CHAPTER 5

USER INTERFACE COMPONENTS LAYOUT PROBLEM WITH MULTIPLE QUALITATIVE FACTORS

The qualitative factors, such as familiarity, interface type, fatigue, attention, anxiety, fear, monotony, boredom, etc. will have different kinds of effects on the final layouts of user interface components. Hence, it is required to handle the closeness relationships of all factors concerned with novice, intermittent, and expert users individually in the objective function of the user interface components layout problem. This chapter presents an alternate model, handling the distance weighted multiple normalized qualitative factors assigned with the relative weights in the objective function of the user interface components layout problem. The results of the proposed model are compared with that of an existing model, which handles distance weighted attribute values of a single qualitative factor in the objective function of the user interface component layout problem for the example task under consideration. Finally, the contents of chapter are briefed in the summary.

Next section of the chapter presents the various qualitative factors that affect the layouts of user interface components.

5.1 EFFECT OF QUALITATIVE FACTORS ON THE LAYOUT DESIGN OF USER INTERFACE COMPONENTS

The qualitative factors concerned with the novice, intermittent, and expert users are characterized as familiarity, interface type, instruction
type, fatigue, attention, monotony, boredom, anxiety, fear, etc. Based on the type of users, each of the qualitative factors influence the layout of user interface components considerably.

Generally, a novice user is less familiar with the tasks compared to the intermittent and expert users. As a result, for a novice user, using a poorly designed HCI system may require heavy cognitive effort, whereas for an expert user, the same HCI system becomes routine and uses the system without much cognitive effort. It results in the variation of the desired closeness relationships between the user interface components for the novice, intermittent, and expert users.

The desired closeness relationships between the components for the novice, intermittent, and expert users may also vary based on the menu-based and direct-manipulation interfaces. The time required to complete a task in direct-manipulation interface will be less than that in a menu-based interface [Lim et al., 1996], and hence the closeness relationships between the components (icons) for the various types of users may be different to complete a task in less time in direct-manipulation interface.

Within each type of interface, there may be specific instructions and interpretive instructions. For less familiar tasks, it is required to implement specific instructions, whereas familiar tasks require the interpretive instructions [Lim et al., 1996]. Hence, the desired closeness relationships
between the components for the novice users having less familiarity with tasks are different from that of the expert users having high familiarity with tasks.

Less familiar tasks of novice users cause the fatigue at high rate compared to the familiar tasks of expert users. Fatigue in the users may also vary with the type of interface and instructions. Sometimes, interpretive instructions on both direct - manipulation and menu - based interfaces may cause fatigue in expert users too at fast rate. On the other hand, both in direct manipulation and menu - based interfaces, when the novice users implementing specific instructions may cause fatigue at less rate. These issues result in the different desired closeness relationships between the components for the various types of users to perform the task.

When the routine tasks are performed, there is a possibility of developing monotony and hence the boredom in an expert user. As a result, fatigue is developed in the user. Similarly, even a novice user employing the specific instructions with the same tasks is continuously subjected to monotony and boredom and hence the fatigue. Hence, it is required to take into account the desired closeness relationships between the components for the different users, in order to design the human - computer interface components layouts.
The novice users are subjected to anxiety soon compared to intermittent and expert users [Shneiderman, 2000]. When, the objects (components) are not arranged in order, there is a possibility of developing an anxiety in expert users too. Sometimes, the time constraint may also result in anxiety in the users. The anxiety resulting from all kinds of factors causes the fear in the user. When the objects (component) are arranged properly any user can perform the task with minimum anxiety and fear. It requires to consider the various desired closeness relationships between the components for the different users.

The qualitative factors concerned with novice, Intermittent, and expert users are required to be considered, in order to design the user interface components layout for all sorts of users to perform a task. An alternate model with multiple qualitative factors presented in this chapter for the layout design of user interface components is one of the variations of the proposed multi-factor facilities layout model, handling a number of qualitative and quantitative factors in different manner separately included with cost of assigning the facility to the location in the objective function. The user interface components do not have weight or thickness and they are pixels that can be moved and copies in ways that represent real-world task objects (components) with feedback to guide users [Shneiderman, 2000]. Hence, the proposed model that handles multiple qualitative factors is not included with the cost of assigning facility to the location in the objective function. The results of the proposed model are
compared with that of an existing qualitative approach, in which the effects of all qualitative factors are combined into one single qualitative factor for the example task under consideration.

Next section of the chapter presents the various qualitative approaches, handling a single qualitative factor in the objective function for the facilities layout problem.

5.2 QUALITATIVE APPROACHES FOR THE FACILITIES LAYOUT PROBLEMS

Several qualitative approaches have been developed for the design of the facilities layouts. Seehof and Evans (1967), Lee and Moore (1967), Muther and Mc Pherson (1970), and Muther (1973) have developed algorithms based on qualitative criteria to obtain the layouts. The distances \(d_{ij}\) between the locations \(j\) and \(l\) weigh the closeness relationship ratings to obtain the cost term in the objective function to be minimized as given in equations (1) to (4).

\[
\text{Minimize } Z = \sum_{i} \sum_{j} \sum_{k} r_{ik} d_{ij} x_{ij} x_{kl} 
\]

\[
\text{Subject to : } \sum_{i} x_{ij} = 1, \quad j = 1, 2, \ldots, n
\]

\[
\sum_{i} x_{lj} = 1, \quad l = 1, 2, \ldots, n
\]
\[ x_{ij} = 0 \text{ or } 1, \quad \forall i, j \]  

Where, \( x_{ij} = \begin{cases} 1, & \text{If facility } i \text{ is assigned to location } j \\ 0, & \text{Otherwise.} \end{cases} \)

\[ r_{ik} = \text{Closeness relationship rating between facilities } i \text{ and } k \]

\[ d_{ij} = \text{distance between locations } j \text{ and } i. \]

The distance weighted cost of closeness relationships rating is considered as total numerical rating (TNR) [Sayin, 1981]. All these approaches are distinguished primarily by the scoring system used for the closeness relationship ratings and the solution procedures. For example, the ALDEP procedure presented by Seehof and Evans (1967) used the numerical values as \( A = 64, E = 16, I = 4, O = 1, U = 0, \) and \( X = -1024. \) Similarly, Lee and Moore (1967) presented the CORELAP procedure to obtain the layouts.

The major shortcomings of the qualitative approaches are as follows.

1. A method of scoring is based on pre-assigned numerical values for different closeness ratings. That is, irrespective of the category of the problem, the scoring systems presented in the procedures are used.

2. The strong assumption that all qualitative factors can be aggregated into one criterion. That is, the qualitative factors such as familiarity, interface type, instruction type, fatigue, etc. are combined and considered as a single qualitative factor.
To overcome these shortcomings, an alternate qualitative approach is proposed that handles a number of weighted normalize qualitative factors in the objective function of the layout problem.

5.3 PROPOSED APPROACH INVOLVING MULTIPLE QUALITATIVE FACTORS

The proposed model is involved with assigning the relative weights to each of the normalized qualitative factor, so that the final layout reflects the relative importance of each factor. The methodology begins with normalizing an individual qualitative factor. To normalize a factor, each closeness relationship value is divided by the sum of all closeness relationship values for that factor. Next, the normalized individual qualitative factors are assigned with relative weights based on their relative importance, and are combined into a single qualitative composite factor.

5.3.1 MATHEMATICAL MODEL FORMULATION

First, the closeness relationship ratings range from A to X for all qualitative factors are quantified so that they may be handled mathematically.

To normalize a factor, each relationship value is divided by the sum of all relationship values for that factor as given in equation (5).

\[ R_{ikp} = \frac{r_{ikp}}{\sum_{i} \sum_{k} r_{ikp}} \]

(5)
Where, \( r_{ikp} \) = relationship value between components \( i \) and \( k \) for factor \( p \).

\( R_{ikp} \) = normalized relationship value between the components \( i \) and \( k \) for factor \( p \).

Next, the weight \( (\beta_p) \) is assigned to each factor \( p \) so that the final layout appropriately reflects the relative importance of that factor. Then, the total of all values for each pair of components is computed to obtain a single composite factor \( (R_{ik}) \) as given in equation (6).

\[
R_{ik} = \sum_{i} \sum_{k} \sum_{p} \beta_p R_{ikp}
\]

(6)

Where,

\( u = \) number of qualitative factors.

\( R_{ik} = \) Composite relationship value between the components \( i \) and \( k \).

The composite relationships are weighted by distances \( (d_{jl}) \) between the locations \( j \) and \( l \), and then the objective function is to minimize the total composite numerical rating (TCNR) as given in equations (8) to (11).

\[
\text{Minimize } Z = \sum_{i} \sum_{j} \sum_{k} \sum_{l} R_{ik} d_{jl} x_{ij} x_{kj}
\]

(8)
Subject to : 

$$\sum_{i}^{n} x_{ij} = 1, \quad j = 1, 2, \ldots, n$$ \hspace{1cm} (9) \\

$$\sum_{j}^{n} x_{ij} = 1, \quad i = 1, 2, \ldots, n$$ \hspace{1cm} (10) \\

$$x_{ij} = 0 \text{ or } 1 \quad \forall \ i, j$$ \hspace{1cm} (11) \\

Where, $$x_{ij} = \begin{cases} 1, & \text{If facility } i \text{ is assigned to location } j \\ 0, & \text{Otherwise} \end{cases}$$

The steps involved in the proposed algorithm to obtain the composite qualitative factor ($R_{ik}$) are as follows.

1. Read input data (i.e., closeness relationship matrices of all factors, number of facilities, number of factors, and weight assigned to each factor).
2. Set $i = 1$, $k = 1$ and $p = 1$ (First facility of first factor).
3. Set $A_p = r_{kp}$
4. Compute $A_p = A_p + r_{kp}$.
5. Check whether $i = n$ and $k = n$. If yes GO TO step 7. Otherwise GO TO step 6.
6. Increase $i$ by 1 and $k$ by 1 and GO TO step 3.
8. Check whether $p = u$. If yes GO TO step 10. Otherwise GO TO step 9.
9. Increase $p$ by 1 and GO TO step 3.

10. Compute $R_{ikp} = r_{kp}/A_p$.

11. Check whether $l=n$ and $k=n$. If yes GO TO step 13. Otherwise GO TO step 12.

12. Increase $i$ by 1 and $k$ by 1 and GO TO step 10.

13. Print $R_{ikp}$.


15. Increase $p$ by 1 and GO TO step 10.

16. Compute $R_{ik} = \beta_p R_{ikp}$.

17. Compute $R_i = R_{ik} + \beta_p R_{ikp}$.

18. Check whether $l=n$ and $k=n$. If yes GO TO step 20. Otherwise GO TO step 19.

19. Increase $i$ by 1 and $k$ by 1 and GO TO step 16.

20. Increase $p$ by 1.

21. Check whether $p=u$. If yes GO TO step 23. Otherwise GO TO step 22.

22. Increase $p$ by 1 and GO TO step 16.

23. Print $R_{ik}$.

24. Stop.

The basic steps involved to obtain the composite qualitative factor ($R_{ik}$) are given in the flow chart as shown in Fig.5.1.
Read \( r_{ikp} \), \( n, u \) and \( \beta_k \)

Set \( i = 1 \), \( k = 1 \), and \( p = 1 \)

\[ A_p = r_{ikp} \]

Compute \( A_p = A_p + r_{ikp} \)

\[ i = i + 1 \]
\[ k = k + 1 \]

NO

Is \( i = n, k = n \)?

YES

Print \( A_p \)

Is \( p = u \)?

NO \( p = p + 1 \)

YES

Compute \( R_{kp} = r_{ikp}/A_p \)

Is \( i = n, k = n \)?

NO \( i = i + 1 \), \( k = k + 1 \)

YES

Print \( R_{kp} \)

\( p = n + 1 \)
Once, the composite qualitative factor ($R_{ik}$) has been obtained then the problem is solved as a single factor problem by either construction or improvement procedures. The composite qualitative factor is involved with qualitative criteria values and hence, the construction procedure based on
the qualitative criteria values [Francis and White, 1974] is used to obtain the initial layouts.

**CONSTRUCTION PROCEDURE:** On the basis of the composite qualitative criteria values, select the pair of facilities (components) with the highest criterion value in the list to place close together in the layout. Next, select the facility (component) from the list with highest criterion value with one, but not both facilities (components) in the layout, to place near to the location of facility (component) in the layout. Another facility (component) is, now to be selected (using previous criterion) having highest priority of getting placement along with already assigned facilities (components). The process is continued till all the facilities (components) are assigned to available locations.

If there exists a tie between facilities (components) for its selection to place in the plan area, the tie is broken randomly with biasness. The constraints with respect to locations available for placement of assigned facilities (components) and breaking of ties, there may exist a number of alternative solutions for each solution.

**IMPROVEMENT PROCEDURE:** The layout generated, using construction procedure is taken as an initial layout for the improvement procedures. A pair-wise exchange process is followed to determine the best exchange of facilities (components) at their locations, exchange incorporated. The exchanged layout will now become the initial layout. The pair-wise exchange process is followed after each new solution till there is no better solution possible. The better solution means that the value of
predetermined objective function is better than the previous solution. When no improvement is possible in the latest solution, the search process is terminated.

It is found that the characteristics of facilities layout problem in a manufacturing plant and the user interface components layout problem in human-computer interface are identical. Hence, there exists one-to-one relationship between layout problem of the manufacturing facilities and the textual and graphical user interface components layout problem in the human-computer interactive systems. This opens up the possibility of using the facilities layout methodologies for the layout design of the textual and graphical user interface components. Hence, the proposed model is used for the layout design of user interface components, and its results are compared with that of an existing facilities layout model that handles a single qualitative factor. In the existing facilities layout model that handles a single qualitative factor in the objective function, it is assumed that all factors are assumed to the combined into one qualitative factor.

5.3.2 EXAMPLE TASK

In order to apply the proposed model for the layout design of the textual and graphical user interface components, a text edited in MS-WORD in the study of John and Kieras (1996a) as presented in chapter 4 is considered as an example task. The text is considered as component 1 and it is required to be modified by deleting the strike-off characters, bringing the rounded phrase to the location indicated by an arrow, setting
the text to have right justification, and spell checking as shown in the Fig.5.2 of the example task. In order to accomplish these tasks, the user interface components to be used are Del, Cut, Paste, Right and Spell check, which are numbered as components 2,3,4,5 and 6 respectively. The rating system used for the qualitative relationships between the pairs of components is: A=5, E=4, I=3, O=2, U=1 and X=0. The qualitative closeness relationship rating values \((r_{ikp})\) between the components \(i\) and \(k\) for factor \(p\) are evaluated, in the computer laboratory considering 3 factors, viz., familiarity, anxiety, and fear of a user, and the distances \((d_j)\) between the locations \(j\) and \(l\) are given in the Table 5.1. The proposed methodology is used to obtain the composite factor \((R_{ik})\), and the layouts with the construction and improvement procedures for the data given in the Table 5.1. The results of the proposed model are compared with that of an existing model, in which the closeness relationships \((r_{ik})\) between the components \(i\) and \(k\) are obtained, considering 3 qualitative factors, viz., familiarity, anxiety, and fear are combined into one qualitative factor for the various users, viz., novice, intermittent, and expert.

In order to understand GOMS models that have arisen in the last decade and the relationships them, an analyst must understand each of the components of the models (goals, operators, methods and selection rules), the concept level of detail and the different computational forms that GOMS models take.

**Fig.5.2:** Example Task: Editing Marked-Up Manuscript for the Proposed Model with Multiple Qualitative Factors
5.3.3 COMPUTATIONAL RESULTS

The results of the proposed model presented as an approach 2 with multiple qualitative factors. On the other hand, the results of an existing model presented as an approach 1 with a single qualitative factor for novice, intermittent, and expert users. The results of approach 1 and approach 2 are compared for the example task under consideration as follows.

Proposed Model (Approach 2)

For the proposed methodology, each of 3 qualitative factors is assigned with weights $\beta_1 = 0.2$, $\beta_2 = 0.5$, and $\beta_3 = 0.3$ such that $\beta_1 + \beta_2 + \beta_3 = 1$. The data given in the Table 5.1 is used to obtain the composite factor ($R_{ik}$), layouts, and scores using the proposed model as given in Fig.5.3 as follows.

\[
R_{ik} = \begin{pmatrix}
1 & 0.033 & 0.24 & 0.035 & 0.028 & 0.038 \\
2 & 0.033 & - & 0.038 & 0.025 & 0.019 & 0.045 \\
3 & 0.024 & 0.038 & - & 0.035 & 0.019 & 0.046 \\
4 & 0.035 & 0.025 & 0.035 & - & 0.042 & 0.046 \\
5 & 0.028 & 0.019 & 0.019 & 0.042 & - & 0.035 \\
6 & 0.038 & 0.045 & 0.046 & 0.046 & 0.035 & - \\
\end{pmatrix}
\]

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An existing model (approach 1) is used for a single qualitative factor of novice, intermittent, and expert users to obtain the layouts and scores. The construction procedure in which the pair of facilities with the highest closeness relationship value is selected to place close together in the layout [Francis and White, 1974] is used to obtain the initial layouts. Further, the initial layouts are improved with the pair-wise exchange process of an improvement procedure.

Existing Model (Approach 1) for novice user

The closeness relationships \( r_{ik} \) between the components \( i \) and \( k \), considering 3 qualitative factors (viz. familiarity, anxiety, and fear), aggregated into a single qualitative factor, layouts and scores for the example task under consideration for a novice user are obtained as given in Fig.5.4 as follows.
The layouts for a novice user, as given in Fig. 5.4 are compared with that of an proposed model (approach 2) based on the attribute values of composite factor \(R_{nk}\) as given in Fig. 5.5 as follows.

The solution of the proposed model (approach 2) is improved by 4.10 percent over the existing model (approach 1), handling a single qualitative factor of novice user.
factor in the construction heuristic, where as the same is improved by 4.70 percent in the improvement heuristic.

The layouts of an existing model (approach 1) for a novice user as given in Fig.5.4 are compared with that of the proposed model (approach 2) as given in Fig.5.3 based on the attribute values of a single factor (r_{nk}) as given in Fig.5.6 as follows.

<table>
<thead>
<tr>
<th>Construction Heuristic</th>
<th>Improvement %</th>
<th>Improvement Heuristic %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach 1</td>
<td>Approach 2</td>
<td>over approach 1</td>
</tr>
<tr>
<td>Score</td>
<td>Layout</td>
<td>Score</td>
</tr>
<tr>
<td>152 241</td>
<td>234</td>
<td>2.90</td>
</tr>
</tbody>
</table>

Fig.5.6: Comparison of the layouts of Approach 1 and Approach 2 based on the Attribute values of Approach 1 with One Qualitative factor (r_{nk}) for novice user

The solution of the proposed model (approach 2) is improved by 2.90 percent over the existing model (approach 1) in the construction heuristic, whereas the same is improved by 7.0 percent in the improvement heuristic.

**Existing Model (Approach 1) for Intermittent user**

The closeness relationships (r_{nk}) between the components l and k, considering 3 qualitative factors (viz. familiarity, anxiety, and fear) aggregated into a single qualitative factor, layouts and scores for the
example task under consideration for an intermittent user are obtained as
given in Fig.5.7 as follows.

\[
r_{ik} = \begin{array}{cccccc}
1 & 2 & 3 & 4 & 5 & 6 \\
1 & - & 3 & 4 & 3 & 4 \\
2 & 3 & - & 0 & 5 & 2 & 3 \\
3 & 4 & 0 & - & 4 & 4 & 3 \\
4 & 3 & 5 & 4 & - & 4 & 3 \\
5 & 3 & 2 & 4 & 4 & - & 5 \\
6 & 4 & 3 & 3 & 3 & 5 & - \\
\end{array}
\]

<table>
<thead>
<tr>
<th>Construction Heuristic</th>
<th>Improvement Heuristic</th>
<th>% of Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layout Score</td>
<td>Layout Score</td>
<td></td>
</tr>
<tr>
<td>4 1 5 3 6 2</td>
<td>4 1 3 5 6 2</td>
<td>247 245 0.80</td>
</tr>
</tbody>
</table>

Fig.5.7: Results of an Existing Model (Approach 1) with one Qualitative factor of intermittent user

The layouts of an existing model (approach 1) for an intermittent user as given in Fig.5.7 are compared with that of proposed model (approach 2) based on the attribute values of composite factor \( R_{ik} \) as given in Fig.5.8 as follows.

<table>
<thead>
<tr>
<th>Construction Heuristic</th>
<th>% Improvement over Approach 1</th>
<th>Improvement Heuristic</th>
<th>% Improvement over Approach 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach 1 Layout Score</td>
<td>4 1 5</td>
<td>2.397</td>
<td>5.90</td>
</tr>
<tr>
<td>Approach 2 Layout Score</td>
<td>5 2 3</td>
<td>4 6 1</td>
<td>2.255</td>
</tr>
</tbody>
</table>

Fig. 5.8: Comparison of the layouts of Approach 1 and Approach 2 based on the Attribute values of Composite factor of Approach 2 for intermittent user

The solution of the proposed model (approach 2) is improved by 5.90
percent over the existing model (approach 1), handling a single qualitative factor in the construction heuristic, where as the same is improved by 4.30 percent in the improvement heuristic.

The layouts of an existing model (approach 1) for an intermittent user as given in Fig. 5.7 are compared with that of the proposed model (approach 2) as given in Fig. 5.3 based on the attribute values of single factor (r_{ik}) as given in Fig. 5.9 as follows.

<table>
<thead>
<tr>
<th>Construction Heuristic</th>
<th>Improvement over Approach 1</th>
<th>Improvement Heuristic</th>
<th>Improvement over Approach 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach 1</td>
<td>Layout</td>
<td>Score</td>
<td>Approach 2</td>
</tr>
<tr>
<td></td>
<td>247</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 5.9: Comparison of the layouts of Approach 1 and Approach 2 based on the Attribute values of Approach 1 with one Qualitative factor (r_{ik}) for intermittent user.

The solution of the proposed model (approach 2) is improved by 6.10 percent over an existing model (approach 1) in the construction heuristic, whereas the same is improved by 7.80 percent in the improvement heuristic.

**Existing model (Approach 1) for expert user**

The closeness relationships (r_{ik}) between the component i and k, considering 3 qualitative factors (viz. familiarity, anxiety, and fear) aggregated into a single qualitative factor, layouts, and scores for the example task under consideration for an expert user are obtained as given in Fig. 5.10 as follows.
The layouts of an existing model (approach 1) for an expert user as given in Fig. 5.10 are compared with that of the proposed model (approach 2) based on attribute values of composite factor (RI) as given in Fig. 5.11 as follows.

<table>
<thead>
<tr>
<th>Construction Heuristic Layout Score</th>
<th>Improvement Heuristic Layout Score</th>
<th>% of Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 5 6 218</td>
<td>6 5 1 243</td>
<td>3.70</td>
</tr>
</tbody>
</table>

Fig. 5.10: Results of Existing Model (Approach 1) with one Qualitative factor of expert user

The solution of the proposed model (approach 2) is improved by 7.90 percent over an existing model (approach 1), handling a single qualitative factor in the construction heuristic, whereas the same is improved by 7.20 percent in the improvement heuristic.
The layouts of an existing model (approach 1) for an expert user as given in Fig. 5.10 are compared with that of the proposed model (approach 2) as given in Fig. 5.3 based on the attribute values of a single qualitative factor ($r_k$) as given in Fig. 5.12 as follows.

<table>
<thead>
<tr>
<th>Construction Heuristic</th>
<th>Approach 1</th>
<th>Approach 2</th>
<th>% Improvement over approach 1</th>
<th>Improvement Heuristic</th>
<th>% Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layout Score</td>
<td>218</td>
<td>209</td>
<td>4.10</td>
<td>6.51</td>
<td>7.10</td>
</tr>
<tr>
<td>210 362 195</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 5.12: Comparison of the layout of Approach 1 and Approach 2 based on the attribute values of Approach 1 with one Qualitative factor ($r_k$) for expert user

The solution of the proposed model (approach 2) is improved by 4.10 percent over an exiting model (approach 1) in the construction heuristic, whereas the same is improved by 7.10 percent in the improvement heuristic.

In this chapter, a proposed model with a number of qualitative factors is presented, as an approach 2. The proposed model is one of the variations of the multi-factor facilities layout model, which handles a number of qualitative factors and quantitative factors separately. The proposed model handles a number of normalized qualitative factors assigned with weights based on their relative importance in the objective function of the facilities layout problem. The proposed model is used for
the layout design of the textual and graphical user interface components for the example task under consideration with 3 qualitative factors (viz., familiarity, anxiety, and fear) concerned with a user. The results of the proposed model (approach 2) are compared with that of an existing model (approach 1), in which the effect of all qualitative factors is combined into one qualitative factor for the various types of users, viz., novice, intermittent, and expert with the help of example task under consideration.

It is observed from the results that solution obtained, using the proposed model (approach 2) is improved by 4.10 percent and 4.70 percent in the construction and improvement heuristics, respectively over the existing model (approach 1) for a novice user, based on the attribute values of composite factor ($R_{k}$) of the proposed model. The solution of the proposed model (approach 2) is improved by 2.90 percent and 7.0 percent in the construction and improvement heuristics, respectively over the existing model (approach 1) for a novice user based on the attributes of closeness relationships values of the novice user.

For an intermittent user, the solution of the proposed model (approach 2) is improved by 5.90 percent and 4.30 percent in the construction and improvement procedures, respectively over the existing model (approach 1) based on the attribute values of composite relationships ($R_{k}$), whereas the same is improved by 6.10 percent and 7.80 percent, respectively over the existing model (approach 1) based on the attributes of closeness relationship values of an intermittent user.
The solution of the proposed model (approach 2) is improved by 7.90 percent and 7.20 percent in the construction and improvement procedures, respectively over the existing model (approach 1) for an expert user, based on the attributes of composite factor ($R_{nk}$) for the proposed model (approach 2). Whereas, the solution of the proposed model (approach 2) is improved by 4.10 percent and 7.10 percent over the existing model (approach 1) with the attributes closeness relationship values of an expert user in the construction and improvement procedures, respectively based on the attributes of the closeness relationships values of an expert user. The better results are obtained with the proposed model and hence, the resultant layouts of the textual and graphical user interface components are expected to reduce the task performance time for all sorts of users. The composite factors and the layouts are obtained, using the C language programs.

Many number of qualitative factors concerned with the various types of users of human – computer interface may be handled in the objective function of the proposed model (approach 2) for the realistic layout design of the textual and graphical user interface components. The proposed model (approach 2) can also be used for the layout design of the controls and other devices in automobiles, aircrafts, etc. with a suitable rating value for the closeness relationship ratings between the components.
In order to obtain the layouts that are of practically acceptable quality, there is a need to develop model, handling a number of individual qualitative and quantitative factors in the objective function.

Next chapter of the thesis presents a model, handling a number of individual qualitative and quantitative factors in different manner separately for the layout design of textual and graphical user interface components.

SUMMARY

The various qualitative factors that affect the layouts of the textual and graphical user interface components of the human - user interface are presented in section 5.1. Section 5.2 presents the various qualitative approaches, handling a single qualitative factor, in which the effect of the various qualitative factors is aggregated. The proposed model, handling the individual weighted normalized qualitative factors for the layout design of the textual and graphical user interface component is presented in section 5.3. This section also presents the comparison of the results of the proposed model (approach 2) with that of an existing model (approach 1) for the example task under consideration.
Table 5.1: Component problem data for 3 qualitative factors

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<th>Factors</th>
<th>Distances between locations (j) and (j')</th>
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