Optimization of a Single Finger Keyboard Layout using Genetic Algorithm and TOPSIS

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ABSTRACT

The aim of this paper is to develop a new layout for single finger keyboard used in smartphones. The layout problem is modeled as a Quadratic Assignment Problem (QAP). The meta-heuristic, Genetic Algorithm is used to solve the QAP problem. Three performance measures such as flow distance, average words per minute and learning percentage are used to evaluate the layouts. The objective of the work is to minimize the flow distance, learning percentage, and maximize the typing speed. As the problem belongs to a multiple attribute decision making problem, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is applied to find out the best layout

Key Words: Layout problem, Single finger keyboard, TOPSIS.

1. INTRODUCTION

Keyboard is the most common and popular devices used for feeding information into text processing electronic devices like computer, PDA and smartphones. The most popular keyboard layout is the QWERTY layout introduced by Christopher Latham Sholes in 1878. Since then, the QWERTY layout became the popular keyboard layout and is still used as the standard keyboard layout. Other keyboard layouts such as DVORAK, ABC, etc, were proposed later, but all these types of layout belong to n-finger layout, i.e. they are used with more than one finger. With the recent widespread use of smartphones and Personal Data Assistants (PDA's), which mostly uses single finger to type, the single finger (s-finger) layout has become a necessity.

The problem of single finger layout is considered as a generalization of the Quadratic Assignment Problem. As this type of problem is NP hard, it is difficult to solve using direct methods. So a meta-heuristic, Genetic Algorithm is used to solve the problem. The main objective considered for solving the QAP is the minimization of the flow distance. After finding out the best layouts, they are tested by typing a sample document using the given layout. From this, the typing speed, in terms of words per minute, and the learning percentage are found out. These three attributes are considered to find out the best layout from the different alternatives. As this is a Multi attribute decision making problem, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), is used to find the best alternative.

The rest of this paper is organized as follows. Section 2 briefly reviews the literature. Section 3 presents the problem description. The methodology adopted and the dataset used for the work are presented in Section 4. Furthermore, the results and the new layout are discussed in section 5. Finally, conclusions are presented in Section 6.

2. LITERATURE REVIEW

In order to optimize the keyboard layout, some creditable works have been proposed. Some of these works are shown in Table 1.

Table 1: Review of relevant Literature

Author(s)	Work	Methodology
Lisa et al. (1993)	Optimizing typewriter keyboards	Simulated Annealing
Eggers et al. (2003)	Optimization of keyboard arrangement by considering ergonomic factors	Ant Colony Optimization
Sorensen (2007)	Multi-objective optimization of mobile phone keypads	Multi-start descent algorithm
Amico et al. (2009)	Single finger layout problem	
Yin et al. (2011)	Optimization for general keyboard layout problem	Cyber swarm method

3. PROBLEM DESCRIPTION

The problem considered is to find out s-finger layout with the assumptions that (i) aall keys are identical (ii) keys are unit squares and arranged in a grid (iii) each symbol is assigned to only one key (iv) only alphabets from A to Z and Space are considered. The problem is modeled as a QAP. The objective function of minimizing the flow distance is given by

Minimize,

$$C = \sum_{i=1}^{M} \sum_{j=1}^{M} F_{ij} C_{ij} D_{ij} \qquad \text{--------- (i)}$$

Where,

D_{ij} is the Euclidean distance between locations of machine *i* and *j*

F_{ij} is the flow of letters between keys *i* and *j*

C is the flow distance

4. METHODOLOGY

4.1 Genetic Algorithm proposed

To solve the model, Genetic Algorithm (GA) is used. The GA is a stochastic search technique. It can explore the solution space by using the concept taken from evolution theory and natural genetics. GA starts with an initial set of random solutions for the problem under consideration. This set of solutions is known as the population. The individuals of the population are called chromosomes. A typical chromosome is shown in Figure 1. The chromosomes of the population are evaluated according to their fitness function, which in this case is the flow distance. The chromosomes evolve through successive iterations called generations. During each generation, through merging and modifying chromosomes of a given population, creates a new population. Merging chromosomes is known as crossover. Crossover is the process in which the chromosomes are mixed and matched in a random fashion to produce a pair of new chromosomes (offspring). In this work, a single point crossover operator is used. Modifying an existing one is known as mutation. Mutation operator is the process used to rearrange the structure of the chromosome to produce a new one. Swap mutation is used in this work. The selection of chromosomes to crossover and mutate is based on their fitness function. The popular roulette wheel selection technique is used in this paper. Once a new generation is created, deleting members of the present population to make room for the new generation forms a new population. The process is iterative until the stopping criterion, here number of generations specified, is reached.

5	1	3	4	10	17	……………	27

Figure 1: Chromosome representation

4.2 Algorithm

Step 1: Select initial parameters and generate an initial population

- Set the values for population size, maximum number of generations, crossover probability and mutation probability
- Generate an initial population of specified size
- Calculate the objective function value and map this to the fitness value

Step 2: Evaluate each individual's fitness
Step 3: Determine population's average fitness
Step 4: Select best-ranking individuals using elitist strategy
Step 5: Apply crossover operator (single point crossover)
Step 6: Apply mutation operator (swap mutation)
Step 7: Evaluate each individual's fitness
Step 8: Compare the chromosomes of old population and new population
Step 9: Generate new population by replacing the existing chromosomes with the offspring which outperforms the previous population
Step 10: Continue till number of generations specified is reached

4.3. Multiple Attribute Decision Making Problem

The proposed algorithm is run multiple times and the best 10 solutions are noted. From these layouts, the best layout is found by considering three attributes such as flow distance, average words per minute and learning percentage. The flow distance is equal to the sum of products of flow volume and the Euclidean distance. The flow distance is calculated by taking a list of most frequently used words in English language. The average words per minute are obtained by testing the layout with an English poem by Robert Frost titled 'Stopping by the Woods on a Snowy Evening'. The learning percentage is found out from the learning curve for the time taken to type the poem ten times using the given layout. Among the three attributes, the typing speed is to be maximized,

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while the other two attributes, the learning percentage and the flow distance is to be minimized.

To type the document, the keyboard is tweaked using the software KeyTweak. Then the characters are pasted on the physical keyboard to change the keyboard layout to the one obtained using the meta-heuristic. The document is typed 10 times using the given layout by giving equally spaced time interval between two successive attempts to account for fatigue.

This is a multiple attribute decision making problem. The aim is to select the best from existing alternatives by considering multiple attributes which are in conflict with each other. TOPSIS is used in this work to find out the best layout. TOPSIS selects the alternative that is the closest to the ideal solution and farthest from negative ideal alternative.

5. RESULTS

A Scilab program for GA is coded and is run multiple times for 1000 iterations and the best ten solutions are noted. The GA parameters used here are, crossover probability (Pc) of 0.8, mutation probability (P_m) of 0.1, population size of 54. The attribute values for all the ten layouts, shown in figure 2, are found out. TOPSIS is used to rank the alternatives.

No	Layout
L1	V I R L N O D P J Q Y W Sp E F A X M Z B S U T H C G K
L2	V S C N I Q W Z F X M L E Sp O H Y B J G P A R T K D U
L3	Q F B T Sp O Y L K X C Z I M S A G D P J V U N E H R W
L4	R J F O D S G C I Q Z P M E Sp N K B X L V Y W A T H U
L5	W D E A I N Q Y L Z R H S Sp T M K C X V B F J O U P G
L6	B R M H D L A K C V U N I S T E F G Q J O W Sp P Y X Z
L7	L Y J N I U T Q V Z P F D E Sp W A S C K X G O H B R M
L8	V S C N I U W P F X M L E Sp O H Y B J G Z A R T K D K
L9	C V G Y I F U B Z P M N A D Sp T X W Q L E O R H S K J
L10	K B Y T S E Q M J V P I X W Sp A F H G Z U O N R D C L

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Figure 2: 10 layouts

The experimental data is shown in Table 2 and the result obtained from TOPSIS is shown in Table 3.

Table 2: Experimental data

Alternative	AVG Words per Minute	Learning %	Flow distance
L1	15.89	84.38	19459974
L2	16.89	91	19491196
L3	13.03	94.5	20101942
L4	17.7	88.5	20621655
L5	16.39	87.4	20139277
L6	13.88	91.6	20861637
L7	13.18	86.8	20862576
L8	14.05	87.7	19563421
L9	13.59	85.32	20452663
L10	14.87	86.4	20809853

Table 3: TOPSIS Rank

Alternative	Relative closeness to ideal solution	Rank
L1	0.654784674	4
L2	0.75622726	2
L3	0.101674596	10
L4	0.812270492	1
L5	0.715887576	3
L6	0.197642076	9
L7	0.233201205	8
L8	0.344293388	6
L9	0.290962056	7
L10	0.435674678	5

From the relative closeness values obtained from TOPSIS, the fourth layout, L4, is the best among the ten alternatives, when all the three attributes are considered. The layout is shown in Figure 3.

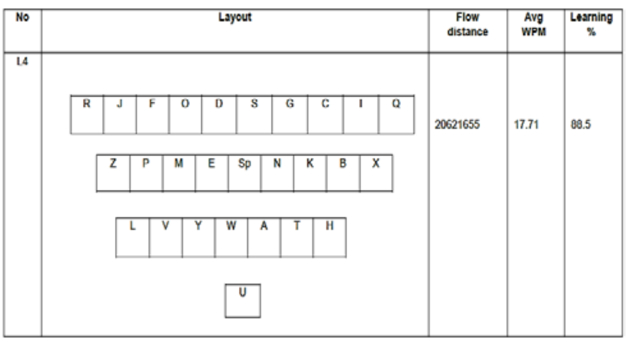

Figure 3: Best layout

6. CONCLUSION

In this work, Genetic algorithm is used to find a new keyboard layout that will reduce the flow distance while maximizing the typing speed and minimizing the learning percentage. A Scilab program is developed and run ten times to find out ten best layouts. From these ten layouts, the best layout is found out by using TOPSIS.

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