational Software Corporation in 2003. RUP takes an element from the iterative and incremental development model in its process. This process is structured around six "Best Practices" which are developing software iteratively, managing requirements, using component-based architecture, visually modeling software, verifying software quality, and controlling changes to software [6].

This development method is chosen primarily because of its iterative approach to development. It is difficult to define a problem and plan a whole set of solutions from the very start, therefore, the iterative approach enables a developer to understand the needs of the project along their progress and refine initial solutions. This process is also suitable for a project with a restricted timeline as every phase will end with a milestone. The development framework as seen in Fig. 1 below shows an overall view of the development processes.

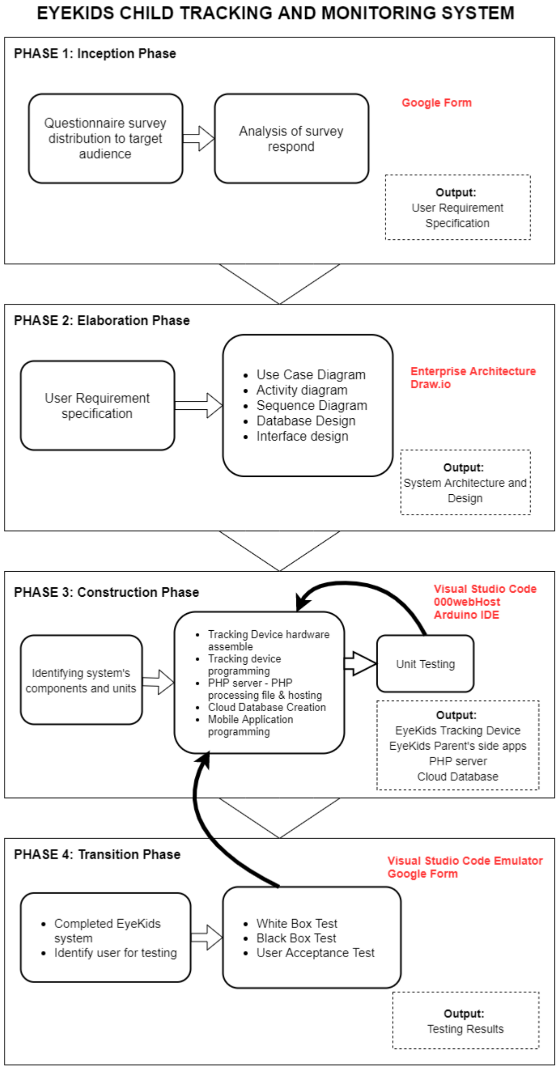

Fig. 1. EyeKids development framework

A. *Inception Phase*

This phase will be the starting point of the whole development where this is when the case study is identified, objectives and scopes of the project will be determined, and it will provide developers with an initial understanding of the whole development. User requirements gathering will also take place in this phase. Requirement gathering is done by distributing a questionnaire to target users by sharing the survey form online. The online form is created using Google Form as it is easier to distribute the form and it is also convenient for the respondents. The target users of this project are parents, guardians or close relatives with children between 5 to 12 years old. Results from the survey describe the relevance of this project and the need of parents that can be implemented in the system.

B. Elaboration Phase

This phase involves analysis of the problem domain, building the architectural base, and developing the project plan. At this phase, developers should already have a good understanding of the surface of the project before they can proceed to make an architectural design. The elaboration phase is considered the most critical out of the four phases as the success of a project depends on the decision made in this phase.

C. Construction Phase

This phase is where the coding and programming of the system features start to take place. Every component and application feature is developed and tested thoroughly before integration. It is important to have a proper architecture and plan laid out during the elaboration phase so that it will ease the construction process.

D. Transition Phase

The transition phase is the last phase of the RUP development process. It is a process of transitioning the developed system to the user. The development will enter this phase only once the system is considered ready to be deployed to the end-user. This is when issues regarding the system are found and developers need to fix the issues and finish any postponed features. This phase will include several iterations of getting user feedback and fixing the issues before a well-developed system is achieved. For this project, user acceptance testing is conducted with target users to get their feedback and to make sure that the system works the way it is supposed to. Functional testing will be conducted to assess the system's correctness to fulfil the required project objective.

IV. REQUIREMENT AND DESIGN

The requirement analysis of this project will be presented in a use-case diagram, sequence diagram, and activity diagram. The diagrams represent the functions involved in the system and their flows. It should provide a better view of how the whole system works. This section will also include the database design, system architecture, and security implementation

A. Use Case Model

There are two actors involved actively in the EyeKids system which are parent and child tracking devices as shown in Fig. 2. A parent is the user of the mobile application used to monitor and track the child, meanwhile, the child tracking device is the device that is used to collect location information and trigger an alert to the parent application.

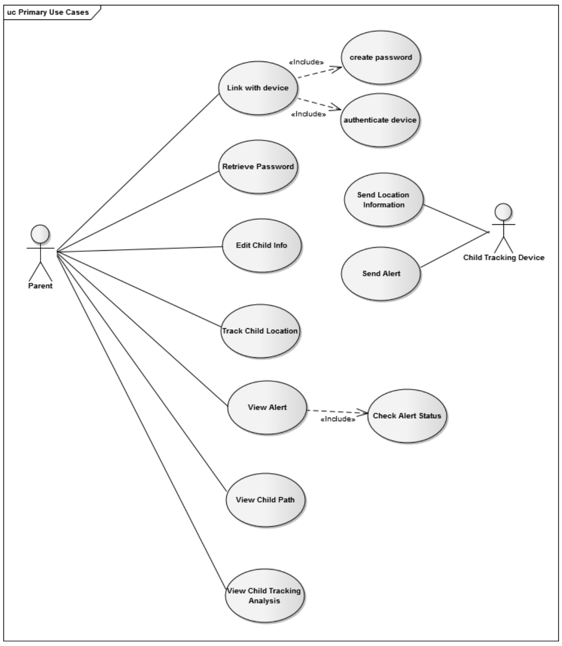

Fig. 2. EyeKids use-case model

TABLE 2. USE CASE DESCRIPTION

Use Case	Description
Link with Device	When parents access the application for the first time, they will need to link with the child tracking device to start tracking. The device will hold a unique key and the parent registers an account using the key. Many accounts can link to one tracking device.
Retrieve Password	When parent forgets their password to access the application, they can retrieve their password through email.
Edit Child Info	Allow parents to set child information (name and picture) associated with the tracking device.
Track Child Location	Allow parents to obtain the child's last updated location information.
View Alert	Parents receive an alert message on their device when an alert is triggered from the child tracking device.
View Child Path	Allow parents to view paths taken by the child filtered by day.
View Child Tracking Analysis	Parents may view an analysis of location visited (top five visited locations) by child filtered by month.
Location mation	The device obtains the location coordinate and sends it to the PHP server together with the device's unique ID.
Send Alert	When an alert is triggered, it will send an alert message to the parent application.

B. System Architecture

Eyekids system includes a parent-side application and a child tracking device. The communication and data transmission is done through a cloud server where data from both sides are kept in a cloud-based database. The child tracking device will use a GPS signal to obtain location information as well as from the cellular network. Data obtained from the device will be transmitted to the cloud database via 2G network, more specifically GPRS.

1) Hardware Architecture

There are three main components in the tracking device, a push button used to trigger distress alert, a GSM/GPRS/ module used to obtain location data and provide a communication network, and a microcontroller board. Data collected from the child tracking device will be aggregated to a PHP server first before where storing process to the cloud database is done. The HTTP protocol is used for connecting to the PHP server while HTTPS is used for the cloud server. The overall view of the architecture can be seen in Fig. 3.

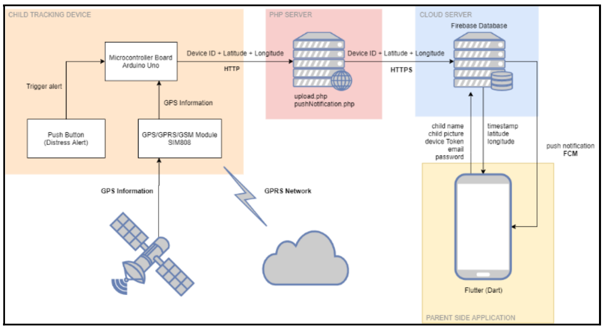

Fig.3. EyeKids hardware architecture

2) Tracking Device Flowchart

Fig. 4 describes the process when the distress button is triggered and when obtaining tracking data. The hardware components involved are a push button, a breadboard, GSM/GPRS/GPS module, and a microcontroller board as shown in Fig. 5. When the distress button is triggered it will send an HTTP request to the PHP server which then pushes a notification to the parent's device linked to the child tracking device ID using Firebase Cloud Messaging (FCM.). As for tracking data, the GPS module will request location data before forwarding it to the microcontroller for data parsing and transmission. Device ID and coordinate of child location are sent to a PHP server using an HTTP request through the GPRS network.

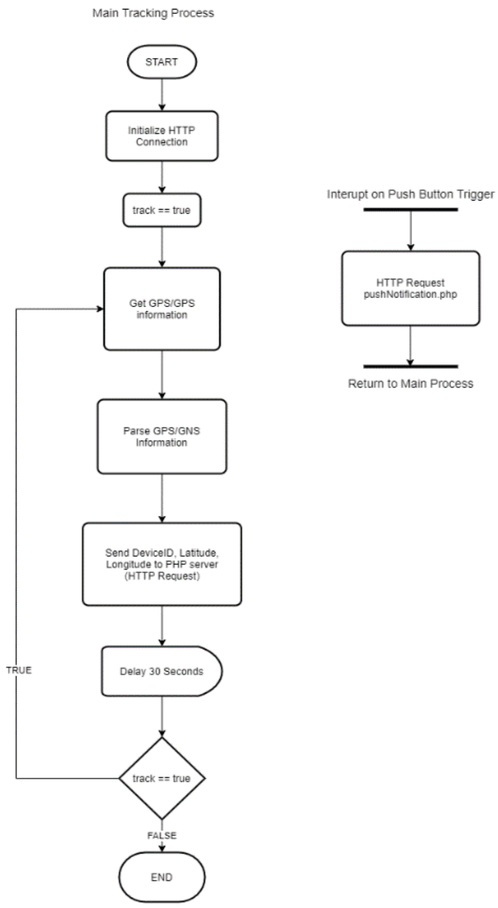

Fig. 4. EyeKids tracking device flowchart

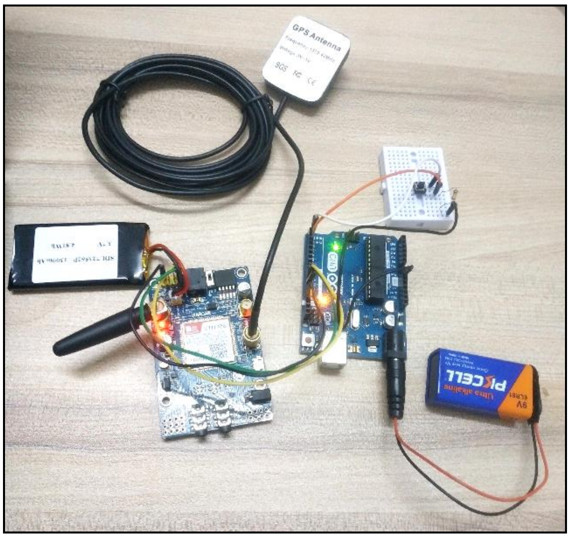

Fig. 5. EyeKids tracking device

3) Database Design

In this project, a NoSQL data store will be used. NoSQL is an alternative to a traditional SQL database where it is a non-relational database. NoSQL is more dynamic than SQL and more useful for handling a large amount of data. Fig. 6 shows the database design for EyeKids system. There is a separate child directory to store parent information and child tracking data. The child's name and tracking device ID are also stored in the parent directory. Tracking data collected from the tracking device are latitude and longitude while the timestamp is generated in the database when the tracking data is uploaded to the database.

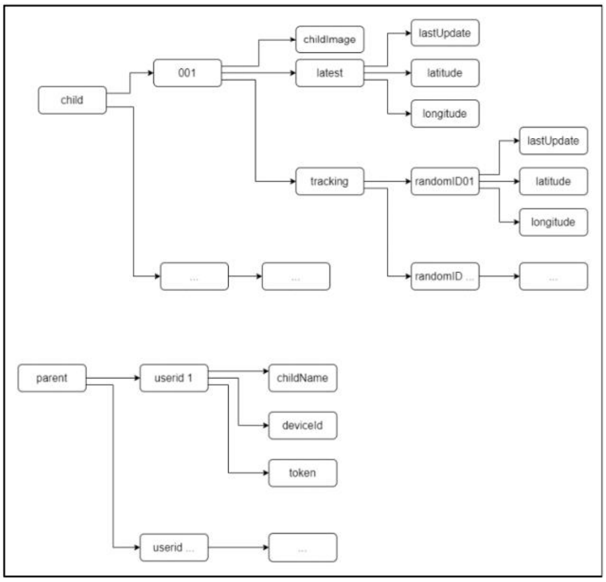

Fig. 6. EyeKids database design

C. Hardware Requirements

Table 3 below includes all the hardware used for both modules in this project, the parent-side application and child-side device. Requirements are stated in the minimum specification for the system development process.

TABLE 3. HARDWARE REQUIREMENT

Module	Requirement	Justification
Child-Side Tracking Device	Arduino Uno Microcontroller Board	The board is the main component of the tracking device. It will be integrated with a GPRS and GPS shield and programmed to send data to cloud server.
	Sim808 GSM/GPRS/GPS Shield	The shield is necessary for data transmission over the internet and for obtaining location information. All necessary modules are combined in one shield hence reduces the cost and size of final device.
	GPS and GSM Antenna	SIM808 shield requires an antenna for the GPS and GSM function to work.
	Push Button	To act as trigger button for alert function included in the tracking device.
	9V Battery	To provide power supply for Arduino Uno microcontroller board.
	3.7V 1300mAh Lithium Ion Battery	To provide power supply for SIM808 shield.
	2G supported SIM Card (Digi)	To allow 2G connection for data transmission over the internet.
Parent-Side Application	Android Smartphone (Android Version 7 and above)	The application is developed and tested for Android 8 environment to avoid any incompatibility issue.
	Desktop Computer/Laptop: Intel i5 or above, 3GB RAM, 10GB available disk storage, 1280x800 screen resolution, Window OS (Window 7 or above)	Required software for programming and coding are installed in this machine, it is also used to manage cloud server database.

D. Software Requirement

Table 4 below listed out all the software used for the development process along with their respective justification.

TABLE 4. SOFTWARE REQUIREMENT

Requirements	Justification
Visual Studio Code with installed Flutter and Dart plugins	Used to code parent's side application and debugging. Visual Studio Code is one of IDEs suitable with flutter framework.
Arduino IDE	Used to write program and upload code to the Arduino board.
Enterprise Architecture	Used for system modelling process. It can be used to model use case diagram, sequence diagram, activity diagram and more.
Web Browser	To access cloud server database, PHP server, and to install necessary software and plugins.
Microsoft Word	Used for project reporting.
GanttProject	Used to create project Gantt chart. This tool is solely for creating Gantt chart therefore it is easier to use and can be installed for free.
Microsoft Powerpoint	Used to prepare presentation slide especially for project progress presentation and final project presentation.

Note that the specification stated is the minimum specification required for the system development process.

V. RESULT

This section will discuss the achievement of the project.

A. System Results and Achievement

EyeKids Tracking and Monitoring system are successfully developed according to its objectives and project scopes. Every component of the system is working properly on its own and when integrated together.

1) Child Tracking Device

EyeKids tracking device which is used by the child is able to capture the child's location and send tracking data (deviceID, latitude longitude) to the server every 30 seconds interval. The distress alert trigger function proposed for this device is also able to send notifications to the parent's device when triggered. The tracking device is made portable with the use of external batteries to power up both the microcontroller board and GPS/GPRS/GSM shield.

2) Parent-side Application

EyeKids tracking system enables users to view the last updated location from the tracking device on its mobile application. The child's location is displayed on a map along with the location address as shown in Fig. 7 and the top locations visited by the child can be obtained as shown in Fig. 8. Users are also able to navigate to a child's location using any available navigation apps on their device.

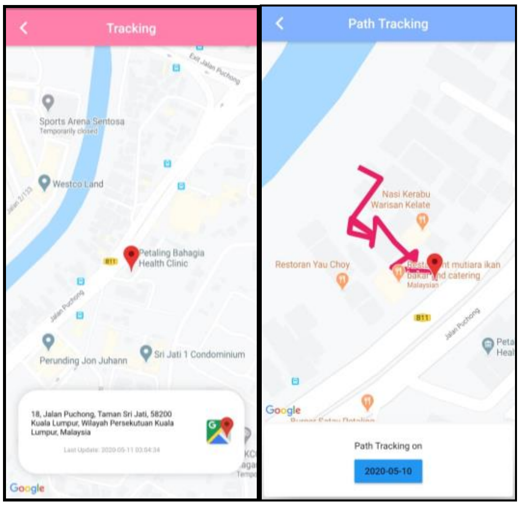

Fig. 7. Tracker and path tracking page

Fig. 8. Tracking analysis page

VI. CONCLUSION

Overall, EyeKids system has successfully developed according to its objectives and within its appropriate scopes. Every component within the EyeKids system works properly together allowing location information obtained from EyeKids tracking device transmitted to the cloud database and can be accessed by parents from the EyeKids parent-side application. Child movement can be tracked using EyeKids system whenever the child tracking device is turned on. The parent-side application is able to display the last updated location tracked from the child tracking device.

EyeKids system also fulfills its second objective which is to provide child location reports on a monthly basis based on history stored in the cloud database. every time tracking data is obtained from a tracking device, it will be stored in a cloud database. data stored is then used to provide a monthly tracking analysis of the most visited place which can be viewed from the parent-side application.

Lastly, to measure the correctness of EyeKids system, user testing is performed by EyeKids' users. Results from the testing indicate the functionality of the system as well as suggestion for future improvement.

The current Eyekids system only allows parents to track one child using one parent account. For parents who have more than one child, it is a hassle for them to change accounts for every child. Therefore, the EyeKids system will be better if it allows the parent to add more than one child to their account. Another feature that can be considered to be included in the EyeKids system is the geo-fencing function.

Furthermore, improvements can be made to the tracking device by installing a small screen to display the device battery status so that the user will know when they need to change or charge the battery. It is also more convenient if parents can remotely turn on and off the device from their application

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