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DEPARTMENT OF SOFTWARE ENGINEERING

Amharic Online Handwriting Recognition

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Amharic Online Handwriting Recognition

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JUNE 2017

Declaration of Originality

We declare that this project is our original work and has not been presented for a degree in any other university.

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ABSTRACT

Growth in the demand of touch screen devices such as smartphones, tablets and PDAs on global market is influencing the way we interact with computers. because of their architectural design these devices does not include attached keyboards as a text entry mechanism rather they use their screen as input device and let the user touch the screen to operate them. This text entry is mostly similar to the traditional way of text entry. For example works that are usually done like text entry are done using virtual keyboards which have same functionality as the hardware keyboard.

Amharic is the second most popular Semitic language in Africa and it is the working language of Ethiopia. Despite its popularity no valid and workable research is found that can simplify the text entry and input system of this language.

In Spite of rapid technology advancements, text entry on handheld devices is still inconvenient since there is a chance of missing buttons due to their small size specifically input mechanism for Amharic language the use of a keyboard is awkward due to the number of alphabets present in the language. Recently developers are making different keyboard applications but that doesn't seem to solve the problem.

Using the touch screen capabilities of handhelds input method which is similar to handwriting is the best way to replace the current text entry approach. most people learn writing by using a pen and a pencil not a keyboard so writing on a touchscreen device like you write on a piece of paper is the natural and easiest way for the users .users can stroke their hand on a given canvas and the application reads what they write .

Online handwriting recognition (OHWR) is getting renewed interest as it provides data entry mechanism that is similar to natural way of writing.

This project mainly focuses on using this technique to solve the problem mentioned above. The online handwriting recognition project is not new idea .in recent years many researchers are adopting this method for their language use.

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ACRONYMS

OHWR	:	Online handwriting recognition
AOHWR	:	Amharic online handwriting recognition
PDA	:	Personal digital assistant
FDA	:	Fisher's Linear Discriminant Analysis
HMM	:	Hidden Markov model

Chapter 1: INTRODUCTION

1.1 Background

The first touch screen technology was invented in Royal Radar Establishment, Malvern, UK, around 1965 - 1967 by a man named E.A. Johnson. [9] this invention become the door to touch screen devices that don't have physical keyboards attached to them and the screen was being used as both the display area and by using virtual keyboards and other virtual input methods.

QWERTY keyboard is the base for most virtual keyboards. Starting from the first typewriter people use this keyboard arrangement .English alphabet has only 26 letters. Because of this reason it's easier to type letters in English than languages with multiple characters like Chinese and our own Amharic.

Ethiopic alphabet has been used over the past two millennia as a writing system for languages spoken in Ethiopia, which has a population of over 80 million at present. Currently, the alphabet is largely used by Amharic language which is the official language of Ethiopia. Amharic belongs to Afro-Asiatic language family, and today it has become the second most widely spoken Semitic language in the world, next to Arabic [7].

Amharic alphabet has more than 400 characters of which 238 of them are alphabetic characters. The remaining are punctuations, Ethiopian numerals and some infrequently used special characters. The set of Ethiopian characters is arranged in a table form with seven character columns and thirty four character rows. There are thirty four main different alphabets and the rest are derived from those main alphabet by adding common sounds for their respective place. There are also additional alphabets that are not seen in the table above which are used rarely like "ሻ" which does not have seven derived like the thirty four above.

The size of Amharic alphabet doesn't make them fit perfectly on the QWERTY keyboard because it was made for the 26 English alphabet .currently most system use the multiple combination of English alphabet letter to write Amharic letters. Even in the case of customized one we have to touch multiple times to write one letter. This process makes writing Amharic in current handheld devices very hard work .most of the time people use Latin or English alphabets to write Amharic.

	Base Sound	Orders						
		1st (ä)	2nd (u)	3rd (i)	4th (a)	5th (e)	6th (ə)	7th (o)
1	h	ሀ	ሁ	ሂ	ሃ	ሄ	ህ	ሆ
2	l	ለ	ሉ	ሊ	ላ	ሌ	ል	ሎ
3	h	ሐ	ሑ	ሒ	ሓ	ሔ	ሕ	ሖ
4	m	መ	ሙ	ሚ	ማ	ሜ	ም	ሞ
5	s	ሠ	ሡ	ሢ	ሣ	ሤ	ሥ	ሦ
6	r	ረ	ሩ	ሪ	ራ	ሬ	ር	ሮ
7	s	ሰ	ሱ	ሲ	ሳ	ሴ	ስ	ሶ
8	š	ሸ	ሹ	ሺ	ሻ	ሼ	ሽ	ሾ
9	q	ቀ	ቁ	ቂ	ቃ	ቄ	ቅ	ቆ
10	b	በ	ቡ	ቢ	ባ	ቤ	ብ	ቦ
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
31	p'	ጰ	ጱ	ጲ	ጳ	ጴ	ጵ	ጶ
32	f	ፈ	ፉ	ፊ	ፋ	ፌ	ፍ	ፎ
33	p	ፐ	ፑ	ፒ	ፓ	ፔ	ፕ	ፖ
34	v	ቨ	ቩ	ቪ	ቫ	ቬ	ቭ	ቮ

Table 1 Ethiopic Alphabet [7]

ᳫ	ᳬ	᳭	ᳮ	ᳯ	ᳰ	ᳱ
ᳲ	ᳳ	᳴	ᳵ	ᳶ	᳷	᳸
᳹	ᳺ	᳻	᳼	᳽	᳾	᳿
ᴀ	ᴁ	ᴂ	ᴃ	ᴄ	ᴅ	ᴆ

Table 2 Extended characters of the Ethiopic Script [1]

This project aims to solve the problem of android smart phone users while writing Amharic on their smart phones. The project is not a new idea there are many researches and studies on the field of online handwriting recognition .there are many thesis and projects on Amharic online handwriting recognition but there is no available product found in current Android application market that's suited for Ethiopia. In this project we aim to release Working application for android devices that eradicates this problem.

1.2 The Existing System

Currently Amharic text input is processed with virtual keyboard applications on touchscreen devices. Even Though there are many keyboard software's on the smartphone market for language, the fact that the language have a standardized 435 characters [7] still results in using up to three key combinations (in Latin-based keyboard) to enter single character which makes entering text on those devices inconvenient.

On Apr 2015, Google Research Lab announced the release of Google Handwriting Input, a Google Play app for Android allowing users to handwrite text on their mobile devices in 82 different languages. Unfortunately this app up to the start of this project does not include

Amharic on the list of supported languages. However the fact that Google able to make available this app for production level with a lot of languages which are believed to be even more difficult in there cursive nature such as Arabic and number of character sets such as Chinese script opens the door that the current computational resource on those device can be sufficient to implement the current state of the art online handwriting recognition researches.

1.3 Statement of the Problem

In Ethiopia, the usage of handheld devices has increased significantly in the last couple of years. Most of these devices do not support Ethiopic scripts by all means as they are usually built to support English and some other international languages. Text Entry to handheld devices is still inconvenience in spite of technology advancements. The problem tinued on languages with large collection of character set , due to the size of the keyboard it is difficult to display all the character on the language at a time this as a result keyboards are design in the way user have to touch multiple key combinations to enter single character. Recently many smartphone vendors are working on OHWR to solve the problem. To the knowledge of the authors, there is no commercial or open source Amharic OHWR system developed on the smartphone market.

Thus, the potential application of online handwriting recognition system for Amharic is broad because it would help lessening the need for special coaching that is obtained with difficulty currently, to write Amharic text into computers efficiently

1.4 Objective of the Project

1.4.1 General Objective

To explore previous works done on online handwriting recognition and using those works to make a production level usable android Amharic online handwriting recognition system that users will use as a text entry application.

1.4.2 Specific Objective

- explore and analyses thesis and works of study that are based on online handwriting recognition systems for Amharic language
- Analyze and examine the implementation techniques of the projects and theses and find the best way to implement this project
- To find out why most of the projects and thesis fail by that we mean why we do not see more working applications despite all this study
- Design an unconstrained, writer independent Amharic online handwriting recognition system (AOHWRS) for Android platform to support Amharic handwriting entry.
- Implement best workable efficient Amharic online handwriting recognition (AOHWR) keyboard for android environment that's used as a keyboard
- Test and evaluate the performance and usability of the developed system

1.5 Proposed System

This project will use study of previous works on online handwriting recognition to implement functional and workable Amharic online hand recognition systems that will be used as text entry input mechanism for Ethiopic script android users.

There are around 400 alphabetic and numeric characters in Ethiopic script .compared to the English online handwriting recognition systems the task of making a system that will perfectly recognize all the 400 characters is not going to be a simple task. Additionally the system will also incorporate a mechanism that will also identify the Ethiopic punctuation marks.

To account for the systems incorrect understanding of the letters we will put the three close predictions and we will automatically choose the best one, but user has an ability to choose between those suggestions .there is also a choice to delete a word or a letter. The system will try to account for the completion of word and will try to add a space between the words automatically. Users will have the ability to recognize the Arabic numerals like "1" because Amharic numerals are not used that much in recent times.

There will be enter button to proceed to the next line and a free space or a canvas so that people would use their hand to draw the pattern of the letter and that pattern will be recognized.

1.6 Feasibility Study

In this section we will try to analyses project's viability and its degree of being easily or conveniently done. There are many challenges on this project and we will try to be prepared for them as much as possible .that way we will not have problem after the project start.

1.6.1 Economic Feasibility

1.6.1.1 Developmental cost

The technical resources used in this process are mostly found freely .for example Android studio for android development. And more software products that can be used as a technical input for the project are mostly free. Therefore the development process will not be affected negatively by the process of getting those materials.

1.6.1.2 Operational Cost

There will be a primary fee of 25$ to register to Google developers account. That way we are able to put our application in Google play. Other than that there will be no additional fees.

1.6.2 Technical Feasibility

Technically speaking we have firm background knowledge of machine learning approach of this project .we studied the work of previous studies and we have a detailed plan how we are going to solve problems .we have a working dataset for English OHWR and we start making a training sample of this project as soon as possible.

In this project the difficult part will be training the system and getting the dataset .there are no prepared dataset for this project that are available online. The previous people who did the research did not document their datasets so the work will be a bit harder.

1.6.3 Schedule Feasibility

The project will take time around the stage of training and making the datasets. Therefore we will try to finish most of the work and give some extra time for that task. We know this is the most important part of the project so we will use the time management policy listed in time management plan section.

1.7 Scope

Handwriting recognition researches are generally challenging mainly due to the variability in handwriting styles. Moreover, standardized online handwriting recognition data set is not available for the language. The number of characters in the Amharic character set is also large relative to the Latin characters for which researches have been conducted for decades to come up with improved approaches that can bring about a better recognition accuracy. Thus, we put some boundaries on the recognition engine after examining these situations. As result, the scope and limitations of this project are that:

- Only character-level recognition is considered.
- The online handwriting recognition system developed will limit writing style on constrained manner.
- Only the basic Amharic characters and symbols are considered in this project.

1.8 Methodology

There are some generally known steps for implementing OHWR. This include Data collection, Preprocessing Segmentation, Feature Extraction, Training Classification and Post Processing. [3, 5]. This steps are the common steps for online handwriting recognition and we found this while studying previous researches.

1.8.1 Data collection

We will be collecting data by android phone electromagnetic sensors. That means we will get our data by letting user stroke in the android phone. Additionally we will use sample dataset provided by UNIPEN organization.

1.8.2 Preprocessing

Preprocessing techniques are applied to the raw data to end up with a clean, standardized and reduced data removing noises and any unnecessary data points extracted in data collection process.[1] UNIPEN data is prepared for this purpose so it will be clean and standardized and reduced. The collected data might be unclean, inconsistent and with too much noise.

1.8.3 Segmentation

Segmentation is an important task for recognition engines dealing with cursive scripts as it is difficult to distinguish where exactly a character ends and another begins.[1] so we will divide the entire region into smaller pieces to be processed.

1.8.4 Training

This is the part where we train the system with certain dataset to give certain output.

1.8.5 Classification

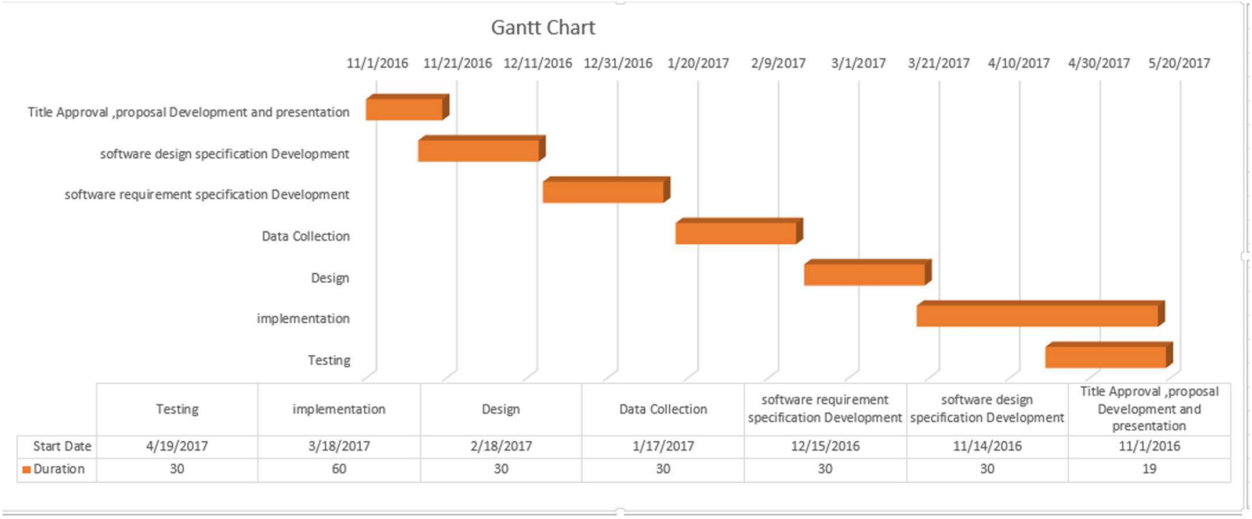
The major task in classification consists of examining features of unknown, newly presented handwritten input pattern against classified saved templates and assigning it to one of the predefined character set class labels. In doing so it needs to apply classification technique.[1]

1.8.6 Post Processing

Post Processing is processing of the output from shape recognition. Language information can increase the accuracy obtained by pure shape recognition [10]

1.9 Project Management plan

1.9.1. Time Management plan



	Testing	implementation	Design	Data Collection	software requirement specification Development	software design specification Development	Title Approval ,proposal Development and presentation
Start Date	4/19/2017	3/18/2017	2/18/2017	1/17/2017	12/15/2016	11/14/2016	11/1/2016
Duration	30	60	30	30	30	30	19

Figure 1: Gantt chart

1.9 .2 Quality Management Plan

There is going to be a minimum standard of quality that we aim to achieve .our minimum requirement is to build efficient workable app. this requirement consists or includes response time, efficiency and workability of the product.
Considering efficiency or response time of the product we want it to be as responsible as possible .that means we want the user to give the app the input and the app should respond in seconds .the user should not wait the app to respond .we would also consider recent versions of android and we want it to satisfy recent material design standards

1.9 .3. Communication Management Plan

Type of Communication	**Method / Tool**	**Frequency/ Schedule**	**Information**	**Participants / Responsibilities**
Internal Communication:				
first meeting [kickoff meeting]	face to face	once	• decide project idea • talk about team structure and working schedule	Project team members Advisor
Project Meetings	face to face	3 times a Week	Project status, problems, risks, changed requirements	Project Team members
weekly report meetings	face to face	once a week	project status , project report , task assessment ,problem identification	Project team members Advisor
Sharing project date	shared Git repository	When available	All project documentation , codes and reports	Project Team Members
Sprint meeting	face to face , shared trello account	once every two week	plan the next sprint, talk about issues raised in the previous sprint , check fulfilment of the previous sprint ,Project status (progress)	Project Team Members Advisor
Daily scrum	shared slack account	once a day	team member posts what he does ,problems he faced and his progress	Project Team Members Advisor
Final Project Meeting	face to face	When available	report project reults	Project Mgr Project Team

External Communication and Reporting:				
Project weekly Report	Word Document , Shared Google Doc file	weekly	Project status - progress - risks	Advisor, project team members, project committee
project report	Word Document	as needed	project proposal SDS SRS	Advisor, project team members, project committee

Table 3 Communication Management Plan

Chapter 2: LITRATURE REVIEW

2.1 Introduction

In this section related researches and projects are reviewed mainly by focusing on the methodologies those researches followed and there result.

2.2 Reviewed System

Late 2005, Abinet Shimels [3], starts the first attempt to develop an online handwriting character recognition engine for Ethiopic characters. In his study, a model for Ethiopic online handwriting character recognition is proposed and a writer-dependent online handwriting character recognition engine for the 33+1 basic Ethiopic characters is designed. In the work a training algorithm and a three-layered recognizer is designed and a reasonably good accuracy is obtained by implementing the proposed algorithms. On the average, a recognition accuracy of up to 99.4% is achieved for the sampled two writers. Recognition accuracy 93.4%, 99%, 99.8% are also obtained for each of the layers of the recognizer respectively.

Yaregal Assabie and Josef Bigun [7], presented pioneering researching on OHWR of Ethiopic script. This work is based on the spatio-temporal relationships of primitive-shaped strokes whose combination forms complex structures of characters. The sequences of primitive strokes and their relationships of the unknown character symbols are matched against a knowledge base for recognition. This paper also presents dataset for Ethiopic script based on the UNIPEN format. The dataset can be used as a benchmark for testing and comparing online recognition systems for Ethiopic script.

The proposed recognition system does not need training because the knowledge base stores possibly occurring sequences of primitives and connectors for each handwritten character. The system also does not require size normalization as we encode only the relative length of primitives. Therefore, the recognition system is reasonably size-insensitive and writer-independent reaching 96% recognition rate. The structural and syntactic analysis provides efficient mechanism to handle neatly and properly written characters. The recognition is improved by employing characteristics of primitives, which helps to predict plausible set of characters for the unknown input [7].

Fetiya Beshi [1], works on implementing Ethiopic online handwriting recognition for android based smartphones. In this work, an Ethiopic Online Handwriting Recognition (EOHWR) input method is
Developed for an Android-based Smartphones where users of the script shall benefit from it by using the developed input method in different applications that exist on the device. In its integration, the work considered previous efforts exerted on the EOHWR.
The work followed a constrained, writer independent approach for its recognition. It developed representation symbols for thirty four basic characters, a numeral and punctuation of the Ethiopic script resembling the natural script and stored their references persistently. Users need to learn the symbols prior to usage. It also puts some restrictions on the orders in which strokes that build a character should be inserted. In its recognition, it followed a template matching technique computing the directional distances between segments of a stroke for each character. As a result its usability and accuracy is affirmed getting an average accuracy of about 80 percent.

[5], presented writer independent online handwriting recognition for Ethiopic characters. The work uses Dynamic Time Warping method for the recognition stage because of its applicability regardless of character sets. Twenty nine major experiments were carried out. Samples of thirty four first order Ethiopic characters were collected from each candidate that were stored in corresponding text files. A total of nine hundred and eighty six Ethiopic character samples were tested for recognition. The recognition rates per subject ranged from a low of 73.53% to a high of97.06%. The average recognition rate for this experiment is 86.917%.

Recently Bekalu Mamo [2], presented a writer independent, online handwritten Amharic word recognition using fisher discriminant analysis and HMM. As part of character recognition, three approaches were adopted and tested. The first one using Fisher's Linear Discriminant Analysis (FDA) to discriminate vectors. The second approach is to extract features from a given input sequence using a predefined set of primitives using HMM model. And the third approach is by scanning the input sequence horizontally, vertically and hybrid of the two scanning.
The result for the character recognizer diminishes as the number of character increases for the first case. For the case of HMM the character recognizer engine predicted an average of 3.94 %. Using the scanning approach, first a vector of 300 length is used and resulted in an average

40.51%, 44.41% for vertical scanning and 63.11% for the hybrid. However, when the vector size is reduced to 70 to increase operational performance, the result is impacted accordingly to 25.66% for the horizontal scanning, 18.77% for the vertical scanning and 39.85% for the hybrid approach. Word recognition using the hybrid approach resulted in 37.9% recognition performance.

Finally the work concludes that hybrid approach increases the performance of the recognition system than individual approaches. Even though the importance of handwriting recognition is without doubt, by taking the whole character set into a single training set, in case of HMM and FDA approach, impacts the recognition result.

2.3 Summary of the review

To wind up the survey, we have provided the following points to summarize what we obtained from the survey:

- Based on the fact that the number of characters in the Ethiopic character set is more than 400 which is a big number as compared to the 26 Latin characters. The Japanese character set contains 6000-7000 characters that makes it more complex than the Ethiopic character set. Moreover, the complexity of Japanese/Chinese characters is expressed in terms of the large number of strokes used in a single character. The main difference between Ethiopic and Arabic characters is that Arabic characters are cursive in nature and Ethiopic characters are not.

- The training data size will have an impact on the accuracy rates achieved. If the recognition system is to be designed for handheld devices, increasing the training data size will have a problem due the storage limitations of such devices. Moreover, the classification algorithms are computationally expensive. Hence, if the recognition system is to be designed for handheld devices we must take into consideration the storage limitations and computational capability of the devices and come up with a design that can fit these limitations.

- From the pioneering research on OHWR for the Amharic the structural approach seems to be more appropriate for Ethiopic character set as HMMs are good options for cases in which segmentation is a big problem and the number of character is less in number. Since Ethiopic characters are naturally written in discrete manner, segmentation would not be a big problem [3]. Besides, the number of characters is above 400, which is not a small number. From experience, we observed that different Ethiopic writers write similar characters with different stroke type, number and order. Thus, we underlined that the structural approach should not be based on prior identification of strokes in the

Ethiopic characters. Rather the set of strokes must be obtained from the writer's style. This also makes the system to be writer-dependent and evidently increase the recognition accuracy [3].

Chapter 3: Requirement Analysis

3.1 Introduction

3.1.1 Purpose

This document is the Software Requirements Specification (SRS) for the Amharic Online Handwriting Recognition (AOHWR) system. Its purpose is to convey information about the application's requirements, both functional and nonfunctional, to the reader. Furthermore, this paper provides: 1. A description of the environment in which the application is expected to operate. 2. A definition of the application's capabilities. 3. A specification of the application's functional and nonfunctional requirements 4. A description of use cases in the system. First, it is expected that the application designers will use the SRS. Developers will use the information recorded here as the basis for creating the application's design. Second, the client for the project, the examiner in our case is expected to review this document. The SRS will serve to establish a basis for agreement between the customer and development team about the functionality to be provided by the system.

3.2 Scope

This software development project will develop Amharic Online Handwriting Recognizer. The system will be an Android based application, allowing its users to enter Amharic text directly by writing on a canvas. It will enable users to write using either their hand or a pen tool. The product is intended to replace the regular QWERTY based virtual keyboard under all aspects. The system will be able to recognize all the basic Amharic characters and symbols on a character level. Moreover, the system will have the capability to enable user deleting, splitting and merging text. Thus, users will have natural writing experience. Users will have to write their text inside a constrained canvas that can serve as a grid. Furthermore, the system will not cover mathematical formula and non-basic Ethiopic character recognition.

3.3 General Description

3.4 Product Perspective

Online handwriting recognition is not a new field of study. Even in Ethiopia, there are a lot of academic researches done in this area, nevertheless none of them develop a system that can used in production environment. This system is a replacement of virtual keyboard which is the popular approach for text entry in smartphones, especially in Android devices. Few similar systems exist for other languages in smartphones and more devices. However, to the best of our

knowledge, the system is the first OHWR implementation for Amharic language.

3.5 Product Functions

This system will provide a primary input method for Android-based devices. Moreover, it will present more natural writing experience for users. Specifically, the system will have the following functionalities.

- The system should recognize handwritten text
- The system should allow deleting text by striking though it
- The system should allow user deleting written character using backspace button
- User shall be able to edit text by splitting, joining and inserting a new one.
- User shall be able to override character while writing
- The system shall consider the linguistic context of text on recognized result.
- The system will improve its recognition accuracy through time

3.6 User Characteristics

Users of this product doesn't have that much specified classes. To use this applications users have to have a smart phone, they must communicate in Amharic, they must know how to write in Amharic.
Users will use this applications more frequently than others because it's embedded keyboard application. It can be used within many applications if we want a text entry.

Frequency of use - on Demand
Subset of product function used - users will use their hand input the characters shape on their device and the application will recognize the shape and insert a letter appropriate with the shape.
Minimum technical expertise - basic knowledge of how to use android phones
Minimum educational level - read and write Amharic Language.

3.7 General Constraints

First of all, the application will have a constrained input field so that user can write the text in predefined area. This will help us to minimize the work overhead in the segmentation section of the work.

Reliability constraint - the system must be available 24/7

Criticality of the application - the system is important for users who want to use Amharic as their text input, it aims to replace keyboards that do so.

Security - this application will not store any User data.

Language constraint - this application works for only Amharic language input so the interfaces will also be in Amharic.

3.8 Assumptions and Dependencies

One assumption of this application is that the user must have a basic know-how about android phones and must need this application for text entry, this requires basic Amharic writing skill.

3.9 External Interface Requirements

3.9.1 User Interfaces

Here are different parts of the system from use case perspective.

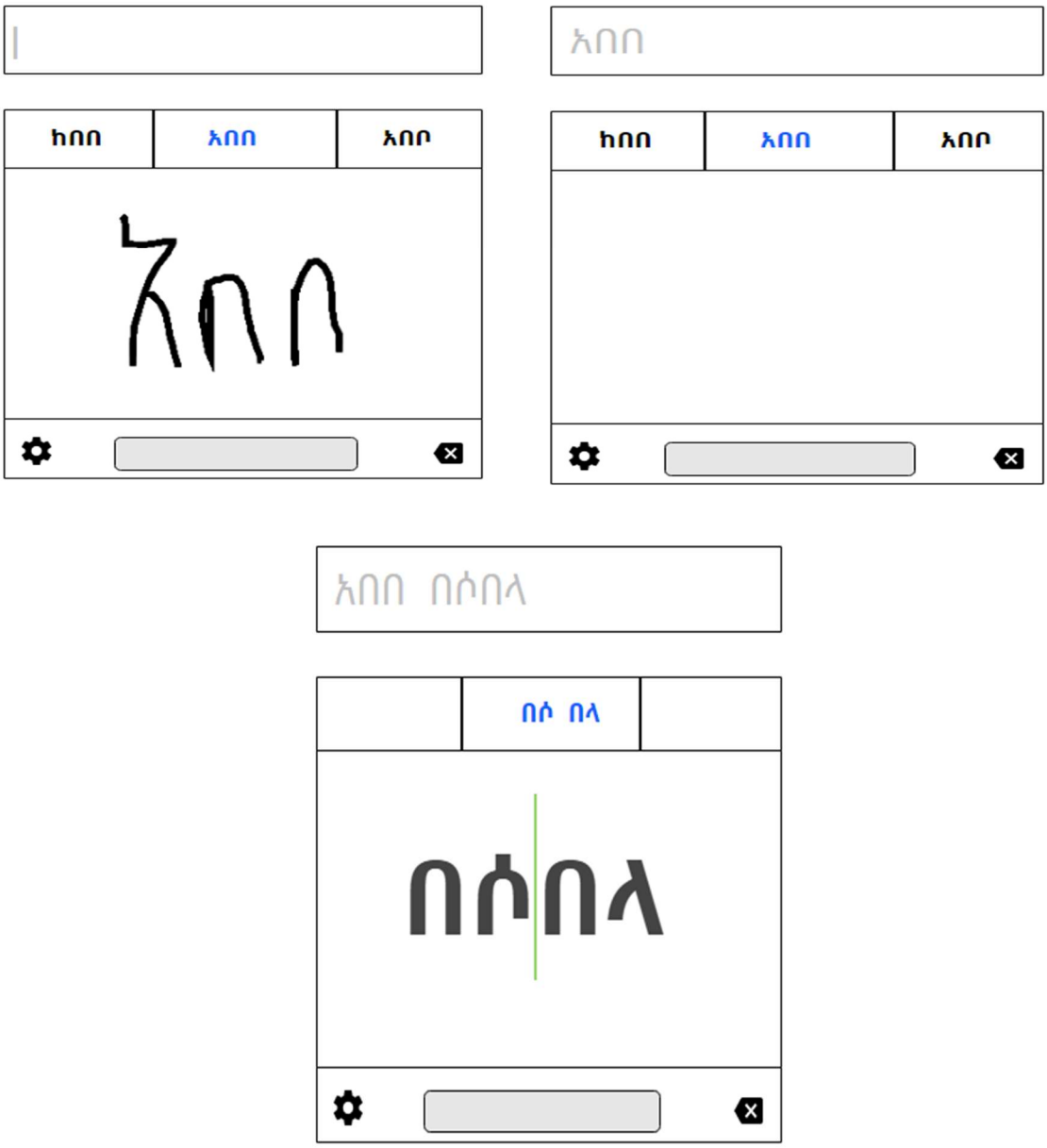


Figure 2 Keyboard UI

Figure 3 Settings Panel

3.9.2 Hardware Interfaces

The system is intended to run android enabled devices with the following specification.

- ARM processor
- Estimated 20MB disk space

3.9.3 Software Interfaces

The system requires android operating system with the following version specification.
Name: Android OS
Specification Number: Android 4.4 + (Kitkat)
Version Number: API level 19.0 +
Source: Google Inc.

3.9.4 Communications Interfaces

3.10 Functional Requirements

This section describes specific features of the software project. If desired, some requirements may be specified in the use-case format and listed in the Use Cases Section.

- The system should recognize characters written by user
- The system should allow deleting word
- The system should enable user deleting written character
- User shall be able to edit word by splitting a word, joining words and inserting a new one.
- User shall be able to override character while writing
- The system shall have word prediction feature

3.11 Use Cases

3.11.1 Use case #1 Write Character

Item	Description
User Case Name	Write Character
Description	This use case allows to insert a character to intended text field
Actor	End User
Pre-Condition	The OHWR should be selected as input method
Flow events	1. The user focus on edit box of any application 2. The system shows an interface that enable an actor to write character 3. The user write on the canvas provided by the system UI 4. The system concurrently draws on position where the actor places his/her pen. 5. The system listen for pen up event and sets the scrolling timer[Alternate A1] 6. The system recognizes the handwritten input and present results on result panel based on system accuracy order 7. The user select one of results presented on result panel 8. The system inserts the selected result on the text field 9. The system clears the writing canvas 10. Use cases ends
Post Condition	The actor will be able to get the intended text inside the desired text field.

Alternate A1:	5.1. The actor touch space button[Alternate A2] 5.2. The scrolling time expires 5.2. The system will reset the scrolling timer
Alternate A2:	5.1.1. The system recognizes that the writing is completed 5.1.2 The system will reset the scroll timer

Table 4Use Case Write character

3.11.2 Use Case #2 Delete Character

Item	Description
User Case Name	Delete Character
Description	This use case enable the actor to delete a written character
Actor	End User
Pre-Condition	The Actor should write at least one character
Flow events	1. The actor select the text which he/she want to edit 2. The system present the selected text on the canvas 3. The actor deletes required amount of character from the presented text by clicking the backspace button 4. The system concurrently updates the text on the text field 5. The system clears the writing canvas 6. Use cases ends
Post Condition	The required text will be modified as intended

Table 5 Use Case Delete character

3.11.3 Use Case #3 Split Text

Item	Description
User Case Name	Split Text
Description	The system will enable the actor to split written text into two separate texts
Actor	End User
Pre-Condition	The Actor should write at least two characters
Flow events	1. The actor selects the text intended to split from the text box 2. The system present the selected text on the canvas 3. The actor split the presented text by drawing a vertical line on the desired point 4. The system inserts a space character at the splitting point 5. The system concurrently updates the text on the text field 6. The system clears the writing canvas 7. Use cases ends
Post Condition	The required text will be splitted as intended

Table 6 Use Case Split Text

3.11.4 Use Case #4 Join text

Item	Description
User Case Name	Join Text
Description	The system will enable the actor to join two written text into a single text

Actor	End User
Pre-Condition	The actor should write at least two characters separated by space character
Flow events	1. The actor selects the written text intended to split from the text box 2. The system present the selected text on the canvas 3. The actor join the presented text by drawing a horizontal curve between the texts. 4. The system removes the existing space character and join the text to a single text. 5. The system concurrently updates the text on the text field 6. The system clears the writing canvas 7. Use cases ends
Post Condition	The required texts will be joined as intended

Table 7 Use Case Join Text

3.11.5 Use Case #5 insert text

Item	Description
User Case Name	Insert text
Description	The system will enable the actor to insert new text in between an existing text
Actor	End User
Pre-Condition	The Actor should write at least two characters
Flow events	1. The actor selects the text intended to update from the text box 2. The system present the selected text on the canvas

	3. The actor clicks on the point on which he/she want to insert new text 4. The system focus and shows cursor on the point 5. The actor insert intended text at the specified point 6. The system concurrently updates the text on the text field 7. The system clears the writing canvas 8. Use cases ends
Post Condition	The required text will be updated as intended

Table 8 Use Case insert text

3.11.6 Use Case #6 Erase text

Item	Description
User Case Name	Erase Text
Description	The system will enable the actor to erase single character or part of the written text.
Actor	End User
Pre-Condition	The edit box should have at least one character
Flow events	1. The actor selects the written text intended to modify from the edit box 2. The system presents the selected text on the canvas 3. Alternate A1 or Alternate A2 4. The system concurrently updates the text on the text field 5. The system clears the writing canvas 6. Use cases ends
Post Condition	The required texts will be joined as intended
Alternate A1:	3.1.1. The actor erases a character from the presented text

	3.1.2. The system removes the character from the text on the canvas
Alternate A2:	3.2.1. The actor writes horizontal line on the presented text on the canvas 3.2.2. The system removes the part of the text on which the horizontal line touches.

Table 9 Use Case Erase text

3.11.7 Use Case #7 Overwrite Character

Item	Description
User Case Name	Overwrite character
Description	The system will enable the actor to overwrite written character.
Actor	End User
Pre-Condition	The Actor should write at least one character
Flow events	1. The actor selects the text intended to overwrite from the text box 2. The system present the selected text on the canvas 3. The actor overwrite on the intended character from the presented text 4. The system replace the former character by the new one. 5. The system concurrently updates the text on the text field 6. The system clears the writing canvas 7. Use cases ends
Post Condition	The required text will be updated as intended

Table 10 Use Case Overwrite Character

3.11.8 Use Case #8 Scroll Writing Canvas

Item	Description
User Case Name	Overwrite character
Description	The system will enable the actor to review written text and make required updates
Actor	End User
Pre-Condition	The system should scroll at least on character
Flow events	1. The actor scrolls the writing canvas 2. The system presents queued text proportional to the scrolling. 3. Use cases ends
Post Condition	The required text will be shown

Table 11 Use Case Scroll Writing Canvas

3.11.9 Use Case #9 Change inc thickness

Item	Description
User Case Name	Change inc thickness
Description	The system will enable the actor to change the inc thickness of drawing pen.
Actor	End User
Pre-Condition	The Actor should open OHWR
Flow events	1. The actor clicks on setting button 2. The system presents the settings panel

	3. The actor adjusts the inc thickness using the scroll option presented 4. Use cases ends
Post Condition	The inc thickness of the pen is adjusted as required

Table 12: Use Case Change inc thickness

3.11.10 Use Case #10 Change scrolling speed

Item	Description
User Case Name	Change scrolling speed
Description	The system will enable the actor to change the scrolling speed of the canvas (the duration by which the system scroll the writing canvas).
Actor	End User
Pre-Condition	The Actor should open OHWR
Flow events	1. The actor clicks on setting button 2. The system presents the settings panel 3. The actor adjusts the scrolling speed using the scroller. 4. Use cases ends
Post Condition	The scrolling speed of writing canvas is adjusted as required

Table 13 Use Case Change scrolling speed

3.11.11 Use Case #11 View help

Item	Description
User Case Name	View help
Description	The system will enable the actor to view system usage help.
Actor	End User
Pre-Condition	The Actor should open OHWR
Flow events	1. The actor clicks on setting button 2. The system presents the settings panel

	3. The actor clicks on the help button 4. The system loads the help view 5. Use cases ends
Post Condition	The actor explore the help section

Table 14 Use Case View help

3.11.12 Use Case #12 Change Color

Item	Description
User Case Name	Change color
Description	The system will enable the actor to change the color of the drawing canvas
Actor	End User
Pre-Condition	The Actor should open OHWR
Flow events	1. The actor clicks on setting button 2. The system presents the settings panel 3. The actor clicks on color picker icon 1. The system presents the color picker 2. The actor selects color of his/her choice 3. Use cases ends
Post Condition	The drawing color of the canvas is changed as intended

Table 15 Use Case Change Color

3.11.13 Use Case #13 Update usage data sharing policy

Item	Description
User Case Name	Update usage data sharing policy
Description	The system will enable the actor to enable or disable sharing usage data to improve the system's recognition performance.
Actor	End User
Pre-Condition	The Actor should open OHWR
Flow events	1. The actor clicks on setting button 2. The system presents the settings panel 3. The actor updates the toggle switch button for sharing usage data 4. The system updates and apply setting 5. Use cases ends
Post Condition	The usage data sharing policy is updated.
Alternate A1:	2.2 The actor erases a character from the presented text 2.2 The system removes the character from the text on the canvas
Alternate A2:	2.2.1. The actor writes horizontal line on the presented text on the canvas 2.1.2. The system removes the part of the text on which the actor writes the horizontal line.

Table 16 Use Case Update usage data sharing policy

3.12 Non-Functional Requirements

3.12.1 Performance

The system should take an acceptable response time to recognize and display hand written user input. To be specific the system must take 1 second to respond to the user.

3.12.2 Reliability

The system should be able to explicitly recognize user input.

3.12.3 Availability

The system should be available for any editable application on the host device.

3.12.4 Security

The system should not share application data and log without user's permission.

3.12.5 Maintainability

The system shall provide cloud service to collect crowd dataset and improve systems recognition accuracy throw time. Users shall update the system from remote server that it will provide better features from systems experience.

3.12.6 Portability

The system will be portable around any android enabled device that fulfil the minimum requirements.

3.14 Design Constraints

The fact that user couldn't update the system at all will result the systems performance being limited to the initial stage of deployment. As a result users will not benefit from the system's recognition performance improvement that is resulted by data collected from peer system users.

3.15 Change Management Process

Any team member or stakeholder may submit a change request for the AOHWR Project. The Advisor for the project will chair the team and any changes to project scope, cost, or schedule must meet his approval. All change requests will be logged in the change control register and tracked through to completion whether approved or not. In general, the following steps comprise the change control process:

- Identify the need for a change
- Log change request, to maintain all change requests
- Conduct an evaluation for the request
- Advisors decision
- Implement change

If a change is approved by the advisor, the team will update and re-baseline project documentation if necessary as well as ensure any changes are communicated to the team and stakeholders.

Chapter 4: SYSTEM DESIGN

4.1 General Overview

The purpose of Amharic online handwriting recognition Application is to enable users to have a natural way of writing the Amharic language. It will give the users the ability to enter Amharic text in most efficient and secure way and will be used as embedded keyboard, but since users might need to write English, it provides simple virtual English keyboard.

The system will have three main components the Android application, the recognition engine and the server for better recognition and prediction performance. The Android application will have the main canvas that user write to input the text. It also gives the deletion, scrolling, joining, splitting and erasing functionality. The recognition Engine does most of the work it processes the input test and recognizes the input character and using a simple dictionary it suggests user with a couple of choices including the row identified input. Finally, the server will collect data to increase prediction accuracy and gives the system better and accurate performance over time.

4.2 Development Methods & Contingencies

This project will follow the standard object-oriented development approach using Black Box Design Pattern.

Scrum will be used as a Software development Methodology. We will be developing this application in Different Iterations, and there will be different outputs or release at the end of each iteration.

The Software Designs may change due to various requirement changes. the fact that we use scrum means we are open to any design changes throughout the development process.

4.3 System Architecture

4.3.1 Subsystem decomposition

The System has three principal components. The Android App Comprises the user input collector element and the primary recognition engine that consists of the main recognition task the system does. The Server has a component that gives additional functionality .it enhances the rate of suggestion by collecting user choice data after prediction.

The recognition Component has four parts. The preprocessing part eliminates unwanted drawings, normalizing the text and slope correction Tasks. The feature extractor identifies the features for recognition task, and the recognizer does the recognition task using Neural network.

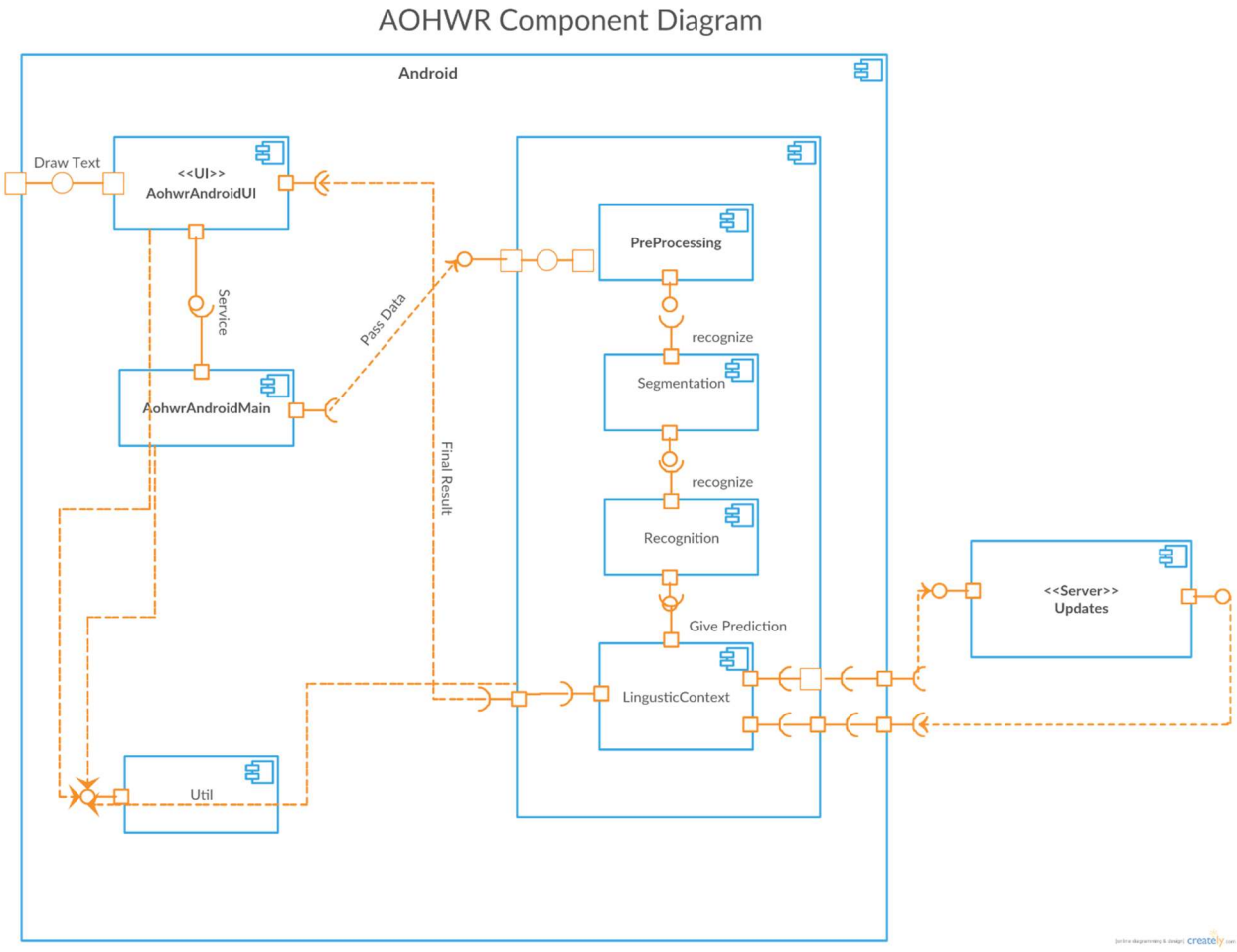


Figure 4 AOHWR Component Diagram

4.3.2 Hardware/software mapping

This segment demonstrates architecture of a system as the placement of software objects to installation targets. It describes the hardware used in the system implementation and execution environment.

The Application is mainly operational on the Android Device. It can operate without the server interaction, offline.

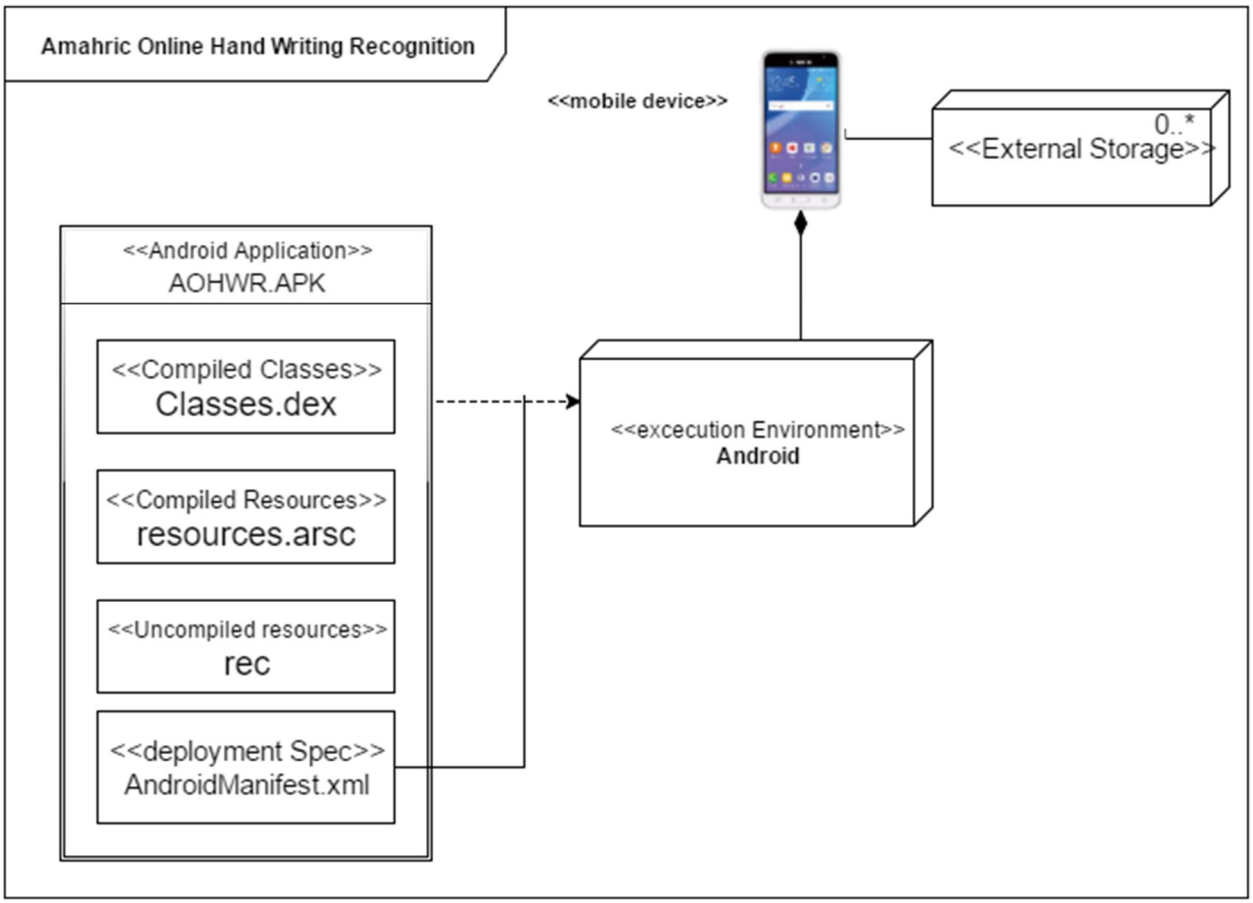


Figure 5 Hardware/Software mapping

4.4 Object Model

4.4.1 Class Diagram

Class Diagram delivers a summary of the target system by relating the objects and classes inside the system and the associations between them. This sections describes objects classes and relationship between the two that is needed to build the AOHWR application.

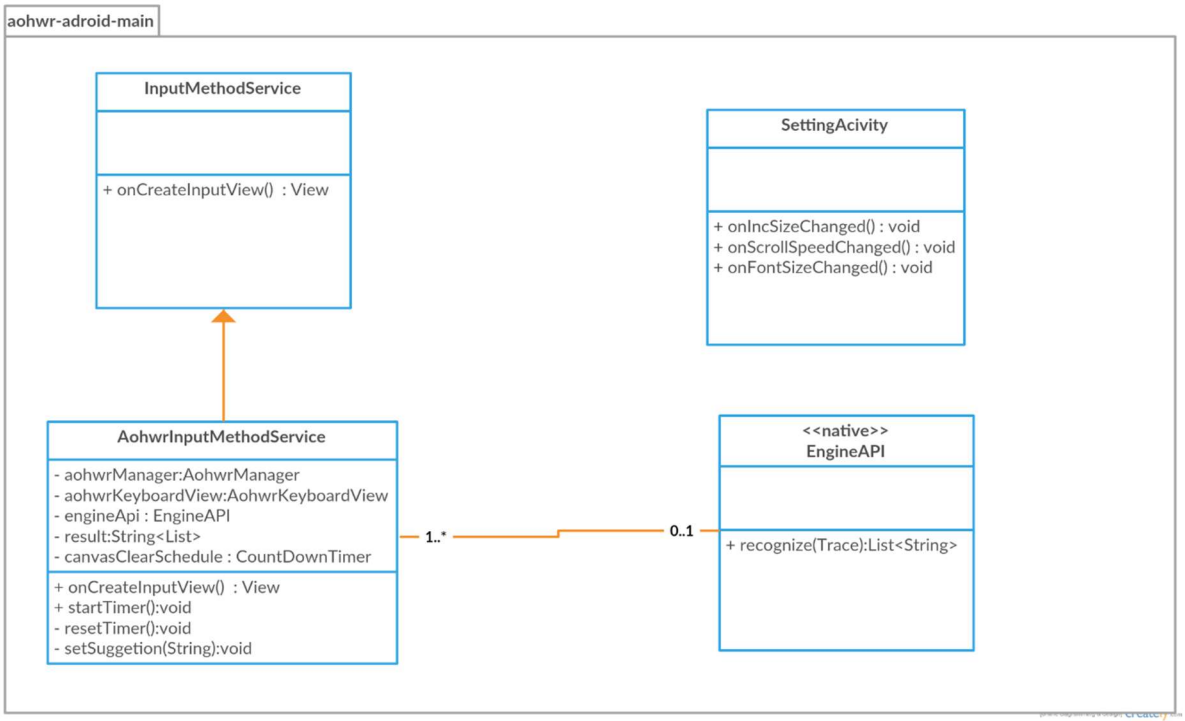


Figure 6: aohwr-android-main

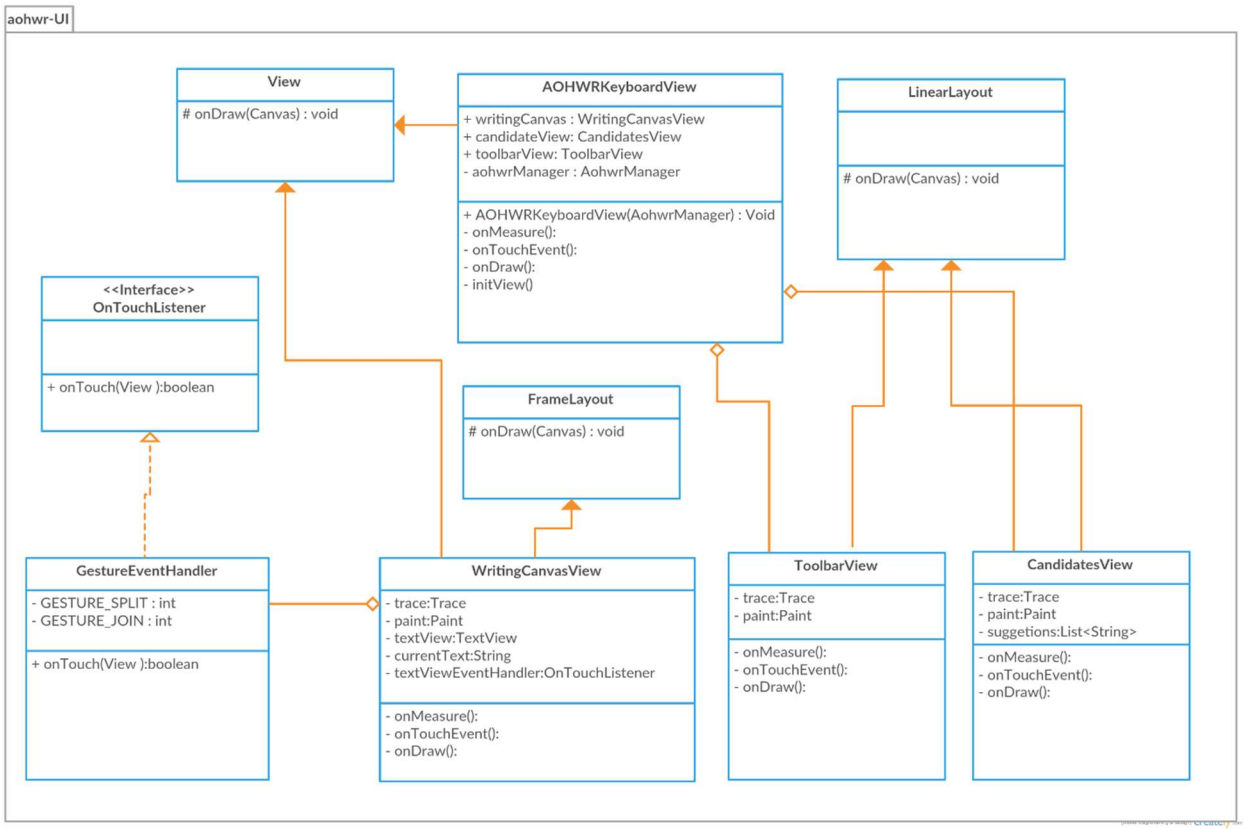


Figure 7 Class Diagram - Android UI

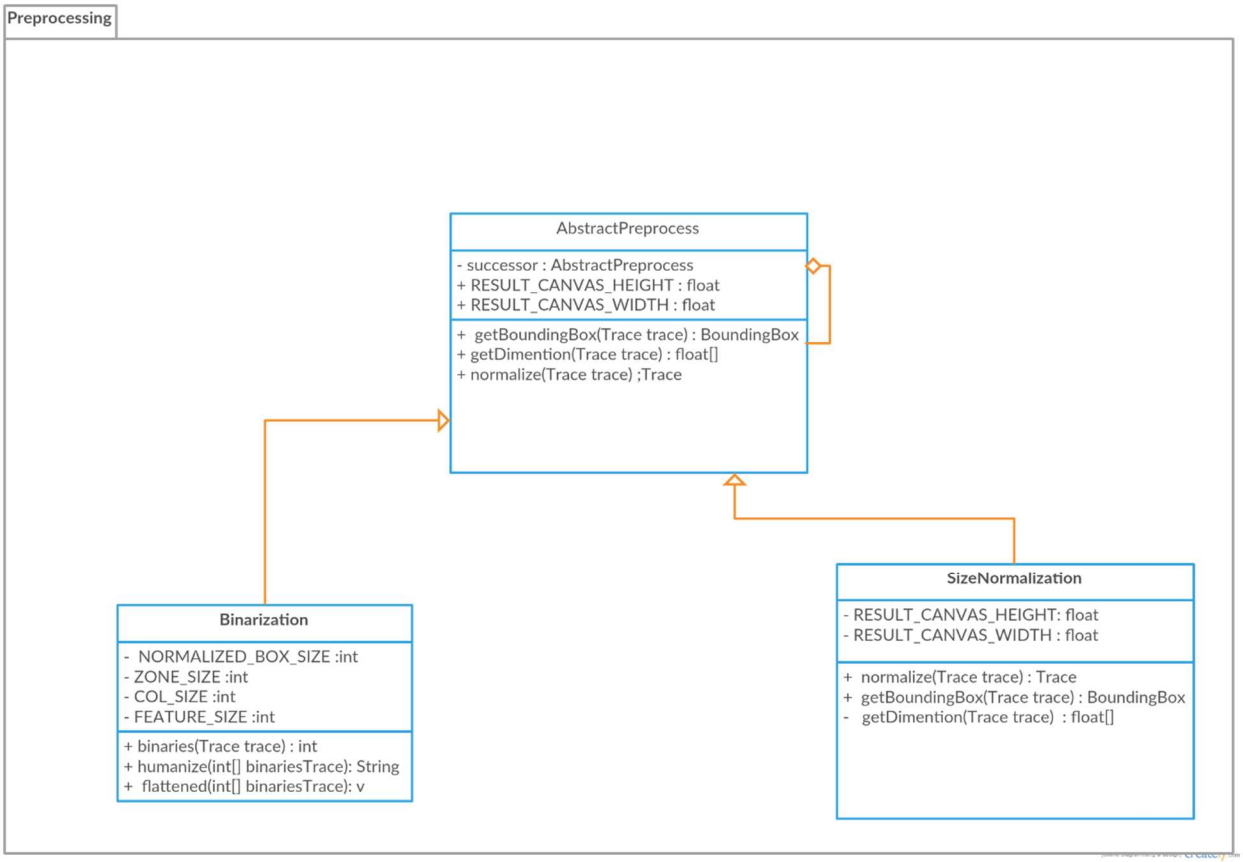


Figure 8 Class Diagram - Preprocessing

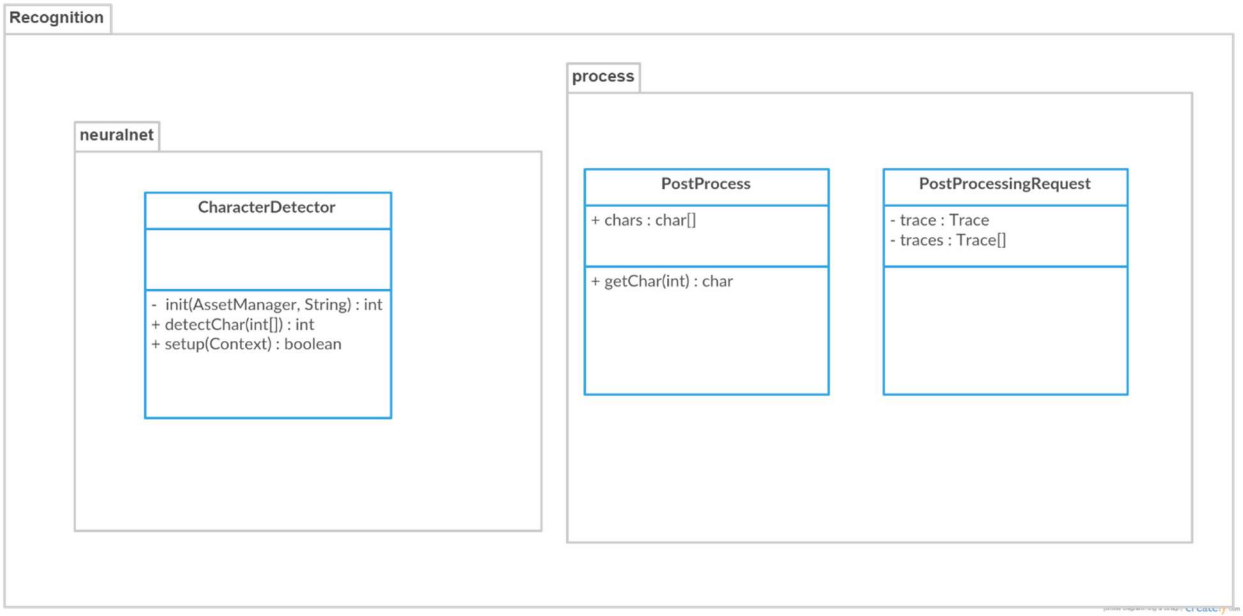


Figure 9 Class Diagram – Recognition

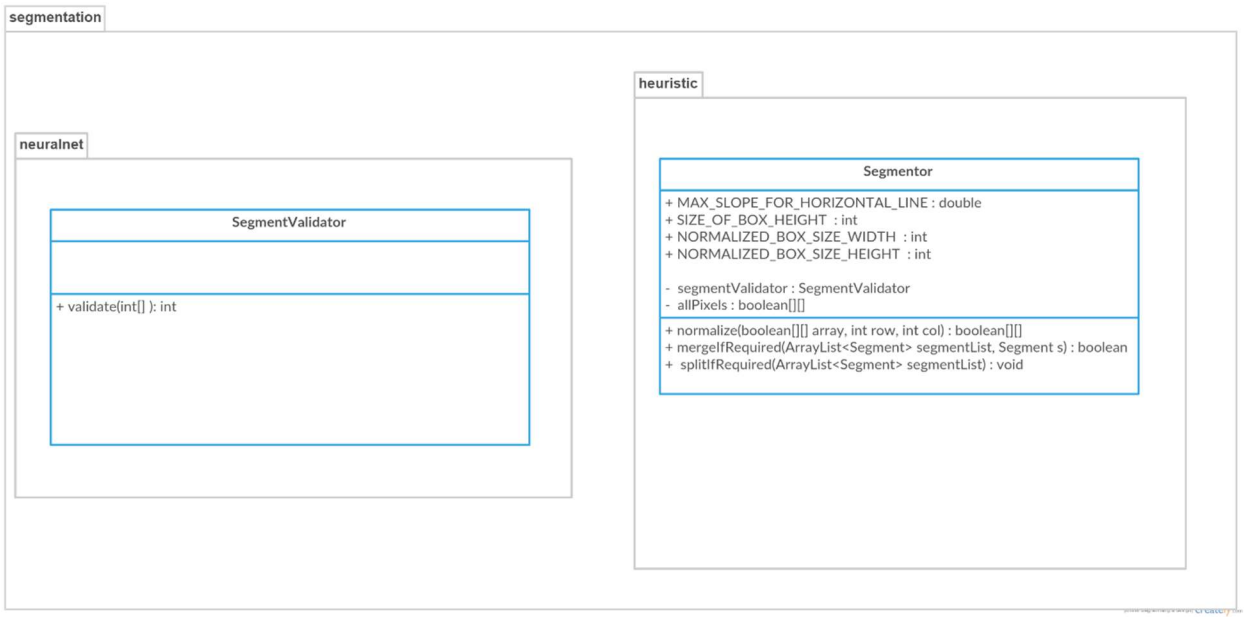


Figure 10: segmentation module

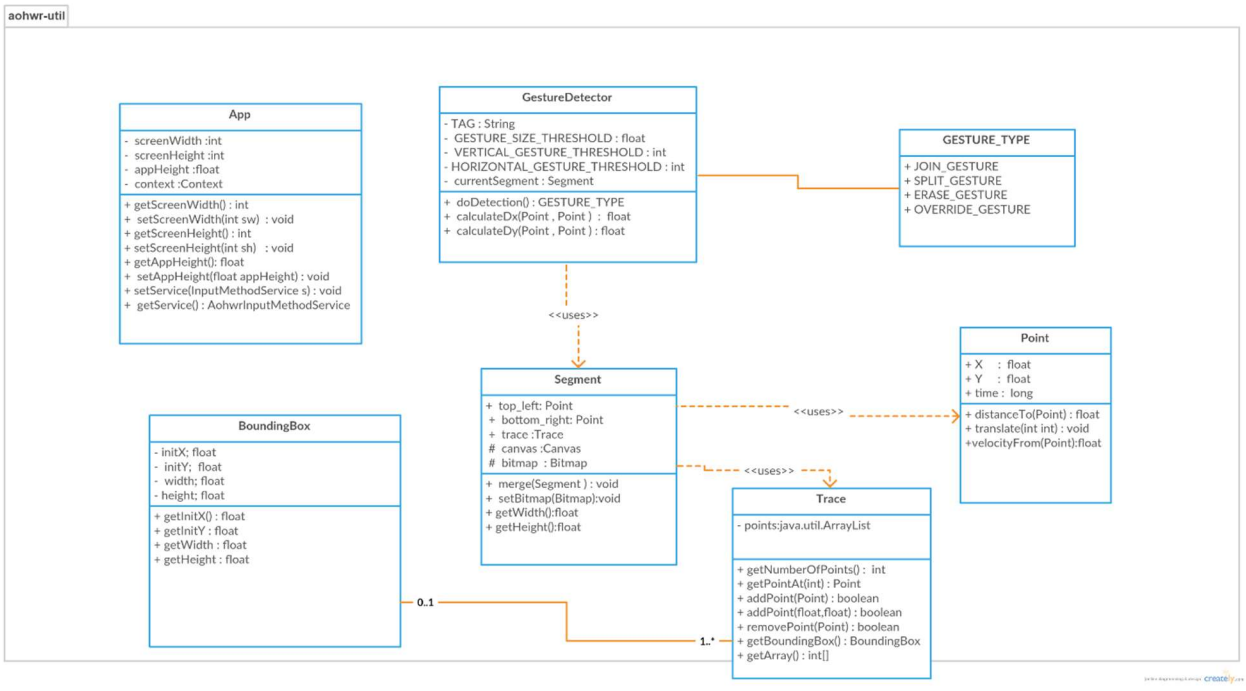


Figure 11 : aohwr – Util

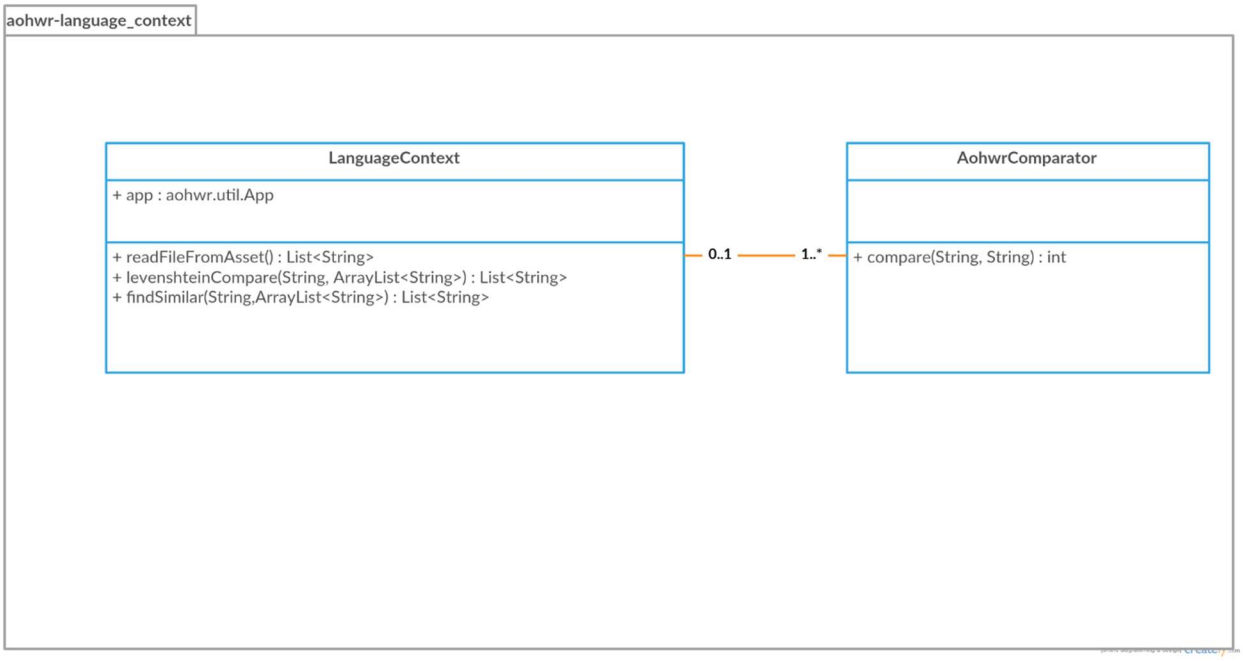


Figure 12: Language Context module

4.4.2 Sequence Diagram

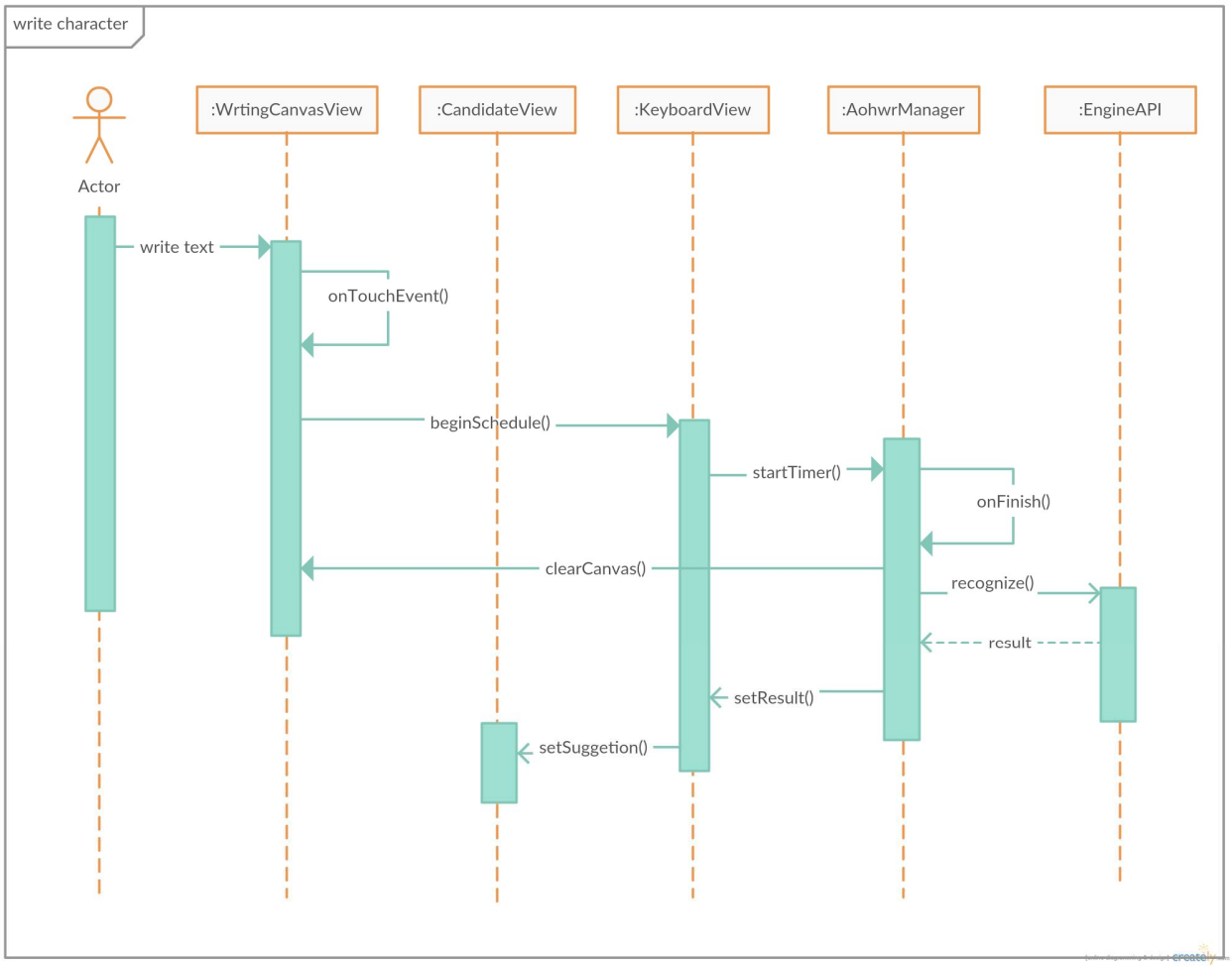


Figure 13 Sequence Diagram - Write Character

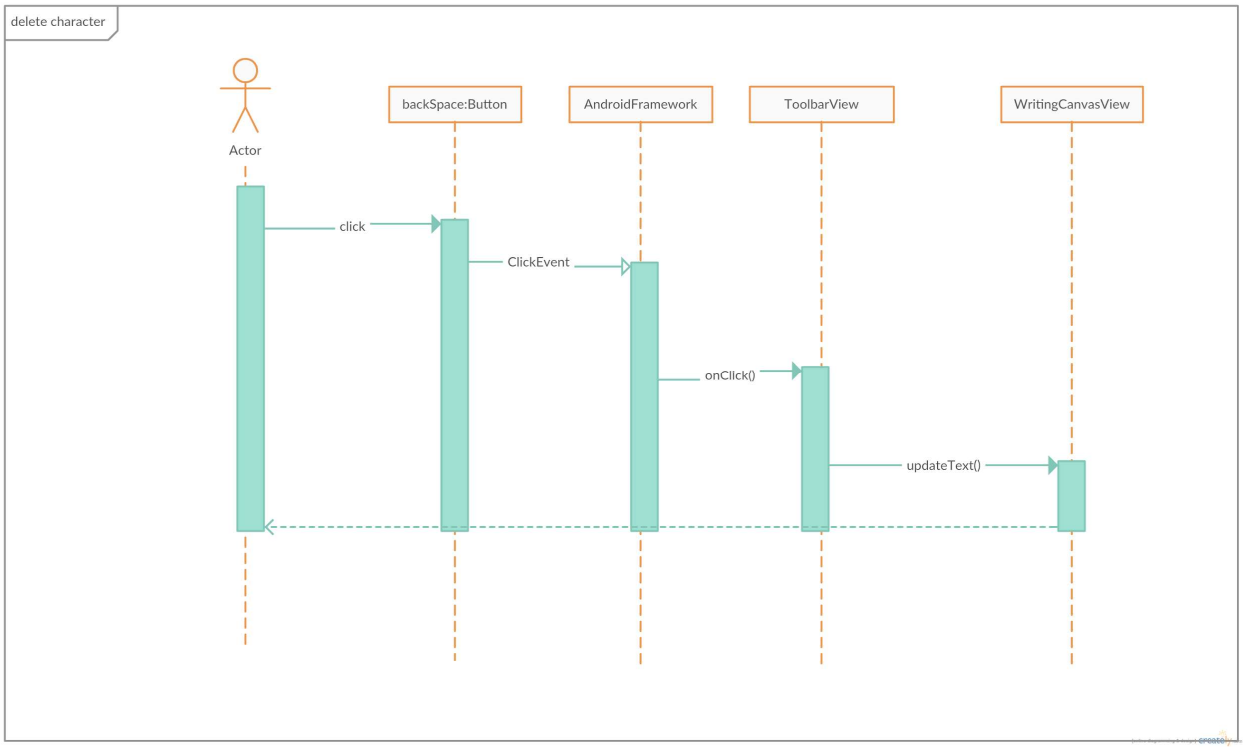


Figure 14 Sequence Diagram - Delete Character

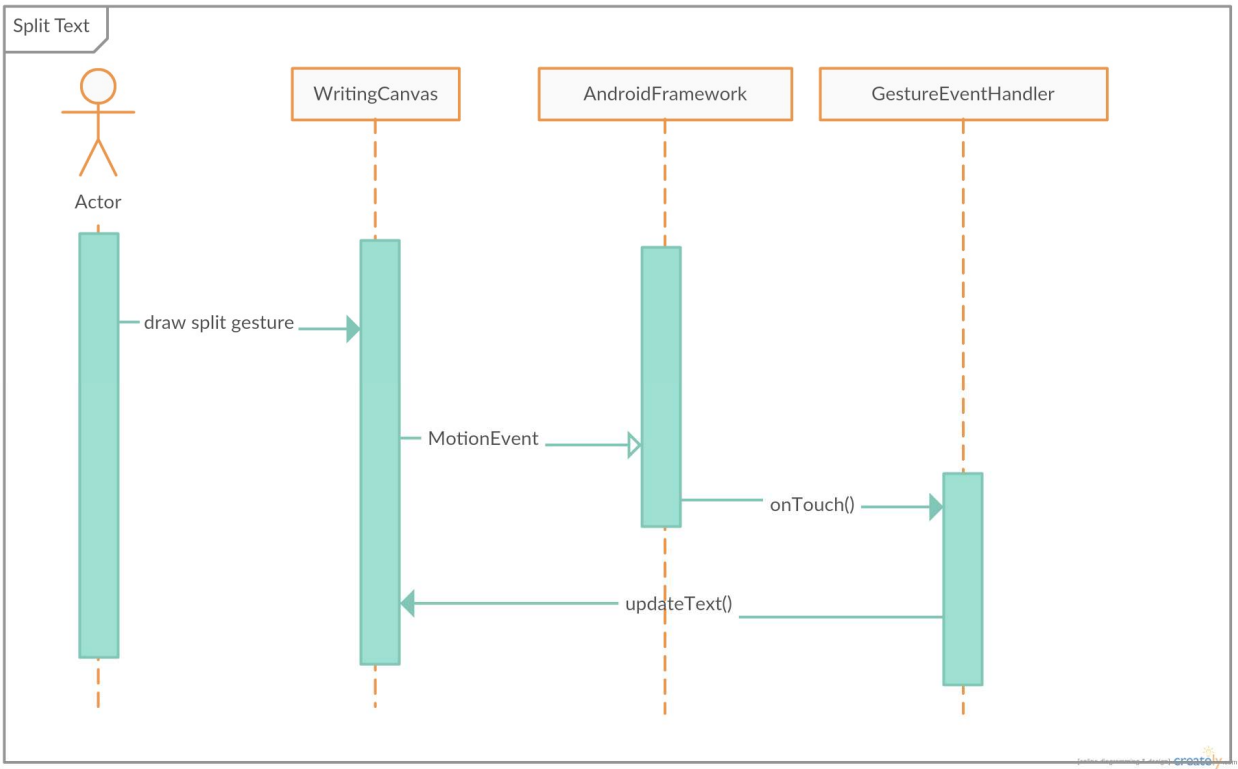


Figure 15 Sequence Diagram - Spit Text

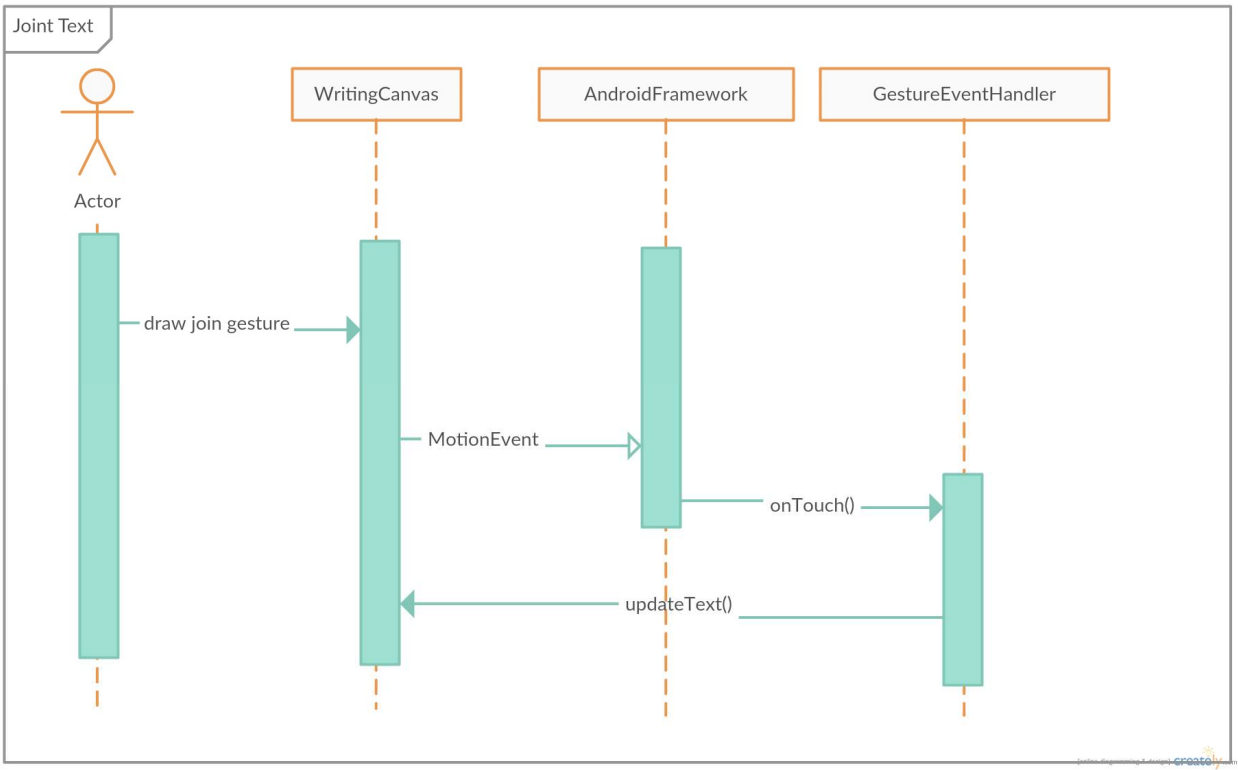


Figure 16 Sequence Diagram - Join Text

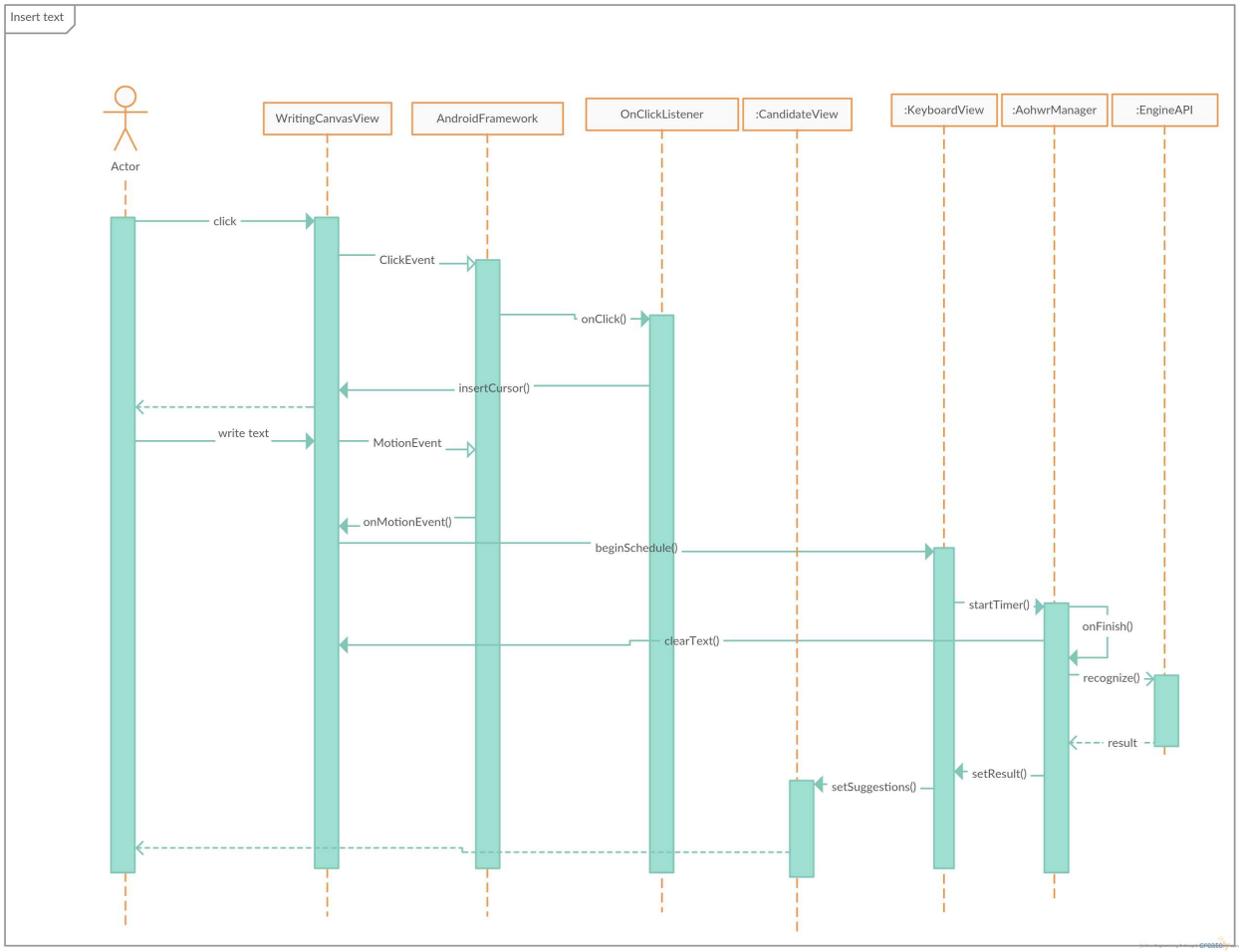


Figure 17 Sequence Diagram - Insert Text

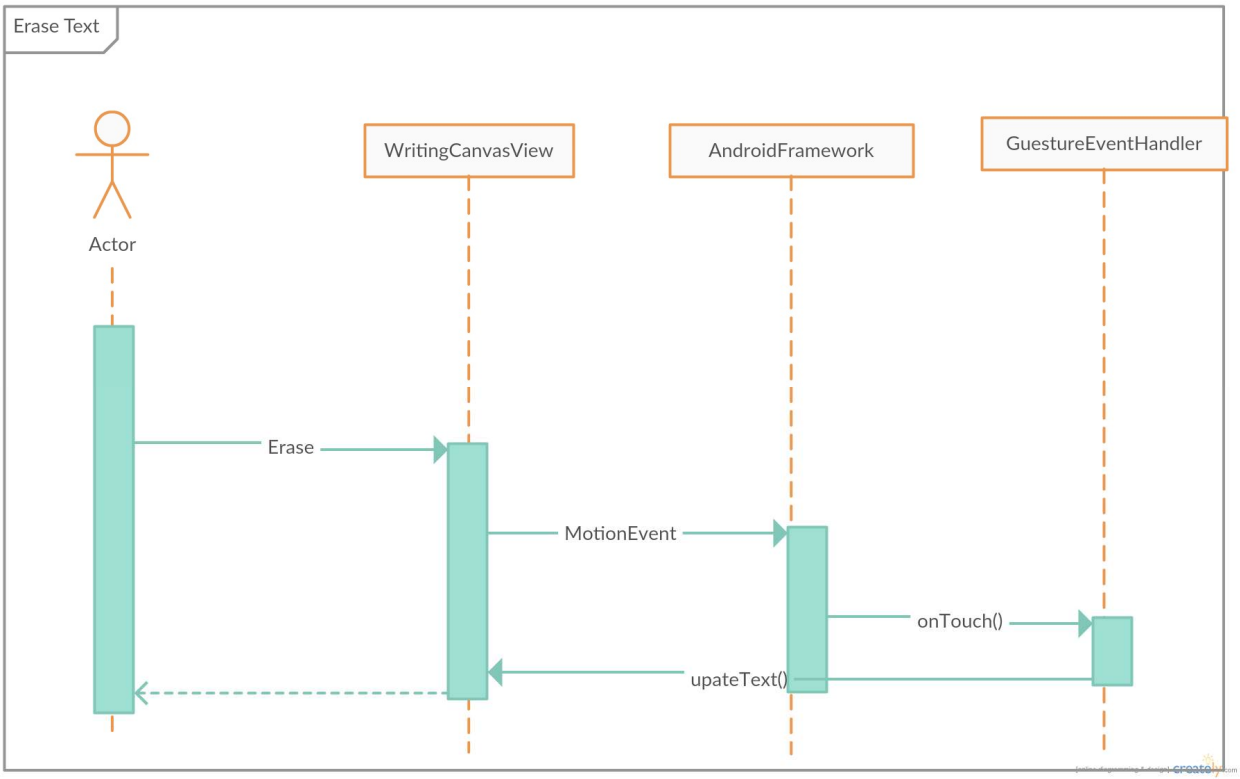


Figure 18 Sequence Diagram - Erase Text

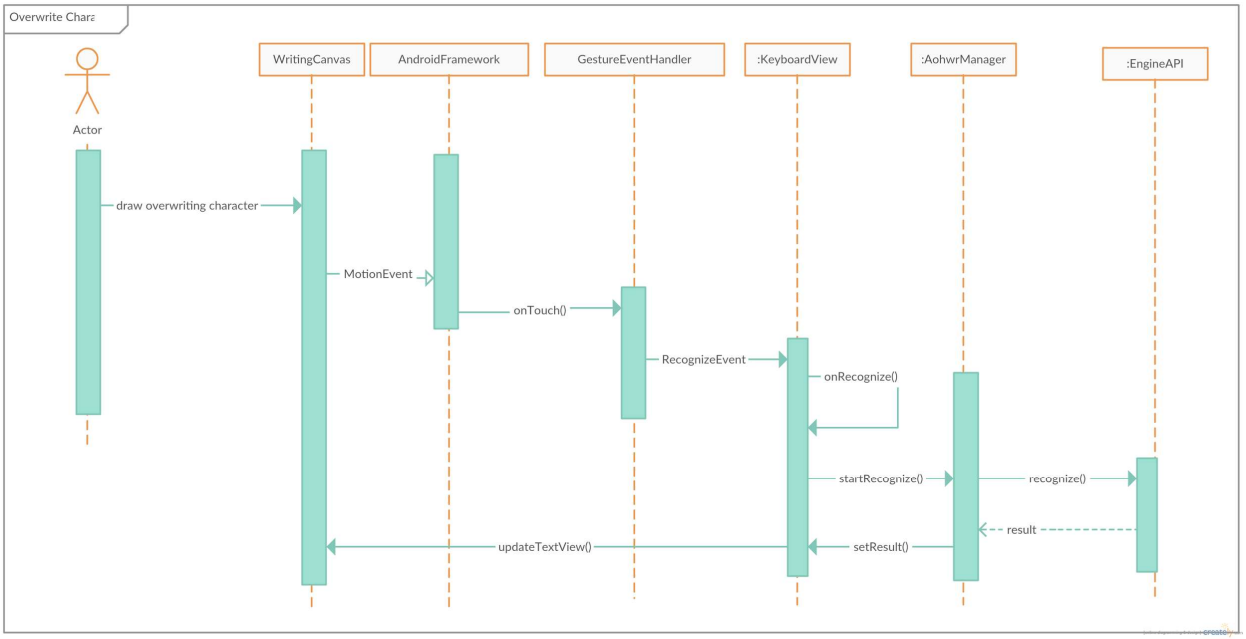


Figure 19 Sequence Diagram - Erase Text

4.5 Detailed Design

PreprocessMain

Attribute	Type	Visibility	Invariant
request	Request	Public	Request <> NULL and must contain a Trace object

Operation	Visibility	Return type	Argument	Pre-Condition	Post Condition
process	Public	List<Trace>	Trace	The Trace must contain unprocessed matrix of vertices to be recognized	List of segmented and normalized matrices should be available.
getChain	private	AbstractPreProcess	-	Request object must be composed.	The first preprocessing object in the chain of preprocessing should be ready.

Table 17 Detailed Design - PreProcessMain

Request

Attribute	Type	Visibility	Invariant
trace	Trace	Private	trace <> NULL and must contain a matrix of vertices to be preprocessed.
traces	List<Trace>	Private	traces contains lists of segmented vertices after preprocessing.

Table 18 Detailed Design - Request

AbstractPreprocess

Attribute	Type	Visibility	Invariant
successor	AbstractPreprocessor	Private	successor <> NULL contains the next operation in the preprocessing chain

Operation	Visibility	Return type	Argument	Pre-Condition	Post Condition
process	Public	void	Request	-	Provides declaration for process method
setSuccessor	Public	void	-	-	Provides declaration for setSuccessor method

Table 19 Detailed Design - AbstractPreprocess

NoiseRemoval

Attribute	Type	Visibility	Invariant
NOISE_TRESHOLD	int	Private	NOISE_TRESHOLD <> NULL contains the threshold value to label vertices as noise

Operation	Visibility	Return type	Argument	Pre-Condition	Post Condition
getCenter	private	Point	-	-	
getDistance	private	float	Point	Center Point must be set.	The distance from a certain point to the center should be calculated
process	public	void	Request	A matrix containing vertices to be verified must be provided in the request object.	Noise free set of vertices will be provided to the next stage.
setSuccessor	public	void	-	-	The next preprocessor object will be assigned.

Table 20 Detailed Design - NoiseRemoval

Segmentation

Attribute	Type	Visibility	Invariant
TRESHOLD	int	Private	TRESHOLD <> NULL contains the threshold value to segment a set of vertices

Operation	Visibility	Return type	Argument	Pre-Condition	Post Condition
getConectedComponents	private	List<Trace>	Trace	A Trace object must be provided	A list of connected vertices, potentially to be segmented to a single group will be returned
isConnected	private	Boolean	Point, Point	Whether a point is a member of a segment is unknown	Whether a point is connected to a set of vertices is decided
process	public	void	Request	A matrix containing vertices to be segmented must be provided in the request object.	segmented set of vertices will be provided to the next stage.
setSuccessor	public	void	-	-	The next preprocessor object will be assigned.

Table 21 Detailed Design - Segmentation

Normalization

Attribute	Type	Visibility	Invariant
NORMALIZATION_WIDTH	int	Private	NORMALIZATION_WIDTH <> NULL contains the width of a normalized segment
NORMALIZATION_HEIGHT	int	Private	NORMALIZATION_HEIGHT <> NULL contains the height of a normalized segment

Operation	Visibility	Return type	Argument	Pre-Condition	Post Condition
getScale	private	float	Int[], Int[]	The dimension of the matrix in the request object must be known.	Each vertices in the request object matrix should be mapped to a normalized metrix
process	public	void	Request	A matrix containing vertices to be normalized must be provided in the request object.	normalized set of vertices will be provided to be recognized.
setSuccessor	public	void	-	-	The next preprocessor object will be assigned.

Table 22 Detailed Design - Normalization

Chapter 5: Testing

5.1 Introduction

This section registers the essential information that are crucial to describe the method of testing of the Amharic online Handwriting recognition product. It addresses the project advisor and project team. Any kind testing that happen in the Project development phase will follow the guideline put in this section.

5.2 Unit testing

5.2.1 Features to be tested/not to be tested

Items to test	**Test Description**	**Responsibility**
UI-Keyboard	A handwriting canvas should accept user input	Kasim
UI-Candidate View	Predicted words should be provided as a candidate	Israel
UI-Back, Return, Space	Backspace, new line input and whitespace	Israel
Linguistics- Word prediction	Candidate prediction based on char array as an input	Israel
Segmentation-Heuristic Segmentation	Heuristic algorithm that can segment bitmap into pieces	Mehari
Normalization-Segment normalization	resize a piece or segment of bitmap to 28*28	Mitiku
Segmentation-Segment Validation	whether a segment is valid or not	Kasim
Segmentation-Segment Reconstruction	Merge if segments are not valid	Mitiku
Recognition-Character recognition	Recognize a normalized segment	Kasim

Table 23 : Features to be tested/not to be tested

5.2.2 Pass/Fail criteria

Under the unit test of AOHWR there are three deliverables aside from this test plan. The first is Test Cases Documents (TCD), this document contains the following

1 list of test cases

2 test steps

3 test data

4 expected result

5 actual result

6 pass/fail

The TCD document's main goal is to provide a working specification of our functional code while remaining as agile as possible regarding documentation.

The second deliverables are Test Scripts this scripts will be written before the code for most components of the system. Mock objects and stubs will be created to achieve the unit test. The third deliverable is the Test Summary Report (TSR) this report will be out after the test has been run. The TSR will consist test results and defect reports.

5.2.3 Approach/Strategy

The test strategy of AOHWR categorizes units into General Purpose and Domain specific. General purpose units solve common computational problems and require minor priority due to their static nature. Domain specific unites on the other hand are more dynamic and focus on specific requirement. The Unit Test approach for AOHWR gives higher priority for such units to attain a cost-effective unit test.

We use Test Driven Development (TDD) for all prioritized or Domain specific units to enforce good architecture. Requirements and units are used to write stubs before writing the tests to simplify writing tests prior to code and retain the naming of tests and code.

5.3 Functional Testing

5.3.1Test Risks /Issues

Risk Type	Description	Causes
Schedule risks	Schedule risks in functional testing are risks associated with planning the date for functional tests. The delivery date for the project gets slipped when the functional tests are not scheduled properly.	• Tracking for the resources is not done properly • The complex tasks are not identified properly • The project scope has been expanded unexpectedly
Operational risks	These risks occur due to failed system, external risks due to events and lack of process implementation	● Lack of resources ● Lack of communication in the team ● Responsibilities have not been resolved properly
Technical risk	Technical risks in functionality testing are associated with lack of implementation of functionalities	● The project requirements are changing continuously ● Lack of technical advancement ● Project implementation is complex ● Integration of modules has become difficult

Table 24 : Test Risks / Issues

5.3.2 Features to be tested/not to be tested

Item to Test	Test Description	Test Date	Responsibility
Write Character	User can write characters Using Aohwr keyboard	As specified in project deliverables	Mehari
Delete Character	User can delete character using backspace button	As specified in project deliverables	Israel
Split Text	User can split a word into to to texts	As specified in project deliverables	Kasim
Join text	User can join two texts into a single text	As specified in project deliverables	Kasim
insert text	User can insert text in the middle of another text	As specified in project deliverables	Mitiku
Erase text	User can erase existing text	As specified in project deliverables	Mitiku
Overwrite character	User can modify existing text by overwriting a character	As specified in project deliverables	Mehari
Scroll writing Canvas	User can go to previously written texts by scrolling the writing canvas	As specified in project deliverables	
Change ink thickness	User can change the writing ink thickness	As specified in project deliverable	Kasim
Change scrolling speed	User can change the scrolling speed of the application	As specified in project deliverables	
View help	User can view help by clicking on help button	As specified in project deliverables	Israel
Change ink color	User can change the color of the writing ink color	As specified in project deliverables	
Update usage data	User can change	As specified in	

sharing policy	update the usage sharing policy	project deliverables	

Table 25: Features to be tested/not to be tested

5.3.2 Pass/Fail criteria

Entry Criterions

- All user interfaces have been completed
- All modules are integrated
- All prior bugs are fixed
- Application is installed
- Text cases are ready

Exit Criterions

- all test cases specified have passed
- Internal document are updated to reflect current state of the product

5.3.3 Approach/Strategy

The project will be tested using the following approach for each functional testing.

- Random testing for
  - Writing character
  - Scroll writing canvas
  - View help
  - Update usage data sharing policy
- Boundary testing
  - Delete character
  - Split text
  - Join text
  - Insert text
  - Change ink thickness
  - Change ink color
  - Change scrolling speed
- Equivalence class testing
  - Erase text
  - Overwrite character

Chapter 6: User Manual

6.1 scope

The manual covers the following:

- How to install the Application
- How to Configure the Application
- How to Write Character
- How to use candidate view suggestion
- How To Erase Word
- How to Split Character

6.2 How to install the Application

Installation of this system can be done by simply clicking the application package (apk) fie and clicking install

6.3 How to Configure the Application

After installing the applications you must follow this steps to make AOHWR keyboard your default keyboard.

Step 1: Go to **Settings - Languages and Inputs - Manage Keyboard** and activate AOHWR active

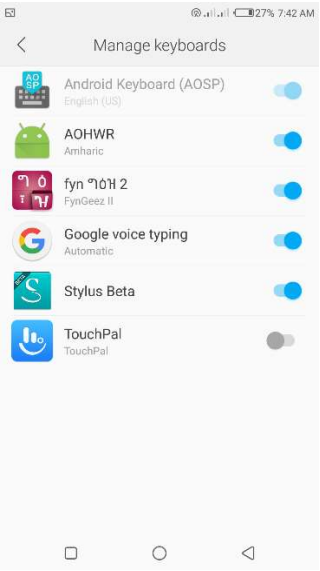


Figure 20: configuration step 1

Step 2: Open application you want to use and touch the button indicated in a circle (See the Picture), in different android versions this option might be found by sliding the notification bar.

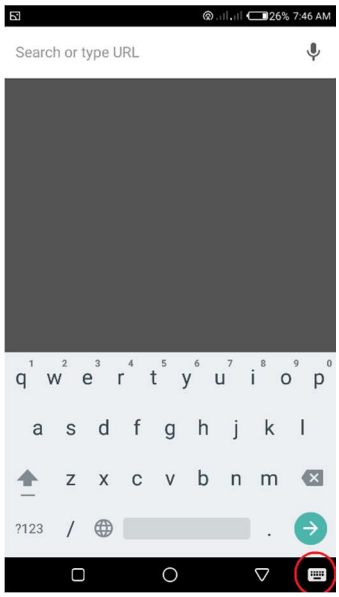


Figure 21: configuration step 2

Step 3: choose Amharic (AOHWR)

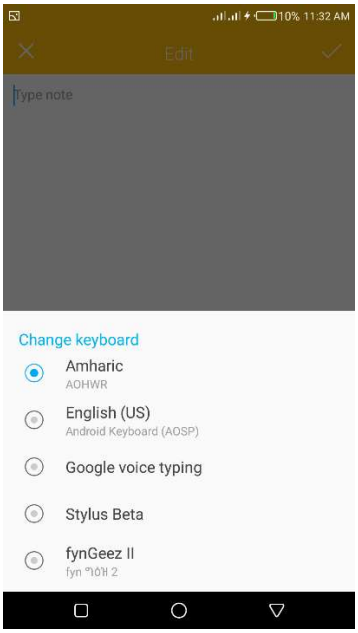


Figure 22: configuration step 3

Figure 23: configuration end result

6.4 How to Write Character

To write a character stroke the canvas as seen on images below

Figure 24: How to Write Character

Figure 25: How to Write Character - result

6.5 How to use candidate view suggestion

To use suggestion in the candidate view press the desired candidate

Figure 26: How to use candidate view suggestion

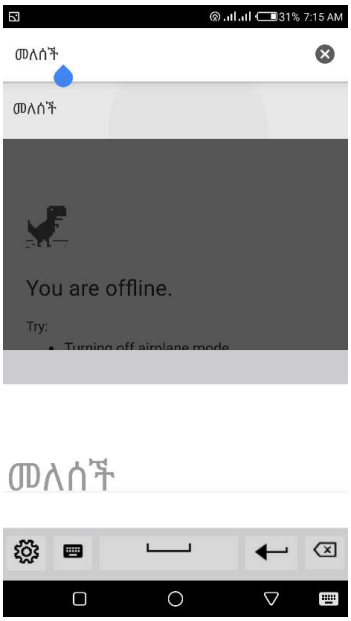


Figure 27 : How to use candidate view Suggestion - result

6.6 How to Erase Word

To delete character see the image below

Figure 28 : How to Delete Character

Figure 29: How to Delete Character 2

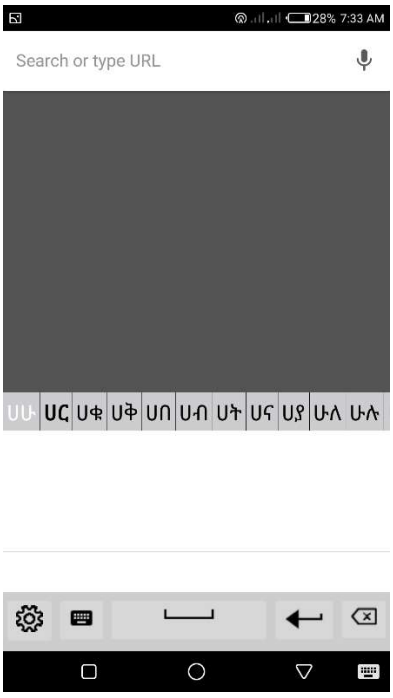


Figure 30 : How to Delete Character – result

6.7 How to Split Character

To split characters or make space between them draw like below image seen below

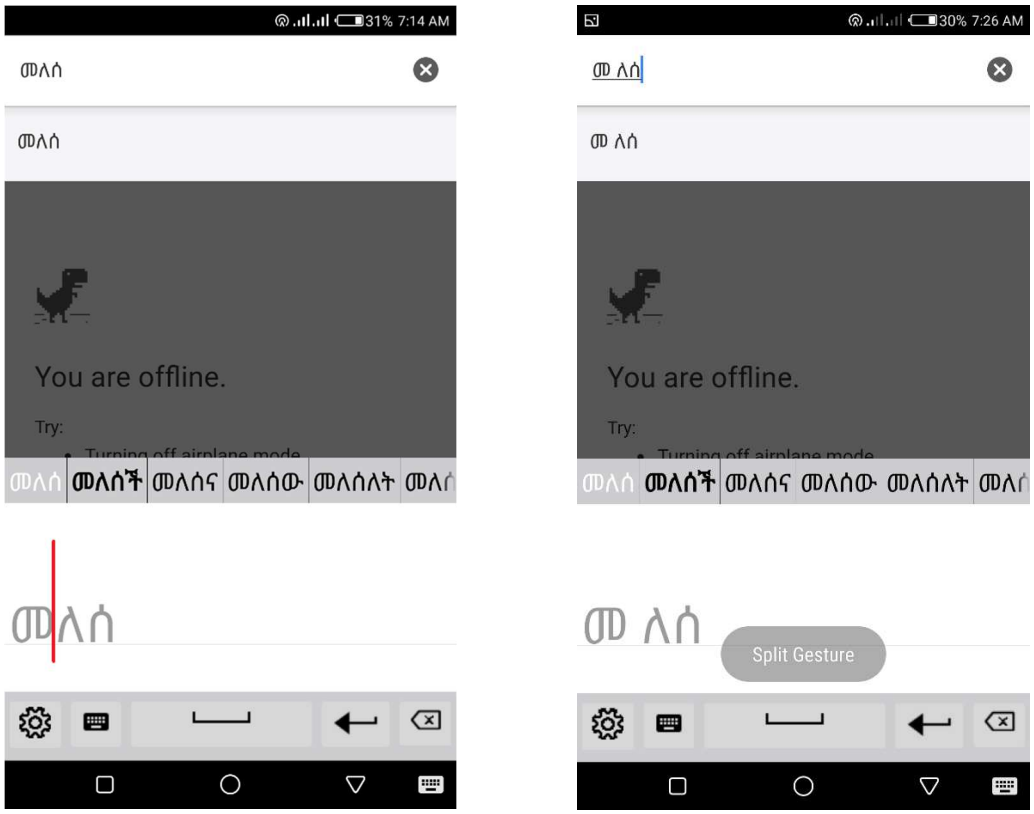


Figure 31 : How to Split Character

Chapter 7: CONCLUSION AND RECOMMENDATION

7.1 Conclusion

Virtual Keyboards are modern day text entry software that are vastly used in current smart phone and Tablet market. English has only 26 characters in their alphabet and the structure of this virtual keyboards is designed for that. Because of this text character size and best UI/UX designs on the market this keyboards are first choice of anyone who needs to use a text entry compared to audio or similar text entry technique.

Amharic having 400 characters in its alphabet was unable to be used in the technology as much as people use it in day to day life. Since writing Amharic on virtual keyboard is a very difficult task people either use English letters to communicate in Amharic or they use English language itself.

Based on this problems this project planned build Amharic Online Handwriting Recognition app. The app supports all Amharic characters and have acceptable accuracy. It also integrated some features that help the writing experience.

In the project handwriting data of many people was collected and used as a training data, and produce two models to be used in recognition and segmentation later. The system accepts user inputs using canvas, and based on segmentation model the system splits the user input into distinct segments. The distinct segments will be recognized as characters using recognition model.

This project will initiate Amharic android users to write Amharic comfortably. This enables many non-English speaking Ethiopian android users to communicate with each other.

7.2 Recommendation

Based on current work accomplishment and observed problems and development approach the following points show what must be done to improve this project

- The shortage of Amharic hand writing data corpus affected this project. Most of our time we tried to collect data by making data collection app designed specifically for project and collected sufficient data , but if this data was huge in number we would

accomplish great accuracy better than what we have now . So In the future increasing data set will be a major task.

- The linguistic context was made by dictionary search and it serves what its intended to do, but if its implemented based on better prediction algorithms it would supplement the writing experience.

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