Object-Oriented Modeling of Transportation Problem Using Modified Neural Network Model

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ABSTRACT

Transshipment problem is an instance of a transportation problem that deals with the shipment of a homogenous product from various supply origins through different transshipment points to various demand destinations with the general objective of minimizing the total transshipment cost. Transshipment problem has been solved using the Stepping Stone method and the Modified Distribution Method (MODI) where the transshipment problem is transformed to an equivalent transportation problem by classifying the transshipment points as being parts of the supply origins and the demand destinations. These methods do not reference the supply origins, transshipment points and demand destinations as objects that have properties and behaviours. In this paper, the researcher has deployed the Object-Oriented (O-O) technique, using the Unified Modeling Language, to design the requirements of the system. The model was implemented using C++ programming language. The result has showed that the supply origins, transshipment points and demand destinations can be modeled as objects having both attributes and methods using the Unified Modeling Language.

Keywords: Supply points, Demand points, Transshipment points, Neural Network, Object-Oriented Model and Transshipment problem

1. INTRODUCTION

Transportation Problem is a subclass of a linear programming problem that deals with the shipment of a homogenous product from various supply origins, to different demand destinations with the objective of minimizing the total transportation cost. Transportation problem can be classified as direct transportation problem, where the homogenous product is shipped directly from various supply origins to different demand destination or indirect Transportation Problem, where the homogenous product is shipped from various supply origins to different demand destinations through various transshipment points [1].

2. TRANSPORTATION MODEL

Transportation model is a mathematical expression used to illustrate the distribution of a homogenous commodity from various supply origins to different demand destinations. The mathematical model for a transportation problem is stated in equation (1)-equation (5)[2]:

Minimizing \( Z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}x_{ij} \) \( \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldOTS
the product that can be transported from the $i^{th}$ origin to
the $j^{th}$ destination.

3. REVIEW OF RELATED WORKS

Several researchers have solved the Transportation
Problem with various methods to obtain an optimal
solution. [3] Proposed solving Transportation problem
using object-oriented model. They used C++
programming language to model the five methods
(northwest corner method, minimum cost method, vogel’s
approximation method, row minimum method and
column minimum method) using flow chart and algorithm
as the design tools. [4] Developed a platform for solving
Transportation problem using an interactive system for
optimal solution. They used Microsoft visual basic 6.0
and northwest corner rules to automate the analysis of the
system. [5] Proposed a study of south east corner method
and use of object oriented programming model to find the
initial feasible solution of a transportation problem. They
implemented the transportation problem using C++
programming language. [6] Proposed transportation
problem and its object oriented programming languages.
He used C programming language to compare the results
obtained my various transportation methods.

4. MATERIALS AND METHODS

Neural Networks are models designed to imitate the
human brain through the use of mathematical models. A
neural network consists of a set of artificial neurons
(nodes) grouped in a number of layers [7]. Figure 1
illustrates a single layer neural network with three input
elements and three neurons. In the network each element
of the input vector $p$ is connected to each neuron input
through the weights matrix $w$.

The neural network used the learning rule to modify the
weights and the biases of the network and the training
process for selecting parameters for a given problem. The
training procedure used in multilayer perceptron neural
network is one of the supervised learning algorithms
called the back propagation algorithm. The back
propagation algorithm uses the computed output error to
adjust the weights so as to minimize the error in its
predictions on the training dataset.

Back propagation neural network requires that all training
input data must be normalized between 0 and 1 for
training. It cannot be used to train un-normalized input
data.

Conceptual Framework of the Proposed System

Conceptual design of a system is concerned with making
a prototype of the proposed system. It provides a
description of the proposed system in terms of a set of
integrated ideas and concepts about what the system
should do, behave and look like. The conceptual
framework of the proposed system is illustrated in Figure
2.

![Figure 2: Conceptual framework of the proposed system](source: Jamal, Ibrahim and Salam, 2009)

The proposed system accepts both normalized and un-
normalized input data. It normalizes the data using the
normalized function ($\lambda$). There are two basic
normalization techniques namely max-min normalization
and decimal scaling techniques. In this work we use the
decimal scaling technique to normalize the data by
moving the decimal unit of values of the attributes as
shown in equation (6).
\[ v^j = \frac{v}{10^j} \] ............................................................(6)

where \( j \) is the smallest integer such that \( \max |v^j| < 1 \).

The Multi-Layer Perceptron Neural Network model analyzes the transshipment problem in two propagations namely the forward and backward propagations. The forward propagation algorithm first computes the total weighted input \( x_i \) by using the formula in equation (7).

**Input** \( j = x_j = \sum y_jw_{ij} \) ...........................................(7)

Where \( y_j \) is the activity level of the jth unit in the previous layer and \( w_{ij} \) is the weight of the connection between the ith and the jth unit.

The algorithm uses the activation function to predict the calculated output. The activation function used in a multi-layer perceptron neural network is a sigmoid function which is expressed in equation (8).

\[ f(x) = \frac{1}{1 + e^{-x_i}} \] .......................................................(8)

The multi-layer perceptron neural network is trained to solve the transportation problem by using the backward propagation algorithm which determines the output error by using the expression in equation (9).

**Error** \( = T_k - O_k \) ......................................................(9)

The overall performance (net error) of the Multi-Layer Perceptron Neural Network is measured by the mean square error (MSE) expressed in equation (10).

\[ MSE = \frac{1}{N} \sum_{p=1}^{N} e_p^2 = \frac{1}{N} \sum \sum (y_j - d_j)^2 \] .......(10)

The algorithm is successfully finished if the net error is zero (perfect) or approximately zero. Where the net error is not zero, we apply the back propagation algorithm to calculate the back propagation errors and new weight.

The back propagation error in the output neuron is calculated by using the formula in equation (11)

\[ \delta_k = Err_k = O_k (1 - O_k) (T_k - O_k) \] ...........(11)

Where

\( O_k \) is the calculated (actual) output expressed in equation (12)

\[ O_k = \frac{1}{1 + e^{-x_i}} \] ............................................................(12)

\( O_k \) is the observed (True) output

The back propagation error in the hidden layer is calculated by using the formula in equation (13).

\[ \delta_j = Err_j = O_j (1 - O_j) \sum \delta_k w_{jk} \] ...........(13)

Where \( w_{jk} \) is the weight of the connection from unit j to unit k in the next layer and \( \delta_k \) is the error of unit k.

The weight adjustment formula in equation (14) is used to adjust the weights to produce new weights which are fed into the input layer.

\[ W_{new} = W_{old} + \eta \delta \times input \] .........................................(14)

where \( \eta \) is a constant called the learning rate (\( \eta = 1 \)). The learning rate takes value between 0 and 1.

\( \delta \) is the output error calculated by equations (15) and (16).

\[ \delta_j = o_j (1 - o_j) (\sum_k \delta_k w_{jk}) \] ...........(15)

and

\[ \delta_k = o_k (1 - o_k) (T_k - o_k) \] .....................(16)

The objective function is:

\[ Minimize F = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \] ..................... (17)
Object-Oriented Analysis of Transportation problem using Unified Modeling Language

The most popular system development options are structured analysis, object-oriented (O-O) analysis and agile method. Object –Oriented methodology is popular because it integrates easily with object-oriented programming languages such as Java, Smalltalk, C++ and Perl. Programmers like object-oriented code because it is modular, reusable and easy to maintain. Object-Oriented analysis describes an information system by identifying objects as real life entity with properties and methods. The object-oriented programmers use the unified modeling language (UML) to visualize and document the software system design. The concepts used to model object-oriented modeling of Transshipment Problem using modified neural network model are the use case diagram, class diagram, sequence diagram and activity diagram.

Use Case Diagram

A use case diagram is used to model and identify the static functional requirements of the system. It describes what a system does from the standpoint of an external observer [8]. The use case diagram of the proposed system is illustrated in Figure 3.

Class diagram of the proposed system

The class diagram is a static structure that describes the structure of the system by showing the system’s classes, their attributes and the relationships that exist among the classes [9]. The class diagram of the proposed system is illustrated in Figure 4.

Figure 3: Use case diagram of the proposed system

Figure 4: Class diagram of the proposed system
Activity Diagram of the Proposed System

An activity diagram resembles a horizontal flowchart that shows the actions and events as they occur. It shows the order in which the actions take place and identify the outcomes. The activity diagram of the proposed system is illustrated in Figure 5.

Sequence diagram of the proposed system

A sequence diagram is a dynamic model of a use case, showing the interaction among classes during a specified period. It demonstrates the behaviour of objects in a use case by describing the objects and the messages they pass [8]. The sequence diagram of the proposed system is illustrated in Figure 6.

5. RESULTS ANALYSIS AND DISCUSSION

Table 1 shows a firm that has two factories to ship its products from factories X and Y through two retail stores A and B to destination C. The Table shows also that number of units available at factories X and Y are 200 and 300 respectively, while those demand at retail stores A and B are 100 and 150 and at the destination the demand is 250.

Table 1: Quantity of goods located at the factories, retail-stores and demand destination

<table>
<thead>
<tr>
<th>Factories</th>
<th>quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>200</td>
</tr>
<tr>
<td>Y</td>
<td>300</td>
</tr>
<tr>
<td>Retail-stores</td>
<td></td>
</tr>
</tbody>
</table>
Table 2 shows the transportation cost per unit in naira.

<table>
<thead>
<tr>
<th>Demand destination</th>
<th>A</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>150</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factory</th>
<th>Retail store</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factory</td>
<td>X</td>
</tr>
<tr>
<td>factory</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>Retail store</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
</tbody>
</table>

Applying the Vogel Approximation Method, the initial feasible solution is illustrated in Table 3.

<table>
<thead>
<tr>
<th>Demand</th>
<th>8</th>
<th>9</th>
<th>7</th>
<th>8</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>150</td>
<td>250</td>
<td>500</td>
</tr>
</tbody>
</table>

Using the Modified Distribution method, the optimal solution of the transportation problem is shown in Table 4:

![Table 3: Initial solution using VAM](image)

Since opportunity cost corresponding to each unoccupied cell is positive, therefore the total transportation cost is:

\[
\text{total cost} = 100 \times 7 + 100 \times 8 + 50 \times 4 + 250 \times 0
\]

\[
\text{total cost} = 700 + 800 + 200 + 750 = 2450
\]

Applying the Modified Neural Network using C++ simulator, the total transshipment cost is calculated as follows:

Enter the number of input neurones

+----------------------------------+
| 2                               |
+----------------------------------+
Enter the number of neurones in the hidden layer
+++++++++++++++++
2
Enter the number of neurones in the output layer
+++++++++++++++++
1

INPUT PARAMETERS
200
300

OUTPUT PARAMETERS
250

The weights between the input and the hidden layers are:

input[1].weight[1]=0.00125126
input[1].weight[2]=0.563585
input[2].weight[1]=0.193304
input[2].weight[2]=0.80874

The weights between the hidden and the output layers are:

hidden[1].weight[1]=0.585009
hidden[2].weight[1]=0.479873

The input to hidden layer [1] is: 1
The input to hidden layer [2] is: 1
The output quantity [1] is: 1
the error is 249
the diff 0.256378
The error 249.256
The output_hidden error 47.5203
the sum 50.6035

input[1].weight[2]=0.563585
input[2].weight[1]=0.193304
input[2].weight[2]=0.80874

The unit cost between the input and the hidden layers are:

input[1].cost[1]=7
input[1].cost[2]=8

The unit cost between the hidden and the output layers are:

hidden[1].cost[1]=1
hidden[2].cost[1]=4

the sum of neural 18.71893
the sum of neural 2240.106
The total Transportation cost ==248.825
Press any key to continue...

6. DISCUSSION OF RESULTS

The results have shown that transportation problem requirements can be modeled as objects with attributes and methods using Object-oriented modeling technique. Also, the results have shown that the optimal solution of the transshipment problem can be obtained using MODI method and the Modified Neural Network Model. The Modified Neural Network Model can be used by the producers or consumers to predict the total cost transportation from various supply origin to a particular demand destination through different transshipment points.
7. CONCLUSION

Transshipment problem is a multilayer perceptron problem with three layers namely sources, transshipment points and demand destinations. Also, it can be concluded that the supply origins, transshipment points and demand destinations can be modeled using Object-Oriented Modeling technique where each of the layers is treated as an object having attributes and methods. Finally, the network was simulated using Object-Oriented programming language (C++) to generate the total transportation cost of the problem.

REFERENCES


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