Declan Urbaniak-Dornstauder
DVU072 / 11284744
CMPT 481
Final Report

Title: GestureType – A Touch Gesture Based Input Device Application

Repository: git.cs.usask.ca/dvu072/cmpt-481-project

Project Members: Declan Urbaniak-Dornstauder

I. Interaction problem

This project addresses the challenge of optimizing text input and command execution, particularly for users who encounter difficulties with traditional keyboard-based methods. Whether due to physical constraints, lack of technical proficiency, or individual preferences, typing may be impractical for certain user groups. The objective of this project is to develop and explore a user-friendly alternative to text input and text-related functionality that accommodates a diverse range of users.

II. Interaction technique

The interaction technique explored in this project entails using an external touchscreen device as an alternative input method for devices that support the HID keyboard protocol (*section VI.1*). Rather than typing on a physical keyboard to provide input to one of these devices, users can draw the equivalent letters, numbers, and symbols directly on the screen of the touch enabled device.

The interaction technique uses a state system that can be in one of two modes. Insert mode is used for text entry, while command mode is used for executing a set of basic text related commands (*figure A*). In insert mode, users can insert and delete characters at the position of the text cursor of the connected host device. Command mode allows users to perform various touch gestures to control the cursor and execute commands such as selecting, copying, cutting, and pasting text. This approach provides a natural and user-friendly way to interact with devices that require keyboard input, catering to diverse user needs and preferences.

Figure A. Table of the full functionality supported by the interaction technique

Touch input	Function
Double tap	Toggle between insert and command mode
Insert mode	
Draw alphanumeric character or symbol	Insert equivalent ASCII character/symbol at cursor
One finger swipe left	Delete character/symbol at cursor
One finger swipe right	Insert space at cursor
Two finger swipe left	Insert comma at cursor
Two finger swipe right	Insert period at cursor
Command mode	
Modifier* + one finger swipe left/right	Move cursor one character left/right
Modifier* + two finger swipe left/right	Move cursor one word left/right

Modifier* + draw ‘S’ + one finger swipe left/right	Select character to left/right at cursor
Modifier* + draw ‘S’ + two finger swipe left/right	Select word to left/right at cursor
Draw ‘C’	Copy selection
Draw ‘X’	Cut/delete selection
Modifier* + Draw ‘V’	Paste selection at cursor

*Repetition modifier: Optionally draw a number 1 – 9 and execute the command this many times. If the repetition modifier is not specified, the command will execute once.

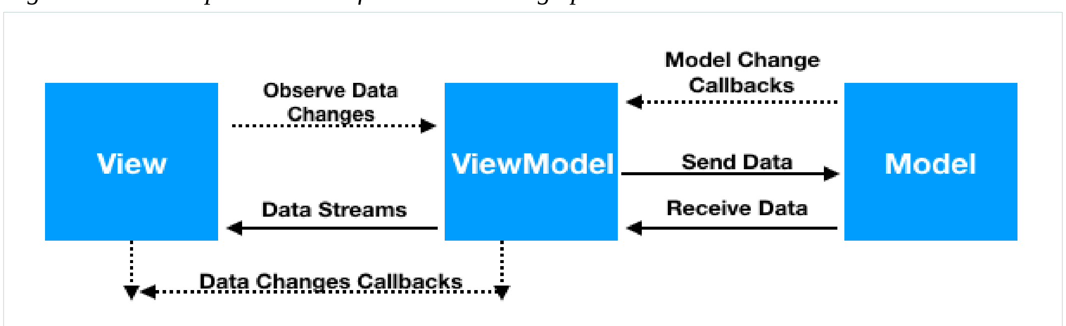
III. Technical overview

Architecture

As the project’s interaction technique requires a touch based interface to function, it is implemented in the form of an Android application for mobile devices. This choice of platforms supports a wide range of devices, increasing the accessibility of the application and its interaction technique. The application itself is implemented in Kotlin, a high-level Java-like programming language considered to be the modern standard for native Android development (section *VI.2*).

The GestureType application uses the model-view-view-model (MVVM) design pattern (*figure B*). As seen in the model-view-controller pattern (MVC), MVVM shares two of its core components, the model and view. The model consists of the data and business logic necessary to the function of an application. In the case of the project application, the model is comprised of the optical character recognition (OCR) client, the input processing layer, and the Bluetooth client. The view represents the user interface or any visual user-facing elements, and reflects the current state of the model and view-model. The application’s user interface is built using Android’s Jetpack Compose toolkit, which provides a flexible and intuitive way to build modern mobile interfaces (*section VI.3*) Unlike MVC, the MVVM design pattern features a view-model, which as its name suggests, serves as bridge between the view and model. This component is primarily responsible for data binding and view state management, and can be closely compared to the concept of an interaction-model or ‘i-model’ that is present in many MVC derived design patterns.

Figure B. Visual representation of the MVVM design pattern



OCR and pre-processing

The primary function of the GestureType application lies in its ability to recognize handwritten characters, numbers, and symbols. To enable this functionality, the application leverages Google’s ML Kit text recognition v2 API (*section VI.4*), providing a convenient implementation of basic OCR capabilities. Despite this convenience, issues arose in early production regarding the accuracy and consistency of character recognition. The text recognition v2 API is primarily used to detect text in real-world images where there are many non-text elements in the environment. It excels in particular at detecting sequences of characters, such as words and sentences. For this reason, ambiguously shaped characters such as ‘I’, ‘O’, and many others may be difficult to detect when they are not part of a sequence, as they could be mistaken for a non-text element in the environment.

When a user draws a character in the GestureType application, the pixels of the drawn strokes are saved onto an initially blank bitmap that is sent to the OCR client for additional processing. This bitmap is cropped, scaled and appended to a static bitmap depicting the characters ‘AA’ (*figure C*). The combined bitmap is then parsed by the OCR, and only the first character of the returned string is used. This processing technique provides context for the drawn character and addresses the previously mentioned issue through the creation of a bitmap containing a sequence of characters. Since its implementation later on in production, the accuracy and reliability of interpreted characters has dramatically improved, though there are still issues with reliably interpreting lower case letters and symbols.

Figure C. Visual example of a combined bitmap provided the drawn input ‘Q’

State machine

Once drawn input is processed by the OCR client or a user performs a gesture, the output of these actions is provided to the state machine for interpretation. As mentioned earlier, the interaction technique is state based, operating in either insert mode or command mode. The state machine contains the logic that determines the functional flow of the application given an input and the current mode, and prepares the input to be translated into meaningful data that will eventually be interpreted by the HID keyboard protocol *(section VI.1*).

In insert mode, the state machine processes basic text inputs such as adding and deleting characters or inserting punctuation based on gestures. Command mode allows for more complex operations such as text selection, copying, cutting, pasting, and moving the cursor. An important aspect of the state machine lies in the character to key-code map. This a comprehensive mapping from character inputs to Android KeyEvent codes and shift-key states, which is necessary in preparing the input for the HID keyboard protocol.

Bluetooth and HID emulation

In order to communicate with the host device that should be receiving the input of a user, the GestureType application leverages Bluetooth connectivity and emulates a Bluetooth keyboard. The layer enabling this functionality is comprised of the Bluetooth client, keyboard report object, and transmission client, which in combination, extend the functionality of an Android device to act as a human interface device (HID).

The Bluetooth client establishes and manages Bluetooth connectivity, allowing the Android device to scan for and connect to available devices. It is also responsible for initializing the HID device profile. This is accomplished using the Android BluetoothHidDevice API with the keyboard HID descriptor (*section VI.6*), which defines an input device’s capabilities to the host and is essential for the device to be recognized and function as a Bluetooth keyboard.

The keyboard report object consists of a byte array that represents the current state of the ‘keyboard’, such as which keys are pressed and the status of key modifiers like the control and shift keys. Like the state machine, it also uses a mapping system, translating Android key events into HID compatible key codes that can be interpreted by the host device.

Lastly, the transmission client functions an intermediary that communicates directly with the Bluetooth client to send the prepared key reports. It receives input from the state machine, and ensures the input is processed and transmitted correctly.

IV. Evaluation

Overview

To evaluate the GestureType interaction technique, it is compared to two use cases of a standard keyboard setup. The first use case replicates expert keyboard usage through key-shortcuts to execute text commands. For example, moving the cursor to the next word can be accomplished with a two-finger swipe using the interaction technique, which is equivalent to pressing the right arrow key modified by the control key in expert usage (*figure D*). The second version replicates novice keyboard usage. Using the previous example, the equivalent function for this method is using the mouse to reposition the cursor to the next word.

Figure D. Supported GestureType cursor commands and their equivalent keyboard methods

Command	Expert method	Novice method
Move cursor one character left/right	Left/right arrow key	Move to character position with mouse
Move cursor one word left/right	Ctrl + left/right arrow key	Move to word position with mouse
Select character to left/right at cursor	Shift + left/right arrow key	Select character with mouse
select word to left/right at cursor	Ctrl + shift + left/right arrow key	Select word with mouse
Copy selection	Ctrl + C key	Right click + select ‘copy’ from menu
Cut/delete selection	Ctrl + X key	Right click + select ‘cut’ from menu
Paste selection at cursor	Ctrl + V key	Right click + select ‘paste’ from menu

It is important to not that prior to completing the evaluation, there were no expectations that the GestureType interaction technique would outperform the keyboard methods. With enough proficiency, it is not uncommon for one’s keyboard typing speed to surpass their handwriting speed. Given this, it would be unreasonable to assume that a writing based interaction technique such the GestureType interaction technique would be an exception. The goal of this is evaluation is to explore the challenges and opportunities of the interaction technique, even if the analysis realistically reduces to focusing on the lengths to which it under performs in comparison to the keyboard methods.

Setup

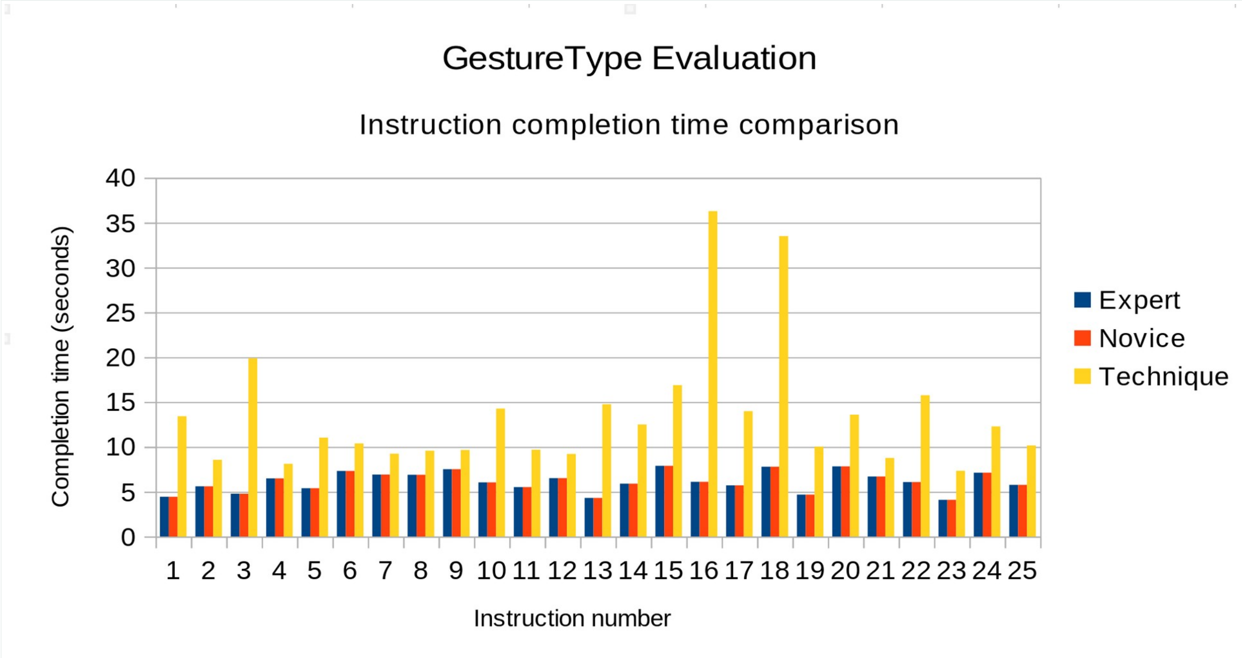
To compare the performance of the three methods, each method is used to perform a series of text entry and modification tasks (referred to as instructions) on a block of text. The same text is used for each method, along with the same set of 25 instructions presented in the same order. Each instruction consists of a task whose operation can be classified as one of word insertion, character insertion, character deletion, select and cut, or paste. Upon the completion of a prompted instruction, the instruction completion time is automatically recorded. To compare the cursor manipulation functions of each method, the number of characters places between the text locations that are modified from instruction to instruction (where the cursor is positioned after completing an instruction, and where it needs to move to to complete the next instruction) are prerecorded and will be considered in the analysis. The system enabling the evaluation functionality is built with a simple Tkinter Python application, and is available in the project repository.

For the keyboard methods, the function required to complete a given instruction is limited to that in the table of commands depicted in *figure D*. For example, the expert method is strictly limited to using the arrow keys for cursor manipulation. As a side note regarding this example, only the left and right arrow keys were are used to manipulate the cursor. This was done in attempt to make this functionality comparable to the interaction technique, which does not support vertical cursor manipulation.

Results

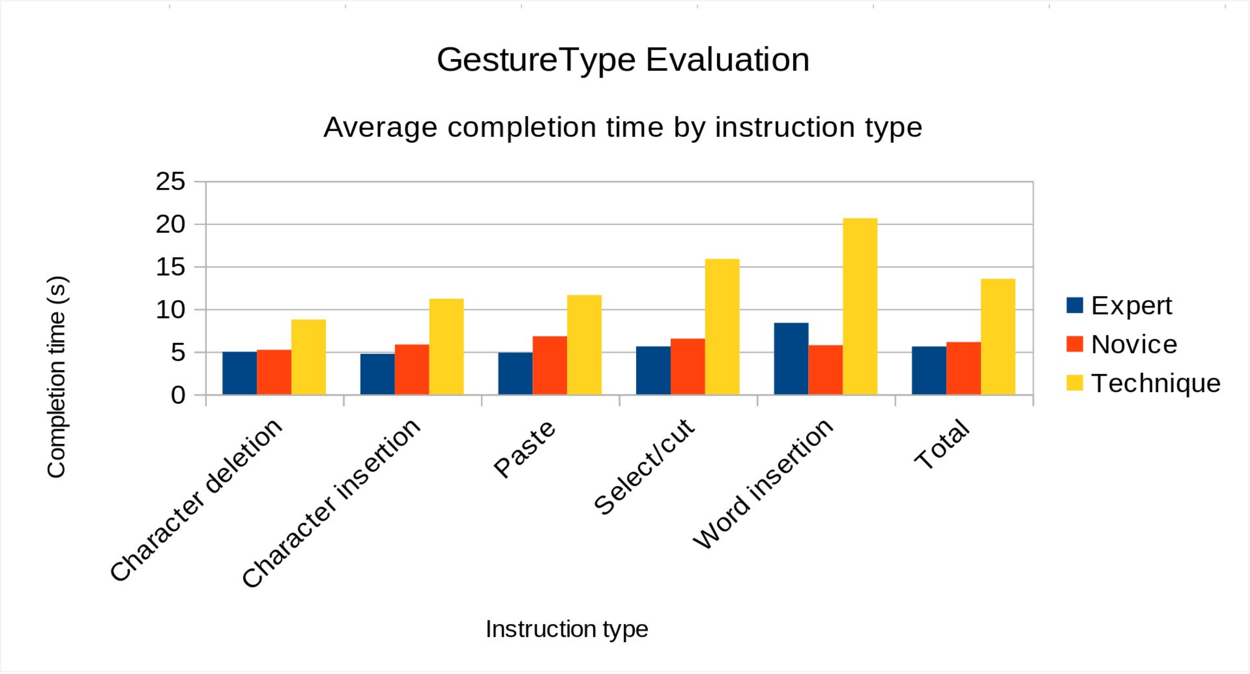
To little surprise, the GestureType interaction technique falls significantly short of the keyboard methods in overall performance. As depicted in *figure E* and *figure F*, the instruction completion times achieved with the interaction technique generally range between two to three times the duration of those achieved with the keyboard counterparts. Word entry instructions see the largest increase in completion time at approximately four times that of the keyboard methods. Select and cut instructions follow closely at three times the completion time. This can be attributed to the overhead required to execute these commands. Consider the case of cutting five words using the interaction technique. First and foremost, this requires the user to count the number of words in the string they want to cut, assuming this is not obvious at a glance. After drawing the number to register the modifier, they must draw an ‘S’, then two finger swipe to select the words. The keyboard methods require fewer, or less complex steps to accomplish the same action. As for the remaining instruction types, all of those using the interaction technique take the approximately twice the time to complete as the keyboard methods.

Figure E. Line chart of the instruction completion times



The interaction technique’s relatively poor performance in instruction completion time can be attributed to many factors. Firstly, and as mentioned in an earlier section, proficient keyboard users are generally able to type faster than they write. This is likely the most significant factor affecting the technique’s performance, especially considering that inputs are processed on a character by character basis and not in the form of whole words. The input processing mechanism itself is also a limiting factor and manifests in two ways. Firstly, there is noticeable input delay resulting from input processing in the back-end. While this has not been measured or thoroughly investigated, it likely the result of the OCR functionality, the Bluetooth connection, or a combination of both. The application also uses a timer mechanism to register the input of the user. It is not until three-hundred milliseconds after the last stroke drawn by the user that their input begins to be processed. This means that while inserting characters, there is a fixed delay between each input, which quickly accumulates with the length of the word or sentence that is inputted. Finally, the application's OCR capabilities are at fault for the last factor significantly affecting instruction completion time. Despite the benefit of the additional pre-processing discussed in the technical overview, it is still possible for the OCR client to misinterpret the character drawn by user. This can generally be abated by minding one's input to ensure it is drawn clearly, though this in itself can slow down input time due to the extra drawing precision required.

Figure F. Line chart of the average instruction completion times by instruction type

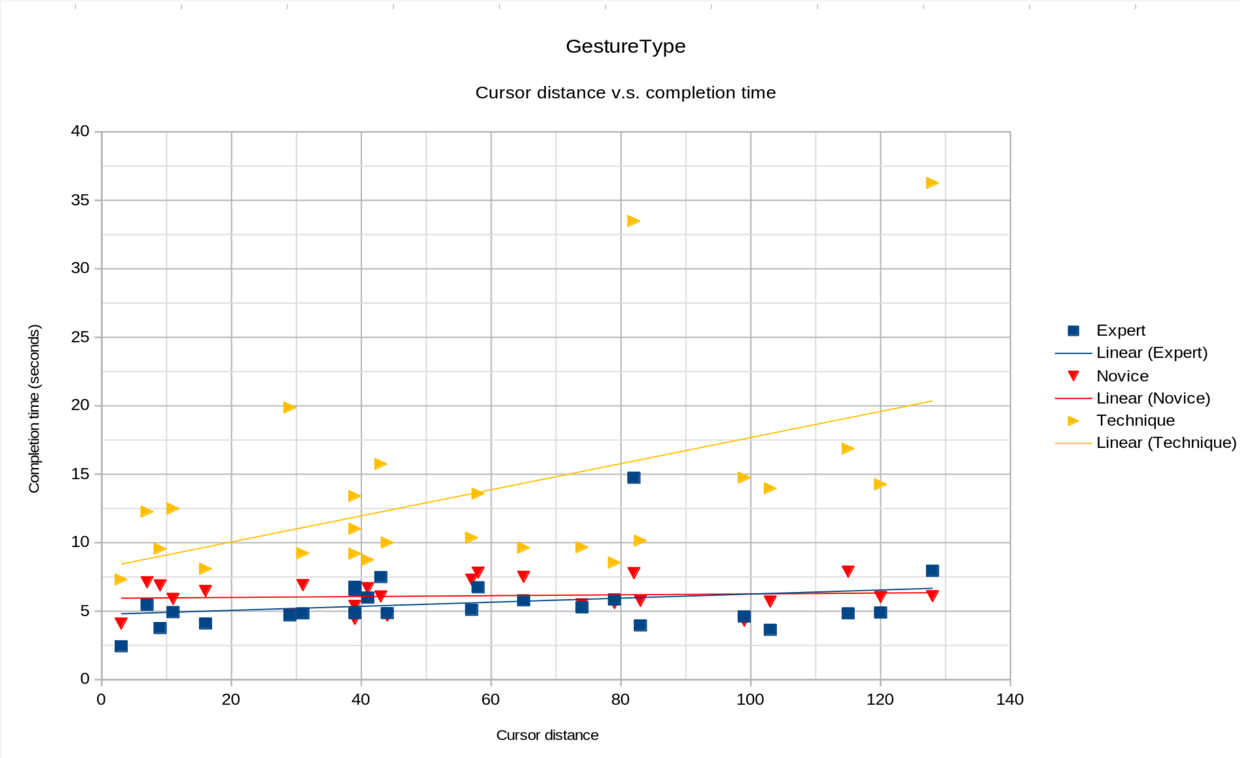


Due to the limited functionality of the evaluation program, the cursor manipulation commands of all three input methods could not be directly compared alongside the five groups used to classify the different instruction types. As described in the evaluation setup, the number of character places required to move the cursor to the edit location of the succeeding instruction is prerecorded for each instruction. This was done in attempt to quantify the varying effort required to reposition the cursor with the expectation that the effectiveness of cursor manipulation functionality would vary across the different input methods. As seen in *figure G*, this generally does not appear to the case.

Considering the keyboard input methods first, the cursor distance not does not appear to affect the time taken to complete an instruction, as evident in the flat trend lines depicted in the plot. In the case of the novice keyboard technique, this is expected due to the fact that all cursor manipulation is done with a mouse. Unlike the other methods where cursor movement is limited to moving backwards or forwards through each word or character, the use of a mouse allows free manipulation of the cursor. Despite its limitation, the expert keyboard method performed on par with its counter part. This is likely due the ability to quickly move and correct the position the cursor word by word with the press of a button.

The results of the interaction are notably more variable compared to the keyboard methods. Despite the clear upward trend line in *figure G*, the relationship between the instruction completion time and cursor distance is likely as not as strong as it appears due to the outlier data points in the sample. Despite this, it still appears as if there is an upward trend in the scatter plot. This aligns with the subjective experience of using the cursor manipulation commands in the evaluation. Due the input delay present in the application, it is common to misplace the cursor from the intended target using quick repeated swipes, especially when travelling longer distances. The alternative approach to moving the cursor quickly is with the addition of a modifier. However, as previously mentioned, this requires counting the number of words to move the cursor, or at the very least, requires the extra input to set the modifier.

Figure G. Scatter plot of the relationship between the cursor distance and instruction completion time



V. Conclusion

This interaction should not be used in place of a keyboard by anyone unless they are blind or missing everything but a pinky finger. In the case of blindness, its possible that the interaction technique may have a use case due to its reliance on gestures and touch input. Assuming the system is modified to provide auditory feedback after an input, its possible that the visually impaired could use the technique for simple, continuous text input, though its cursor manipulation commands would be of no benefit. In the case of missing fingers, the utility of the interaction increases with the number of fingers that are missing, unless that number is ten, in which it has no utility at all. Even in the case that an individual is left with a single finger, they are probably still better off using using a keyboard, though they may have issues using command shortcuts and inserting characters that require a modifier key. Until humanity has the technology to reliably edit and manipulate text using nothing but an individual's thoughts and neural impulses, system designers and researchers should consider the data gathered in this analysis as an absolute truth to the fact that the keyboard will not replaced any time soon, and they should abandon their future aspirations to design a system similar to GestureType (especially if they are a CMPT 481 student with the intention of doing a solo project).

VI. References and Documentation

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