Scheduling algorithms for a flexible machining system with multiple setup stations and multi-fixturing pallets

Literature review

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## Literature review

### FMS scheduling problem with Multi Loading/Unloading Stations

- **Separated Loading/Unloading Function, Single Station**
  - Most studies in the field of FMS are included in this scope (Basic configuration in FMS).

- **Separated Loading/Unloading Function, More than one Stations**
  - Layout problem
  - Loading
  - AGV scheduling

- **Multi Loading/Unloading Function, A Single Station**

- **Multi Loading/Unloading Function, More than one Stations**
  - (2004) Effect of dynamic and static dispatching strategies on dynamically planned and unplanned FMS.
FMS scheduling problem with Multi Loading/Unloading Stations

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- Seperated Loading/Unloading Function, More than one Stations
  - Layout problem
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  - AGV scheduling

- Multi Loading/Unloading Function, A Single Station

- Multi Loading/Unloading Function, More than one Stations
  - (2004) Effect of dynamic and static dispatching strategies on dynamically planned and unplanned routings
  - (2016) Reentrant FMS scheduling in loop layout with consideration of multi loading-unloading stations and turntable shortcuts
  - (2018) Non-dominated sorting biogeography-based optimization for bi-objective reentrant flexible manufacturing system scheduling
1. Introduction
2. Literature review
3. Problem description
4. Approach
5. Description of model experiments
6. Measuring performance criteria
7. Experimental results and evaluation
8. Conclusion
1. Introduction

Review

➢ The field of research
  ✓ FMS scheduling problem

➢ Objective
  ✓ To determine the dispatching rule that will perform the best.

➢ Contribution
  ✓ The Effect of dynamic and static dispatching strategies on dynamically planned (deterministic date) and unplanned (undeterministic date) FMS.

 ✓ The combination of different dispatching rules in a dynamic manner is better than a single rule in a static manner.
1. Introduction

- Review

- General two approaches to solve the problem of switching to proper dispatching rules in Manufacturing system.

- **Dynamic dispatching** - also called the **look-ahead simulation approach**, a dispatching rule is determined for each short period just before the implementation occurs.

- **Static dispatching** - also called the **rule-based (heuristic) approach**, scheduling of changing dispatching rules is first acquired and then this knowledge is into the manufacturing system to make intelligent decisions in real-time.
2. Literature review

- The performance of dispatching rules in dynamic FMS

- Developing a combined scheduling approach with machine layout
- Developing a search algorithm to find and appropriate dispatching rule combination

- A learning-based methodology

- The effect of machines layout
3. Problem description

- Model description
  - Objective
    - Through-put rate
    - Makespan
    - Mean flow time
    - Mean tardiness
    - Sum of mean flow time and mean tardiness
    - The number of tardy jobs
  - Decision variable
    - Sequence the operations assigned to each machine. (Basic Job Shop Scheduling)
  - Constraints
    - Buffer capacity
    - Operation precedence
  - Assumptions
    - Each part type requires one or more operation(s).
    - There are one or more machine(s) which can process each operation and each machine can process one operation at a time.
    - Tool change-over times are included in processing time and tool magazine capacities are not binding constraints.
    - Data on all alternative routes and processing times can be provided.
    - Arrival rate, due dates, transporter speed, resources, setup and tear down times are deterministic.
    - Each operation can be processed by one machine only at a time.
3. Problem description

- Physical layout and transfer network of the model

### Parameters

<table>
<thead>
<tr>
<th>Part type</th>
<th>Operation specification</th>
<th>Due date (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Operation required</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>Processing time</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Machine number</td>
<td>1</td>
</tr>
<tr>
<td>P2</td>
<td>Operation required</td>
<td>1300</td>
</tr>
<tr>
<td></td>
<td>Processing time</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Machine number</td>
<td>2</td>
</tr>
<tr>
<td>P3</td>
<td>Operation required</td>
<td>2400</td>
</tr>
<tr>
<td></td>
<td>Processing time</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Machine number</td>
<td>3</td>
</tr>
<tr>
<td>P4</td>
<td>Operation required</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>Processing time</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Machine number</td>
<td>4</td>
</tr>
<tr>
<td>P5</td>
<td>Operation required</td>
<td>1800</td>
</tr>
<tr>
<td></td>
<td>Processing time</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Machine number</td>
<td>5</td>
</tr>
<tr>
<td>P6</td>
<td>Operation required</td>
<td>1000</td>
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<tr>
<td></td>
<td>Processing time</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Machine number</td>
<td>6</td>
</tr>
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</table>

Enter/exit at LOAD

Enter/exit at LOAD1
4. Description of model experiments

**Model implementation**

- The look-ahead Simulation approach (Dynamic dispatching)
  - Schedule horizon
  - Output → Input
  - Stage 1 → Stage 2 → Stage 3 → Stage 4
  - Dynamically changing point (Undeterministic date)
  - Part type
  - Part quantities

  "The combination of different dispatching rules" leads to:

- The rule-based (heuristic) approach (static dispatching)
  - Schedule horizon
  - Output → Input
  - Stage 1 → Stage 2 → Stage 3 → Stage 4
  - Dynamically changing point (Deterministic date)
  - Part type
  - Part quantities

  "A single rule" leads to:

※ The combination of different dispatching rules in a dynamic and multi-pass manner will create better result than applying a single rule in a static manner.
5. Approach

- Simulation tool and dispatching rules

- Simulation tool: SIMFACTORY II.5

- For evaluation of the present work, 12 dispatching rules are applied.
  - Random
  - Closest
  - Farthest
  - Fewest parts
  - Most parts
  - Oldest parts
  - Newest part
  - Shortest idle
  - Longest idle
  - Low usage
  - High usage
  - By turn

- Pattern of arrival

<table>
<thead>
<tr>
<th>Part type</th>
<th>Arrival time</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>First stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>100</td>
<td>55</td>
</tr>
<tr>
<td>P2</td>
<td>100</td>
<td>75</td>
</tr>
<tr>
<td>Second stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>1060</td>
<td>55</td>
</tr>
<tr>
<td>P4</td>
<td>1060</td>
<td>75</td>
</tr>
<tr>
<td>Third stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>2020</td>
<td>55</td>
</tr>
<tr>
<td>P6</td>
<td>2020</td>
<td>75</td>
</tr>
<tr>
<td>Fourth stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P7</td>
<td>2980</td>
<td>55</td>
</tr>
<tr>
<td>P8</td>
<td>2980</td>
<td>75</td>
</tr>
</tbody>
</table>

※ Different data files are attained in the simulation process for different dispatching strategies for both planned and unplanned models.
6. Measuring performance criteria

- A few important parameters in performance measure applied in this work

- Throughput rate
- Makespan
- Sum of mean flow time and mean tardiness
- The number of tardy jobs
- Mean flow time

\[
\sum \frac{C_i - R_i}{n}
\]

- Mean tardiness

\[
\sum \frac{\max(0, L_i)}{NT}
\]

where \( C_i \) is the completion time of part \( i \), \( R_i \) the time of entry, \( D_i \) the due date of part \( i \), NT the number of tardy jobs, \( L_i \) the lateness of part \( i \) \((C_i - R_i - D_i)\), and \( n \) is the number of complete parts.
## 7. Experimental results and evaluation

- Measuring performance criteria of simulation test

### Table 5
Throughput and make span for **planned case**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Throughput</th>
<th>Make span</th>
</tr>
</thead>
<tbody>
<tr>
<td>By turn: first stage (rule 1)</td>
<td>45.750</td>
<td>66.190</td>
</tr>
<tr>
<td>Low usage: second stage (rule 2)</td>
<td>48.625</td>
<td>40.020</td>
</tr>
<tr>
<td>Low usage: third stage (rule 3)</td>
<td>51.260</td>
<td>58.400</td>
</tr>
<tr>
<td>Farthest parts: fourth stage (rule 4)</td>
<td>54.995</td>
<td>81.591</td>
</tr>
</tbody>
</table>

### Table 3
Throughput and make span for **unplanned case**

<table>
<thead>
<tr>
<th>Dispatching rule</th>
<th>Throughput</th>
<th>Make span</th>
</tr>
</thead>
<tbody>
<tr>
<td>By turn: first stage (rule 1)</td>
<td>16.250</td>
<td>23.71750</td>
</tr>
<tr>
<td>Low usage: second stage (rule 2)</td>
<td>32.500</td>
<td>24.15500</td>
</tr>
<tr>
<td>By turn: third stage (rule 3)</td>
<td>48.750</td>
<td>84.79420</td>
</tr>
<tr>
<td>Fewest parts: fourth stage (rule 4)</td>
<td>54.935</td>
<td>74.47937</td>
</tr>
</tbody>
</table>
7. Experimental results and evaluation

Measuring performance criteria of simulation test

<table>
<thead>
<tr>
<th>Best rules</th>
<th>Throughput</th>
<th>Make span</th>
<th>MFT</th>
<th>MT</th>
<th>MFT + MT</th>
<th>TJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>By turn: first stage (rule 1)</td>
<td>54.935</td>
<td>82.0906250</td>
<td>906.44240</td>
<td>75.386130</td>
<td>981.82858</td>
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</tr>
<tr>
<td>Low usage: second stage (rule 2)</td>
<td>54.935</td>
<td>81.5231250</td>
<td>897.45950</td>
<td>73.588040</td>
<td>971.04540</td>
<td>31</td>
</tr>
<tr>
<td>By turn: third stage (rule 3)</td>
<td>54.870</td>
<td>80.7548750</td>
<td>898.75115</td>
<td>74.300415</td>
<td>973.051565</td>
<td>28.5</td>
</tr>
<tr>
<td>Fewest parts: fourth stage (rule 4)</td>
<td>54.935</td>
<td>74.4293700</td>
<td>899.04590</td>
<td>75.833000</td>
<td>974.879000</td>
<td>29</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Best rules</th>
<th>Throughput</th>
<th>Make span</th>
<th>MFT</th>
<th>MT</th>
<th>MFT + MT</th>
<th>TJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>By turn: first stage (rule 1)</td>
<td>54.995</td>
<td>81.103750</td>
<td>903.02665</td>
<td>77.954610</td>
<td>980.98306</td>
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</tr>
<tr>
<td>Low usage: second stage (rule 2)</td>
<td>54.810</td>
<td>82.311250</td>
<td>907.02130</td>
<td>70.061505</td>
<td>977.08280</td>
<td>36</td>
</tr>
<tr>
<td>Low usage: third stage (rule 3)</td>
<td>54.745</td>
<td>83.215625</td>
<td>902.42505</td>
<td>67.578680</td>
<td>970.00373</td>
<td>33</td>
</tr>
<tr>
<td>Farthest parts: fourth stage (rule 4)</td>
<td>54.955</td>
<td>81.59375</td>
<td>907.8598</td>
<td>72.685235</td>
<td>980.544053</td>
<td>35.5</td>
</tr>
</tbody>
</table>
7. Experimental results and evaluation

- Machine utilization of simulation tests

**Fig. 4.** Machine utilization of simulation tests for the *planned* case.

**Fig. 2.** Machine utilization of simulation tests for the *unplanned* case.

**Fig. 3.** Resource utilization of simulation tests for the *unplanned* case.

**Fig. 5.** Resource utilization of simulation tests for the *planned* case.

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Utilization rate

\[
\text{Utilization rate} = \frac{\text{Actual hours} \times 100}{\text{Total available hours}}
\]

Dispatching rule

- By turn: first stage (rule 1)
- Low usage: second stage (rule 2)
- Low usage: third stage (rule 3)
- Fewest parts: fourth stage (rule 4)
8. Conclusion

- FMS scheduling problem
  - ✓ 8 machines, storage buffer areas, receiving area, a transporter, 2 L/U stations and three robots and pallets.
  - ✓ A study of the effect of dynamic and static dispatching strategies on dynamically planned and unplanned FMS.

- Objectives
  - ✓ Throughput rate, Makespan, Mean flow time, Mean tardiness, Sum of mean flow time and mean tardiness, The number of tardy jobs.
  - ✓ Determining the dispatching rule that will perform the best. And evaluating and comparing the effect of dynamic and static dispatching strategies.

- Contribution
  1. An overall improvements (throughput, make span) have been achieved for a dynamic dispatching schedule than that obtained in static dispatching schedule.
  2. Both machines and resources are not best utilized for the best schedule, but they are close to the best conditions with the evaluated dispatching mechanisms.
  3. The overall measuring performance criteria under consideration for planned model are better than those for unplanned case. This leads to the fact that as long as the real life models are dynamic in their changes, the planning should be oriented to these dynamic changes to make it predictable and to achieve the best schedule.
9. Advantage VS Disadvantage

- Advantages
  ① Implementation efficiency
  ② Study on how to apply dispatching rules on dynamic situation

- Disadvantages
  ① Unrealistic (→ Improve the realistic system by adding constraints )
  ② Possibility of limited system configuration depending on the function of the simulator
  ③ Experiments is not varied (just 2 test results)
  ④ The best rules by measures.

Thank you!