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A2: Project Report
Mathematics Equation Solver

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Declaration Sheet

Award Title: BSc (Hons) Computer Science

(Award Title for your project, if in doubt refer to your course/Module Registration)

Declaration Sheet

(Presented in partial fulfillment of the assessment requirements for the above award.)

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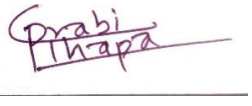
Signature: 

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Abstract

Various method and system are used to solve the mathematical equations. But with the technology developed today we can solve those equations smartly. Math Equation solver is developed using AI to solve the equation that is in the form of image and written with hand. Math Equation solver is the system to simply solve the simple mathematical equations to help the students to get the right answer of the problem they solves. It is to solve the simple equation and motivate student to solve the problem by themselves and check the answer through the system. It is to help the parents to check the answer of their children and make sure that they are doing well. The report and project are developed answering the academic questions. Here how the system will work and how is the system is developed is discussed. The report contains the overall introduction of topic, literature review, main section where the system diagram are presented, testing and the conclusion.

Acknowledgement

I would like to express my special thanks of gratitude to my supervisor FYP Mr. Raj Prasad Shrestha and reader Mr. Subiran Shrestha for the guidance by providing feedback on every progress of report and supporting me to complete my report and project. I would also like to thanks to my friends those who give me support on confusion that arises while completing project and reports.

I would also like to thank University of Wolverhampton for giving this opportunity to do the project on ‘Math Equation Solver’ and learn about Artificial Intelligence and explore more about. The university allow me to use my knowledge that we studied from first semester for developing the real world application.

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1. Introduction

1.1. History of calculator

Calculation of mathematical equations has been done using various method or technology. Abacus was the device used at the very beginning. It consists of series of rod having ten sliding beads on each. Other beads were only moved when all the beads of first rod is moved. Addition and subtraction was much faster. Later on slide ruler is developed to perform calculations. It uses the logarithmic scale to perform multiplications and division.

Later on the electronic calculator was developed. It was developed in late 1930s due to the war. Trigonometry was calculated to drop bombs from 30,000 feet 'into a pickle barrel', to hit a Japanese warships with a torpedo. Then the calculator is developed named ENIAC (Electronic Numerical Integrator and Computer) that could solve four basic athematic functions. The world's first all-electronic calculator was ANITA (A New Inspiration to Arithmetic/Accounting). Later the digital calculator was developed that could do different operations. (Valentine, 2019)

Nowadays, mobile devices and digital calculator being used to perform the small and large calculations. We can use our mobile device to do the calculation. With the help of CNN (Convolution Neural Network) we can develop the mathematical equation solver. We can develop the model by feeding the datasets to the neural network and train the model to obtain better accuracy.

1.2. Mathematics

Mathematics is practices of measuring, counting and defining the shapes of objects that is evolved to science of structure, order and relation. Mathematics deals with quantitative calculation and logical reasoning. It has become necessary supplement since the 17th century also assumed as vital role in quantitative aspects of life science. (Gray, et al., 2020)

Mathematics is also concerned to the intuition, imagination and reasoning to solve puzzle and finding new ideas. (Khan, 2015) Including the relationship, measurements and operations mathematics is defined as the scientific study of quantity expressed by numerical values and symbols. (Yadav, 2017)

1.3. Project introduction

Math Equation solver helps to recognize the digits and symbols that are handwritten. It calculates the equation after it is getting recognized. It provides the solution after performing certain operations in the system. This system helps student to know the correct answer of their solution and help them identify the mistake. To recognize the digit the result is processed in vote by CNN. With the help of CNN the system can recognize the digits and operators as in CNN the error gets calculated each time and only those adjustment were kept that makes less error. Therefore it helps to get the correct digit and operators. And it can be used to solve simple mathematical equation by scanning them. (Brandon, 2016)

1.4. Problem statement

i. Sometimes students solves the problem but cannot know the correct answer.
ii. Some parents may be less educated and they might not know to guide their children.
iii. Student may feel disappointment if they did not know the right answer.

1.5. Reason to choose this project

As nowadays many children or students uses mobile devices for entertainment except that these devices can be used to for learning purpose as well. I have chosen the project mathematical equation solver so that students would get facility to check the answer of their equations without depending on others. If they can check that the solution is correct or not they can move to solve other equations with confident. If the students are not sure about the correct solution then they might get demotivated and leave the work.

1.6. Academic Question

- How the digit and operators recognition will be done?
- How the AI will be deployed in Android?
- What methodology will be used to develop the system?

1.7. Aims and Objective

The aim of the project is to create the system to solve the simple mathematical equation. It intends to make student learn themselves even if there is no guidance and check their answers. The system is about to recognize the digits and symbol and provide the final answer.

1.7.1. Aims

i. Create login dashboard
ii. Collect the required dataset
iii. Research on algorithms and the similar system that are developed
iv. To create a system that recognize handwritten digits and operators.
v. To calculate the problem and display the final solution in screen.

1.7.2. Objectives

i. to clearly define about computer vision and how it works
ii. create better accuracy model
iii. to provide services to user
iv. Develop the UML diagram and flow chart on the basis of project.
v. Understand the working flow of CNN.
vi. Test the performance of the system
vii. to complete report on time

1.8. Artifact proposed

1.8.1. Android app

Mathematical equation solver is an android application which will be developed using java and python where AI model will be created using python on Jupyter notebook and app development will be done on Android Studio.

1.8.2. Recognize handwritten digits

The system is developed to recognize the digits and operators that are written by hand. The dataset from the Kaggle will be used. 0-9 and +, - and * symbol will be downloaded from Kaggle. Those dataset will be trained to create a model that can be used in app.

1.8.3. Equation solving system

Mathematical equation solver solves the simple equations that are in hand written form. User need to scan over the handwritten equations and the app recognize the digit and operators and calculates the solution and return final result on the screen.

1.9. Scope and Limitation of the project

The project is developed with the certain scope that it can handle and work with. It can work with the limited numbers of dataset for example 0-9 and +, - and * operators. This system is developed to perform certain activities remaining in its scope.

Scope

1. To recognize the digit from 0 to 9 and the symbol like +, - and *.
2. Scanning the image containing simple equation and the system will solve the mathematical equations.

Limitation

1. Project is not trained to recognize alphabet, brackets, / and other symbol than mentioned above.
2. The final solution is displayed on the screen rather than the solution steps.
3. Cannot solve the equation that is in words.
4. Solves only simple equations.

1.10. Structure of the Report

i. Introduction:

This section contains the introduction part of the report. Overall introduction of the system, history or the evolution of technology, problem statement, aims and objectives and artifact to be developed are included in this section.

ii. Literature Review

In this section the review of similar system is done and discussed. Further the problem domain is discussed along with their solution. Here the background research on the similar system will be done and feature will be included. The AI algorithm and its component to be used in the system is discussed. Technical term about the AI will be discussed in this section.

iii. Development

The SDLC, tools and technique are considered and used in this section. How the system will be developed with the methodology is mentioned here in the section. Flowchart, use case diagram, ER Diagram and prototype is developed.

iv. Implementation (Digit recognition)

The digit recognition is done in this section. With the trained model the prediction is done to recognize the digits and operators.

v. Implementation (Android Application)
The work flow of android application is shown in this section. The wireframe and the layout of the system is presented here.

vi. Testing
Testing the android application and the digit recognize system is done in this section. The aim of this section is to make sure that the system works fine by finding out the bugs and mistake in the system. Also the requirement to be fulfilled will be identified.

vii. Conclusion
The overall conclusion of the project is done by summarizing about the system developed and possibilities in future of the project is discussed in this section. What changes can be made to improve the system is mentioned in this section.

2. Literature review

Nowadays, technology is growing rapidly. Every people has access with the internet and a mobile devices. Even kids uses mobile devices for entertainment. As use to devices is increasing we can use those devices for learning purpose and saving the time. We can use the mobile devices to learn mathematics. Apart from calculator that solves the problem when equation is inserted manually, we can use artificial intelligence to make mobile device solve the problem with a simple scan of an equation. With the advancement in technology we can use our devices for learning with fun due to the emergence of Artificial Intelligence.

2.1. Emergence of AI

According to the study performed by PricewaterhouseCoopers (PwC), by 2030 up to 14% of the global GDP can be increased with the development of AI. Also by 2035, it is forecasted that the annual economy of the world could get double with the adoption of AI. With the innovative tools and technology, it is said that up to 40% there will be increase in the productivity of labor. Virtual workforce will be created with the AI which could do self-learning, and can solve various problems. (Szczepanski, 2019) Computer are able to communicate with the humans due to the machine learning algorithm, write reports and find suspects and a self-driving cars. (Marr, 2016) Without explicitly programming the computer getting computer to act is defined as the Machine learning. Machines, based on the computational learning and pattern recognition, construction and study of algorithm is done by the machine to predict the data. Building the right data model and with the use of an algorithm the correct decision can be made. (NISHA.OOMMEN, 2018)

Since 2018, AI was involved in every sector and the AI experts is hired by tech companies and Ai development has huge amount of investment. Different sectors such as agriculture is benefitted with the AI technology. The Health of crop can be predicted and monitor despites of climate changes and

pollutions. It proves that AI has reached everywhere. (Gladstone, 2018)

2.2. Machine Learning

Machine learning provides the ability for the machine to learn atomically and improve with the experience. Machine learning falls under the application of Artificial Intelligence. Development of the computer program which can learn themselves by accessing the data is the main focus of Machine learning. Machine learning match the pattern by learning from the data or observation like instruction or direct experience. (expertsystem, 2020)

Machine learning, without instruction that is given step by step allows computer to learn from the data. For the complicated task that could not be manually be programmed in such places computer can be used. Firstly, training data is given to the learning algorithm, it is the basic process of machine learning. Based on the conclusion obtained from the data, the new set of rules are generated by learning algorithm. Different models can be obtained from the same learning algorithm with the different training data. (internetsociety, 2017)

2.3. Convolutional Neural Network (CNN)

The Brain is the major inspiration of CNN. New model is suggested by the research done on mammal in 1950s and 1960s by D.H Hubel and T.N Wiesel. (Cornelisse, 2018)

For every image related problem CNN is the best model. It is the most popular architecture of deep learning and we can see CNN in many places. The effectiveness and popularity of convnets is the major reason that it is popular. In 2012, with AlexNet the interest in CNN is started and the growth is exponent. From the 8 layer AlexNet researcher progressed u to 152 layers in just three years of period. CNN is successfully applied for natural language processing, recommender system and many other. Detecting the important feature is the major advantage of CNN without human supervision. (Dertat, 2017)

The image are classified by taking input of image, processing it and classify it. Input of images are in the form of array of pixel when given input to computer depending upon the image resolution. The height, width and dimension will be seen by the computer. CNN consists of layers and they are- convolutional layers with filter, pooling layer and fully connected layer. Each images passes through these layers. (Prabhu, 2018)

2.3.1. Convolution Layer

Firstly, to extract the feature from an input image Convolutional layer is used. Using a small squares in input image the relationship between pixels is preserved by learning the features. Image matrix and a filter is taken input in this mathematical operation. (Prabhu, 2018)

- An image matrix (volume) of dimension **(h x w x d)**
- A filter **(f_h x f_w x d)**
- Outputs a volume dimension **(h - f_h + 1) x (w - f_w + 1) x 1**

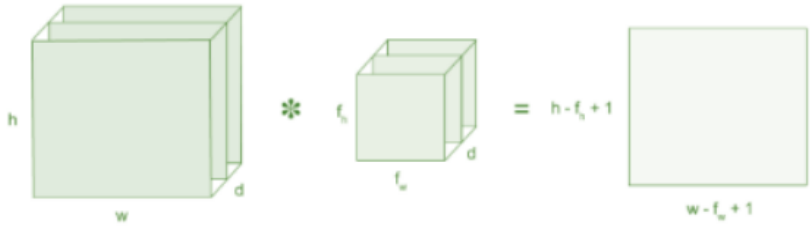


Figure 1: Image matrix being multiplied by filter matrix (Prabhu, 2018)

In the following figure we can see the 5 * 5 image with the pixel values of 0, 1 and 3 * 3 filter matrix that convolve over the image with the stride of 1. Shifting of pixel over the input matrix is known as Stride. Filter matrix is also known as Featured Map. With the different filter in Convolution operation such as edge detection, sharpen and blur can be performed.

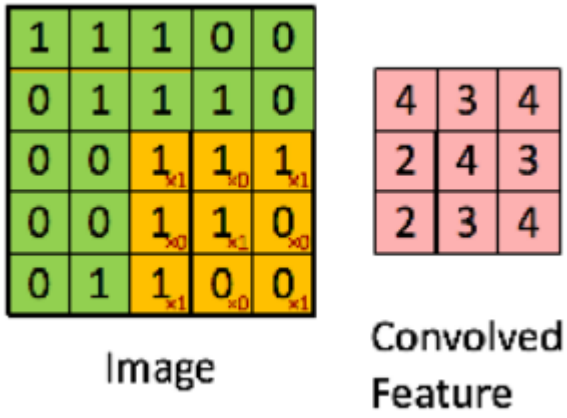


Figure 2: Output matrix (Prabhu, 2018)

2.3.2. Pooling layer

Pooling layer is the next layer added after the convolutional layer. Repeated layer for one or more time is ordered with the pooling layer in CNN. To create the new set of pooled feature map of same number operation of pooling take place upon each feature map separately. Pooling operation like filter to be applied is selected in the pooling. The pooling size is smaller than the featured map and generally the size of pooling layer is 2 * 2 pixel that is applied with the stride of 2 pixels.

The down sampling operation is performed on the basis of width and height of an image which result to reduce the volume of an image. The pooling layer is used to reduce the spatial dimensions of an image but not the depth. The number of parameter and computation amount is reduced with the help of pooling layer. Over fitting is also controlled with the pooling layer. (Brownlee, 2019)

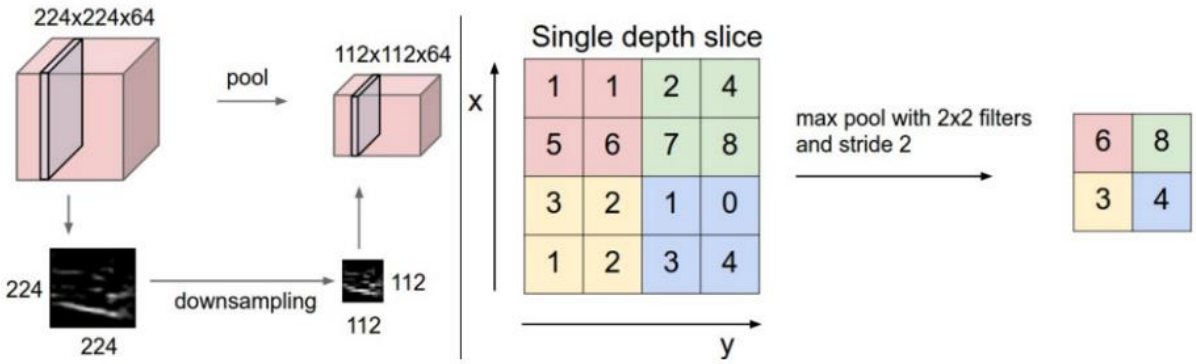


Figure 3: Down Sampling and Max pooling (dhedok, 2018)

Average pooling:

In average pooling it calculate the average value from the feature map.

Maximum pooling:

In Max pooling it calculates the maximum value from the feature map. It extracts the important feature from the image such as edges. It only retains the maximum value form the feature map by rejecting big chunk of data. (Brownlee, 2019)

2.3.3. Fully connected layer

Fully connected layer is the essential layer in CNN. On recognizing and classifying images it is very successful for Computer vision. (missinglink.ai, 2020)

The output obtained from the conv or pooling later is taken input by fully connected layer and gives the N dimensional vector as output where N is the classes in the program. It determines the most correlate feature to a particular class by looking the output produced by the previous layer. (Deshpande, 2019)

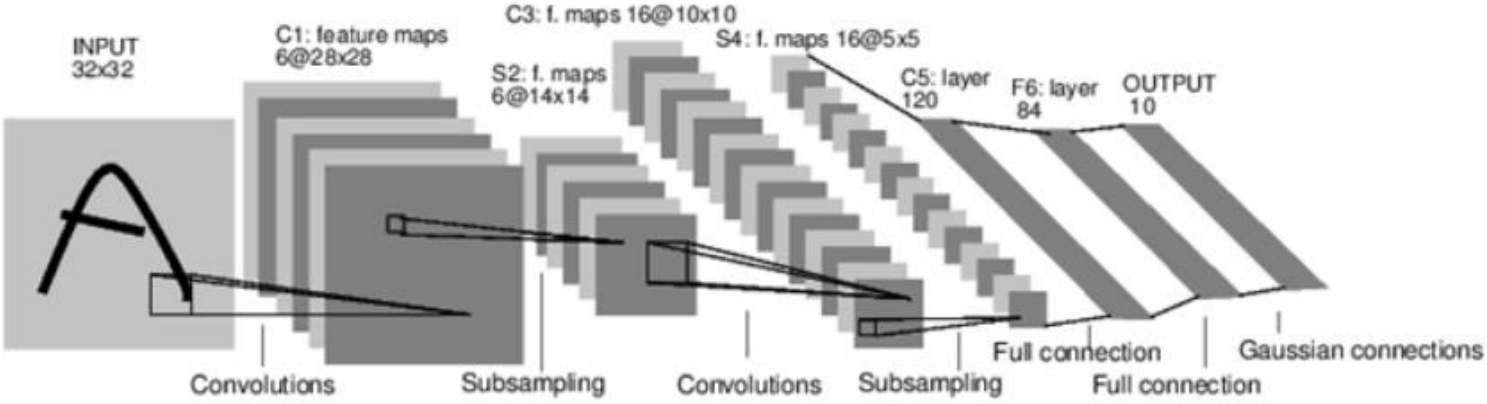


Figure 4: A full Convolutional Neural Network.(Deshpande, 2019)

2.4. Activation function

By calculating the weighted sum and adding the bias with it Activation function provides the decision to activate the neuron or not. Activation function decides whether to activate the neuron or not. Introducing the non-linearity is the main purpose activation function into the output of a neuron. (Tiwari, 2019)

2.4.1. ReLu activation function

ReLu is used in deep neural network and is a non-linear activation function.

$$f(x) = \max(0, x) \qquad (1)$$

Where x is an input value.

The above equation explain that the output obtain from ReLu is the value between zero and the value given input. When the input value is negative, the output is equal to zero and output value is input value when input value is positive. The equation can be expressed as-

$$f(x) = \begin{cases} 0, if\ x < 0 \\ x, if\ x \geq 0 \end{cases} \qquad (2)$$

Where x is an input value. (deepai, 2019)

Advantage and disadvantage of Relu (Rectified Linear Unit)

Benefits of ReLu is vanishing gradient problem is avoided and rectified also as ReLu consists of simpler mathematical operations it is less computationally expensive than sigmoid and tanh. As it can be used only with Hidden layer it can be considered as its limitation. ReLu could also result on dead neuron that some neuron may never get activated. The activation can be blow up due to the range of ReLu i.e (0,

infinite). (Karpathy, 2016)

2.4.2. Sigmoid Activation function

Sigmoid is the activation function range between 0 and 1. It is used to make useful prediction of probabilities. Sigmoid function retains the 'S' shaped curve and is the type of logistic function. (deepai, 2019)

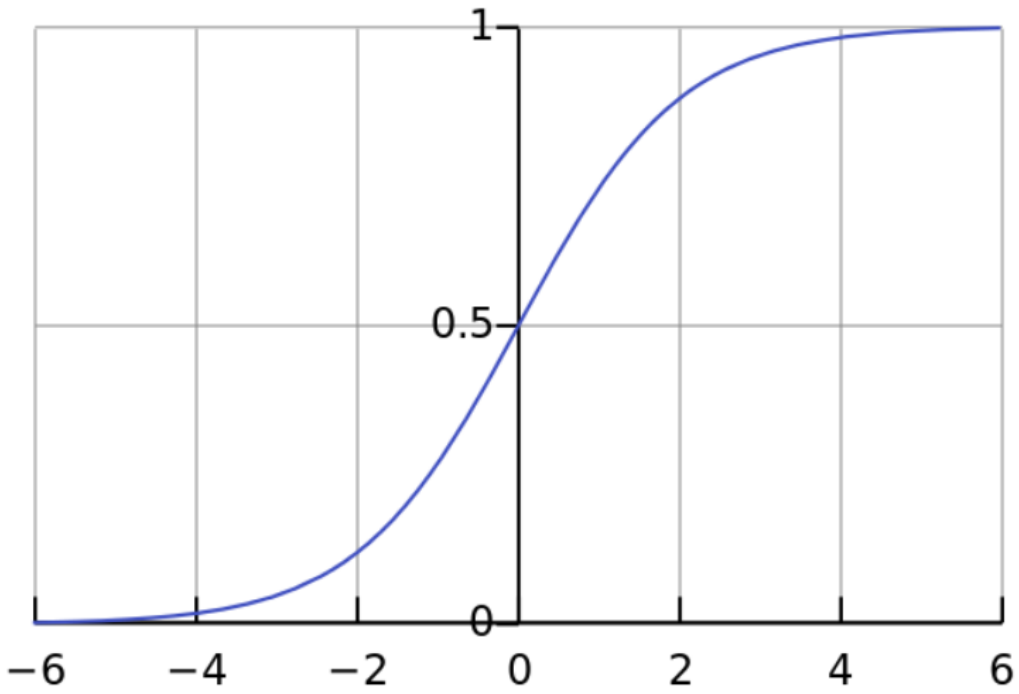


Figure 5: Sigmoid function ranging from 0 and 1. (ailephant, 2020)

The output of the node is always in the range of 0 and 1 is ensured by Sigmoid activation function. After applying the weights to input data sigmoid is used to normalize the sum of input data. The formula of sigmoid function in neural nets is:

$$\text{Output of neuron} = \frac{1}{1 + e^{-(\sum weight_i input_i)}}$$

The derivative of sigmoid function is used to modify the weights during the training period on training data during gradient descent. (ailephant, 2020)

2.5. Computer Vision

Computer vision is the field of study to develop the technique to make computer see and recognize and understand the content of digital images such as image or videos. Understanding the content of digital images is the main goal of computer vision. To extract the useful information from an image is its main target.

It was believed to be the simple problem and can be solved by connecting camera to computer but computer vision, after a decades of research also remained unsolved in term of meeting capabilities of vision of the human. (Brownlee, 2019)

3. Main Content

3.1. Fact finding technique

The process of collecting the data and information on the basis of technique such as research, document sampling, observation, interviews and questionnaires is known as fact finding technique. From the fact obtained it is identified that which tools can be used for the system development. Here, we use document sampling and research for the fact finding. (Uk essay, 2018)

3.1.1. Document sampling

The existing system is analyzed by collecting the fact from their documentation. Fact can be collected from suggestions, e-mails and document of the system. Studying the document of existing system and finding how and which technology was used to develop the system so that we can apply similar technique to develop the system. It is the original and effective fact finding technique as the documentation done by the organization will be more realistic as they develop the system.

3.1.2. Research

Research is another fact finding technique. In this process the problem solved before is examined either by human or documents. The research paper in which it is explained that how the problem is solved can be viewed to find the fact and follow the similar technique in our system. We can use the obtained knowledge differently as compared with other as we can gain much more different techniques from research.

3.1.3. Survey

The survey was done with the help of Google form to know the number is people who prefer to use mobile application to solve the mathematical problems. So the outcome of survey is that 62.2% of the people wants to use mobile application to solve the problem and 37.8% do not prefer to use it. We can conclude that the majority of people prefer to use mobile application to sole the mathematical problems.

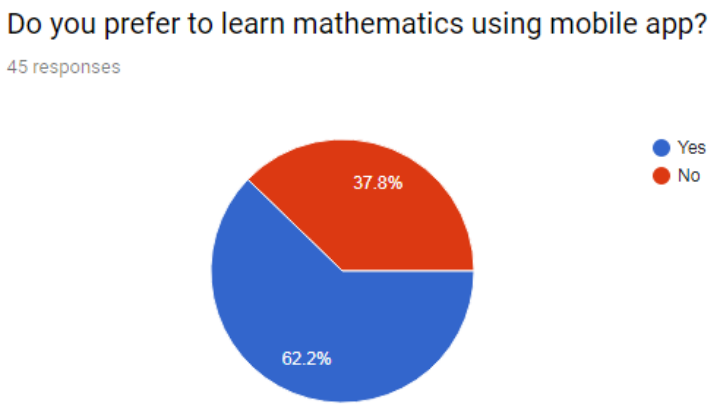


Figure 6: Outcome of survey conducted

3.1.4. Past project

According to the research paper, there are many project related to the Mathematics problem solving apps developed. Most students and teacher all over the world uses the smart phones, tablet and laptops and the online tools has become the integral part. With the increase in the technology it is challenging part for the educator to develop the learning system in the technology. Mobile learning provides the facility for the student to learn even outside the school. Students can utilize their free time to learn online with the app or websites. As the technology is growing, mobile learning can be mush effective way of learning. (Drigas & A.Pappas, 2015)

As explained in the paper, to solve the problem of larger number of students mobile learning would be the best for the training and education. As there is new learning technique, it has ensured the improvement in the teaching-learning process as many people are connected with the mobile devices and internet. If student are unable to solve the mathematical problem then they could use the mobile learning to get the immediate solution. (Al-khateeb, 2018)

3.2. Related Projects

Some of the related projects are listed and discussed below:

3.2.1. Photo math

Mathematical expression can be solved in real time using Photo math. Photo math provides step by step solution of the problems that helps the students who do not have tutor. Athematic, decimal numbers, linear equations and fractions are supported by photo math. Optical character recognition is used to read equations and calculates the answer within a seconds. It can recognize both printed and handwritten digits. The app also keeps on mistaking the 'X' variable as multiplication symbol. Advanced OCR (Optical Character Recognition) technology developed by Micro blink is used by an app in order to read and recognize both handwritten and printed characters of a particular problem. (Chowdhry, 2014, p. 1)

Photomath is developed using DeepOCR technology that is developed by Microblink. The technology is highly optimize for mobile devices to work faster, to provide high accuracy and offline and can be easily integrated into any app. Deep learning and deep neural network is used in OCR in photomath. (Microblink, 2014)

3.2.2. Solve4x

Solve4x is the iOS app that can solve the equations where we can type an equation manually or can snap a picture. Photo that are already taken can also be used to sole an equation. It works with printed text and with a garbled text so it takes little more time to do light text editing. This app does not supports equations that are with brackets. (NDTV Correspondent, 2014)

3.2.3. Socratic

Socratic is the app that is powered by Google. This app provides solutions for math, science, language and other subjects. If anyone wants to solve the math problem then the app will help them find the answer. The photo of the question needs to be simply clicked or type the question. The math equations with roots and fractions can also be identified by an app. The app works on the typed questions rather than the handwritten digits. The app uses sophisticated text recognition to identify the digits. (Meenal, 2019)

3.3. Comparison table of the similar apps

	Photomath	Solve4x	Socratic	Math equation solver
Objective	Solves handwritten and printed equations	Solves printed equations	Solves printed and typed equations	Solves handwritten equations
Limitations	The variable X is	Cannot solve	Cannot solve	Solves simple

	taken as multiplication.	handwritten equations	handwritten equations	equations including operator +, - and *.
Technology used	DeepOCR developed by Microblink	Optical character recognition	Optical character recognition	Convolutional neural network, Firebase MLkit
For which platform it is available	Android	IPhone	Android	Android

3.4. Functional decomposition diagram

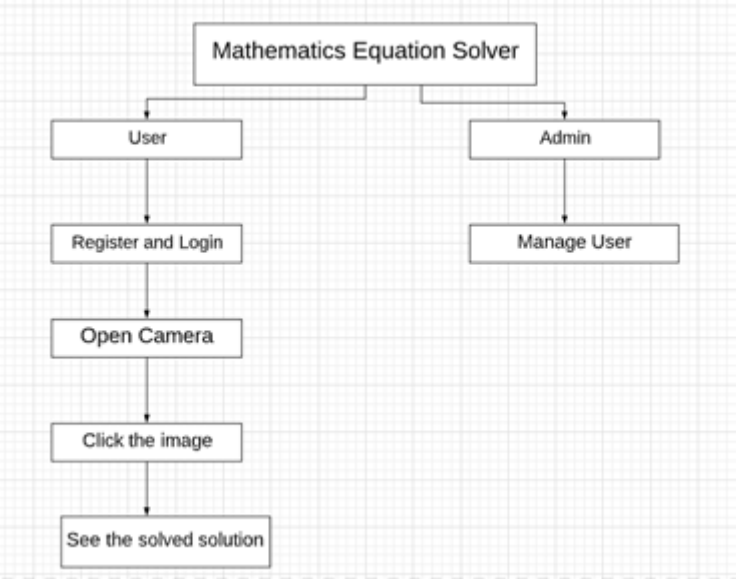


Figure 7: Functional decomposition Diagram

3.5. System Requirement Specification

The feature and behavior of a system is defined in the SRS document. To satisfy the customer needs the document contains variety of elements. (Inflectra, 2020)

The document contains the functional and non-functional requirements. How the user is going to interact to system is explained through the use-case diagram. How the system interact with internal modules, hardware, communication with other program and human user interactions in the real life scenario is defined in SRS. (softwaretestingclass, 2015)

3.5.1. Functional Requirement

The service offer by the system is known as functional requirement. It explains the system or the components of a system. The input, behavior of the system and output is the function of a system. (Guru99, 2019)

Following are the functional requirement of the system.

1. The registration is compulsory for the new user with the valid email address.
2. To work with application user must login with their registered id.
3. System automatically validate the users.
4. User should be allowed to upload an image.
5. User should get the error message if there is no equation to solve in image.
6. Only the authorized user can view the upload history.
7. System should get the camera access permission.
8. User must be able to log out from the application.

3.5.2. Non-functional Requirement

The quality proposed of a software system is known as non-functional requirement. On the basis of responsiveness, security, usability and other non-functional requirement the system is judged. (Guru99, 2019)

Following are the non-functional requirement of the system.

1. The security of the user's data should be maintained.
2. Number of user in the application should be handle by the database.
3. System should allow user to upload image as much as they want.
4. System should be available 24/7 and offline.
5. The user interface should be easy to read and user friendly.
6. Changes in the system should be done overtime.

3.5.3. Usability requirements

Usability requirement is the specification design so that the system is easy to use. It defines that the interface should be easy to use and learn. Each time user uses the system they should not refer to manual. The interface should be easy to use. And the user should be use the system without any instructions.

Following are the usability requirement that the system should support:

1. The result should be achieve quickly without any user error.
2. The user interface should be easy to learn and navigate buttons, heading and instructions.
3. The system interface should be easy to load without any frustration and demands. (usabilityfirst, 2019)

3.6. Tools and technique

Various tools and techniques are used in the Math Equation solver. The tools and techniques are discussed below:

Python

Python is high level, interpreted, general-purpose programming language with dynamic semantics. For Rapid Application Development its high-level built in data structures can be combined with dynamic binding and dynamic typing. Python is easy to learn, simple syntax and its readability therefore it is also a popular programming language. The extensive library and the Python library are available in source without charge and can be freely distributed. Here, python is used to do data analysis and most important for training the model and Machine learning to predict the data. (python, 2020)

Keras

Keras is the open source library written in python to build the deep learning models. Keras is easy to extend, user friendly and works with python. The API is “Designed for human beings, not machine” and “follows best practices for reducing cognitive load”. The new model can be created by combining the standalone models like neural layers, cost function, optimizers and activation functions. (Heller, 2019)

Java

Java is a general purpose programming language that is object-oriented, class based. Its purpose is to write once, run anywhere. Without need of recompilation compiled java code can run on all platform. Here, java is used to develop android application in Android Studio.

Android Studio

Android Studio is the Integrated Development Environment for the development of Android App. Android Studio has the flexible Gradle-based build system, feature-rich and fast emulator, better frameworks and testing tools. It is used to code for Android app and also integrate the trained model and android app.

Matplotlib

The library of Python that has amazing visualization for 2D plot of arrays. It is built on Numpy arrays and is multi-platform data visualization library. Pyplot is its module name. It makes the plotting easier by providing feature like font properties, styles, axis formatting and many other features.

Numpy

For working with arrays we use the Numpy library of Python. Numpy is 50 times faster than the traditional Python lists. It is the general-purpose array-processing package. High performance multidimensional array object and tools are provided by Numpy to work with arrays. For scientific computing Numpy is a fundamental package.

Jupyter Notebook

Jupyter Notebook is an open source web application where we can create the code, equations, visualizations and narrative text and share documents. Here, Jupyter Notebook is used to run the python code and creating the training model for Machine learning.

Google chrome

Google chrome is used to do the research for the project also running jupyter notebook.

OpenCV

OpenCV is the open source computer vision and machine learning library. It enable us to extract important feature and required information from image and video.

Convolutional Neural Network

CNN is the special type of neural network that is used for image recognition. It is the algorithm of deep learning. CNN is mostly popular for image recognition. For the face detection, object detection and generating vision on self-driving car CNN is used.

Firebase database

The Firebase is NoSQL database hosted on cloud that helps to store the data and sync between users in real time. For the user register and login we are using firebase database for android application. (Firebase, 2020)

TensorFlow

Tensor flow is the famous library for Machine learning. It is open source library for large scale machine learning and numerical computation. The input is taken as multi-dimensional array so it is called tensors. The flowchart can be created that can be performed on the input. The training and running of handwritten digits classification can be done using TensorFlow. (Yegulalp, 2019)

TensorFlow lite

The tools that help the developers to run the model developed in TensorFlow on mobile and IoT devices. Firstly, the model is converted into tensorflow lite so that it can be used for android devices. (Tensorflow, 2020)

Draw.io

Draw.io is online tools that can be used to create the diagrams such as class diagram, use-case diagram and flow diagram and ERD diagram.

3.7. System requirement

3.7.1. Hardware requirement

RAM = 8 GB RAM
ROM = 50 GB or above
Internet connectivity = Router

3.7.2. Software Requirement

Operating system: Windows 10
Integrated Development Environment (IDE): Jupiter note book, Android Studio
Programming language: Java, python
Library: Pandas, Numpy, OpenCV

3.8. Process design

The process of defining the elements such as modules, architecture, components and the interface is known as system design. (economictimes, 2020)

The model that is used for modelling the software and non-software systems is known Unified Modelling Language (UML). UML is used to model the object oriented application even though it is for the non-software system. UML is to represent the object of real world that are around us and the concept of abstraction, inheritance, polymorphism and encapsulation. Anything exist in object-oriented analysis and design can be represented by UML diagrams. (tutorialspoint, 2020)

Some of the UML diagram required for the system are designed below:

3.8.1. Use Case diagram

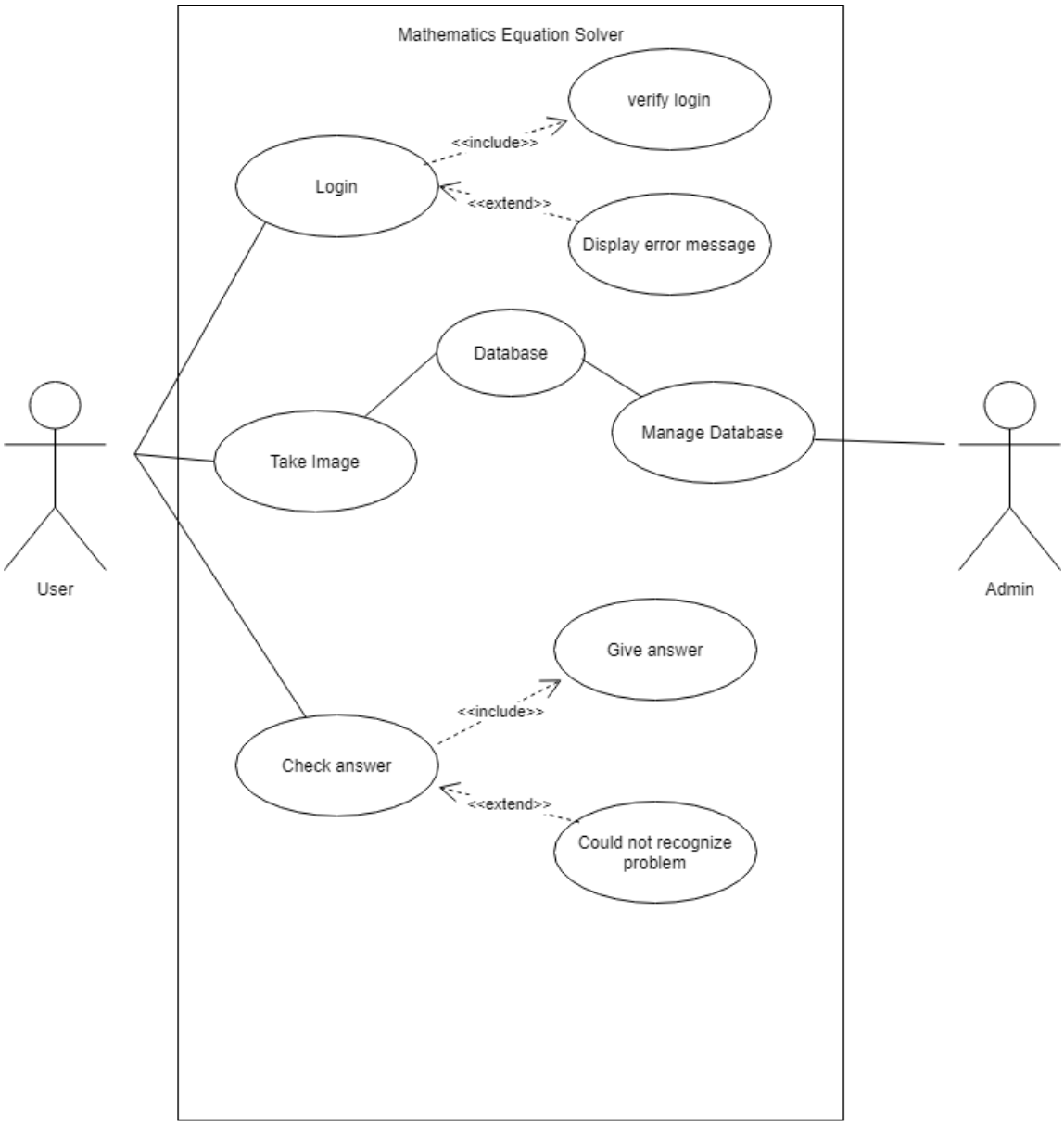


Figure 8: UML diagram for the system

3.8.2. Sequence Diagram

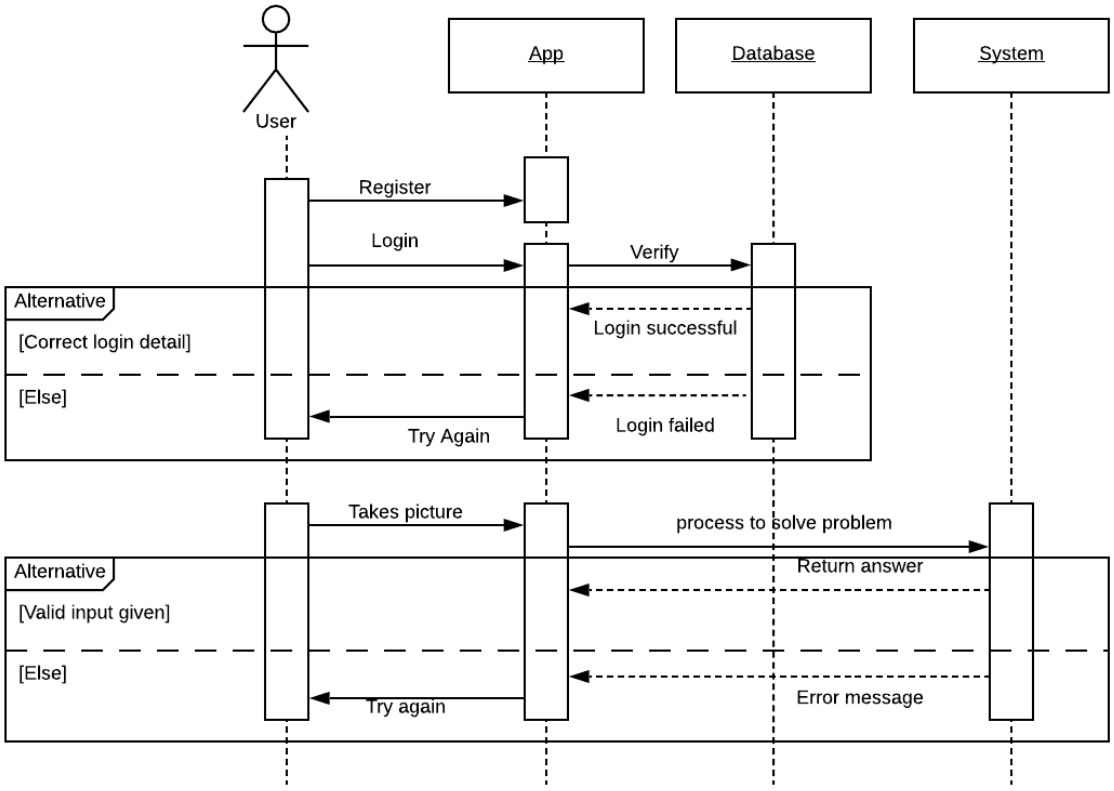


Figure 9: System sequence diagram

3.8.3. State Transition Diagram

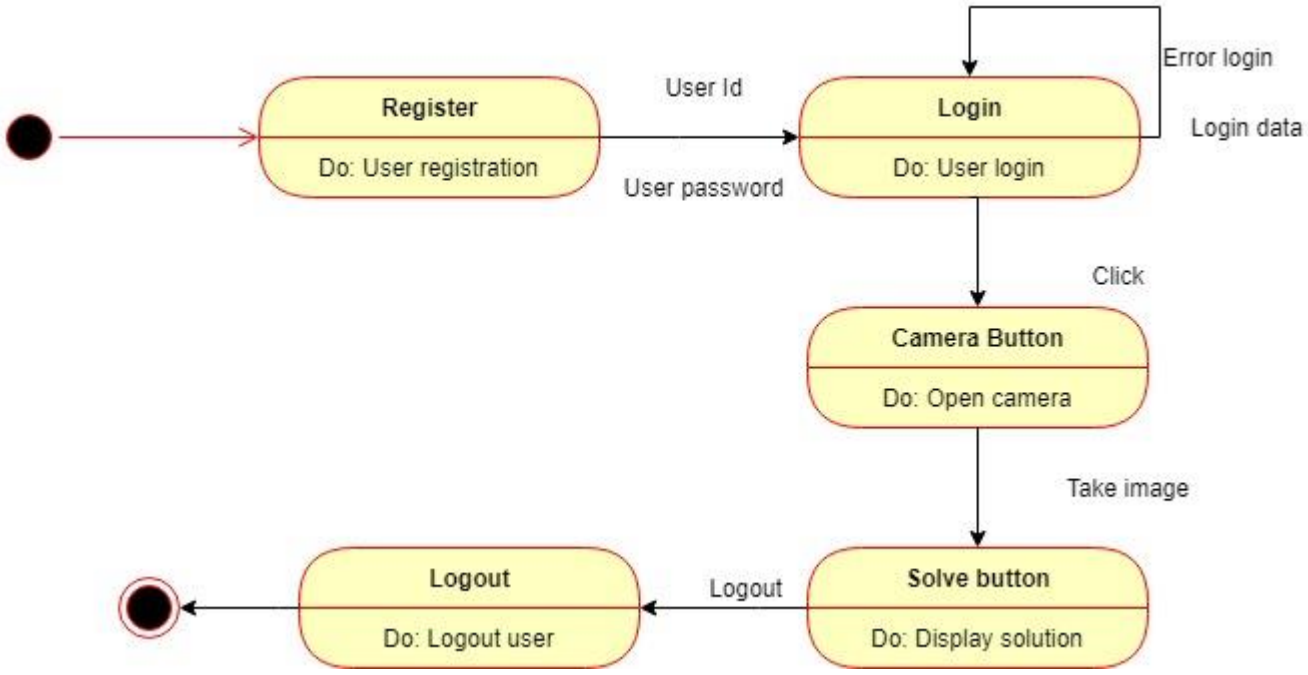


Figure 10: State transition diagram of the system

3.8.4. Class Diagram

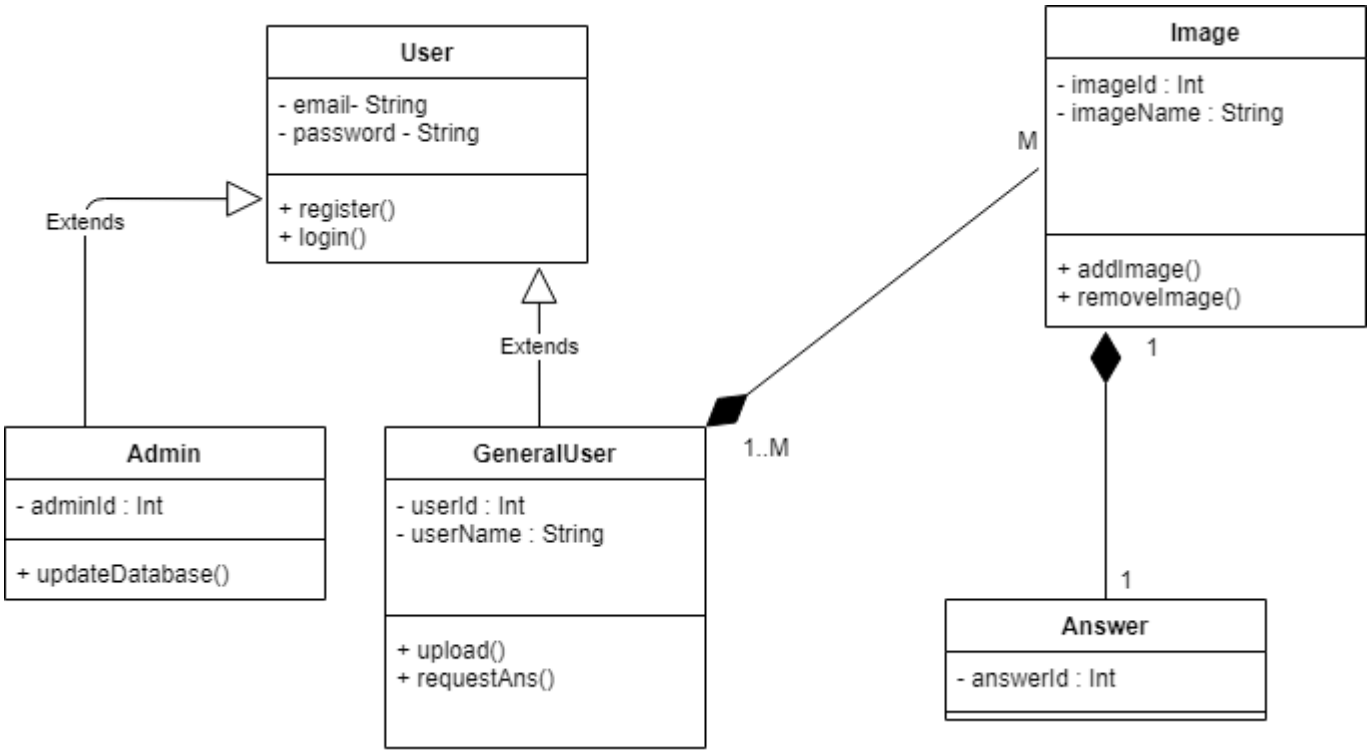


Figure 11: System class diagram

3.9. Database design

3.9.1. Entity relationship diagram

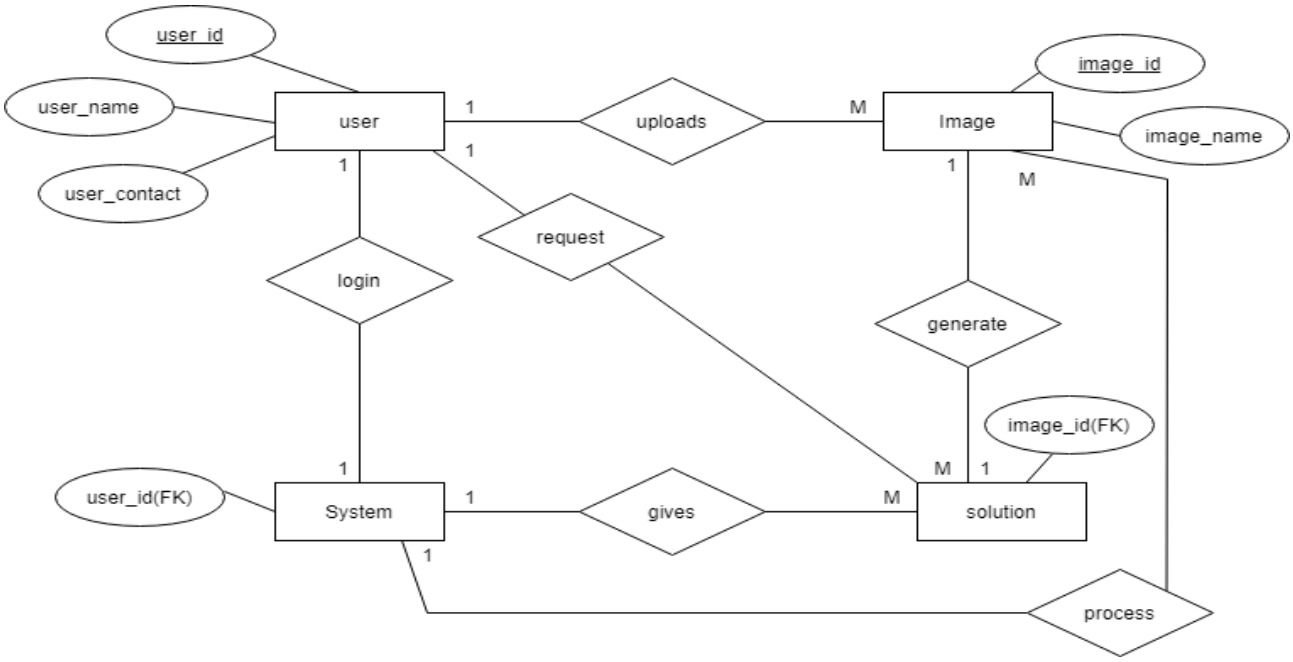


Figure 12: Entity relationship diagram

3.9.2. Data dictionary:

Field Name	Data type	Field size	Description	Example
User Id	Integer	5	Unique Id for each user	011
User name	Text	20	Name of the User	Prabee
User contact	Integer	10	Contact number of User	9876543210
User email	email	25	Email address of user	prabee@gmail.com
Image Id	Integer	5	Unique Id of an image	002
Image name	Text	20	Name of an image	Image002

Figure 13: Data dictionary

3.10. User Flow Diagram

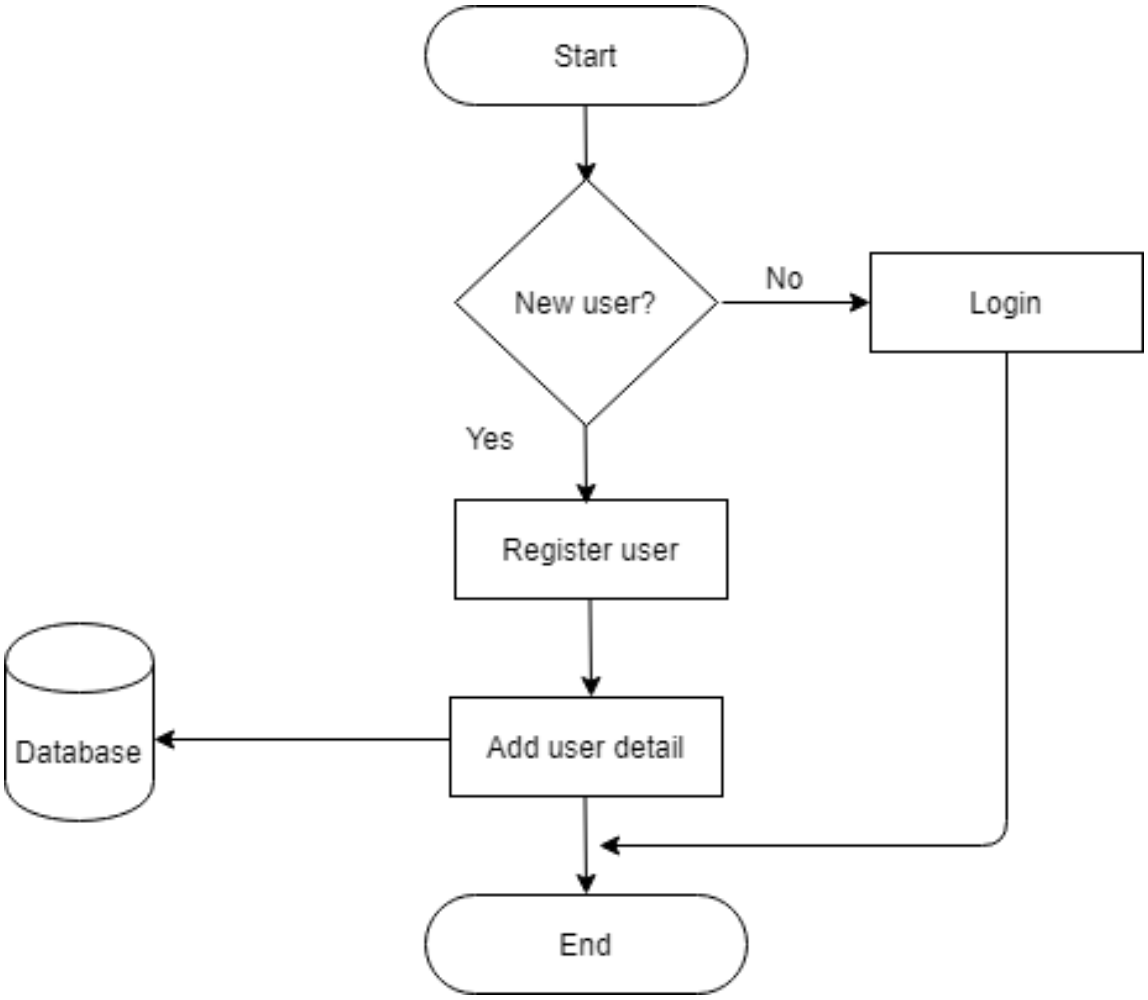


Figure 14: User's flow diagram

3.11. System Flow Diagram

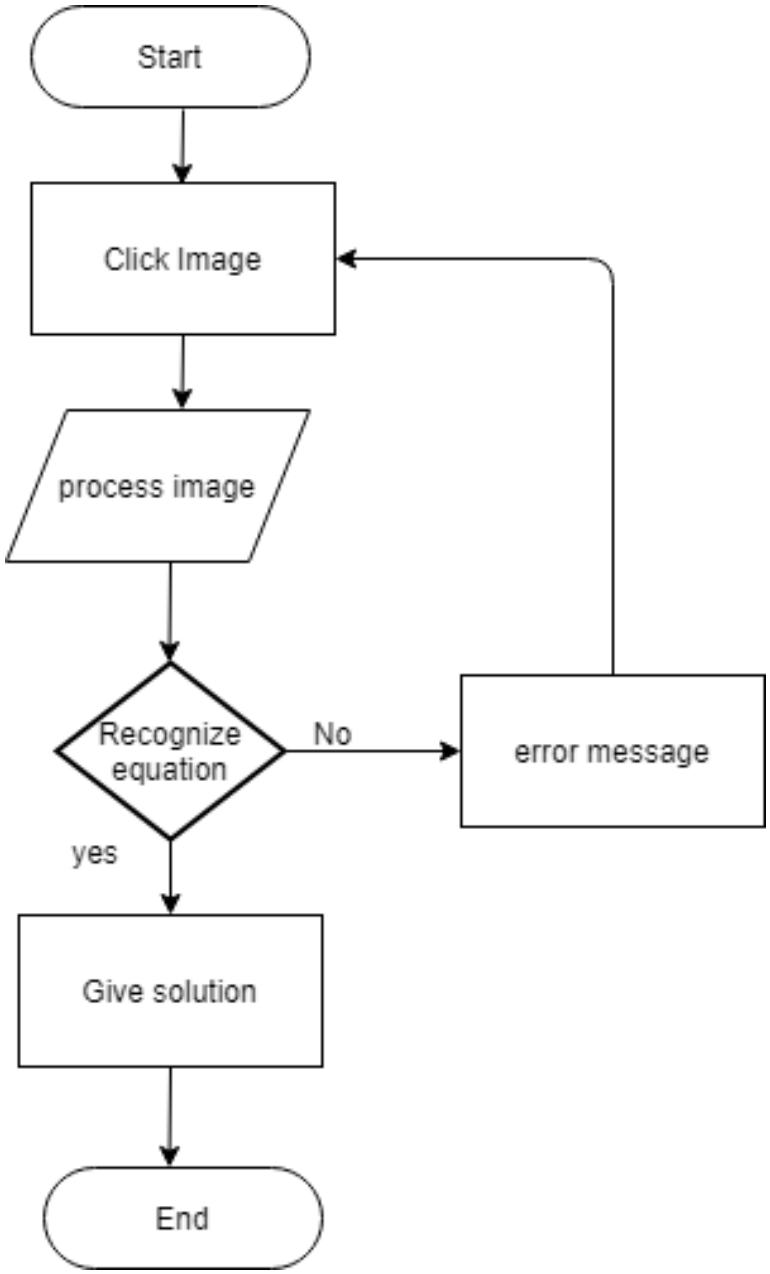


Figure 15: System flow diagram

3.12. User Interface (design document)

3.12.1. Wireframe

Splash screen

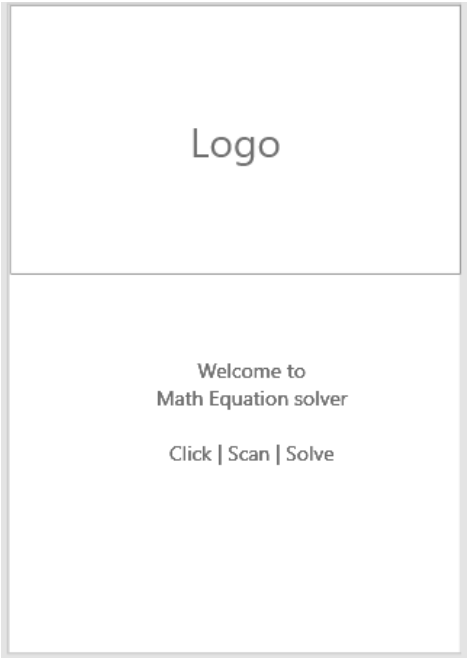


Figure 16: Splash screen of an application

Register the account

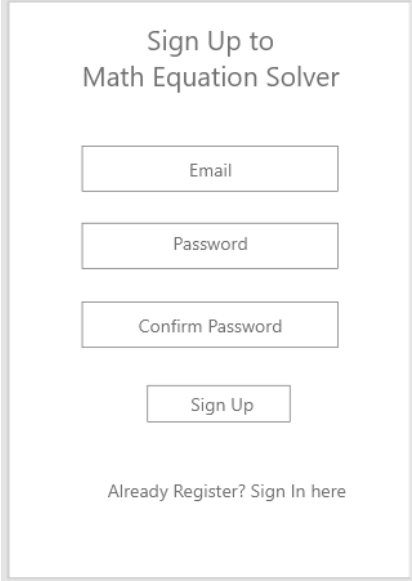


Figure 17: User registration form

Sign in into the account

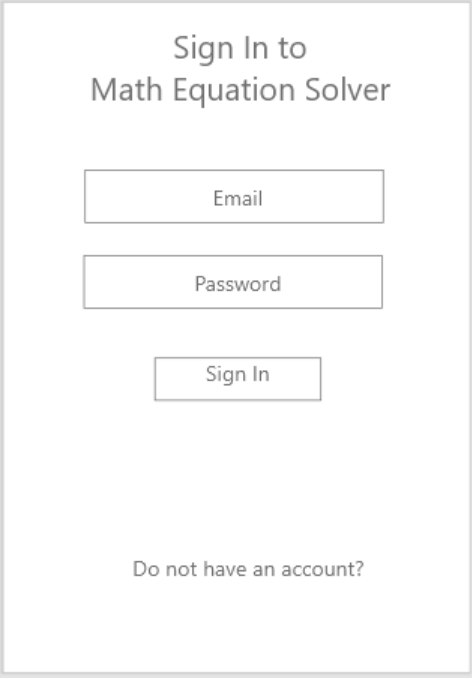


Figure 18: User sign in page

Main Page

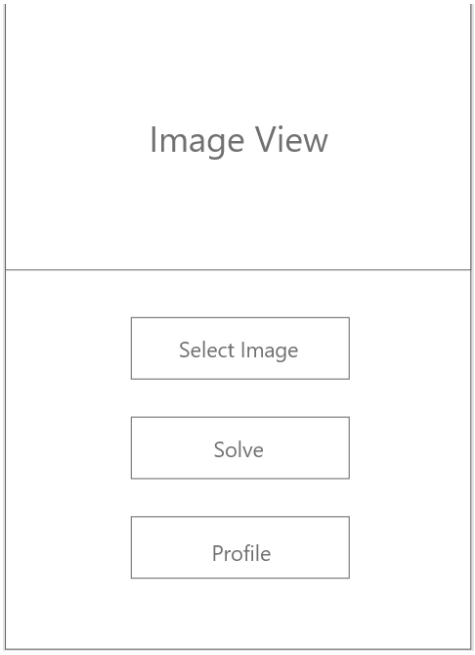


Figure 19: Main page of an application

Click the image using the camera

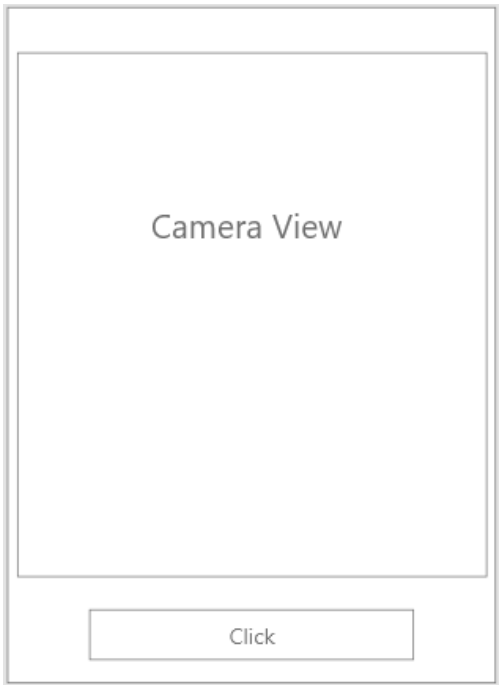


Figure 20: Camera view of an application

Check the solution in this activity

Figure 21: Solution displaying page

3.13. System architecture

From the centralized server many clients request and receive the services, it is called client server architecture. An interface is provided by the client computer that allows a user to request service from the server. As the request arrive to the server it respond to them. Server are located on the network on more powerful machine and client are situated at personal computer or workstation. (Augustyn, 2019)
One Tier, Two Tier, Three Tier and N-Tier are the architecture in the Software Architecture. Tier is also known as Layer. The layers involve in the application are Presentation layer, Business layer and Data layer.

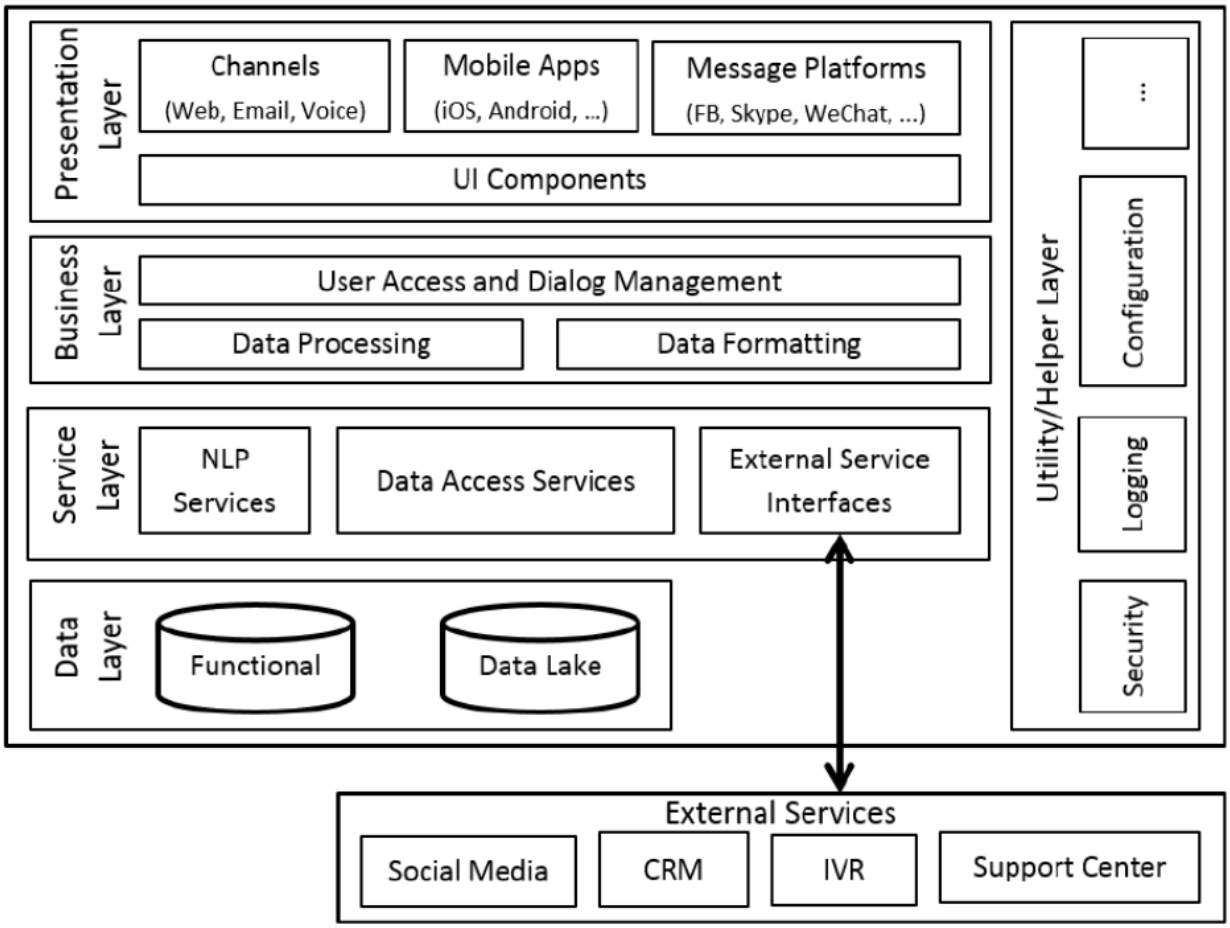


Figure 22: System Architecture (Deshpande, 2019)

Presentation layer:
It is also kwon as client layer. It is the top most layer of an application. When we use the software we see this layer. Communicating with the application layer is the main function of this layer. The information given by the user is passes to the application layer by presentation layer.

Application layer:

It is also known as logical layer or business logic layer. While using the application and as the button on app is clicked the required information is sent to presentation layer by the application layer by interacting to database layer. Between the presentation layer and database layer it act as a mediator.

Data layer:

This layer store the data. From the database layer the application layer retrieve the data. Database is connected by this layer and perform the action like insert, update and delete.

3.13.1. Types of Software Architecture

- One Tier Architecture

One tier application is known as standalone application. In the single package of software one tier architecture contains presentation, business and data layer. Application such as MP3 player, MS office are some example of one tier application.

- Two Tier Architecture

Two tier application is known as Client server application. Client and database tier are the parts where two tier architecture is divided. Presentation and Application layer is handled by client system and database layer is handled by server system. The server system receive the request from the client system and the processed request is sent back to client system by server system.

- Three Tier Architecture

Three tier application is known as web based application. Presentation, Application and Database layer is the part where the three tier architecture is divided into. Presentation layer is handled by client system, Application layer is handled by application server and Database layer is handled by server system. (Rajkumar, 2017)

3.14. Testing

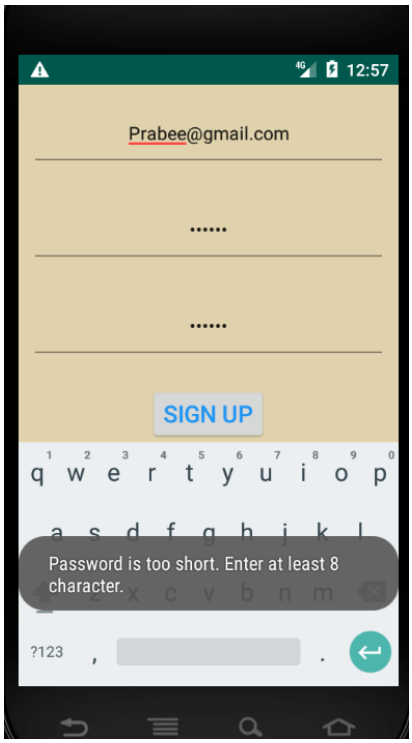
This section of the report consist of the testing of the system. In general, testing is done in terms to find out any sort of error in the client product. Testing is important part in case of the real world. It is actually done to check whether the user requirement are fulfilled or not. So, considering this point testing of the designed system is conducted thoroughly in this section. Different types of testing are available in the market such as: white box testing, black box testing and validation testing and unit testing. Among all these types of testing, validation testing is done in our designed system.

Test case	Objectives
1.	Registering the user in the system
2.	Successful login of the registered user
3.	Displaying the front view to the logged in user
4.	Successful click of the image of the math problem
5.	Solving math problem
6.	Successful logout of an user

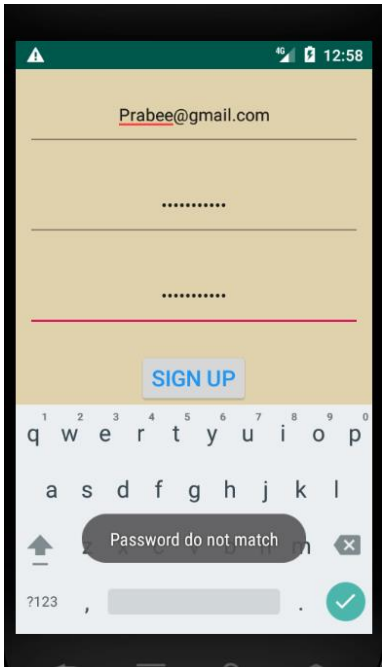
Test case 1:

Case 1:	Registering the user in the system
Steps followed:	User filling up the register form Password should be 8 character long Password and confirm password must match Clicking on the Sign Up button
Expected result	The user should be registered and home page should open.
Actual result	Home page open successfully
Conclusion	Successful

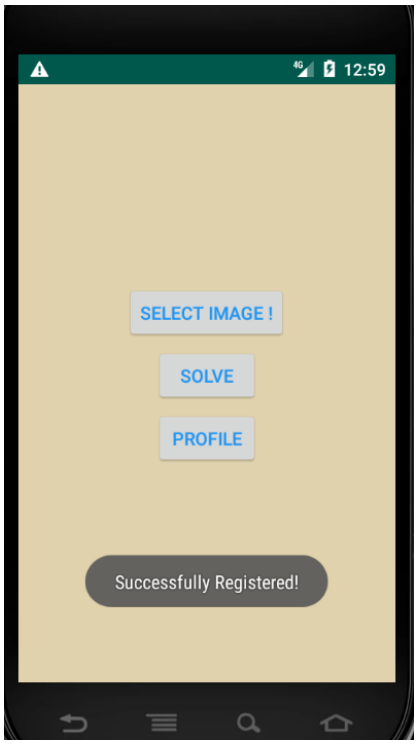
If the password is not 8 character long then the following error “Password is too short. Enter at least 8 character” will be displayed.



If the password and confirm password does not match then the error message “Password do not match” is displayed to the user.



If the register is successful then the “Successfully Registered!” message will be displayed and home page should open where user can interact with the buttons select image, solve and profile.

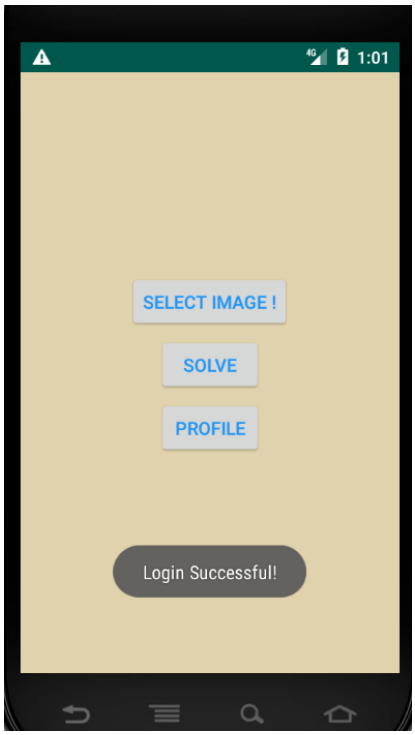


Test case 2:

Case 2:	Successful login of the registered user
Steps followed:	User filling up the login form Email and password should be correct. Clicking Sign in button
Expected result	The user should be logged in to the system.
Actual result	User logged into the system.
Conclusion	Successful

If the email and password does not match the “Username or password do not match” message will be displayed to user.

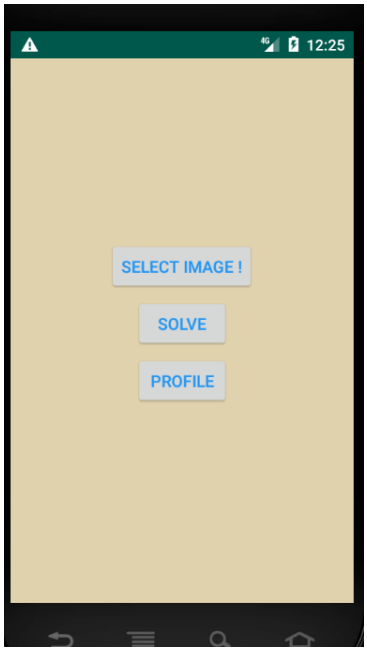
If the user provide valid login information then the user is directed to homepage displaying message “Login Successful!”



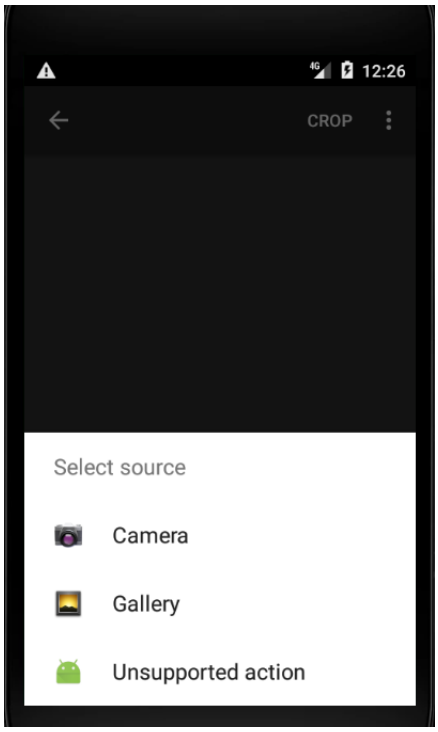
Test case 3:

Case 3:	Displaying the front view to the logged in user
Steps followed:	After filling login form the user is directed to main page. User can click on the button available in the main page for interaction.
Expected result	Logged in user should be able to see the main page.
Actual result	User who have logged in to the system is able to view the main page and use the button available.
Conclusion	Successful

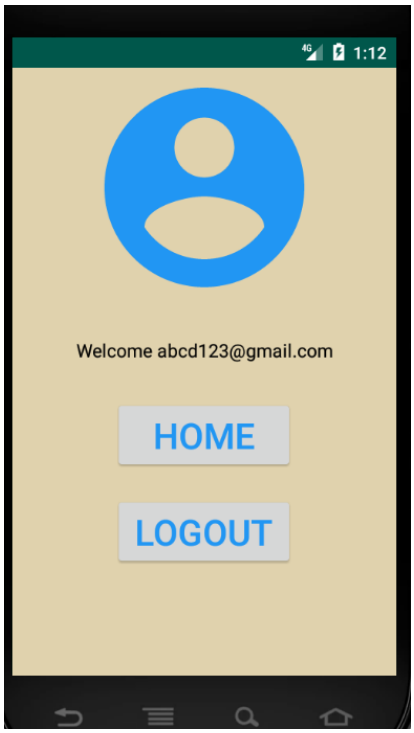
Now the user should be able to interact with the buttons.



When the select image button is clicked then the user should get the interface to choose the Camera or Gallery option.



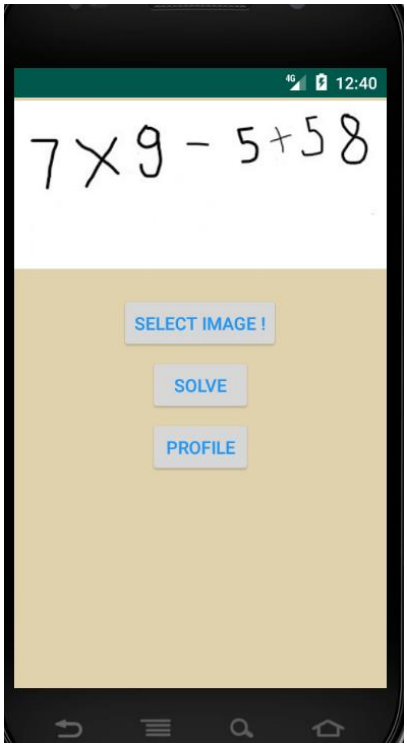
When user click on the Profile button the user profile should be displayed where user can use Home button to return to Home page and Logout button to log out from the application.



Test case 4:

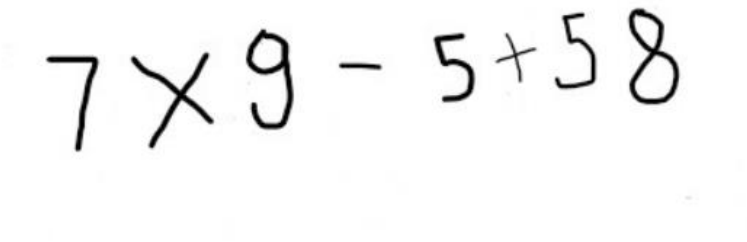
Case 4:	Successful click of the image of the math problem
Steps followed:	While clicking the image the user should place the camera correctly.
Expected result	User should be able to use camera from the app.
Actual result	Camera can be opened from the app.
Conclusion	Successful

The image clicked or selected from Gallery should be displayed in the image view of an application.

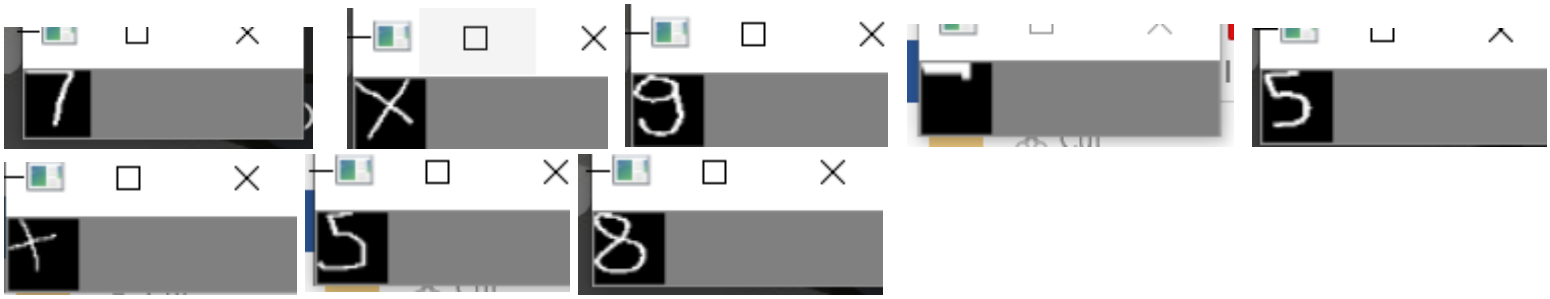


Test case 5:

Case 5:	Solving the math problem
Steps followed:	After clicking the image, the user should click the button “solve” for the solution.
Expected result	The solution of the math problem should be displayed.
Actual result	Solution of the user desired problem is displayed.
Conclusion	Successful



The image is given input with the image location. Then the contour is found and the image is turned into grayscale. Each recognized digit and symbols are displayed separately as below.



Then the recognized digits are displayed as follows and calcualtion is perofrmed.

```
    if(result[0]==9):
        s=s+'9'

print(s)
```

```
7*9-5+58
```

Then the final solution is displayed.

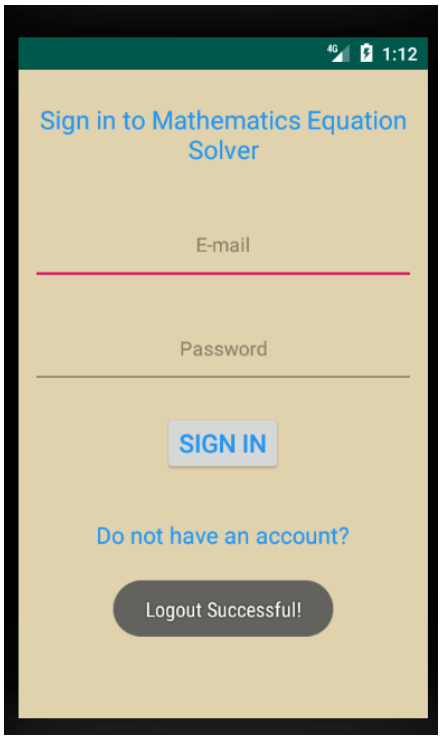
```
eval(s)
```

```
116
```

Test case 6:

Case 6:	Logout of an user
Step followed	Click on the logout button
Expected result	The user should be logged out successfully and open login page for new login
Actual result	User logged out of the application and opens login page
Conclusion	Successful

When the log out button is clicked in the Profile page the user is logged out and “Logout Successful!” message is displayed and login page opens.



3.15. Working of system

3.15.1. Deploying model

The trained model for handwritten digit and operator will be deployed using ML Kit. It provides the label for the trained dataset which makes the deployment easier.

3.15.2. Taking input from an user

The android application is the system that takes an image as input from user. User will allow to use the camera of a device to take the image of equation that they are willing to solve.

3.15.3. Using OpenCV

OpenCV will be used to convert the image into grayscale and find contour of the digits.

3.15.4. Recognizing the character using CNN

CNN is the specialize algorithm for image classification and image processing. When the image is filtered using computer vision now the CNN will proceed to recognize digits and operators. It match the feature from the trained model and compare with the given input image.

3.15.5. Solving the equation

When the digit and operators are recognized the process of solving the equation will started. The equation will be solved and the final solution will be displayed in the screen.

3.16. AI model Development

3.16.1. Data collection

The data need to be search for developing the model. The handwritten digits and symbols are downloaded from Kaggle for developing the model. The dataset contains digits from 0 to 9 and symbols +, - and *. The image size is 28 * 28. There are altogether 49410 images in the dataset.

These are the different folder that contains the images of the digits that are required to train the model.

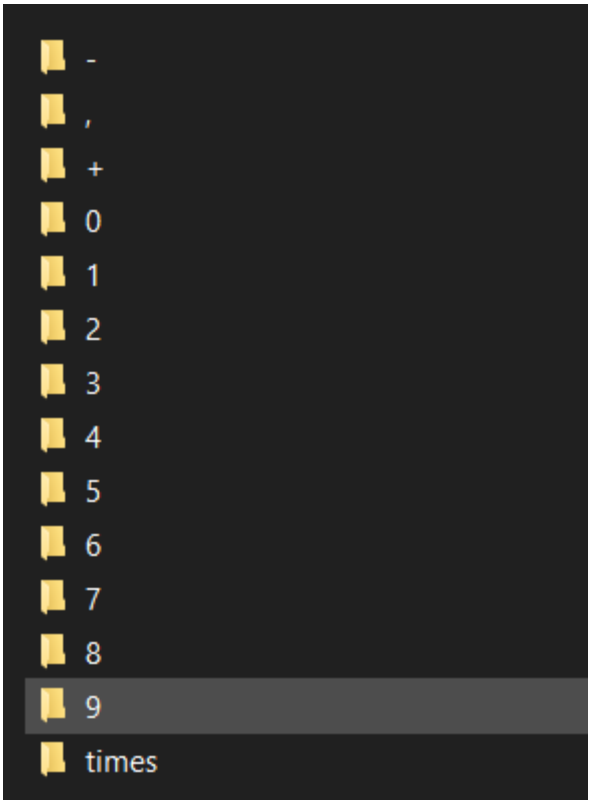


Figure 23: Folders of dataset

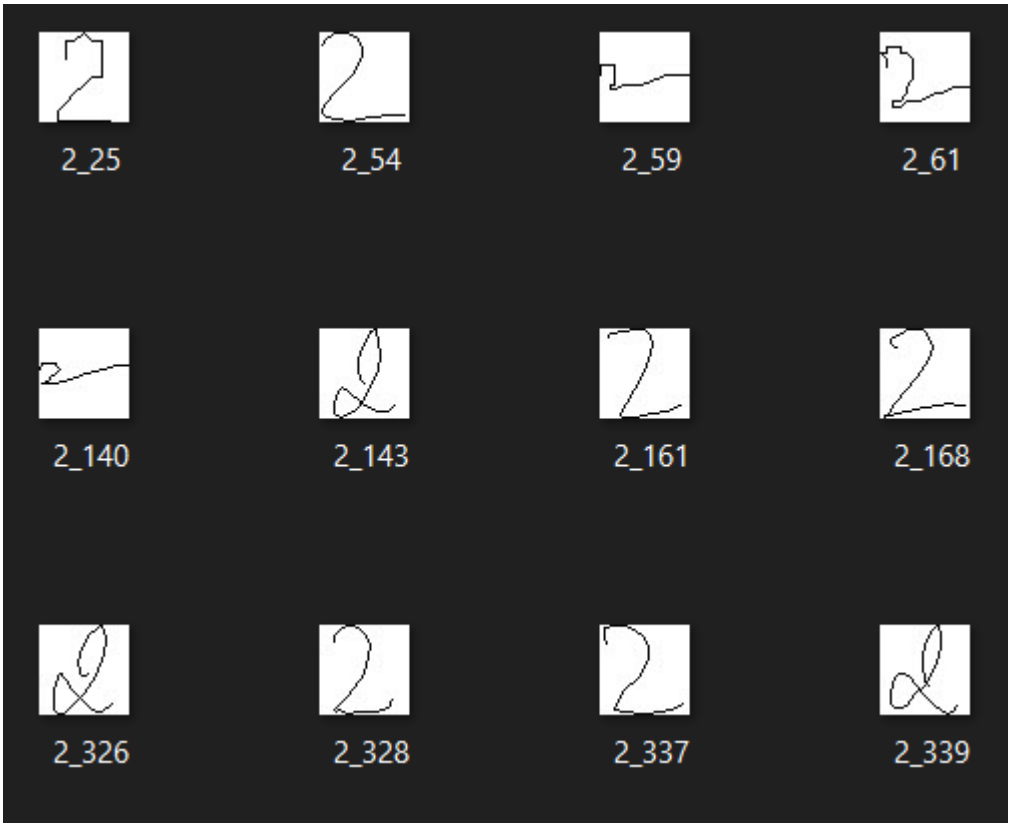


Figure 24: Images of digit 2 in the handwritten form

3.16.2. Data Preprocessing

The process of converting the data in which the machine understating model is known as data preprocessing. The preprocessing of data is important for developing machine learning model.

3.16.3. Data extraction

```
In [1]: # importing required libraries

import numpy as np
import cv2
from PIL import Image
from matplotlib import pyplot as plt
%matplotlib inline
import os
from os import listdir
from os.path import isfile, join
import pandas as pd
```

Figure 25: Library used in python

The imported library for data extraction are as follows:

numpy: Numpy is imported to work with the arrays.
CV2: Python library to solve the computer vision problem.
PIL: In python interpreter image processing capabilities is added by PIL.
pyplot: It is the plotting library.
os: Function for interact with Operating system.
isfile: Identify if the specified file is existing file or not.
listdir: Get the file and directories list in a specified directory.
Pandas: Padas is Data analysis and manipulation tools.

When the data is collected the data need to be extracted so that they can be used in training the model. So, from each respective folder the image is extracted and the number of image presented is printed.

```
In [4]: #assign '-'=10
        data=load_images_from_folder('D:/EqunSolver/-')
        len(data)
        for i in range(0,len(data)):
            data[i]=np.append(data[i],['10'])

        print(len(data))
```

```
4152
```

Figure 26: Extracting the '-' operator from the local folder.

From the folder ‘D:/EqunSolver/-’ the symbol is extracted. 10 is indicated as ‘-’ symbol. All the images in the folder are extracted and the count is 4152. There are 4152 ‘-’ symbols.

```
In [5]: #assign + = 11
data11=load_images_from_folder('D:/EqunSolver/+')

for i in range(0,len(data11)):
    data11[i]=np.append(data11[i],['11'])
data=np.concatenate((data,data11))
print(len(data))
```

```
8184
```

Figure 27: Extracting '+' operator from local folder.

Same as above 11 is indicated as '+' symbol. '+' is extracted from 'D:/EqunSolver/+' folder. 4152 from the above symbol is added and there are 4032 '+' images. So the total is 8184 images.

```
In [6]: data0=load_images_from_folder('D:/EqunSolver/0')
for i in range(0,len(data0)):
    data0[i]=np.append(data0[i],['0'])
data=np.concatenate((data,data0))
print(len(data))
```

```
12018
```

```
In [7]: data1=load_images_from_folder('D:/EqunSolver/1')

for i in range(0,len(data1)):
    data1[i]=np.append(data1[i],['1'])
data=np.concatenate((data,data1))
print(len(data))
```

```
16074
```

```
In [8]: data2=load_images_from_folder('D:/EqunSolver/2')

for i in range(0,len(data2)):
    data2[i]=np.append(data2[i],['2'])
data=np.concatenate((data,data2))
print(len(data))
```

```
20334
```

```
In [9]: data3=load_images_from_folder('D:/EqunSolver/3')

for i in range(0,len(data3)):
    data3[i]=np.append(data3[i],['3'])
data=np.concatenate((data,data3))
print(len(data))
```

```
23850
```

Figure 28: Extracting required digits

```
In [18]: df=pd.DataFrame(data,index=None)
         df.to_csv('train.csv',index=False)
```

Figure 29: Saving the extracted data in the CSV file

The extracted data from the folder are saved in train.csv file which can be used for training the model.

3.16.4. Training the model

When the data is extracted then the training the model is done using train.csv. 1

```
In [2]: import pandas as pd
        import numpy as np
        import pickle
```

Figure 30: Library used to train model

The new imported library for the training the model is pickle that convert a python object into character stream.

```
In [3]: df_train=pd.read_csv('train.csv',index_col=False)
        labels=df_train[['784']]
```

Figure 31: using CSV file to train model

The train.csv file that contains extracted data of all the images is read using Pandas library.

```
In [12]: model = Sequential()
         model.add(Conv2D(32, (3, 3), activation='relu', kernel_initializer='he_uniform', padding='same', input_shape=(1,28,28)))
         model.add(MaxPooling2D(pool_size=(2, 2), padding='same'))
         model.add(Conv2D(64, (3, 3), activation='relu', kernel_initializer='he_uniform', padding='same'))
         model.add(Conv2D(64, (3, 3), activation='relu', kernel_initializer='he_uniform', padding='same'))
         model.add(MaxPooling2D(pool_size=(2, 2), padding='same'))
         model.add(Dropout(0.2))
         model.add(Flatten())
         model.add(Dense(128, activation='relu'))
         model.add(Dense(50, activation='relu'))
         model.add(Dense(14, activation='softmax'))
         # Compile model
         model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
```

Figure 32: CNN and its layers for training the model

The above is the Convolutional Neural Network (CNN). There are three layers of size 32, 64 and 64 with the filter of 3 * 3 and pooling size of 2 * 2 where the important feature is extracted. The dropout is 0.2. Dropout layer is used to prevent the model from over fitting. The relu activation function and softmax activation layer is sued for last layer. Categorical cross entropy is used for loss function.

```
In [14]: model.fit(np.array(l), cat, epochs=15, batch_size=500,shuffle=True,verbose=1)
         Epoch 7/15
         49410/49410 [==============================] - 4s 88us/step - loss: 0.1133 - accuracy: 0.9653
         Epoch 8/15
         49410/49410 [==============================] - 4s 88us/step - loss: 0.0978 - accuracy: 0.9683
         Epoch 9/15
         49410/49410 [==============================] - 5s 97us/step - loss: 0.0830 - accuracy: 0.9732
         Epoch 10/15
         49410/49410 [==============================] - 5s 94us/step - loss: 0.0754 - accuracy: 0.9753
         Epoch 11/15
         49410/49410 [==============================] - 5s 101us/step - loss: 0.0668 - accuracy: 0.9784
         Epoch 12/15
         49410/49410 [==============================] - 5s 92us/step - loss: 0.0608 - accuracy: 0.9789
         Epoch 13/15
         49410/49410 [==============================] - 4s 90us/step - loss: 0.0529 - accuracy: 0.9822
         Epoch 14/15
         49410/49410 [==============================] - 5s 101us/step - loss: 0.0496 - accuracy: 0.9836
         Epoch 15/15
         49410/49410 [==============================] - 5s 108us/step - loss: 0.0440 - accuracy: 0.9850
Out[14]: <keras.callbacks.callbacks.History at 0x2a8a77bec50>
```

Figure 33: Training process

The training the model is actually done in this step. 15 epochs is set to run and batch size is 500 where it takes 500 images at a time and runs for 15 times.

4. Detail explanation of the academic question

To develop the system the library of computer vision OpenCV will be used. The recognition of digits will be done using CNN by passing image through various layers of CNN.
There are layers of neuron in CNN. CNN consist of convolutional layer that is slides over the image that is given input. Random value of filter match with the image pixel values and gives new set of values that helps in identifying the properties of an images. Relu activation function will be used to activate the neurons in CNN. Adam optimizer is used to reduce the loss function and get accurate data. The training dataset for the handwritten digit will be fed. And handwritten mathematical operator will be fed with kaggle. The deploying of AI in the Android is done by converting the model in to tflite format and with firebase MLKIT, deploy of the model is done into the Android app.

Prototyping methodology will be used to develop the system and need to be completed within 6 or 7 months. Requirement gathering and analysis, Design, Build prototype, Evaluation, Refining prototype, Engineer product are the phases in prototyping methodology.

5. Conclusion and Future Escalation

5.1. Conclusion

The Artificial Intelligence has taken the place in many things such as self-driving cars, in restaurant and banking system. In upcoming days AI will cover most of the sectors. The project was developed to solve the simple equation that is in handwritten form. The system is developed to solve the handwritten equation by scanning them. The system is developed using Computer vision and Convolutional Neural Network for Android. The AI in the system solves the equation by recognizing the digits and symbols.

Some children feel difficult to solve the mathematical equations. So as to guide them by providing the solution to equation and encourage to solve the problem by themselves. Nowadays every children has access to mobile devices for entertainment purpose. But the devices can be used to learn as well. Students can used the mobile devices to solve the problem they can face. Also children will become excited to solve their mathematical problem by scanning them. The system does not give the steps but gives the solution to the user which let the user know the final solution and let them work on their own.

Dataset is downloaded from Kaggle from 0-9 and +, -, *. The system is developed in android to make available for android devices so that is becomes easy to use in mobile devices. CNN is used to recognize the digits and operators as CNN is more specialized in image recognition. The equation solving code will execute after the recognition is done. Prototyping methodology was selected for developing process of an application.

The mathematical equation solver will help the students to learn by themselves by providing the final solution and also check their answer if it is correct or not. This will help the parents to ensure that their children are doing well.

5.2. Project fulfillment

The project is completed in time successfully with the use of the Android Studio (the best platform to make an android app). Within the span of 5-6 month, the app has been designed and it is only possible due to the support from supervisor and dear colleagues. While designing the app, there was a time when I started to feel bored and I took it as a hectic task. But building up the confidence in myself, I worked day and night to complete this project on time. Finalizing the project has helped me to improve my research and coding skills.

Working in this project, has provided me an insight to the working with a project in a real world and how the development methodology is interrelated with the system. In comparison to other programming language, JAVA is always a challenging programming to learn and implement. So, coding with the JAVA language was a burdensome task but I managed somehow to overcome this problem. Regarding the achievements I have made from this project is now I am able to fix the bugs in the JAVA and error in the Android Studio. The final coursework of this module has really helped me to cope with the real world and helped me to develop an app developer skill.

6. Critical Evaluation

6.1. Future Escalation

There are many possibilities for this project in future. Recently this project is developed to recognize limited number of symbols such as +, - and /. There are many other symbols used in mathematics such as brackets (), %, {}, []. So, the system can be trained to recognize such symbols and work on them. Also it can be trained to recognize alphabets so that the system can solve the complex equations. The system can be developed to solve the equation and also plot the graph as the solution.

As Math equation solver gives the final solution to the user it can be further developed to give the solution step wise so that the user can get the knowledge of who the solution is generated. The system can be created for iOS as well in coming future.
So these are some future escalation of this system that can be developed in coming future.

6.2. Insight from the project

“Math” subject has always been a boring subject to the majority of students. So, to make it interesting and interactive, this app has been designed. Designing the app and writing the document related to the project was a great learning experience. New terms and new technologies were applied in this project which has built my vocabulary to some extent. It was the first opportunity for me to work with the real world project and following the development methodology side by side. There is a vast difference in between reading thoroughly the terms of CNN and working with it. The project has been completed due to the proper research done and at the same time I was able to develop my research skills. Being a student I can reflect myself to the skills I have in past and the skills I have now. In today’s date, I have improved my skills and gained knowledge and is only possible due to this project. Several problems were faced at the initial stage and I loosed hope, it was due to the less experience I had. As days passed by, I worked harder and conducted a proper research which is the main reason behind the successful accomplishment of the project. At last, this project has helped me to manage the time and taught me the importance of the time management as well as now I am familiar to my weakness and strength.

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