TANGIGURU: TANGIBLE LEARNING SOLUTION FOR EARLY CHILDHOOD DEVELOPMENT

2022-287

Project Proposal Report

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B.Sc. (Hons) Degree in Information Technology
Specialized in Computer Systems and Network Engineering

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DECLARATION

We declare that this is our own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

Signature of the supervisor:

Date:

ABSTRACT

With the drastic improvement of technology in the last few decades, the teaching and learning process has been modified accordingly in most cases. These modifications have been affected positively to the students as well as teachers. However, when it comes to early childhood education, there have not been many positive modifications compared to the technological improvement in the rest of the education field that has been come across. Traditionally, early childhood development activities were mainly based on tangibles and human interactive sessions with supervised and guided learning. Such methods are proven to be more efficient to that age range rather than unsupervised, unguided, virtual learning methods based on books used for higher ages. However, many modern virtual solutions are available for early childhood development, such as mobile applications and tangible toys. However, they tend to be less efficient compared to the existing traditional teaching methods. Therefore, this proposed research focuses on developing a tangible learning kit for early childhood development using modern technologies while improving the effectiveness of the traditional learning methods. This learning kit combines students' tangible experience in traditional learning methods while supervision and guidance are done using modern technologies. This research proposes a solution where students can interactively learn using the tangible items in this learning kit as they do in traditional learning methods. In contrast, learning activities are presented to the student and evaluated virtually.

Keywords: Tangible Learning, Early Childhood Development, e-Learning

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LIST OF ABBREVIATIONS

API	Application Program Interface
LKR	Sri Lankan Rupee
DBMS	Database Management System
GUI	Graphical User Interface
TUI	Tangible User Interface
ReST	Representational State Transfer
AWS	Amazon Web Services
S3	Simple Storage Service
CAL	Computer Assisted/Aided Learning
IR	Infrared
MERN	MongoDB, Express, React, NodeJS

1 INTRODUCTION

1.1 Background & Literature Survey

Technology has been vastly advanced in the last 7 decades with the improvements in electronics, especially the invention of transistor. These advancements have hugely affected on human lifestyles in many ways as most of the human activities have modified accordingly to catch-up with the new technologies. Same has been applied to the educational activities also. This was drastically changed in the early 2020s due to covid-19 outbreak making most of educational activities switching to virtual remote methodologies. However, early childhood education has not been evolved much when compared to the advancements in overall education system.

1.1.1 Early childhood development

Early childhood, defined as the period from birth to eight years old, is a time of remarkable growth with brain development at its peak [1]. During this stage, children are highly influenced by the environment and the people that surround them. As they interact with their surrounding environment, they develop their creative skills. These creative skills they acquire during their early childhood affects their whole life. The following factors are directly responsible for child’s creative learning skills as shown in [2].

- Knowledge
- Motivation
- Personality
- Environment
- Cognitive ability

For better productivity in early childhood development, tangible learning is used as it let children to physically interact with learning objects. According to [3], tangible learning is defined as emphasizing the use of body in educational practices. It includes gestures, motion, or full-body engagement. According to [4] and [5], Frobel and Montessori are the first to discover the potential of manipulative tool and sensory experience of children in early childhood education. Also, study in the book [6] has proved that manipulating physical objects with haptic perception helps children in their constructive learning.

1.1.2 Computer aided learning

Computer aided learning aka computer assisted learning has been around since early 1990s. However, it has been firstly introduced as early as 1969 where personal computing was not even discovered [7]. With this rapid advancement of technology, it is vital for new generation to be familiar with technology as they will be born and living in a much technological world. Therefore, use new technological devices such as computers should be familiar for them as a day-to-day lifestyle rather than a skill [8]. Therefore, education methods for this technology native generation should also be incorporated with technology. As a result, the whole education system has been started transforming to technology rich Computer Aided Learning.

Currently, computer aided learning is mostly based on personal computing using GUIs. It is being widely used in schools, universities as well as beyond that, it is very rare to find CAL in education for young children below the age of 8 years. These is due to GUI based learning approach which are monotonous and unable to provide mechanized interactions to the students [9]. This does not affect much for students over the age of 8 years as they are learning through virtual or text-based resources, but students in their early childhood requires tangible objects-based learning which is not currently provided by the existing GUI based CAL.

As now day-today mobile devices such as smartphones and tablet PC have got popular, they are not suitable for the early childhood users as they are designed to use by adults [10]. These devices are equipped with Graphical User Interfaces (GUI) which are based on Windows-Icon-Menu-Pointer (WIMP) paradigm. These graphics are mapped and presented to user as their everyday actions and objects. To address this issue, tangible learning methodologies have been started to use in computer aided learning.

1.1.3 Tangible user interfaces (TUIs)

Instead of interacting with virtual graphics on screens, [11] introduces the term ‘Tangible User Interfaces’ (TUI) in 1997 which couples digital information into real world objects. There, they aim to transfer computing into ubiquitous and invisible by augmenting the real physical world to computing.

Even though TUIs were introduced in 1997, it has not been introduced to the field of education till the very recent years. As TUIs are the most natural way to integrate digital interactivity to physical objects, it can be considered as the best method to digitalize tangible learning for early childhood development.

Therefore, TUIs have been found to be effective in many applications as mentioned in [10]. The effectiveness of TUIs is mainly come from their following features as shown in studies [12], [13].

- Playfulness
- Trial and error
- Sensory engagement
- Spatial learning
- Social connection
- Feeling of competence

Using these features, TUI applications have been developed to address the needs related to education as follows [7].

- to support social engagement between children
- to convey and communicate emotions
- to engage readers in tangible storytelling
- to teach programming
- to teach composing music

Studies on using TUIs for children’s creative learning have been conducted mainly since 2015 [9]. Prior studies were mostly focused on the age group of 8 to 12 years and there was only a less attention towards early childhood.

1.2 Research Gap

There have been many studies for modern tangible learning solutions in the last decade for. These have resulted a considerable amount of new tangible learning solutions with modern features such as improved interactivity which is vital when they are developed for children. But as mentioned earlier in this proposal, there have been only a few studied done on developing a modern tangible learning solution for children in their early childhood [9].

Also, when compared with the elder age groups of children, early childhood is lacking eLearning solutions. Even though there are some eLearning solutions based on mobile devices such as mobile apps, they tend to be less effective and less friendly for children in the age of 4 to 7 years as those devices are built to used by people beyond that age range and they are developed to use via GUI. However, these GUI mobile apps are developed with automated guidance and automated evaluation which is a vital feature for eLearning applications.

Almost all the computer aided learning solutions are based on GUIs because of the ease of dynamic use. Therefore, same equipment can be used to teach or learn many different subject areas without much manual work, but just by clicking few on-screen buttons. But TUIs cannot be made dynamic as much easier as GUIs because of TUIs physical nature. Therefore, almost all the existing tangible learning solutions are developed focusing on a single or couple of subject areas. Even though most of the modern tangible learning solutions are rich with interactive feature, most of them are only capable of using for a single learning activity while some of them are not even portable friendly for children.

The following table shows a comparison among the existing eLearning tools with the proposing tangible learning solution for early childhood development, TangiGuru.

Table 1.1: Comparison with existing solutions

Research/Product	**Ealy Childhood Friendly**	**Tangible/Virtual**	**Dynamic Use**	**Multiple Activities**	**Automated Guidance**	**Automated Evaluation**
Traditional tangible learning kits	✔	Tangible	✘	✘	✘	✘
Mobile Applications for Early Childhood Development	✘	Virtual	✔	✔	✔	✔
Story Blocks	✔	Tangible	✘	✘	✘	✘
Cyber Place	✘	Tangible	✘	✘	✘	✘
Superbleeper	✔	Tangible	✘	✘	✘	✘
TangiGuru	✔	**Tangible**	✔	✔	✔	✔

The proposing tangible learning solution TangiGuru will be developed focusing on all the issues by adding many interactive features with dynamic use for multiple activities alongside with automated guidance and evaluation.

1.3 Research Problem

When developing a modern tangible learning solution for early childhood development, it should be consisted of modern technological features as discussed earlier. In this proposing solution, there will be a set of such features such as,

- child friendly interactions
- dynamic use of tangibles
- multiple activities to be used with
- automated guidance for child
- automation evaluation of child’s work

Also, TangiGuru will be required to update with new features such as new learning outcomes, and share learning analytics with their parents. All these requirements will be fulfilled by developing new technologies or utilizing the existing technologies as follows. Therefore, this study is focusing on how to integrate software-based learning activities to the tangible learning components while maintaining the ability to guide and evaluate automatically.

For automated evaluation of child’s work, the positioning data of tangibles will be required. As these tangibles will be placed within a small space, a new reliable technology should be developed to identify their relative positions. This raises the sub question of how to develop a technology to identify adjacent tangibles.

Automated guidance will be built-in with the learning activities which will be developed as software. To integrate the learning activity software with tangible hardware, an intermediary platform will be required. This arises the sub research question of developing an intermediary platform for hardware and software.

At last, learning analytics of the children should be shared with their parents. Also, proposing tangible learning solution should be updatable with new learning outcomes. To achieve these requirements, a research question is raised as how to utilize cloud technologies to TangiGuru.

2 OBJECTIVES

2.1 Main Objective

This research is focused on developing a solution to provide education for students in early childhood in a more efficient manner with the help of modern technologies. This solution will follow the traditional educational methods and procedures that have been used for the last few decades and proven to be more effective. This research will improve such procedures and methods by combining them with modern technology to ease teachers' and students' efforts. Therefore, this research will be based on tangible educational materials rather than texts and written activities, making this a tangible learning solution. Also, this study will address the issues in remote learning for students in early childhood where most of the remote learning solutions are not supported.

This research tangible learning solution consists of a tangible hardware-based component for students to interact with for learning. It also consists of a software-based component used to guide the student virtually and supervise students' work and evaluate them. As they are interdependent, they need to be communicated to deliver the expected objective of efficient tangible learning. Therefore, an intermediary platform will be developed as another significant research component. This intermediary platform is responsible for controlling the tangible components according to the software applications meanwhile feeding the software applications with the inputs from tangible components. It will be capable of identifying the adjacency of tangible blocks, hosting the software components for learning activities, and acting as a communication medium between tangibles and application software related to learning activities. This research proposal document mainly focuses on proposing the development of the above-mentioned intermediary platform.

2.2 Specific Objectives

The following three specific objectives will be achieved to achieve the above-mentioned main objective.

2.2.1 Development of adjacent blocks identifying technology

Identifying adjacency among tangible blocks is one of the most critical components of the proposing solution. The proposing tangible learning kit will consist of 12 tangible blocks with dynamic values to be assigned. These can be arranged in various forms relative to each other, and such arrangements are used as the evaluation method for the learning activities. Therefore, this objective is to develop a procedure to capture each tangible block's relative position. As shown in the diagram below, block B should be aware that block A is adjoined from its left and block C is adjoining from its right.

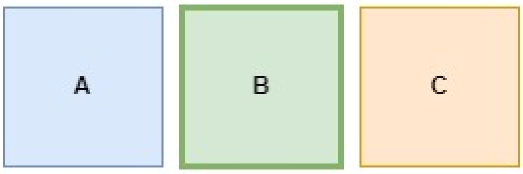

Figure 2.1: Adjoining tangible blocks

Further, the captured data will be analyzed using a specially developed algorithm, and an overall map is dynamically formed for each movement of tangible blocks. That map will be communicated to the learning activity software for evaluation as a part of this objective.

2.2.2 Development of system software as the tangible – virtual communication interface.

To host the application software with the learning activities in this proposing solution, a system software will be required. This system software will be resided on a special device known as the 'Console' which will be the major hardware component of this proposing tangible learning kit. All the tangible blocks will be bound to this console. The system software is responsible for providing network connectivity to application software, handling peripherals, and configuring connectivity among tangible blocks and console. Development of above-mentioned system software is also considered as a prominent objective of this research component of developing the intermediary platform for this proposing tangible learning solution for early childhood development.

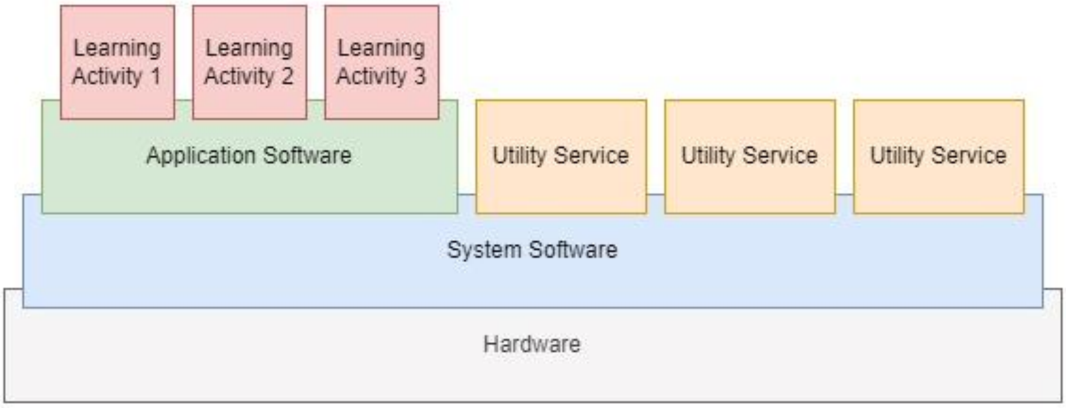

Figure 2.2: System hierarchy

This proposing solution is consisting of a few utility services. These utility services will be responsible for maintaining the communication between tangible blocks and learning activities. Therefore, these utility services can be considered as a vital part of this research component. So, implementing this system software with utility services are considered as a specific objective to be achieved to reach the main objective. These utility services will be consisted of a self-hosted database with real-time trigger capabilities and an API to communicate among application software, database, adjacency identifier service and tangible blocks.

2.2.3 Configuring cloud resources for backend services

This proposing research will be using cloud technology to deliver some services to fulfill some functional requirements such as provide learning analytics as well as some non-functional requirements of the solution such as software updates. Therefore, the required cloud services need to be configured in according to achieve the main objective. So, configuring of following cloud resources can be considered as another specific objective for this research component.

Learning analytics will be available to check via mobile application and the related data will be stored in a cloud database. All the tangible learning kits will upload its analytics to this cloud database once they are connected to internet. Then this proposing mobile application can fetch that data from cloud database and present it to user. For these purposes, an identity management system will also be used in the cloud, and it will differentiate the user data according to user sessions.

Further, these cloud services will also be used to provide software updates to the proposing tangible learning kit. Through this software update, developers will be able to add new learning activities and improve existing learning activities accordingly while users are using the kit.

3 METHODOLOGY

To provide an efficient learning experience to the students in their early childhood, this proposing tangible learning solution, TangiGuru will be developed as follows.

3.1 Requirements Gathering and Analysis

For this study, the major mode of requirements analysis was done from existing research papers and people from the field of early childhood development. They participated in one-to-one interviews over telephone and online message platforms to provide domain knowledge and requirements to be fulfilled in their domain from an early childhood development solution. Gathered information were used to identify and investigate the unfulfilled requirements, unsolved problems, and possible improvements in the domain of early childhood development to plan tasks, objectives and goals which need to be accomplished through this proposing early childhood development kit.

3.2 Feasibility Study

3.2.1 Schedule feasibility

According to the given time constraints, this proposing research project should be completed by the specified time frame of 1 year. By end of this one year of time, each proposed objective should be met with quality output.

3.2.2 Technical feasibility

The final product proposing in this proposal document, TangiGuru will be a combination of electronics, cloud computing, networking, software, and firmware. With the use of these technologies, a central console, tangible playing blocks and an internet based mobile application will be developed. To develop them, research project members should be well-versed with electronics, cloud service providers such as AWS, programming languages, libraries and frameworks like Python, Flutter, MERN and enclosure designing and development.

3.3 Implementation

3.3.1 Overall system architecture

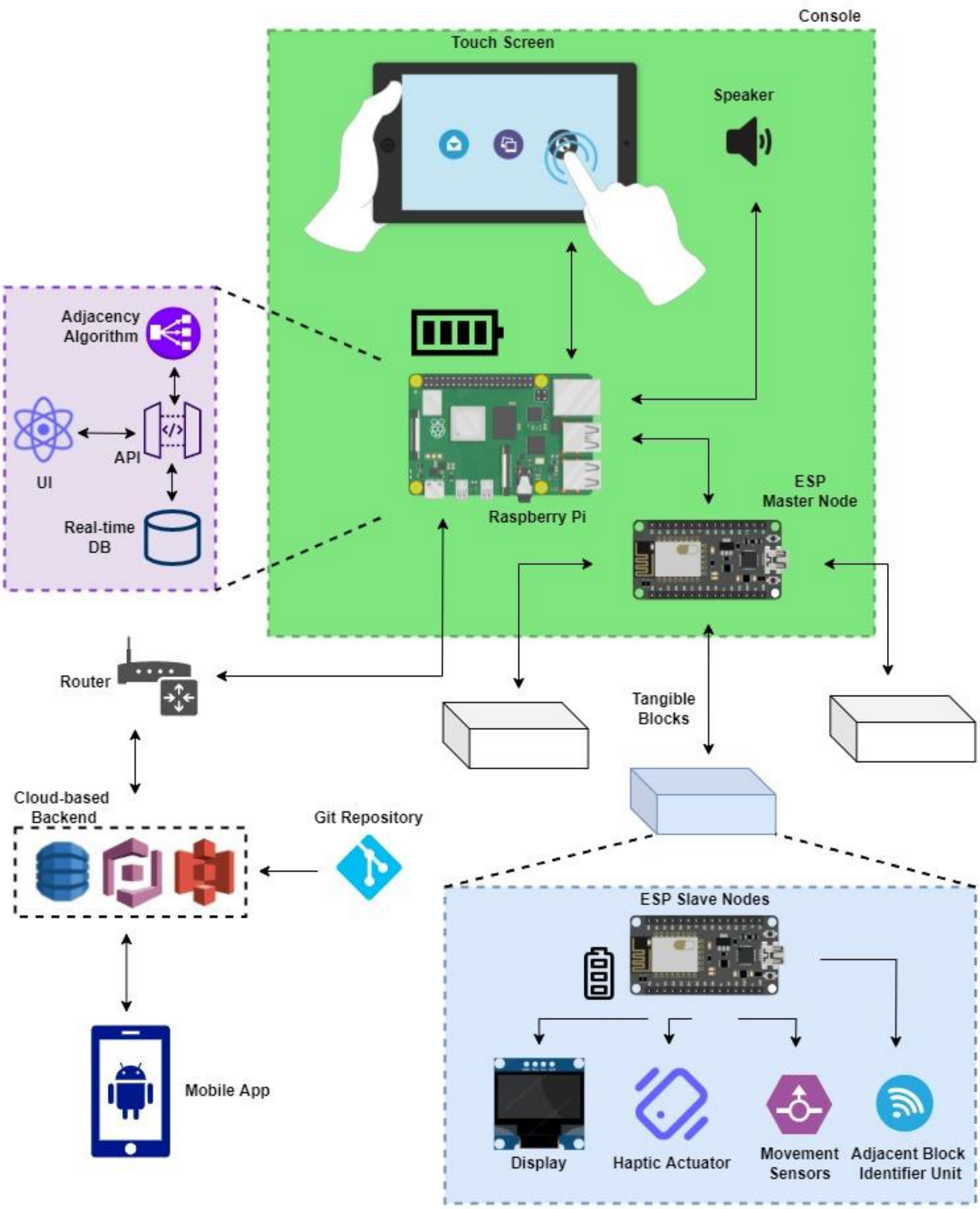

Figure 3.1: System architecture diagram

The above design of TangiGuru is based on the latest hardware, software, and cloud technologies. TangiGuru will be mainly made up of a console, a set of 12 identical tangible blocks and an increasing number of learning activities to be developed focusing on early childhood development. These 12 blocks can be assigned with a value dynamically for each learning activity and blocks will be aware of its surrounding blocks. Proposing console also comes with a built-in touch screen which will be used to present the learning activities to the students. The UI/UX of the content displayed on the touch screen will be highly optimized for the students in the early childhood as they are not capable of following written instructions and, they are not familiar with basic symbolic icons we usually use in day-to-day smart devices. Console will also be equipped with a speaker to provide audio instructions instead of on-screen text instructions. Console will be developed as a portable mobile device which can be carried by a child in that target age range. Therefore, its form factor, weight as well as a rechargeable battery pack will be also developed accordingly. As the motherboard of the console, a 2GB Raspberry Pi 4 model B will be used.

Tangible Blocks will be developed in accordance to fit within the console for greater portability. Therefore, blocks will be in the size of 2” x 2” x 0.75” approximately. Each block will be consisting of a minimized bezel display and a haptic feedback motor for visual and physical output while an accelerometer sensor and a gyroscope sensor for physical inputs. Also, an infrared based optical communication technology will be used for adjacency tracking among tangible blocks. All these components will be controlled via an ESP series chipset. Tangible blocks are also consisted of rechargeable batteries within them, and they will be recharge while placed inside the console.

3.3.2 Adjacent blocks identifying technology

A new technology will be developed for identifying the adjacent blocks as mentioned previously in the specific objectives. This technology will be based on legacy infrared data transmission technology. This allows the learning activities to identify which blocks is situated in 2 sides (Figure 2.1) some specific block. To achieve this, an IR transmitter (Tx) and an IR receiver (Rx) will be implemented in each of these blocks in their opposite edges as shown in the following diagram.

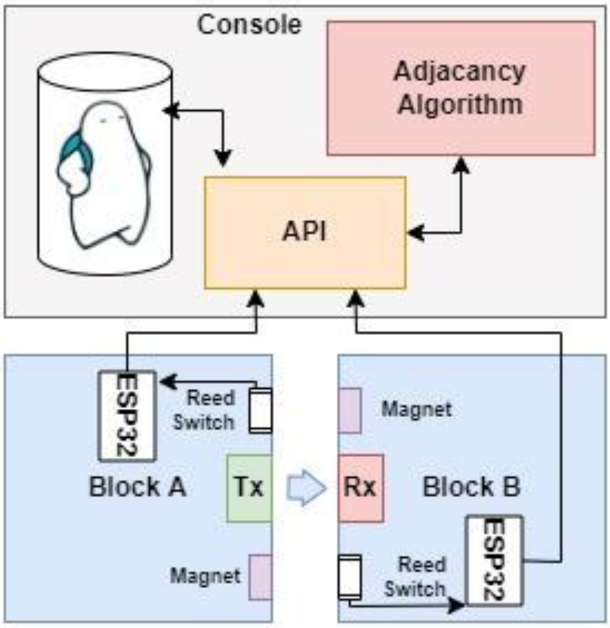

Figure 3.2: Adjacent block identifying technology overview diagram

To maintain the direct line of sight between the Tx and Rx in 2 adjacent blocks, physical shape of the blocks will be designed accordingly.

Tx will transmit data and Rx will read data at newly joined block detected via block’s edge sensors. To avoid any data corruption in transmission, Huffman coding will be used. Via this procedure, each block will be able to identify the block situated left to it. Once a block identifies the block left to it, it will update it in the internal real-time database via an API call. At every database update, adjacency identifying algorithm will be evoked and adjacency map will be generated for the reference of learning activity applications.

3.3.3 System software and core API

Console’s system software will be developed by tweaking the Raspberry Pi OS according to the requirements. This will host the core API, self-hosted real-time database, block adjacency calculating algorithm and frontend application with learning activities. This system software will be responsible for managing network connection via Wi-Fi as well as connection to the tangible blocks. This system software will feature a GUI to present the frontend application via the connected touch screen in the console and its speakers.

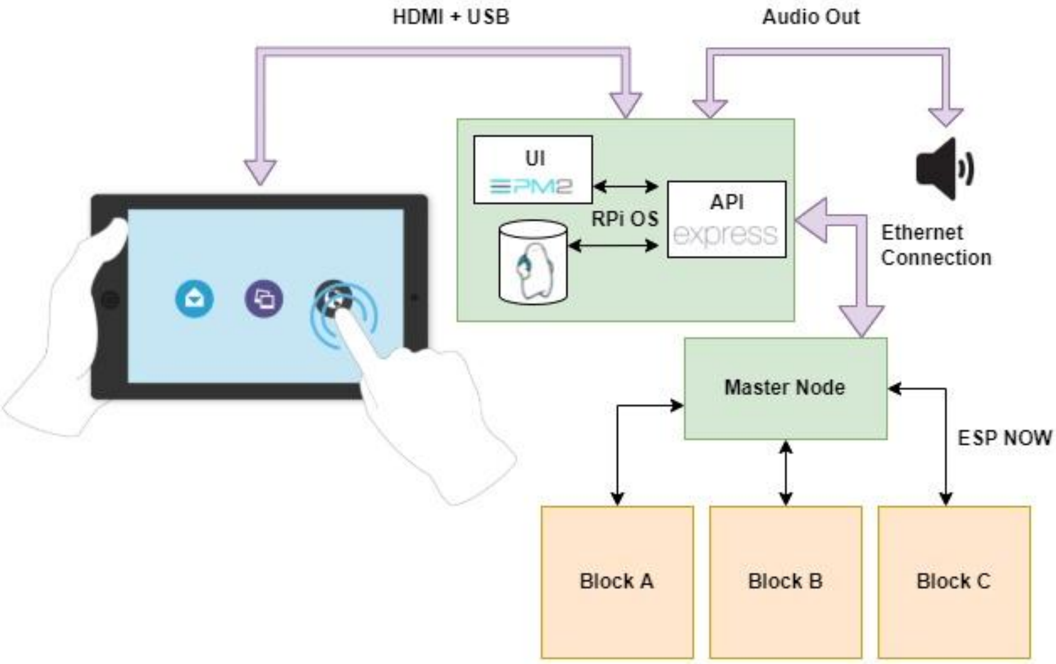

Figure 3.3: System software with core API

An application program interface will be developed for intercommunication purposes among tangible blocks and learning activities. This API will be backed by a self-hosted real-time database. RethinkDB will be used as the DBMS for above-mentioned internal real-time database. All the API calls will be carried out in ReST architecture to make the API universal throughout the solution.

3.3.4 Cloud-based services

Students' learning analytics will be recorded by the application software itself and that data will be uploaded to the cloud database. Amazon Web Services will be used for the cloud-based backend services. Amazon DynamoDB will be used as the DBMS for storing learning analytics and user data. For authentication purposes in console as well as in mobile app, Amazon Cognito will be used.

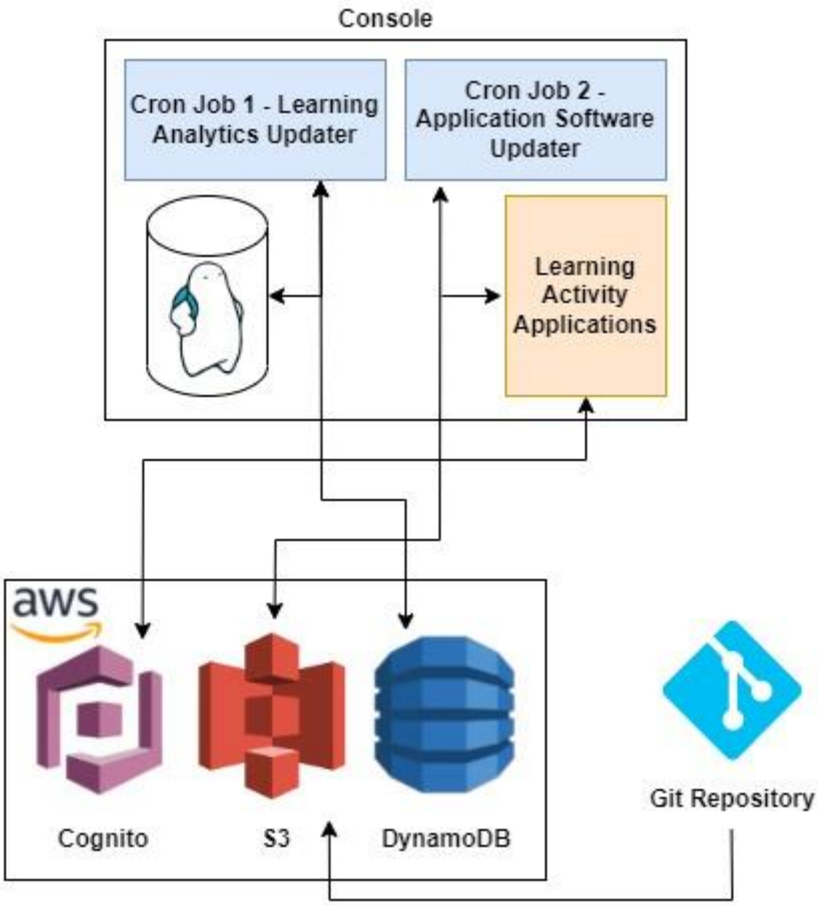

Figure 3.4: Cloud-based backend services

Further, there will be software updates with new learning activities for the console. To rollout the software updates, CI/CD will be configured on Git repository to upload the latest builds to a cloud storage location and system software will be configured accordingly to fetch and update the application software. Amazon S3 will be used as the cloud storage for updates.

3.4 Work Breakdown Structure

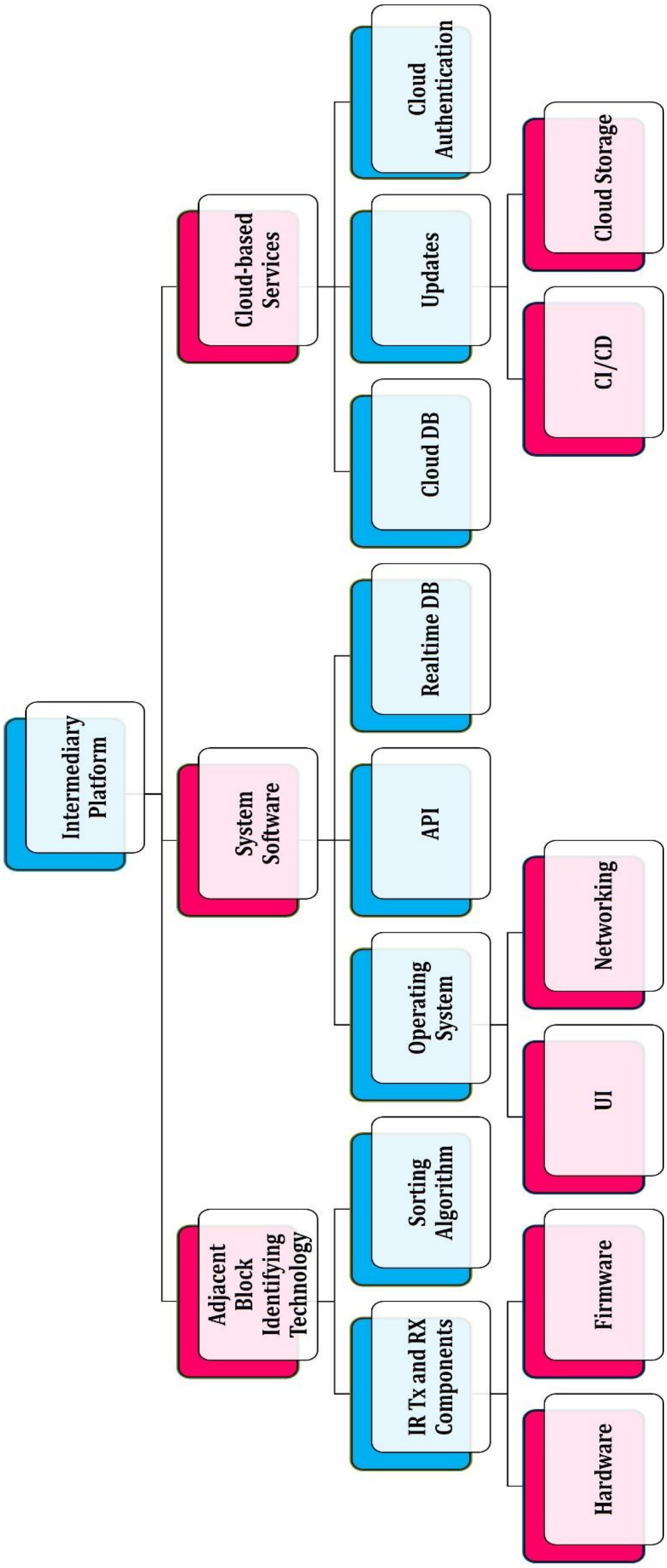

Figure 3.5: Work Breakdown Structure

3.5 Testing

3.5.1 Alpha testing

In this stage, functionality of each functional unit as well as overall system will be tested. Alpha testing will be done by developers themselves. Therefore, unit testing will be carried out alongside development at end of development of each functional unit. However, system testing will be carried out once the whole system is completely developed which is planned for early September.

3.5.2 Beta testing

The completed solution will be tested with its intended audience in this Beta testing stage. Beta testing is planned to be held from mid-September to early November as the development of the proposing TangiGuru kit will be done. In this stage, output of the proposing solution will be tested with the quantitative efficiency relative to the non-tangible alternatives for the same outcome. As the intended audience, 4 to 8 children from each age of the range of 4 to 7years will be taken for testing TangiGuru.

Initially, the test sample will be divided into 2 groups of equal sizes as group A and B within each age group to distinguish the outcomes in TangiGuru and its alternatives respectively. As the alternatives, a mobile application will be provided with similar outcome. Then the students in Group A of some age will be given an opportunity to play with TangiGuru for a specific learning outcome and students in Group B in same age will get the opportunity to play with alternative mobile application with same learning outcome. Time will be measured in each activity and after they complete an activity, the student will be evaluated manually to measure how efficient TangiGuru and its alternative.

3.6 Gantt Chart

This proposing research is planned to carry out as follows to meet the required deadlines without any conflicts. Project implementation will be started in late February and expected to complete by mid-September while testing will be carried out from mid-August to end of October. The proposing research project will be completed by December 2022.

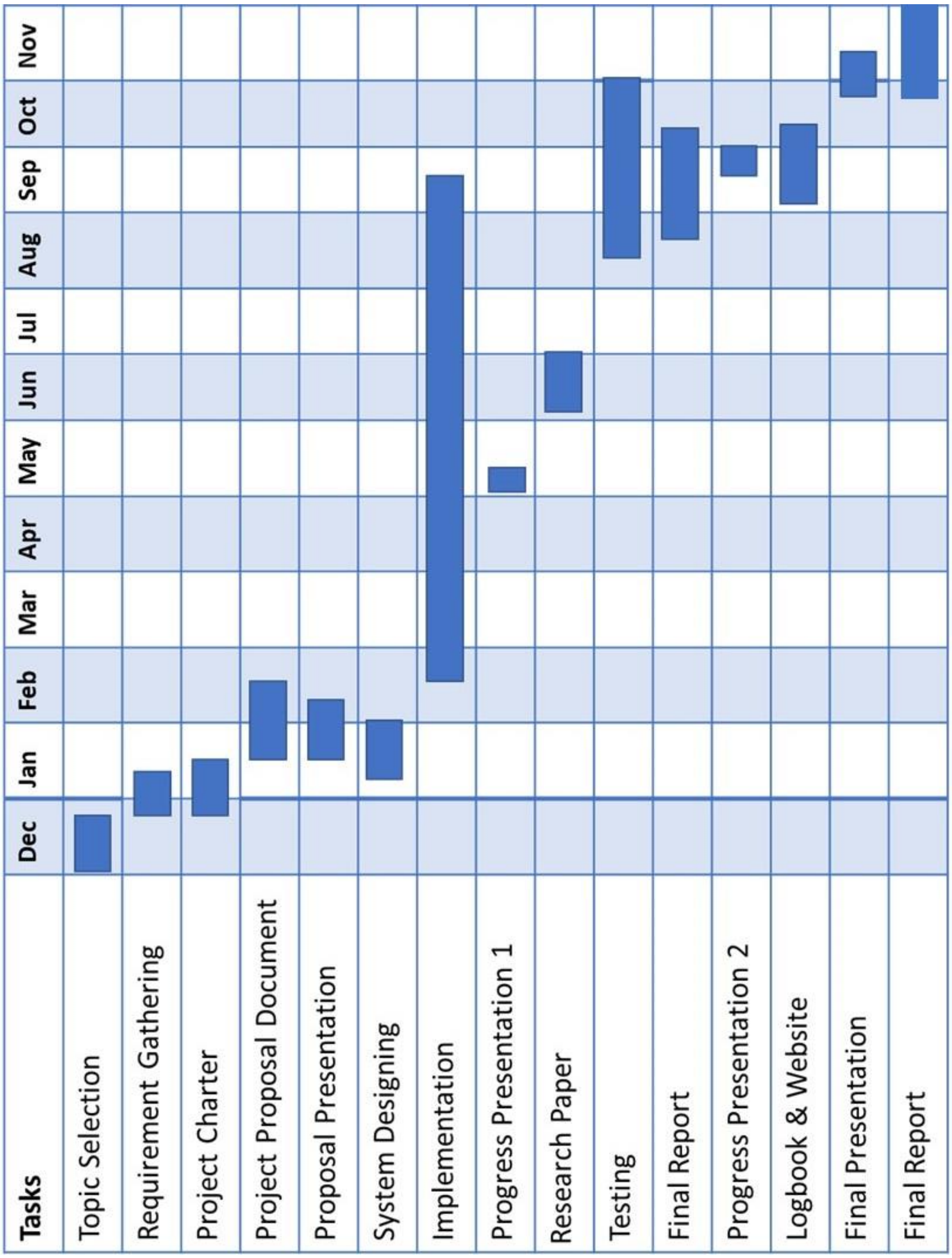

Figure 3.6: Gantt Chart

4 DESCRIPTION OF PERSONNEL & FACILITIES

This research is supervised by Ms. Shashika Lokuliyana. She is a Senior Lecturer in the fields of Information Security, Computer Systems and Networking, and Computer Systems Engineering. Currently, she is attached to Department of Information Systems Engineering of the Faculty of Computing, Sri Lanka Institute of Information Technology (SLIIT), Malabe, Sri Lanka.

Ms. Narmada Gamage is co-supervising this research. is an Assistant Lecturer attached to the Department of Information Systems Engineering, Faculty of Computing, Sri Lanka Institute of Information Technology (SLIIT), Malabe, Sri Lanka.

Mr. Rajitha de Silva joins this research as the external supervisor. He is a PhD scholar of University of Lincoln, England, UK.

This research will be conducted by the following 3 members as shown below.

1. L.S. Semasinghe – He is responsible for developing a technology to identify the adjacent blocks, and intermediary for communication between blocks and applications. This includes,
    a. Development of technology to identify adjacent blocks
    b. Development of system software as the tangible – virtual communication interface.
    c. Configuring cloud resources for backend services

2. T.C.D.S. Hettiarachchi – He is responsible for the parallel research component of developing the tangible blocks with specified features. This includes,
    a. Development of the tangible cubes and communication between blocks and console.
    b. Console development with required hardware.
    c. Power Management of blocks and console.

3. M.M.D. Ratnasuriya – She is responsible for the parallel research component of developing the interactive, child-friendly UI/UX which is easily understandable for children and related learning activities suitable for required learning outcomes in the early childhood development. These include,
    a. UI/UX design for the web application.
    b. Implement the mobile application.
    c. Development of the learning activities suitable for required learning outcomes.

5 BUDGET & BUDGET JUSTIFICATION

This proposing research is dependent on both hardware as there are much electronic components planned to be used in developing the tangible learning solution. Therefore, majority of the budget will be allocated for electronic components as follows. All the following prices are in LKR. Following amounts can be fluctuate due to the changes in exchange rates.

Table 5.1: Budget

Item	Amount
7inch HDMI LCD, Capacitive Touch Screen (1)	14,000.00
Raspberry Pi 4 Model B 2GB (1)	10,000.00
Amazon Web Services charges	2,500
Total	**26,500**

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7 APPENDICES