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Integration of Optimization Methods into Simulation Technology for Manufacturing via Warehouse Optimization

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Digital Factory research group

- Digital Factory is one of the eight research groups of Seinäjoki University of Applied Sciences
- The focus of the research group is RDI of digitalization in the manufacturing industry across the entire value chain
  - Closely working with the industry
  - Mostly applied research and development activities

- Simulation of a multi domain manufacturing and production systems has been long-lasting and continuing service in our RDI
  - First activities around 30 years ago and numerous simulation projects since

Motivation

- Production lines are often very complex and dynamic systems
  - Efficiency
  - Flexibility
  - Sustainability

- Simulation offers a flexible environment for modeling behavior of such systems
- Due to complexity, discrete event simulation tools themself are not able to provide solutions for complex challenges
- Optimization methods integrated with simulation tools can solve complex challenges

Objectives

- Demonstrate the integration of genetic algorithms (GA) with 3D discrete-event simulation (DES)
  - Optimize warehouse operations, specifically pallet transfers within a flexible manufacturing system (FMS)

- Test and validate the benefits of using GA to reduce operation times in a simulated 3D environment
  - Optimize throughput time of 27 pallet transfer operations by re-arranging them

- Foster collaboration between university and industry by showcasing a scalable optimization solution -> Base work for the real use case in industry

Methods

Discrete Event Simulation

- Discrete-event simulation (DES) is a powerful tool for modeling and analyzing the dynamic behavior of complex systems over time
- 3D simulation provides a more accurate, detailed, and visually intuitive representation of real-world processes
- Visual Components software was selected for the simulation tool

Genetic Algorithms

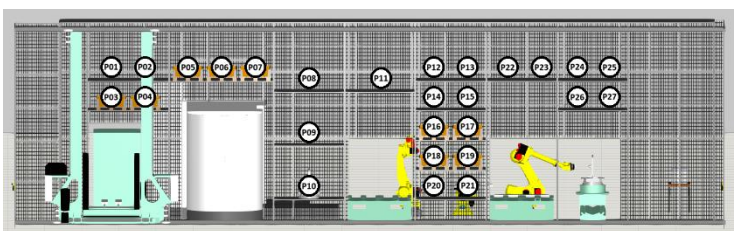
- Genetic algorithms (GA) are optimization techniques inspired by the principles of natural selection and genetics.
- GAs work by evolving a population of potential solutions through processes such as selection, crossover, and mutation.
- Well-known method

Experiment

- The experiment was based on flexible manufacturing cell located at SeAMK's laboratory
- 3D simulation model of the cell was developed using Visual Components software

Experiment

- Genetic Algorithm was implemented to Visual Components using Python API
- Each production sequence was generated randomly (3 sets of 9 transfers)
  - Pallets initial position in the storage
  - Pallets end position in the storage
  - Results production plan (27 operations)



Experiment

- The simulation model was developed to support additional features
  - Option to utilize external Python libraries such as PyGAD
    - Data transfer through TCP/IP sockets
  - Option to choose whether each solution candidate's (production plan):
    - Throughput time is simulated → takes time
    - Throughput time is calculated based on the measurements → real-time solution
      - Transfer times from every point to every point were stored

Experiment

9! = 362 880

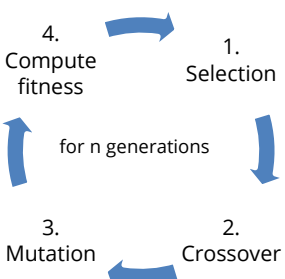
GA

Random production plan as input

```
'1': {'sku': 'epallet', 'src': 'P27', 'dst': 'P03', 'pid': 1},
'3': {'sku': 'epallet', 'src': 'P15', 'dst': 'P23', 'pid': 3},
'2': {'sku': 'epallet', 'src': 'P19', 'dst': 'P14', 'pid': 2},
'5': {'sku': 'epallet', 'src': 'P20', 'dst': 'P26', 'pid': 5},
'4': {'sku': 'epallet', 'src': 'P24', 'dst': 'P02', 'pid': 4},
'7': {'sku': 'epallet', 'src': 'P22', 'dst': 'P13', 'pid': 7},
'6': {'sku': 'epallet', 'src': 'P05', 'dst': 'P18', 'pid': 6},
'9': {'sku': 'epallet', 'src': 'P07', 'dst': 'P17', 'pid': 9},
'8': {'sku': 'epallet', 'src': 'P12', 'dst': 'P01', 'pid': 8}
```

Init population

Compute fitness



Optimized production plan as output

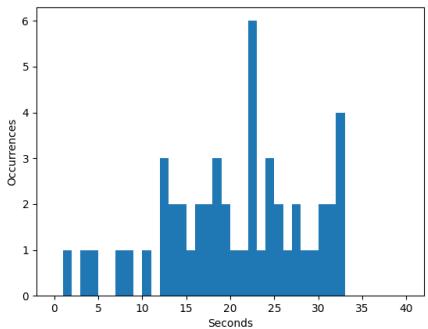
```
'2': {'sku': 'epallet', 'src': 'P19', 'dst': 'P14', 'pid': 2},
'8': {'sku': 'epallet', 'src': 'P12', 'dst': 'P01', 'pid': 8},
'9': {'sku': 'epallet', 'src': 'P07', 'dst': 'P17', 'pid': 9},
'7': {'sku': 'epallet', 'src': 'P22', 'dst': 'P13', 'pid': 7},
'3': {'sku': 'epallet', 'src': 'P15', 'dst': 'P23', 'pid': 3},
'4': {'sku': 'epallet', 'src': 'P24', 'dst': 'P02', 'pid': 4},
'6': {'sku': 'epallet', 'src': 'P05', 'dst': 'P18', 'pid': 6},
'5': {'sku': 'epallet', 'src': 'P20', 'dst': 'P26', 'pid': 5},
'1': {'sku': 'epallet', 'src': 'P27', 'dst': 'P03', 'pid': 1}
```

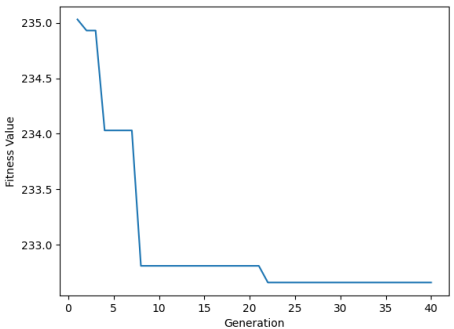
- Direction: minimum
- Genes: [1, 2, 3, 4, 5, 6, 7, 8, 9]
- Population size: 1000
- Number of generations: 40
- Elite size: 10
- Mutation rate: 11 %
- Selection: tournament of 3 chromosomes
- Crossover: partially matched crossover (PMX)
- Mutation: swap.

Randomized initial and end locations for each transfer

Results

- The simulation was run 50 times with and without the genetic algorithm
- The total duration of the transfers was reduced by circa 20,5 seconds on average. This represents about an 8,1 % reduction in transfer time





Conclusions

- Succesfully integrated optimization algorithm with Visual Components
  - Flexible environment for algorithm testing and validation
  - Platform for future work
  - Platform for education

- Significant (8,1%) reduction in the use case production throughput time
  - Real time optimization of the problem

- Future work
  - Collaboration started with a company that delivers high-bay warehouse systems globally

Thanks!

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OPLITE

Source codes (GitHub)