CHAPTER 3

HAMMING NUMBER TECHNIQUE FOR
ROBOT SELECTION BASED ON
QUANTITATIVE ATTRIBUTES
3.1 INTRODUCTION

The problem of robot selection is a complex task as discussed in chapter 2 involving multi-criteria decision based on various attributes of robots. These attributes may be tangible or intangible, qualitative or quantitative, subjective or objective. There are a number of research papers in the selection of robots but there still is no single method established to provide a final decision. This scenario gave us the motivation to view the problem. The attempt to select the best robot for the given application is going on for sometime. The methods vary vastly from strictly rigorous to highly empirical. However, there is no single method, which is both reliable and simple. In this chapter, a method based on hamming distance borrowed from digital communication theory inspired from Rao AC [98, 99] has been used for selection of robot considering quantitative attributes. The technique provides an easy, efficient, reliable and robust method to select a robot based on objective parameters.

3.2 THE PROBLEM

The Problem of robot selection has increased manifold due to following reasons

1. Wide number of alternatives is available and hence a large number of candidate robots are available for selection.

2. A number of parameters and criteria are required to be analyzed.
3. Parameters that are context dependent need to be considered.

4. There are no widespread acceptance and benchmarks available in the industrial setup. Hence it becomes all the more difficult for decision makers to compare among available robots.

5. The robot tends to be obsolete due to product variation technological reasons.

3.3 SELECTION PARAMETERS

Although there are large number attributes identified, a robot which is compatible to numerical controlled machines will be the one which is best suited. As the quantitative attributes are considered, we have selected the pertinent attributes as load capacity, repeatability, tip speed, reach and memory for application of hamming number technique. The approach is both reliable and simple. Hamming number is a concept from digital communication theory. The attributes matrix of different robots is made and subsequently the hamming matrix is computed. The biggest advantage of the method is that the rank or importance of the robot is revealed at a glance without complex calculations.

3.4 METHOD

In this chapter, hamming number technique provided by digital communication theory has been borrowed and used for robot selection. The concept of hamming technique and its application to detect isomorphism among kinematic chain has been already reported \([89,90]\). This concept has great potential and can be used further to make the selection of robots. The hamming number is computed on the lines of hamming distance, a concept used in digital communication theory. The hamming number \(h_{ij}\) related to the attributes \(i\) and \(j\)
is defined as the number of digits at which the codes of attributes \( i \) and \( j \) differ.

To write hamming matrix \((H)\), element \( h_{ij} \) of which is given by the expression

\[
h_{ij} = (a_{ik} + a_{jk})
\]  \( (3.1) \)

subject to the condition:

\[(a_{ik} + a_{jk}) = 0 \text{ if } a_{ik} = a_{jk}\]

where \( a_{ik} \) and \( a_{jk} \) are the elements of the attributes matrix.

As an illustration, suppose the robot is to be selected for a particular application having some minimum criteria for a pick n place operation from the database available, the robots with the desirable attributes may be tabulated in table 3.1.

**Table 3.1 Attributes for the short listed candidate robots [8]**

<table>
<thead>
<tr>
<th>Robot designation</th>
<th>Names of robot</th>
<th>Load capacity in kg</th>
<th>Repeatability in mm</th>
<th>Maximum tip speed in mm/sec</th>
<th>Memory capacity in steps</th>
<th>Manipulator reach in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_1 )</td>
<td>Asea-irb60/2</td>
<td>60</td>
<td>2.5</td>
<td>2540</td>
<td>500</td>
<td>990</td>
</tr>
<tr>
<td>( R_2 )</td>
<td>Cybotech v15 electric robot</td>
<td>6.8</td>
<td>10</td>
<td>1727.2</td>
<td>1500</td>
<td>1676</td>
</tr>
<tr>
<td>( R_3 )</td>
<td>Cincinnati milacrone T2-726</td>
<td>6.25</td>
<td>6.67</td>
<td>1016</td>
<td>3000</td>
<td>1041</td>
</tr>
<tr>
<td>( R_4 )</td>
<td>Unimation puma 500/600</td>
<td>2.5</td>
<td>9.8</td>
<td>560</td>
<td>500</td>
<td>915</td>
</tr>
<tr>
<td>( R_5 )</td>
<td>Hitachi America process robot</td>
<td>10</td>
<td>5</td>
<td>1000</td>
<td>2000</td>
<td>965</td>
</tr>
<tr>
<td>( R_6 )</td>
<td>Us robot maker 110</td>
<td>4.5</td>
<td>12.5</td>
<td>1016</td>
<td>350</td>
<td>508</td>
</tr>
<tr>
<td>( R_7 )</td>
<td>Yaskawa electric motorman 13c</td>
<td>3</td>
<td>10</td>
<td>1778</td>
<td>1000</td>
<td>920</td>
</tr>
<tr>
<td>( \Sigma = )</td>
<td></td>
<td>93.05</td>
<td>56.47</td>
<td>9637.2</td>
<td>8850</td>
<td>7015</td>
</tr>
</tbody>
</table>
Hamming Number Technique For Robot Selection Based On Quantitative Attributes

For ideal performance the robot must share all these attributes equally and therefore the function generation of the robot as a whole can be thought upon as a combination of function generation by each attribute.

The above data can be represented in the form of new matrix as shown below

\[
\begin{pmatrix}
a_{11} & a_{12} & a_{13} & a_{14} & \cdots & a_{1m} \\
a_{21} & a_{22} & a_{23} & a_{24} & \cdots & a_{2m} \\
a_{31} & a_{32} & a_{33} & a_{34} & \cdots & a_{3m} \\
a_{41} & a_{42} & a_{43} & a_{44} & \cdots & a_{4m} \\
\vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\
a_{n1} & a_{n2} & a_{n3} & a_{n4} & \cdots & a_{nm}
\end{pmatrix}
\]

Where \( a_{ij} \) is the attribute(s)

A new matrix is formed with the help of the attributes mentioned in table -3.1

\[
\begin{pmatrix}
60 & 2.5 & 2540 & 500 & 990 \\
6.8 & 10 & 1727.21500 & 1676 \\
6.25 & 6.67 & 1016 & 3000 & 1041 \\
2.5 & 9.8 & 560 & 500 & 915 \\
10 & 5 & 1000 & 2000 & 965 \\
4.5 & 12.5 & 1016 & 350 & 508 \\
3 & 10 & 1778 & 1000 & 920
\end{pmatrix}
\]

The elements of the above matrix can be rewritten for generalization using the following expression as shown in the table-3.1

\[
(a_{ij}/C_j)
\]

\[
C_j = \sum_{i=1}^{n} a_{ij}
\]

where \( C_j \) represent the elements in the column \( j \)
Hamming Number Technique For Robot Selection Based On Quantitative Attributes

\[
\text{Attributes Matrix} = \begin{bmatrix}
R_1 & 0.64 & 0.44 & 0.263 & 0.056 & 0.1411 \\
R_2 & 0.07 & 0.127 & 0.1792 & 0.169 & 0.2389 \\
R_3 & 0.17 & 0.118 & 0.1054 & 0.338 & 0.1483 \\
R_4 & 0.02 & 0.17 & 0.058 & 0.056 & 0.1304 \\
R_5 & 0.10 & 0.088 & 0.1077 & 0.225 & 0.1375 \\
R_6 & 0.048 & 0.22 & 0.1054 & 0.039 & 0.072 \\
R_7 & 0.032 & 0.177 & 0.184 & 0.1129 & 0.131 \\
\end{bmatrix}
\]

From the above attribute matrix—using equation 3.1—the Hamming matrix is written directly below:

**HAMMING NUMBER MATRIX**

\[
\begin{bmatrix}
R_1 & R_2 & R_3 & R_4 & R_5 & R_6 & R_7 \\
R_1 & 0 & 1.978 & 2.0233 & 1.4664 & 1.7982 & 1.6288 & 1.781 & 10.6757 \\
R_2 & 1.978 & 0 & 1.7133 & 1.2684 & 1.4882 & 1.3168 & 1.471 & 9.2371 \\
R_3 & 2.0233 & 1.7133 & 0 & 1.3137 & 1.5335 & 1.1533 & 1.5163 & 9.2534 \\
R_4 & 1.4664 & 1.2684 & 1.3137 & 0 & 1.0886 & 0.9192 & 1.0714 & 7.1277 \\
R_5 & 1.7982 & 1.4882 & 1.5355 & 1.0886 & 0 & 1.139 & 1.2912 & 8.3387 \\
R_6 & 1.6288 & 1.3188 & 1.1533 & 0.9192 & 1.139 & 0 & 1.1218 & 7.2809 \\
R_7 & 1.781 & 1.471 & 1.5163 & 1.0714 & 1.2912 & 1.1218 & 0 & 8.2527 \\
\end{bmatrix}
\]

Where, for example,

\[
h_{12} = (a_{11} + a_{12} + a_{13} + a_{14} + a_{15} + a_{21} + a_{22} + a_{23} + a_{24} + a_{25}) = 1.978
\]

since \(a_{ik} \neq a_{jk}\)

and \(a_{ii} = a_{ij} = 0\)

The hamming number, for any robot is the sum of all the elements in the \(i^{th}\) row of hamming matrix. Thus hamming number for robot \(R_1\) is

\[
= (0 + 1.978 + 2.0233 + 1.4664 + 1.7982 + 1.6288 + 1.781) = 10.6757
\]

The greater this value the better is the robot. For example, the robot \(R_1\) is having higher hamming value of 10.657, then robot \(R_2\) having value of 9.2371 hence robot \(R_1\) is better than \(R_2\) and so on.
Hamming Number Technique For Robot Selection Based On Quantitative Attributes

The evaluation and ranking of the candidate robots using various methods including ours has been tabulated in the table-3.2

Table-3.2
Evaluation and Ranking of the candidate robots using various methods

<table>
<thead>
<tr>
<th>S. No</th>
<th>Name of Robot</th>
<th>TOPSIS Closeness as to the +ve benchmark robot c*</th>
<th>Rank based on c*</th>
<th>COS based on Line Graph ( \cos^L )</th>
<th>Rank based on ( \cos^L )</th>
<th>COS based on Spider diagram ( \cos^S )</th>
<th>Rank based on ( \cos^S )</th>
<th>Entropy Value</th>
<th>Rank</th>
<th>Hamming number value</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Asea-lrb 60/2</td>
<td>0.625</td>
<td>2</td>
<td>0.635</td>
<td>1</td>
<td>0.284</td>
<td>2</td>
<td>0.6596</td>
<td>1</td>
<td>10.6757</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Cybotec V15 Electric Robot</td>
<td>0.460</td>
<td>3</td>
<td>0.627</td>
<td>2</td>
<td>0.296</td>
<td>1</td>
<td>0.7585</td>
<td>3</td>
<td>9.2371</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Cincinnati Milacron e T3-726</td>
<td>0.345</td>
<td>5</td>
<td>0.515</td>
<td>4</td>
<td>0.232</td>
<td>3</td>
<td>0.7278</td>
<td>2</td>
<td>9.2534</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Unimatti on Puma 500/600</td>
<td>0.239</td>
<td>7</td>
<td>0.345</td>
<td>7</td>
<td>0.069</td>
<td>7</td>
<td>0.9097</td>
<td>7</td>
<td>7.1277</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>Hitachi America Process Robot</td>
<td>0.793</td>
<td>1</td>
<td>0.431</td>
<td>5</td>
<td>0.173</td>
<td>5</td>
<td>0.8208</td>
<td>4</td>
<td>8.3387</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>US Robot Maker1110</td>
<td>0.295</td>
<td>6</td>
<td>0.414</td>
<td>6</td>
<td>0.121</td>
<td>6</td>
<td>0.8250</td>
<td>5</td>
<td>7.2809</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>Yaskawa Electric Motoman L3C</td>
<td>0.389</td>
<td>4</td>
<td>0.533</td>
<td>3</td>
<td>0.201</td>
<td>4</td>
<td>0.8869</td>
<td>6</td>
<td>8.2527</td>
<td>5</td>
</tr>
</tbody>
</table>

From table 3.2 we find that rank obtained of different robots by different techniques such as TOPSIS, Line Graph, Spider Diagram, Entropy and Hamming Number Technique comes closer to a great extent.
3.5 CONCLUSIONS

The chapter presents a robot selection process based on hamming number technique, which is a fresh approach in this area. It is based on identifying and analyzing a number of objective attributes for the selection of the best robot among candidate robots.

The utility of the work is as follows

1. The method is suitable to compare different robots based on quantitative attributes.

2. The concept of hamming number provides us with a valuable tool to evaluate different characteristics of robots before putting to use in the conceptual stage.

3. Each of the attributes reveals the anticipated behavior of the robot. The value of the different attributes is either "must" or "desirable" type depending upon the given application.
CHAPTER 4

QUALITATIVE ATTRIBUTES BASED RATING OF ROBOT