Shuttle-Based Storage and Retrieval Systems with Robotic Order-Picking Shuttle Carrier

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Motivation

Robotic Order-Picking Shuttle Carrier

Elevator

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Method

The assumptions that were used in analytical modelling are summarized as follows:

- The storage rack is divided into two sides (left and right), therefore totes with items are available on both sides of the storage rack.
- The robotic order-picking shuttle carrier is operated on a multi-command cycle collecting four (4) and six (6) items on four (4) and six (6) randomly selected locations.
- The sequences of (i) Acceleration, (constant velocity and deceleration) has been used.
- A randomized assignment policy is considered which means that any order-picking location is equally likely to be selected for picking items with the robotic order-picking shuttle carrier.

The expected one-way travel time (E[SA]) for travelling of the robotic order-picking shuttle carrier is equal to the next expression:

\[ E[SA] = \frac{d_1}{v_1} + \frac{1}{2} \frac{a_1}{v_1^2} f_1 \Delta t_1 \Delta x_1 + \frac{1}{2} \frac{a_2}{v_2^2} \Delta x_2 \]

The expected travel-between time (E[TB]) for travelling of the robotic order-picking shuttle carrier between two randomly selected order-picking locations is equal to the following expression:

\[ E[TB] = \frac{d_1}{v_1} + \frac{1}{2} \frac{a_1}{v_1^2} f_1 \Delta t_1 \Delta x_1 + \frac{1}{2} \frac{a_2}{v_2^2} \Delta x_2 \]

Results

• In this study totes with the following dimensions: length \( L_{tote} = 0.6 \text{ m} \), width \( W_{tote} = 0.4 \text{ m} \) and height \( H_{tote} = 0.24 \text{ m} \) have been used. With regard to the tote, the order-picking location has the following dimensions: length (depth) of the column \( L_{column} = 0.6 \text{ m} \), width of the column \( W_{column} = 0.5 \text{ m} \) and height of one column (tier) \( H_{column} = 0.5 \text{ m} \).

• For the calculation of the throughput performance of the robotic order-picking shuttle carrier, the following lengths \( L_1 = 30 \text{ m} \), \( L_2 = 40 \text{ m} \), \( L_3 = 50 \text{ m} \), \( L_4 = 60 \text{ m} \), \( L_5 = 70 \text{ m} \), \( L_6 = 80 \text{ m} \), \( L_7 = 90 \text{ m} \), \( L_8 = 100 \text{ m} \), \( L_9 = 110 \text{ m} \), \( L_{10} = 120 \text{ m} \) of the storage rack were used.

• Since the throughput performance depends on the velocity characteristics of the robotic order-picking shuttle carrier, the following velocity profiles were used in this study: \( v_1 = 2 \text{ m/s}, \ a_1 = 1 \text{ m/s}^2 \), \( v_2 = 3 \text{ m/s}, \ a_2 = 2 \text{ m/s}^2 \) and \( v_3 = 4 \text{ m/s}, \ a_3 = 3 \text{ m/s}^2 \).

• Constant times were used as follows: \( t_{pick} = 3 \text{ sec}, \ t_{move} = 8 \text{ sec} \) and \( t_{changer} = 5 \text{ sec} \).

Conclusions

• The proposed model allows the calculation of the expected cycle time for multiple command cycles, from which the performance of the robotic order-picking shuttle carrier can be evaluated. Various parameters were examined such as: Velocity \( v \), acceleration / deceleration \( a \), length \( L \) of the storage rack.

• The proposed analytical model demonstrated good performances and satisfactory deviations and could be a very helpful tool for designing automated order-picking systems with robotic order-picking shuttle carriers. It could be of considerable help to professionals in practice, when making decisions in the early stages of design project and when deciding which type of the storage rack configuration or robotic order-picking shuttle carriers will be most promising.

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