Visual Simulation for an Automobile Gearbox Assembling Line

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Abstract: An automobile gearbox assembling line is seen as a discrete system. It is hard to guarantee the layout reasonability and running reliability of the line if only with traditional experiential design method. In the paper, visual simulation method was adopted to design and manage it. In modeling of the assembling line and its simulation of its running process, methods of queuing network and event scheduling were applied, respectively. With simulation experiments, the optimal AGV number needed and reasonable scheduling rules were obtained.

Keywords: assembling line, queuing network, event scheduling, visual simulation

1 Introduction

Generally, to construct an assembling line needs multimillion investment, and it is uneasy to modify once finished. It should also need a reasonable layout in order to avoid lacking productive ability or mass of unused equipments. In addition, an effective scheduling management strategy to guarantee the assembling line active running is also important. For these reasons, many attentions have been paid to achieve an efficient assembling line. However, most of traditional assembling lines are designed based on empirical conclusions, and so that optimal workshop production flows and stable working processes mostly could not be realized.

At present, visual simulation techniques play a very important role in manufacture system design and management [1, 2]. With simulated running process of a manufacture system, all operating parameters are obtained before the line is constructed. In this paper, for the designing of an automobile gearbox assembling line, visual simulation technique is used to decide the optimal AGV number and to determine the effective scheduling management strategy. Firstly, the visual simulation system is achieved for the assemble line in Visual Basic. Furthermore, some simulations for working position failures and overtime tasks are also checked.

2 Visual Simulation Method for Assembling Line

The main process of developing visual simulation system for assembling line includes: describing problem, confirming simulation aim, collection of data, simulation model, making program, simulation experiment and result analysis, shown in Fig. 1.

2.1 Simulation Model of Assembling Line

Queuing network method[3, 4] is taken to model the gearbox assembling line and its principle sketch is shown in Fig. 2, where \( \lambda \) is arriving velocity of the parts, \( \mu \) is average service time.

In the method of queuing network, a queuing network is composed of many service centers according a certain network structure. A service center includes a client and one or more information desks. According to given
sequence rules, the service center works for coming clients in turn, whereas, the clients enter one service center and wait for servicing according to statistical rules. The client, who has accepted services from one service center, will transfer to another one to continue and until its task is finished and leaves the net.

Figure 2  The sketch of queuing network system

2.2 Simulation Algorithms
To simulate an assembling line system, three algorithms, i.e. event scheduling method, activity scanning method, and process interaction method can be taken into account [5]. Here the event scheduling method is adopted.

Event scheduling method is defined that the interval time of event occurring can be used to confirm the least time unit of the whole simulation process, that is, the whole process boosts with every single event. The simulation system picks up event in the future event table, judge the style of event and then manage with corresponded program until reaches the end simulation time settled in advance. Event scheduling method is effective and flexible for simulation of an assembling line.

2.3 Achievement Method of Visualization
The visualization of simulation system includes two parts: one is the visualization of mutual interface; the other is transforming simulation results into graphs or pictures [6]. The visualization of assembling line simulation can make the results more convincing, and help people to make correct decisions. Visual simulation of assembling line can adopt three or two dimensions animation to demonstrate the running process of the whole assembling line. Generally, simulation of three dimensions animation needs such advanced computer scheme and a great deal of special CAD software to support. This article describes the process of assembling line using bitmap animation in two dimensions, which is driven by the same clock with that of numeric simulation. The method of painting or scraping, which are painting or scraping the graph according to the occurring events, is used to describe the occurrence and disappearance of events in the assembling line.

3 Visual Simulation Process for Assembling Line
According to the above methods, the visual simulation system of the automobile gearbox assembling line is realized. The methods of queuing network and event scheduling and bitmap animation were applied on the modeling of assembling line.

3.1 Problem Description of the Assembling Line System
In the example, the automobile gearbox assembling line has nineteen assembling working position, seventeen sub-assemble working position. The sub-assembling is parallel with the main assembling line. All parts are transported with automatic guide vehicles (AGV). An AGV has ten different velocities from 0.1m/s to 1.0m/s. The needed time values of every work place are listed in Table 1.

The maximum simulating period is one day, i.e. 8 hours. The production task of every day is to assemble 40 gearboxes. The simulation object is how to decide the optimal number of needed AGVs and a good scheduling strategy for achieving the given production task.

Table 1  The time costs in assembling process

<table>
<thead>
<tr>
<th>Working Position</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time/min</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

3.2 Determination of Function Structure of the simulation system
The visual simulation system of the automobile gearbox assembling line should have hereinafter functions: (1) the system provides visual interface to make users input experimental parameters easily; (2) it animates in real time, simulates the running condition of
the whole assembling line; (3) it can deal with some specific conditions such as faults and overtimes; (4) it can make out overall report, waiting report, fault analysis report, overtime report, etc.; (5) it can store data into a data-base and be convenient for comparing scheduling regularities.

With the above requirements, visual simulation system of the gearbox assembling line has three modules: modeling module, simulation running module and result analysis report module. The whole structure of it can be referred as Fig. 3.

Figure 3  The structure of simulation system

3.3 Establishment of the simulation system

For the visual simulation system, the module of gearbox assembling line included a configuration model and a mathematic model. In the visual configuration module, bitmap pictures show AGVs and every assembling work place. In the mathematic module, queue network module is adopted to describe the whole assembling line’s running state where each AGV is regarded as a client and each working place is an information desk.

The arrive velocities of AGVs and serve times of information desks are regarded to follow normal distributions. When an AGV arrives at an information desk, the assembling work must be taken at once, otherwise, the AGV waits at a nearby position due to possible fault or other cases. According to the queue model, All AGVs arrive in each working position and accept serves in turn until assembling task is finished. So, some parameters, including AGV number, dispatch AGV regulation, cart running velocity between two workplaces, assembling time in each workplace, probability distribution of assembling time, simulation time limit etc, are needed for the above mathematic module.

In order to dynamically simulate the assembling line, there are two events defined in the system, i.e. assembling event and transporting event. When an assembling event takes place, the system will occur hereinafter reactions: (a) the working position with assembling event is ascertained; (b) the state of current working position is checked, leisure, busy or fault; (c) assembling begins if in leisure position, the next event is set as a transporting event; (d) the event is set into a waiting list if the position is busy or fault. When a transporting event takes place, the system will occur hereinafter reactions: (a) the working position with transporting event is ascertained; (b) checking the transporting event normal, otherwise it needs enter a transporting waiting list.

The simulation clock is driven by a future event list. Table 2 shows the contents of an event list at a given time. Each event has three attributes, namely event occurrence time, event occurrence work place and event type. The driving flow of simulation clock is shown in Fig. 4.

Following the above steps, the visual simulation system is established.

<table>
<thead>
<tr>
<th>Event time</th>
<th>Work place</th>
<th>Event type</th>
</tr>
</thead>
<tbody>
<tr>
<td>56.2708</td>
<td>1</td>
<td>1 transporting event</td>
</tr>
<tr>
<td>56.7435</td>
<td>4</td>
<td>2 assembling event</td>
</tr>
<tr>
<td>56.7487</td>
<td>9</td>
<td>1 transporting event</td>
</tr>
<tr>
<td>56.7804</td>
<td>6</td>
<td>2 assembling event</td>
</tr>
<tr>
<td>57.2024</td>
<td>14</td>
<td>1 transporting event</td>
</tr>
<tr>
<td>57.7063</td>
<td>16</td>
<td>1 transporting event</td>
</tr>
<tr>
<td>60.2133</td>
<td>12</td>
<td>2 assembling event</td>
</tr>
</tbody>
</table>

Table 2  A future event list

Figure 4  The flow chart of event scheduling
4 Simulation Results

This simulation experiment includes two parts: (1) to confirm the optimal number of AGV and reasonable scheduling rule through validating the datum of experiments on the system; (2) to simulate the status when some working position is broken-down and detect the system responses.

4.1 AGV Number and Scheduling Rules

Give the number of AGVs and assume scheduling rules and do simulation, then increase the number of AGVs. When the simulation results approximately satisfy the design requests, change scheduling rules and repeat the previous steps until obtain the optimal data. Table 3 shows the simulation data as follows.

From the experiment, the number of AGVs must be more than 8. If with the same rule and the number of AGV is set as 9, the output does not increase. The obtained optimal number of AGVs is 8 and the reasonable scheduling rule is 3, shown as Tab. 4.

<table>
<thead>
<tr>
<th>AGVs</th>
<th>Scheduling rules</th>
<th>Average Interval Time (min)</th>
<th>Longest Vacant Time (min)</th>
<th>Finished tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3</td>
<td>8.50</td>
<td>27.42</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.99</td>
<td>35.57</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5.93</td>
<td>40.04</td>
<td>35</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>8.50</td>
<td>5.49</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.99</td>
<td>19.74</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5.93</td>
<td>23.69</td>
<td>54</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>8.50</td>
<td>5.47</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.99</td>
<td>13.81</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5.93</td>
<td>18.19</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 3 Some simulation test data

Assume a fault in this simulation, for instance, working position 8 goes wrong and its repairing time is 25 minutes. With the fault analysis module, the fault analysis report is obtained. The fault causes shortage of 3 products and the more than 25 minutes of vacant time for every working position. The fault impacts on working position 7, 8, 9, 10, 11, 12, and 15 seriously.

4.2 Fault Simulation

There are two purposes for simulating some working position which goes wrong: to see the influence on output caused by fault and to show the system’s working status after the fault is repaired.

5 Conclusions

In this paper, we illustrate the simulation principle of the assembling line simply and realize the visual simulation of automobile gearbox assembling line. Some conclusions are pointed out as following:

A visual simulating system is established for the running process of an automobile gearbox assembling line. With the queuing network method the simulation model is built and it can represent numerically all parts of the whole assembling line. An efficient event scheduling method is adopted to drive the simulation clock.

Using the simulation model, the running conditions under both normal and error conditions are simulated.

References (12 points)

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