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# Content Specific Keyboard Layout Design for Smart Tv Applications

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**Abstract**

This research aims to propose a genetic algorithm based methodology to design optimum keyboard layout for video streaming applications designed for smart TVs. Users need to use the arrow buttons on their remote controls to type the title of the movie or the TV show they are searching for. We downloaded approximately 9 million movie and TV show titles from the Internet Movie Database (IMDB) website. After data preprocessing, we calculated the frequency of letter sequences in these titles and used genetic algorithms to determine the optimum keyboard layout that would minimize the total number of clicks required to type the title using arrow buttons on a remote control. The proposed keyboard layout is tested using the movie titles in IMBD Top 100 list and compared with standard QWERTY keyboard and three other keyboards in alphabetical order. It was confirmed that the proposed keyboard layout required fewer number of clicks than other keyboard layouts in 83 titles and tied with one of the other keyboards in 4 titles.

## Introduction

There is a trend of consumers switching from traditional cable television to internet based streaming services for their entertainment needs as more streaming services and online content are becoming available to them (Tefertiller , 2018). The streaming service industry is in its growth stage; therefore, the number of subscribers is expected to increase (Synman & Gilliard, 2019). The digital content provided by these services can be accessed through a variety of devices, such as computers, smartphones, tablets, as well as smart TVs. Although computers, smartphones and tablets come with easy to use physical or touchpad keyboards, the users of smart TVs often need to use the arrow buttons on their remote controller to type. The excess amount of content provided by these services already makes it more difficult and time-consuming to search and browse the desired content (Jan, et al., 2022). Furthermore, the necessity to use the remote control to spell out the titles of the movies and TV shows to search makes it even more troublesome for smart TV users.

Therefore, this research aims to develop a keyboard layout for smart TVs optimized for typing with the arrow buttons of remote controls. For this purpose, we analyzed the movie and TV show titles from the IMDb database, and used genetic algorithms to determine the optimum keyboard layout to minimize the number of clicks. Finally, the proposed layout is tested against the keyboard layouts used in popular smart TV apps.

## Literature Review

The existing literature about keyboard layout design can be organized into three broad categories. The research papers in the first category mainly focus on designing optimum keyboard layouts for different languages, based on the letter frequencies in the words of that language. They either use a dictionary or other forms of literature as the source data for their modelling efforts. The papers in the second category focus on ergonomic designs of keyboards for optimized finger typing using either both hands or a single pointer, such as smart phones or touchpad screens. The papers in the third category try to develop alternative data entry methods for smart TV applications.

### Literature About Optimum Keyboard Layout for Different Languages

The study of Agpak, et al. (2016) aims to create a layout for a two-finger keyboard on virtual devices, in the Turkish language. The goal of the new layout is to minimize the sum of finger movements. A genetic algorithm was developed, along with a distance matrix to find the frequency of letters and the distance of keys. This resulted in the creation of a Ç keyboard with vowels on the right side and consonants on the left.

The studies of Hosny, et al. (2014) aims to optimize the Arabic keyboard layout for a single finger. The goal of this keyboard is to improve speed, comfort, and accuracy. Using a simulated annealing algorithm, the objective was minimizing the distance between frequently occurring pairs of letters. This study chose to gather its data from Arabic Wikipedia articles. To evaluate the effectiveness of the new layout, an algorithm was developed to measure the speed of typing, following Fitts law. This keyboard differs from an English keyboard because the Arabic language has more letters, so a shift key had to be implemented and some letters share a key.

Similarly, the study of Najjar, et al. (2021) tries to optimize a single finger Arabic keyboard for mobile devices. A simulated annealing algorithm was used for optimization, and this study looked at key arrangements based on movement time and character transition frequency. To find movement time, Fitts law was used along with the Euclidean distance. Regarding character transition frequency, characters with a high frequency transition were positioned close to each other. Using 12 participants, they tested the optimized layout and found that it outperforms the currently used layouts, but there is a learning curve to get familiar with it. This research is very similar in terms of the method they used to create the optimized keyboard; however, it is for the Arabic language, and does not apply to smart TVs, it is for mobile devices.

The study of Kazem and Naghsh (2011), aims to create an optimized Persian keyboard layout using evolutionary strategy. This method consisted of encoding chromosomes to find potential solutions, and then using a fitness function, which gives the typing time between letter pairs for each layout. This resulted in 10 commonly used letters in the middle row, and fewer common letters in the 3rd row or corner. The study of Onsorodi and Korhan (2020) discusses keyboard layout problems and aims to optimize a keyboard layout for the English language. This paper used a genetic algorithm with the goal of minimizing the total distance of finger travel, because that would reduce time and fatigue for users. Using the most 3000 common words in the English dictionary, a text analyzer provided frequent letters and common pairs. In addition, an objective function was used to minimize the distance between keys. This resulted in frequent letters in the center of the keyboard and frequent pairs close to each other. The aim of Pradeepmon, et al. (2018) study is to create a better layout for a single figure keyboard that will allow for rapid typing. This research used a QAP genetic algorithm and estimation of distribution algorithm. The paper included 3 stages of experiments, where first, the algorithms were developed, then frequencies for the English alphabet were calculated to find the layout for least finger movement. Lastly, 2 new layouts were created and tested against the already existing QWERTY layout on 10-year-olds who were unfamiliar with QWERTY to reduce bias. It was found that QWERTY is not efficient for single finger typing, and that both their proposed layouts reduce typing time. This research differs in that it aims to reduce typing speed, not the number of clicks.

The goal of Samanta, et al. (2013) study is to optimize key arrangements for minimum eye movement and mouse movement. This study created a new keyboard called iLiPi where frequently used letters were placed in the center. The keyboard follows a rectangular layout to accommodate inflection characters and uses a covering window approach. This study followed both user evaluation and a model-based evaluation which included read and type, listen and type, and type freely experiments. The result of this research was a new keyboard that used a multizonal layout concept and was effective in optimizing the arrangement of characters for 21.3% higher text entry speed. This differs in that it was using the Indian language which has a large character set, more complex characters, and inflexions, in comparison to the English language.

The study of Janthanasub and Meesad (2015) aims to create a new arrangement of Thai characters that’s optimized for single finger entry. The method follows four steps which were collecting texts of the target language, calculating the frequency of characters, designing the keyboard, and determining the proper key position. Using an evolution computation, it was determined that the created keyboard performed at an average of 41 words per minute. This is different from our research because it was performed for Thai, which is a very complex language with several vowels, tone marks, and punctuation marks needed.

The research paper of Perrinet, et al. (2011) evaluated different alternatives for inputting text in Spanish. This study looks at four different keyboard layouts and aims to determine which one is the most efficient. The four methods analyzed were the QWERTY keyboard, alphabetical keyboard, genetic keyboard design, and a mobile phone keyboard. A program was developed to find the minimum number of keystrokes used. It was found that the genetic keyboard was the best in regard to key stroke optimization, and QWERTY was the worst. However, users reported they felt more comfortable with the QWERTY keyboard. Li, et al. (2006) aim to create a keyboard design for single pointer applicants. The goal was minimizing movement time according to Fitts law. In addition, this study used character transition frequency, meaning keys with high frequent transitions from each other were put close together on the keyboard. A data set of words from the Brown Corpus was utilized to calculate frequency of keys, which resulted in frequently used keys in the middle of the keyboard, and keys with low usage in the corners. A two-stage heuristic was used to obtain the results for 3 different keyboards.

**Literature About Ergonomic Keyboard Designs**

Hsiao, et al. (2014) try to develop a miniature keyboard design for small mobile devices. 4 keyboards were created and tested, including a linear keyboard, separated keyboard, edge keyboard, and corner keyboard. Using the character keystroke test and statistical analysis, the input speed, accuracy, comfort, and likeability were measured. It was found that the separated linear keyboard was the best overall. However, the study noted that most people are comfortable with a QWERTY keyboard and do not want other layouts.

Dell'Amico, et al. (2009) discusses the problems surrounding single finger keyboards. The paper recognizes that Fitts law models time and difficulty moving to a target area, and the significant use of a QAP when optimizing a keyboard. This study resulted in several solutions when creating a single finger keyboard, such as formatting the space bar close to the center, no vowels placed on the boarder, and leaving the corners empty and following a circular shape instead.

This study of Banovic, et al. (2013) tries to reduce the mental load of text entry on a mobile device by implementing a sight free text entry approach. The method used was a simulated annealing algorithm which took the frequency for each of the letters and optimized their placement on the screen. The sight free approach uses a thumb on screen and flick motion. The study found people were more familiar with the QWERTY layout so they focused on utilizing that layout in combination with the flick motion, which resulted in 39 words per minute.

The study of Zhai, et al. (2002) estimates the performance of already existing virtual keyboards. The keyboards they are evaluating using Fitt's diagraph energy function, which quantifies movement efficiency, are the QWERTY, FITALY, and OPTI. The results of this study estimates QWERTY creating 28 words per minute, FITALY with 36 words per minute and OPTI at 38 words per minute. This research paper is analyzing already existing keyboards, rather than designing a new layout.

The study of Francis and Oxtoby (2006) explores how to optimize keyboards for information input. This research focuses around using Fitts Law to minimize predicted text entry time. This study made two keyboards using a keyboard tool program and did an experiment where 20 people had to enter their name on a touchscreen. The results of this study showed that people can learn keyboard layouts quickly.

The study Kim, et al. (2019) aims to create new virtual keyboard display systems with the goal of reducing eye movements. This study was conducted on the QWERTY keyboard for the English language. Both a static word by word feedback display, and a dynamic word by word feedback display were tested. This study conducted an experiment where these keyboards were tested by individuals while they wore eye tracking glasses. Based on the findings of this experiment, the word-by-word touch feedback display was proved most effective for boosting user experience. This research is different from ours because it is about having word feedback popping up while you're typing on a mobile device and has nothing to do with keyboard layout design. However, it is similar in that it is trying to improve user experience.

The purpose of the Cha, et al. (2015) study is to create a new text entry system for a smart watch. The paper created a virtual sliding QWERTY keyboard that uses a tap and drag system to move the keyboard to the desired position. When creating the design, this study considered two factors, the key size and the gap size between the keys. The virtual sliding keyboard was tested on 20 people and the result was 11.9 words per minute typed. This differs from our research because it is for a smart watch, and uses the QWERTY layout.

The Trudeau, et al. (2014) study aims to provide insight on different design factors for handheld devices which are typically used by thumbs. The research used a performance evaluation model to generate different geometries of the QWERTY layout. Then, the performance index for 663 designs using combinations of 3 different features were found. The features were the keyboard radius of curvature, orientation, and the vertical location on the screen. It was found that the vertical location on the screen is the most important and that the performance was best when it was located in the middle. This research does not aim to optimize anything and does not have to do with a smart tv keyboard.

The Mitchell , et al. (2022) research paper's goal is to build a personalized keyboard generation where a person's data and movements are used to create a keyboard layout. The study uses an ability-based design which is a system that recognizes motor abilities and then personalizes the keyboard. They implemented an experiment to test the personalized keyboard against an optimized keyboard and the QWERTY keyboard, on 16 different people. It was found that the personalized keyboard had greater performance because it improves speed and accuracy.

The purpose of the Puka , et al. (2021) research is to propose a new keyboard that can be used for both mobile devices and computers. The new layout proposed is a one row keyboard, because the number of keys is significantly reduced, which is good for small mobile devices. The method followed in this paper to create the keyboard was to first calculate the frequency of different character combinations. Then, once the number of keys was defined, determine the position of the keys. Lastly, this paper used optimization criteria and weights, to assign characters to keys. This resulted in a one row keyboard that reduced finger movements and the size of the keyboard, but was found difficult to use. This is similar to our research in that its goal was to create a new optimized keyboard for a limited amount of finger movement, however, it is geared towards mobile devices and a one row layout.

The goal of the Mandyartha, et al. (2021) is paper is to just introduce a design concept that reduces space on the keyboard for smart watches. The design concept is aimed to reduce the number of keys used. This study evaluated three things, learning time, text entry, and text entry accuracy. After evaluating these three things, the design concept introduced was a one-line keyboard with a compressed layout using T9 button grouping. The paper states that this layout will be familiar enough to users. This research is just an introduction to a design idea, and it focused on a small reduced keyboard for a smart watch, which is different than our research for an optimized smart TV keyboard.

The study of Andreas , et al. (2022) aims to design an alternative mouse and keyboard interface for people with neuromuscular diseases. A spectacle frame with integrated motion sensors for head tracking was created as an alternative for a mouse with cursor control through head motion tracking. In addition, a keyboard was created with 10 keys that also provides word suggestions for the user. This alternative mouse and keyboard were tested on three different people without any disabilities and the result was 8.44 words per minute.

The Ciobanu (2014) paper shares information on existing designs for keyboard features. The paper shares that new keyboard layouts are needed with better ergonomics for the elderly and disabled. The paper recommends that the new keyboard should have easy to find keys, the typing be easy to learn, and for there to be minimum errors when typing. After analyzing existing keyboards, it was found that the QWERTY keyboard is the least ergonomic.

The Sears (Sears, 1991) research paper compared touchscreen keyboards against other devices and it argues that touchscreens are useful when keyboards are not practical, and there is only limited data entry. When creating the touchscreen design, the study followed 3 phases. First determining the mounting angle, then the key size, and lastly, comparing their version against the QWERTY keyboard and the utilization of a mouse. Through experiments, a 30-degree angle was chosen and 2.27 cm per side for the keys. The study resulted in QWERTY being the fastest, then the touchscreen, then the mouse. However, it was found that users using the new touchscreen keyboard could type 25 words per minute.

**Literature About Alternative Text Input Methods for Smart TV Applications**

Iqbal and Campbell (2021) argues that COVID19 accelerated the use of touchless technologies, such as voice, gestures, hand interaction, eye tracking, in smart TVs, as well as other devices due to hygiene requirements.

The study of Dinh, et al. (2014) analyzes a hand gesture interface to control smart home appliances. Specifically for a smart tv, features like changing the channel, volume, and powering on and off using hand gestures. This was done using a synthetic hand database, and training RFs for hand gesture recognition. This resulted in a recognition rate of 98.50 for four different hand gestures. This study argued a hand gesture interface system is more natural and intelligent than a keyboard.

The study of Lee, et al. (2019) introduced HIBEY, which is a text entry solution through vision based, free hand interactions. HIBEY uses hand gestures to pick characters and predict words. This is a keyboard-less text input system, that follows an alphabetical order for its characters because they argue that users won't invest time to learn a new layout. This study resulted in HIBEY testing at 9.95 words per minute.

The purpose of the Harezlak, et al. (2022) research is to develop a simple, efficient, and intuitive keyboard interface by using eye typing on an on-screen keyboard. Three different keyboards were tested through in-person experiments, followed by a questionnaire. After statistical analysis, users had difficulties with all keyboards, so further development is needed.

Yang, et al. (2013) propose a virtual keyboard for those who are disabled, using a human machine interface with blink control. An EMG signal from a blink acts as a trigger, acquired by a Bluetooth headset, to activate certain functions in the keyboard. This blink control method was implemented in the Chinese language and was tested by 10 users who suffered from a motor neuron disease.

Erazo and Pino (2018) introduce THGLM, which is a touchless, hand gesture level model, that forecasts performance time for hand gestures. The goal of proposing THGLM was to help designers analyze interfaces based on touchless hand gestures, and be able to predict the execution time. The use of THGLM results in designers being able to test user interfaces to create a valid and usable model.

The study of Jang & Yi (2019) aims to develop a comprehensive set of the most important factors relating to user experience when using a smart TV. Through a think aloud study and a diary study, user's initial reactions when using a smart TV were captured, and flaws in user experiences were documented. The results of this study found that the controllability of a remote control, cognitive ease, and voice control were the most important things to maximize user experience when using a smart TV.

The study of Lee, et al. (2014) aims to design a smart TV system with a client-server architecture. The goal is to implement 3 features, which are body gesture control, social opinions for recommendations, and context awareness. Collaborative filtering was used to create content recommendations. After developing this new system, experiments were run to prove the importance of having this upgraded system.

The study of Togootogtokh and Shih (2017) uses technology to create a machine learning method to replace the remote for a smart tv with a vision keyboard. This uses gesture detection and fingertip detection, and the machine learning takes real time video streams through a web cam to analyze these gestures. This was tested with online and offline users using a QWERTY keyboard. These experiments resulted in high accuracy for both different lighted areas and different backgrounds. This study is very different from ours, as it uses a vision keyboard and hand gestures, and is trying to replace the remote entirely.

Wu, et al. (2019) aim to provide insight into different inputs for smart tv systems. Specifically, it looks at gesture input from 19 user defined freehand gestures. The study determines what gestures are preferred by tv users and what leads to better user experience. Therefore, the research resulted in creating a unified freehand gesture recognition framework. This research is significantly different from our research, it does not try to optimize anything, it just provides insight on different gesture inputs.

The goal of Chen and Li’s research paper (2019) is to create an interface design for elderly users of smart TVs. To measure user experience, this study focused on five elements, which are, turning on the tv, reading content, choosing a video, watching a video, and turning off the tv. This research resulted in the construction of a user experience map which is a visualization tool that optimizes design for elderly use, but does not tackle the keyboard layout.

The goal of the Tuisku, et al. (2013) research aims to explore and test a new text entry system, which is a face interface. This is a head worn device that can point to letters by tracking the user’s gaze, and then select a letter by smiling. Three different keyboard layouts were developed to be used by this new interface. The layouts were different based on the size of the keys and their locations. After running experiments on 10 individuals, it was found that there was no statistical difference between the three keyboards characters per minute, but users preferred the layout that had bigger keys around the edge and smaller keys in the middle.

Hendrik, et al. (2019) research aims to find the useability of a leap motion controller for hand gesture recognition. The goal is for the leap motion hand movements to replace the function of a keyboard, making this a user centered design. In this paper, the leap motion controller has a sense point, grab, wave, and reach function. The method followed was designing the interface, then calibrating the leap motion controller, collecting gesture input of hand movements, and then analyze the results. The use of the leap motion controller resulted in 87.62% accuracy.

**Research Gap**

To the best of our knowledge, there is no other research that tried to develop a keyboard layout specifically for streaming applications for smart TVs. This research uses similar methodology for those in the first category, but instead of using a dictionary or other literature texts, it uses movie and TV show titles as the corpus for the analysis. Besides, this paper proposes a flexible keyboard layout for different streaming applications as it can be customized to only the movie and TV show titles that are listed in that streaming service.

## Methodology

As the corpus of this research, we used the full list of movie and TV show titles from the IMDb database (available at: https://datasets.imdbws.com/, accessed: 9 June 2022). The total number of titles is 8,982.589. The data needed to be cleaned and preprocessed before starting the analysis process. The preprocessing steps includes:

1. Removing all spaces, numbers, and punctuation marks, as these characters are assumed to be located at the peripherals of the keyboard, not in it.

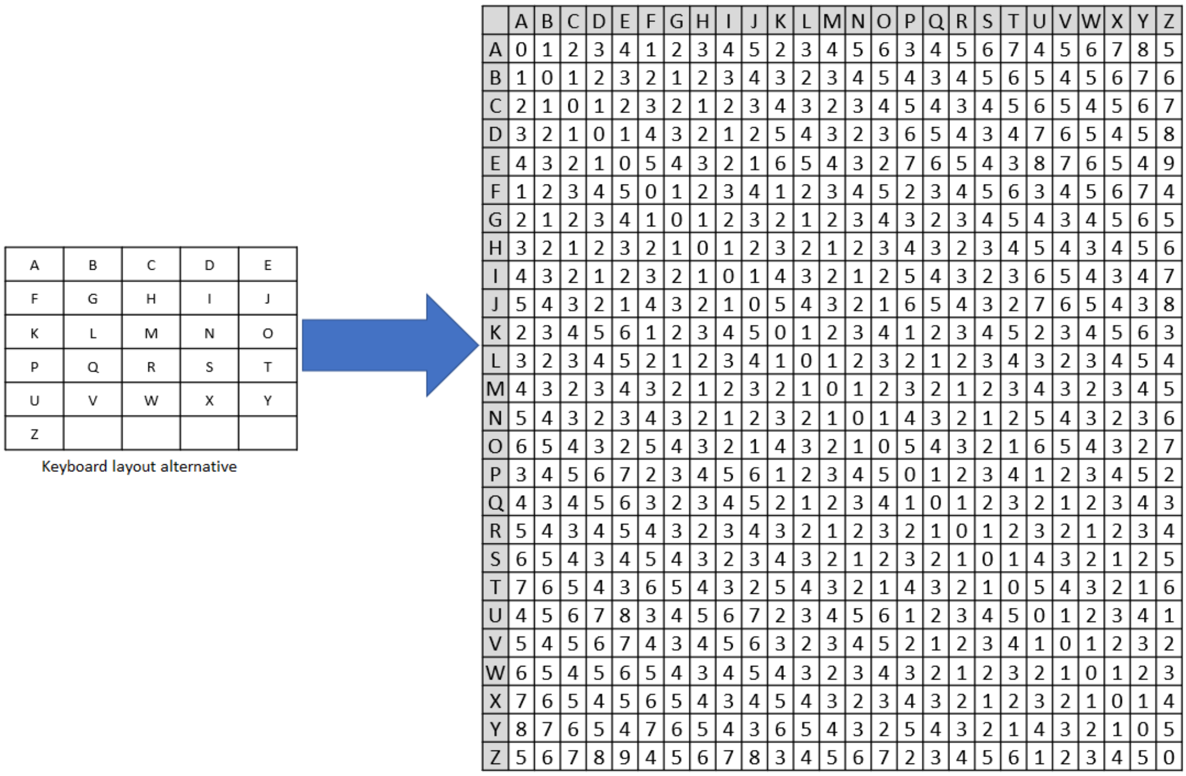
2. Removing all non-English characters, as they are assumed to require a separate keyboard design of their own, and beyond the scope of this research.

3. Removing the titles start with the word “Episode”, as there are 3,651,098 TV show titles in the IMDB dataset that follow the “Episode #1”, “Episode #2”, etc. pattern. We assumed it is highly unlikely that the users would search for any TV show using episode numbers, and the same word appearing so many times in the dataset would affect the letter frequencies.

At the end of the cleaning and preprocessing, 5,331,491 titles were left for the frequency analysis. The next step is to create a frequency matrix for letter pairs that follow each other. As shown in Table 1, each number in this matrix shows how many times the letters in the rows are followed by the letters in the columns.

The third step is creating a function to calculate the rectilinear distances between any two letters in any 6 by 5 keyboard layout in terms of number of remote control clicks. As shown in Figure 1, if the given keyboard layout is simply in the alphabetical order, the distance between A and A would be zero (because no clicks are required to move from A to A), the distance between A and B, and A and F are one, because it takes 1 remote control click to move from A to B (in the horizontal direction), and from A to F (in the vertical direction). However, it requires

2 clicks to move from A to G (it does not matter whether horizontal movement first, or the vertical movement first), therefore the distance between A and G is 2.



| | | | | |
|---|---|---|---|---|
| A | B | C | D | E |
| F | G | H | I | J |
| K | L | M | N | O |
| P | Q | R | S | T |
| U | V | W | X | Y |
| Z | | | | |

Keyboard layout alternative

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 5 | 2 | 3 | 4 | 5 | 6 | 3 | 4 | 5 | 6 | 7 | 4 | 5 | 6 | 7 | 8 | 5 |
| B | 1 | 0 | 1 | 2 | 3 | 2 | 1 | 2 | 3 | 4 | 3 | 2 | 3 | 4 | 5 | 4 | 3 | 4 | 5 | 6 | 5 | 4 | 5 | 6 | 7 | 6 |
| C | 2 | 1 | 0 | 1 | 2 | 3 | 2 | 1 | 2 | 3 | 4 | 3 | 2 | 3 | 4 | 5 | 4 | 3 | 4 | 5 | 6 | 5 | 4 | 5 | 6 | 7 |
| D | 3 | 2 | 1 | 0 | 1 | 4 | 3 | 2 | 1 | 2 | 5 | 4 | 3 | 2 | 3 | 6 | 5 | 4 | 3 | 4 | 7 | 6 | 5 | 4 | 5 | 8 |
| E | 4 | 3 | 2 | 1 | 0 | 5 | 4 | 3 | 2 | 1 | 6 | 5 | 4 | 3 | 2 | 7 | 6 | 5 | 4 | 3 | 8 | 7 | 6 | 5 | 4 | 9 |
| F | 1 | 2 | 3 | 4 | 5 | 0 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 5 | 2 | 3 | 4 | 5 | 6 | 3 | 4 | 5 | 6 | 7 | 4 |
| G | 2 | 1 | 2 | 3 | 4 | 1 | 0 | 1 | 2 | 3 | 2 | 1 | 2 | 3 | 4 | 3 | 2 | 3 | 4 | 5 | 4 | 3 | 4 | 5 | 6 | 5 |
| H | 3 | 2 | 1 | 2 | 3 | 2 | 1 | 0 | 1 | 2 | 3 | 2 | 1 | 2 | 3 | 4 | 3 | 2 | 3 | 4 | 5 | 4 | 3 | 4 | 5 | 6 |
| I | 4 | 3 | 2 | 1 | 2 | 3 | 2 | 1 | 0 | 1 | 4 | 3 | 2 | 1 | 2 | 5 | 4 | 3 | 2 | 3 | 6 | 5 | 4 | 3 | 4 | 7 |
| J | 5 | 4 | 3 | 2 | 1 | 4 | 3 | 2 | 1 | 0 | 5 | 4 | 3 | 2 | 1 | 6 | 5 | 4 | 3 | 2 | 7 | 6 | 5 | 4 | 3 | 8 |
| K | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 0 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 5 | 2 | 3 | 4 | 5 | 6 | 3 |
| L | 3 | 2 | 3 | 4 | 5 | 2 | 1 | 2 | 3 | 4 | 1 | 0 | 1 | 2 | 3 | 2 | 1 | 2 | 3 | 4 | 3 | 2 | 3 | 4 | 5 | 4 |
| M | 4 | 3 | 2 | 3 | 4 | 3 | 2 | 1 | 2 | 3 | 2 | 1 | 0 | 1 | 2 | 3 | 2 | 1 | 2 | 3 | 4 | 3 | 2 | 3 | 4 | 5 |
| N | 5 | 4 | 3 | 2 | 3 | 4 | 3 | 2 | 1 | 2 | 3 | 2 | 1 | 0 | 1 | 4 | 3 | 2 | 1 | 2 | 5 | 4 | 3 | 2 | 3 | 6 |
| O | 6 | 5 | 4 | 3 | 2 | 5 | 4 | 3 | 2 | 1 | 4 | 3 | 2 | 1 | 0 | 5 | 4 | 3 | 2 | 1 | 6 | 5 | 4 | 3 | 2 | 7 |
| P | 3 | 4 | 5 | 6 | 7 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 0 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 5 | 2 |
| Q | 4 | 3 | 4 | 5 | 6 | 3 | 2 | 3 | 4 | 5 | 2 | 1 | 2 | 3 | 4 | 1 | 0 | 1 | 2 | 3 | 2 | 1 | 2 | 3 | 4 | 3 |
| R | 5 | 4 | 3 | 4 | 5 | 4 | 3 | 2 | 3 | 4 | 3 | 2 | 1 | 2 | 3 | 2 | 1 | 0 | 1 | 2 | 3 | 2 | 1 | 2 | 3 | 4 |
| S | 6 | 5 | 4 | 3 | 4 | 5 | 4 | 3 | 2 | 3 | 4 | 3 | 2 | 1 | 2 | 3 | 2 | 1 | 0 | 1 | 4 | 3 | 2 | 1 | 2 | 5 |
| T | 7 | 6 | 5 | 4 | 3 | 6 | 5 | 4 | 3 | 2 | 5 | 4 | 3 | 2 | 1 | 4 | 3 | 2 | 1 | 0 | 5 | 4 | 3 | 2 | 1 | 6 |
| U | 4 | 5 | 6 | 7 | 8 | 3 | 4 | 5 | 6 | 7 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 0 | 1 | 2 | 3 | 4 | 1 |
| V | 5 | 4 | 5 | 6 | 7 | 4 | 3 | 4 | 5 | 6 | 3 | 2 | 3 | 4 | 5 | 2 | 1 | 2 | 3 | 4 | 1 | 0 | 1 | 2 | 3 | 2 |
| W | 6 | 5 | 4 | 5 | 6 | 5 | 4 | 3 | 4 | 5 | 4 | 3 | 2 | 3 | 4 | 3 | 2 | 1 | 2 | 3 | 2 | 1 | 0 | 1 | 2 | 3 |
| X | 7 | 6 | 5 | 4 | 5 | 6 | 5 | 4 | 3 | 4 | 5 | 4 | 3 | 2 | 3 | 4 | 3 | 2 | 1 | 2 | 3 | 2 | 1 | 0 | 1 | 4 |
| Y | 8 | 7 | 6 | 5 | 4 | 7 | 6 | 5 | 4 | 3 | 6 | 5 | 4 | 3 | 2 | 5 | 4 | 3 | 2 | 1 | 4 | 3 | 2 | 1 | 0 | 5 |
| Z | 5 | 6 | 7 | 8 | 9 | 4 | 5 | 6 | 7 | 8 | 3 | 4 | 5 | 6 | 7 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 0 |

Distance Matrix

Figure 1. Calculation of the Distance Matrix

The final step is to generate alternative keyboard layouts to minimize the number of clicks using genetic algorithms. We used GA package (Scrucca, 2013; Scrucca , 2017) in the R environment, using R version 4.1.0 (R Core Team, 2021) and RStudio (Posit Team, 2023) version 2023.3.0.386.

The ga() function generates a random permutation of integers from 1 to 26, each integer is matched with the corresponding letter of the alphabet, and then the permutation is rearranged into a 6 by 5 matrix. We assume that the user would start typing from the upper left corner of the keyboard, therefore we chose a 6 by 5 layout so that the number of rows and columns should be equal. Since there are 26 characters in the English language, we decided to arrange the most frequent letters to fit in the 5 by 5 matrix, and leave the least frequent letter at the bottom as the 26th character.

Once the keyboard alternative is generated, the evaluation function calculates the distance matrix for that layout, multiplies the distance values in the distance matrix with the corresponding frequency values in the frequency matrix, and returns the sum of the products. The genetic algorithm tries to minimize the sum.Figure 2 shows the final layout with the minimum sum of products. As the frequency matrix in Table 1 indicates that Q is the letter that is least frequently used in movie and TV show titles, it ended up in the lower bottom corner of the layout, as expected.

Table 1. The Frequency Matrix

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 96466 | 206572 | 411256 | 388383 | 54573 | 123826 | 242989 | 90906 | 315407 | 40580 | 220141 | 789560 | 490744 | 1454211 | 39902 | 239506 | 12509 | 1077286 | 633701 | 757494 | 205016 | 166824 | 91836 | 19756 | 254829 | 58725 |
| B | 296024 | 32290 | 7324 | 5510 | 353365 | 2660 | 2603 | 10259 | 174443 | 3971 | 8125 | 180540 | 4583 | 3832 | 235210 | 2711 | 977 | 182572 | 28394 | 11332 | 139998 | 1607 | 2981 | 207 | 60328 | 1059 |
| C | 402393 | 7446 | 38590 | 7555 | 314563 | 5356 | 4552 | 636173 | 196392 | 2128 | 269785 | 101911 | 9438 | 7955 | 418834 | 7041 | 2591 | 146933 | 27043 | 160800 | 98279 | 3954 | 4326 | 352 | 28402 | 5113 |
| D | 467893 | 57470 | 57093 | 93249 | 814191 | 40418 | 47277 | 45753 | 392027 | 17019 | 13575 | 56195 | 55359 | 39401 | 331325 | 40592 | 1710 | 156882 | 174439 | 111905 | 99309 | 31612 | 43006 | 1194 | 76999 | 7538 |
| E | 665234 | 255654 | 390284 | 531576 | 357926 | 199725 | 208972 | 135177 | 289317 | 45913 | 114398 | 658625 | 387792 | 1103868 | 190483 | 266877 | 19028 | 1674939 | 1192390 | 613709 | 112148 | 226020 | 238163 | 112753 | 146856 | 41288 |
| F | 214698 | 15956 | 23832 | 23698 | 194748 | 88578 | 12730 | 18067 | 216328 | 7275 | 6117 | 98463 | 22181 | 9621 | 218863 | 15146 | 589 | 177540 | 36177 | 158618 | 86995 | 4495 | 11594 | 770 | 10325 | 1854 |
| G | 267086 | 37735 | 24796 | 31408 | 419246 | 27725 | 51928 | 201395 | 184203 | 7447 | 14427 | 75869 | 29907 | 43862 | 208906 | 22419 | 1576 | 161901 | 97947 | 71215 | 110842 | 6746 | 27556 | 1378 | 26911 | 3411 |
| H | 544150 | 25346 | 20231 | 27370 | 1466840 | 15956 | 11775 | 17205 | 409456 | 9968 | 11639 | 43829 | 36428 | 48277 | 458222 | 15372 | 1717 | 103004 | 41620 | 191809 | 101789 | 8437 | 23575 | 343 | 40277 | 3204 |
| I | 311658 | 67326 | 441469 | 257284 | 500922 | 114437 | 273288 | 26670 | 47321 | 28558 | 136516 | 450475 | 247260 | 1553795 | 359308 | 98072 | 13362 | 308537 | 641886 | 578757 | 20540 | 181007 | 16850 | 27947 | 23019 | 50745 |
| J | 126292 | 1288 | 1462 | 2558 | 82635 | 1128 | 1147 | 2431 | 38343 | 1683 | 3731 | 1986 | 1634 | 4327 | 105482 | 2316 | 70 | 5988 | 4547 | 2257 | 88944 | 1155 | 916 | 26 | 927 | 590 |
| K | 209254 | 15430 | 13690 | 14908 | 287258 | 13736 | 6889 | 26539 | 242040 | 5640 | 26673 | 103947 | 17764 | 40635 | 113592 | 15119 | 426 | 37930 | 88936 | 53386 | 78656 | 8187 | 13275 | 365 | 48803 | 2025 |
| L | 665841 | 45161 | 57414 | 188189 | 831497 | 59986 | 44771 | 29750 | 592649 | 12633 | 55718 | 510656 | 78824 | 25218 | 437188 | 52862 | 2671 | 27898 | 160973 | 124543 | 144720 | 34841 | 25067 | 1383 | 146055 | 5891 |
| M | 687693 | 97444 | 24992 | 18098 | 580780 | 14212 | 11436 | 13263 | 358077 | 4723 | 8860 | 16393 | 96026 | 23669 | 340130 | 131942 | 1011 | 29969 | 75277 | 32813 | 108224 | 6896 | 10139 | 1922 | 94694 | 2618 |
| N | 526504 | 81305 | 257992 | 792550 | 646906 | 90066 | 783803 | 66109 | 432390 | 41789 | 121066 | 68320 | 81661 | 195301 | 375927 | 67004 | 8732 | 56844 | 413405 | 681812 | 84217 | 57441 | 52181 | 4944 | 107171 | 30406 |
| O | 97266 | 131755 | 172024 | 252484 | 81846 | 391927 | 109292 | 67997 | 99995 | 28847 | 136264 | 368838 | 405460 | 1054722 | 283414 | 184230 | 6135 | 793918 | 357001 | 313837 | 522978 | 187875 | 250063 | 23292 | 76372 | 20095 |
| P | 393695 | 10215 | 13177 | 13154 | 327931 | 14569 | 5665 | 72506 | 209794 | 2317 | 9994 | 132156 | 11346 | 6339 | 216967 | 90287 | 585 | 225136 | 68840 | 71291 | 71280 | 2684 | 8673 | 238 | 26085 | 1013 |
| Q | 2853 | 334 | 282 | 198 | 325 | 213 | 76 | 153 | 3456 | 58 | 117 | 371 | 179 | 164 | 232 | 171 | 1140 | 229 | 462 | 461 | 110289 | 221 | 252 | 36 | 59 | 18 |
| R | 748480 | 84387 | 122616 | 233322 | 1034256 | 74553 | 112981 | 50068 | 746886 | 16534 | 110744 | 169703 | 143127 | 168011 | 628516 | 79077 | 6071 | 161018 | 436003 | 442325 | 185188 | 67562 | 49861 | 2663 | 198108 | 18768 |
| S | 447899 | 92095 | 271609 | 111030 | 589015 | 79985 | 61888 | 398981 | 412162 | 23157 | 105493 | 117033 | 130899 | 84709 | 375294 | 241692 | 18306 | 60595 | 384020 | 1025746 | 224674 | 51703 | 92551 | 2750 | 56923 | 13101 |
| T | 566145 | 58601 | 103170 | 69500 | 848786 | 54032 | 32142 | 1491066 | 667646 | 17579 | 28284 | 122752 | 84795 | 50083 | 649635 | 46953 | 2875 | 396523 | 333217 | 307620 | 181578 | 34165 | 82938 | 2135 | 149008 | 27172 |
| U | 84996 | 81714 | 115120 | 85141 | 171468 | 38750 | 97281 | 15938 | 94731 | 13752 | 46522 | 186626 | 155551 | 443927 | 17623 | 118700 | 1739 | 412678 | 342112 | 255228 | 11818 | 17091 | 10364 | 14620 | 16093 | 16894 |
| V | 150595 | 1735 | 3520 | 4513 | 507046 | 1378 | 2318 | 1633 | 281020 | 1009 | 8012 | 7726 | 2669 | 5180 | 94013 | 3041 | 90 | 14289 | 69265 | 4051 | 7238 | 2467 | 1242 | 138 | 11855 | 974 |
| W | 245432 | 13426 | 8716 | 12265 | 193618 | 6748 | 5040 | 111967 | 247668 | 3466 | 5622 | 13927 | 10794 | 58568 | 157425 | 5877 | 294 | 27761 | 43544 | 23410 | 6815 | 1511 | 14889 | 316 | 15986 | 1376 |
| X | 16021 | 3320 | 9915 | 3739 | 14030 | 3994 | 2081 | 3180 | 32969 | 842 | 972 | 3861 | 5590 | 1486 | 8156 | 28298 | 605 | 5613 | 6784 | 25918 | 6401 | 2350 | 2579 | 7350 | 7393 | 397 |
| Y | 134594 | 58483 | 58235 | 47181 | 90111 | 40671 | 30226 | 43604 | 48069 | 11755 | 17872 | 61356 | 60571 | 44963 | 198444 | 56142 | 2129 | 37187 | 156963 | 81828 | 26653 | 14795 | 42104 | 1770 | 9566 | 4313 |
| Z | 58622 | 3637 | 2748 | 5248 | 64533 | 1863 | 2783 | 11492 | 40461 | 1257 | 3735 | 8593 | 4483 | 6260 | 35421 | 2729 | 382 | 2916 | 5359 | 9051 | 26357 | 4398 | 7056 | 120 | 11863 | 16983 |

| | | | | |
|---|---|---|---|---|
| J | B | M | D | Y |
| F | O | A | R | L |
| K | N | I | E | P |
| U | C | T | S | V |
| Z | G | H | W | X |
| Q | | | | |

Figure 2. The Proposed Keyboard Layout

## Testing

In order to test the proposed keyboard layout, we tested it against three other keyboard layouts frequently used in smart TV streaming applications. Figure 3 shows the four keyboard layouts tested. Keyboard 1 uses the same 6 by 5 layout as the layout proposed in this research, in alphabetical order. Keyboard 2 uses 5 by 6 alphabetical layout as used in Amazon Prime Video, Vudu and Netflix apps for Samsung Smart TVs. Keyboard 3 uses a 4 by 7 alphabetical layout as used in YouTube and Disney+ apps for Samsung Smart TVs. Keyboard 4 uses standard QWERTY keyboard layout as used in Samsung Universal Guide. Keyboard 5 is the layout proposed in this research.

Keyboard 1

| | | | | |
|---|---|---|---|---|
| A | B | C | D | E |
| F | G | H | I | J |
| K | L | M | N | O |
| P | Q | R | S | T |
| U | V | W | X | Y |
| Z | | | | |

Keyboard 2

| | | | | | |
|---|---|---|---|---|---|
| A | B | C | D | E | F |
| G | H | I | J | K | L |
| M | N | O | P | Q | R |
| S | T | U | V | W | X |
| Y | Z | | | | |

Keyboard 3

| | | | | | | |
|---|---|---|---|---|---|---|
| A | B | C | D | E | F | G |
| H | I | J | K | L | M | N |
| O | P | Q | R | S | T | U |
| V | W | X | Y | Z | | |

Keyboard 5

| | | | | |
|---|---|---|---|---|
| J | B | M | D | Y |
| F | O | A | R | L |
| K | N | I | E | P |
| U | C | T | S | V |
| Z | G | H | W | X |
| Q | | | | |

Keyboard 4

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Q | W | E | R | T | Y | U | I | O | P |
| A | S | D | F | G | H | J | K | L | |
| Z | X | C | V | B | N | M | | | |

Figure 3. The Keyboard Layouts Used in the Tests

We tested all five keyboards against IMDb Top 100 list, and calculated how many clicks are required to spell out each movie title using each one of the keyboard layouts. The test started from the upper left corner of each keyboard. We only counted the total number of clicks on the arrow buttons on the remote control, while ignored the clicks on the "OK" button that required to confirm the letter, since it would be the same for all the keyboard layouts.

The test results show that out of 100 movies tested, the proposed keyboard layout requires the minimum number of clicks in 87 times, 4 of them tied with one of the other keyboard layouts. For example, in order to spell out "The Shawshank Redemption" with a smart TV remote control, it takes 73 clicks with Keyboard 1, 69 clicks with Keyboard 2, 81 clicks with Keyboard 3 and 75 clicks with Keyboard 4. On the other hand, it only requires 51 clicks with Keyboard 5. Even in the 13 cases where one of the keyboards performed better than Keyboard 5, the difference between Keyboard 5's performance and those of other keyboards was only 3.54 clicks on average. On average, Keyboard 5 performed 14.01 clicks better than Keyboard 1, 13.06 clicks better than Keyboard 2, 18.81 clicks better than Keyboard 3, and 20.77 clicks better than Keyboard 4.

## Conclusion and Limitations to the Research

This paper tries to develop a keyboard layout design for smart TV streaming apps to minimize the number of remote control clicks required to spell out the title of movies or TV shows. Moreover, although the proposed keyboard layout is developed using the entire IMDb database, the method can be applied to the specific content of a streaming service to customize, and dynamically updated as the shows listed on that streaming service changes.

The major limitation to this research is that it showed that the proposed keyboard requires less clicks to spell out titles, but it does not confirm if it requires less time. Although there is literature about people learning new keyboard layouts (Francis & Oxtoby, 2006) and there is literature that argue people would prefer familiar layouts (Lee, et al., 2019; Perrinet, et al., 2011), these arguments were not tested in the smart TV environment. We believe that there is room for further research to test the proposed keyboard layout with users to analyze if the proposed layout can improve the typing speed, as well as the number of clicks.

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