Analysis of decentral order-picking control concepts

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Introduction

- Motivation
- State of the art
- Modeling
- Comparison of strategies
- Conclusion and outlook
Motivation

- Relation between theoretical breakeven performance and real productivity: Dependency on operating strategies
- Development trends
  - Self-controlled material flows
  - Internet of Things
- Importance of order-picking for the efficiency of logistic systems
Motivation

State of the art

Modelling

Comparison of strategies

Conclusion and outlook
Self-controlled material flows and the „Internet of Things“

Drivers

- Development of AutoID especially of RFID technology
- Locating
- Sensor networks
- Coverage
- Standardisation
- Reading security
- Polymer chips

System requirements on plants and networks

- Requirements
- Flexibility
- Availability
- Growing complexity

„Internet of Things“
Change of paradigms in material flow logic towards self-controlled systems

Tasks

- Planing and modelling
  - e.g. logics and components for simulators and reference models
- Optimality and availability
  - e.g. comparison of system efficiency, system-related feasibility
- Design MF technology
  - e.g. adapted components and conveyor elements
Basic problems regarding distributed controls

- Technology and form of the communication among decentral controls
- Reaction to failures
- Determination of the optimal operating point without knowledge of the general system status
- Definition of suitable strategies to optimize the system
- Handling of sequencing problems and priority rules
Initial situation Warehouse operation

- Increasing article range / higher shipping frequencies
- Cost driver order-picking
- Increasing performance of material handling systems

- Selection and planning are mostly based on rough empirical values; potentials are often not analyzed in detail in advance
- The control concept, strategies, etc. are often selected by the system provider
- Effectiveness and efficiency of process and operating strategies are largely unknown
Potentials for a rationalization of order-picking

- Order-picking is one of the main cost-drivers in distribution centers
- In classical, manual picking way and idle times account for the largest share
- Most rationalization attempts aim at optimizing these aspects

<table>
<thead>
<tr>
<th>Time Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Way time</td>
<td>40 to 60%</td>
</tr>
<tr>
<td>Basic time</td>
<td>5 to 10%</td>
</tr>
<tr>
<td>Gripping time</td>
<td>15 to 35%</td>
</tr>
<tr>
<td>Idle time</td>
<td>20 to 30%</td>
</tr>
</tbody>
</table>
Storage technology in order-picking
Goods-to-man

- Small number of order items at a relatively large article master (assortment)
- Typical picking performance: approx. 600 picks/h/person (goods-to-man, paperless, ergonomical arrangement)
- Warehouse performance: depending on operating method 100-600 bins per aisle/h
Target criteria: Optimization of goods-to-man systems

- Utilization of picking capacity (even utilization) and of the possible picking performance
- Minimum of order lead times
- Avoidance of over aging of orders
- Avoidance of deadlocks and utilization of the conveying capacity:
  - Minimum number of cycling bins
  - Control of receipts and issues
- Maximum utilization of warehouse capacity, minimum number of partial bins
Modelling

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Modelling

- **Aims of the study:**
  - Parallel order-picking as a special case of order-oriented picking with required temporal synchronization of article provision
  - Functionalities of central control logics compared to decentral logics
  - Possible optimization due to strategies and algorithms
  - Determination of reference efficiency factors

- **Method**
  - Detailed comparison of strategies
  - Consideration of stochastical interdependencies
  - Event-based simulation with AutoMod™
Modelling

- Automatic 8-aisle miniload store
- 8 picking stations with parallel handling of 1, 6 or 12 orders
- Conveyor loop with windows and a capacity of 25 bins at a speed of 1 m/s
## System loads and parameters

<table>
<thead>
<tr>
<th>Factor</th>
<th>Chosen system load</th>
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<tbody>
<tr>
<td>Size of assortment</td>
<td>500 / 2,000 / 10,000 articles</td>
</tr>
<tr>
<td>Order size</td>
<td></td>
</tr>
<tr>
<td>- Order lines</td>
<td>Exponential distribution 1..20; $\mu = 5$</td>
</tr>
<tr>
<td>- Picks per line</td>
<td>Equal distribution 1..19; $\emptyset = 10$</td>
</tr>
<tr>
<td>Number of parallely handled orders</td>
<td>1 / 6 / 12</td>
</tr>
<tr>
<td>Capacity of article bins</td>
<td>100 parts / bin</td>
</tr>
<tr>
<td>ABC classification</td>
<td>20 % A-articles $\sim$ 80 % order lines</td>
</tr>
<tr>
<td></td>
<td>10 % B-articles $\sim$ 15 % order lines</td>
</tr>
<tr>
<td></td>
<td>70 % C-articles $\sim$ 5 % order lines</td>
</tr>
<tr>
<td>Number of resulting order bins</td>
<td>Exponential distribution $\mu = 3$ bins/order</td>
</tr>
<tr>
<td></td>
<td>max. 1 bin/order line</td>
</tr>
<tr>
<td>Picking performance</td>
<td>6 s/retrieval</td>
</tr>
<tr>
<td>Capacity of branch lines</td>
<td>Supply: 10 bins</td>
</tr>
<tr>
<td></td>
<td>Disposal: 5 bins</td>
</tr>
</tbody>
</table>
Comparison of strategies

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- Different optimization strategies and approaches
- Control logics call for different measures and procedures
- Comparison of central/decentral systems may be distorted because of the use of different strategies

→ Step-by-step procedure
Basic strategies

- **Central control:**
  - Allocation at central scanner station
  - Request of system status at picking stations
  - Allocation acc. to „RemainingCap“ rule: Station with shortest queue

- **Decentral control**
  - Allocation in front of picking stations
  - Request of article demand $Y$ and empty capacity $Q$ on supply track: $Y \land Q \geq 1 = \text{discharge}$
Efficiency comparison central/decentral

Efficiency of both procedures comparable, decentral control slightly better (\(\bar{\Omega} = +1.9\%\))

No uniform tendency
Comparison of the basic strategies

- Performance decreases in line with size of assortment
- A large assortment requires more replenishments from the store and offers less access to movable stocks
Comparison of the basic strategies
Utilization of the supply tracks

- Fluctuating occupancy causes frequent flow breaks
- The weak point is the continuous supply of bins
Target:
Even utilization of the loops and avoidance of overloads at single stations

- Central control:
  - Has already been realized with the „RemainingCap“ strategy

- Decentral control:
  - Immediate allocation reduces utilization along the picking stations and thus leads to an uneven load:
    - Bin quantity $A$ is smaller or equal to the required quantity $Y$ ($A \leq Y$)?
    - Buffer quantity $Q$ is large than threshold $\Gamma$ ($Q > \Gamma$ for $\Gamma = 1, 3, 5$)?
    - Bin already recirculated $R > 1$?
  - $Y > 0 \land Q \geq 1 \land (A \leq Y \lor R > 1) \lor Q > \Gamma = \text{discharge}$
Target:

Limitation of the sporadic, bunch-wise removal of bins at the start of a new order:

- Strategy: Limitation of the absolute number of bins which are started simultaneously; supply only after complete discharge
- Maximum bin quantity = 8 bins

- Decentral control:
  - No central bin tracking available → quantity cannot be controlled
  - Time-based supervision: Definition of an intermediate arrival time $t_A$ for the supply of bins from the store
  - The determination of the intermediate arrival time $t_A$ is a critical process because of the longer reaction time and the possibly reduced utilization of the picking capacity
Hypothesis:
Ideal supply frequency corresponds to the average handling time at the picking station

Reference model:
Average gripping time = 6 s
Average retrieval quantity = 10 pieces/order line
\( t_A = 60 \text{s} \)

- Check by means of parameter variations
- Not profitable in case of serial handling (1 order/station)
Optimization of the basic strategies:
Utilization of the supply track

Central: Idle times
59.97 min ➞ 0 min

Decentral: Idle times
159.81 min ➞ 61.46 min
Comparison of the results

- **Definite improvement with large assortments for central and decentral control**
- **Central control only slightly better** (\(\bar{\varphi}=+3.2\%\)) because of quicker reaction at order setpoint tracing
- **The discharging according to the target value** \(\bar{F}\) **has no effect**
Conclusion and outlook

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Conclusion and outlook

- Generally, decentral controls are suitable to control complex warehouse and order-picking processes.
- Established strategies of central controls can be transferred only to a limited extent.
- They have to be optimized by carefully selecting suitable strategies.
- Further analyses are required, e.g. for systems with routing tasks.
- The linked communication between the units, e.g. via software agents, offers further potentials for optimization.
Thank you very much for your attention!
Questions?