15

# RCS/RS under throughput investigation

Georg Kartnig, Philipp Trost, Michael Eder
Technische Universität Wien

## (1) Introduction

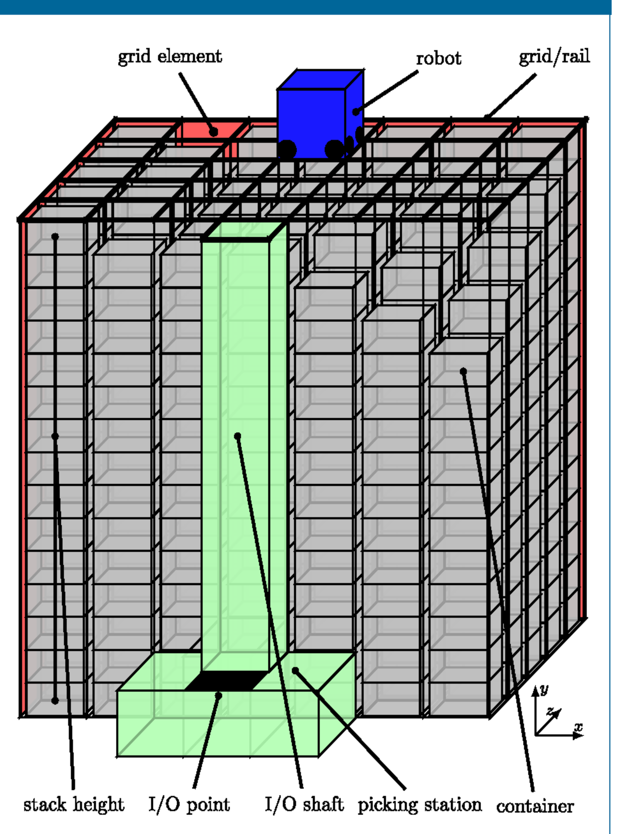
RCS/RS are fully autonomous storage systems operated by robots from above. The goods stored in containers and stacked on each other are arranged in a block. A wide range of parameters, such as the number of robots, the filling degree or the stack height, influences the system's performance. This research gives insights into the throughput of RCS/RS with a parameter variation and answers to the following research questions:

- What possible throughput can be achieved by one operating robot?
- How does the throughput depend on the parameters grid size, stack height, and filling degree?
- Is it possible to determine the throughput by an analytical approximation?
- Which throughput results using several robots?

## (2) System

**Basic components:**

- Containers (to store the goods; stacked on each other)
- Grid (stack division; orthogonal rail network for robots)
- Robot (autonomous storage and retrieval of containers)
- Picking station (with I/O-shaft for article in- and output)




**Advantages:**

- Simple, modular, flexible expandable and scalable
- High storage density, low demand for space
- High system reliability due to high redundancy
- Operated fully autonomously by robots
- Business-independent applicability
- Goods-to-person picking
- High energy efficiency

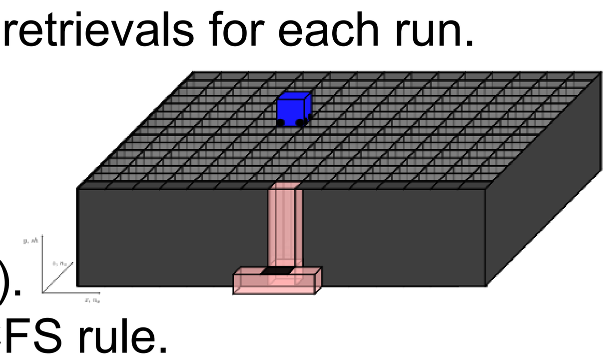
**Storage process:**
A new article to be stored is placed in a container at the picking station. An available robot lifts the container onto the grid level and transports it to the assigned stack.

**Retrieval process:**
A container to be retrieved with direct access can be picked up by the robot and transported to the I/O-shaft. In contrast to retrieval with direct access to the required container, all the others stacked above the requested container must be relocated. The containers to be relocated are moved to other stacks. After the retrieval has been completed, some systems also carry out return-relocations. This means that the robot return-relocates the previously relocated containers into the original stacking order.

## (3) Discrete event simulation

Simulation model was built up in the SIMIO software (version 15). The results were gained out of 30 independent replication runs with 10,000 retrievals for each run.

**Assumptions:**



- The storage strategy within a stack is LIFO.
- The storage is chaotic without zoning along the grid.
- The order list is generated randomly (evenly distributed).
- The robot works in a dual command cycle under the FCFS rule.
- After retrieving, the robot picks up a new container at the I/O-shaft.
- A relocation entity is relocated to the next available stack.
- The filling degree is limited to a value that ensures that relocations can be done.

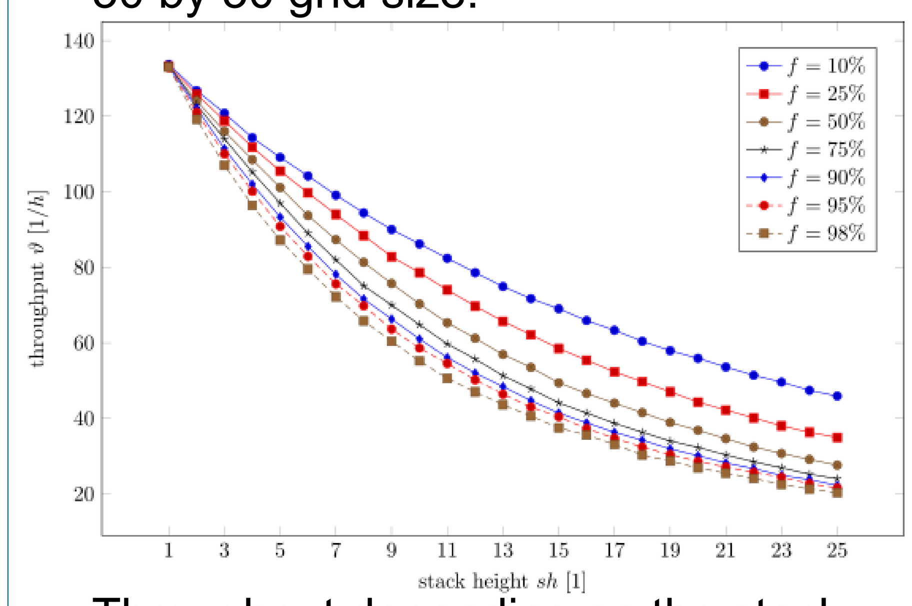
**Input variables for investigation**

| Parameter | Symbol | Value | Parameter | Symbol | Value |
|---|---|---|---|---|---|
| Container dimensions | $L_C$ x $W_C$ x $H_C$ | 0.65x0.45x0.33 m | Number of stacks | $n_{Stacks}$ | 100-2,500 |
| Division x | $\Delta x$ | 0.7 m | Number of stacks along x | $n_X$ | 10-50 |
| Division z | $\Delta z$ | 0.5 m | Number of stacks along z | $n_Z$ | 10-50 |
| Exchange time | $t_{Exchange}$ | 5 s | Robot velocity | $v$ | 2 m/s |
| Filling degree | $f$ | 10% - 98% | Robot lift/lower velocity | $v_y$ | 1.6 m/s |
| Location of the I/O-shaft | $k_0$ | $n_X/2$ | Stack height | $sh$ | 1-25 |
| Lock and unlock time | $t_{L/U}$ | 1 s | Wheel exchange time | $t_{WE}$ | 1 s |

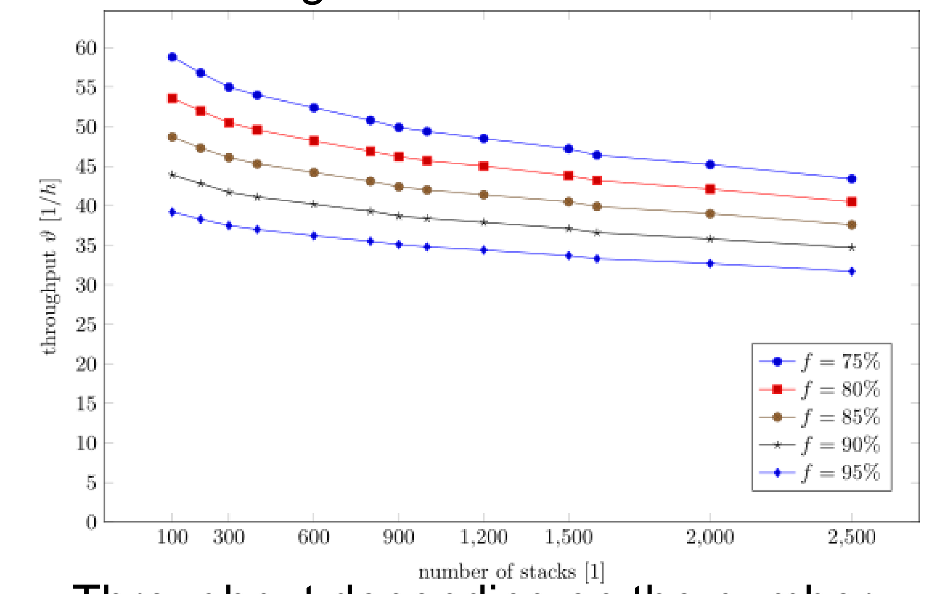
## (4) Results

**Parameter variation:**

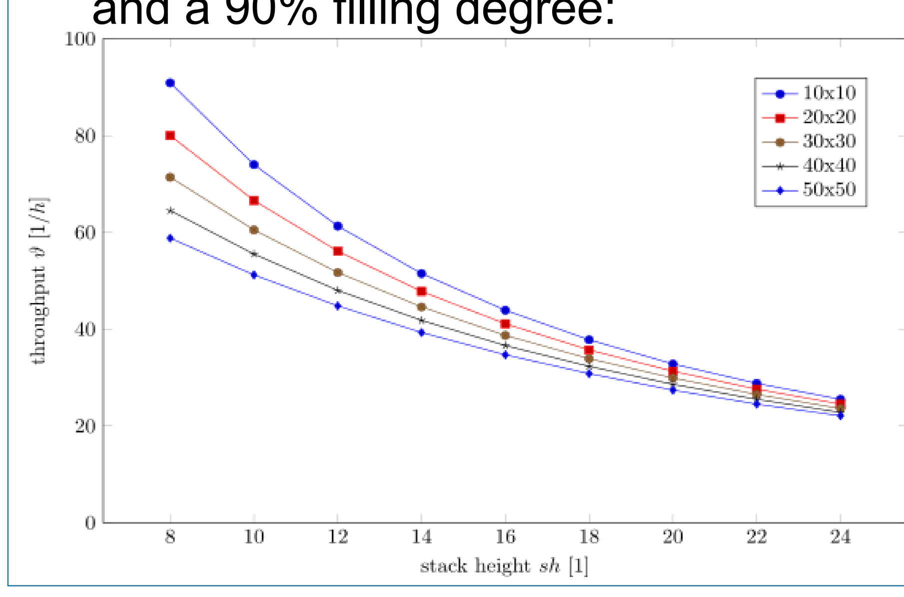
- Throughput depending on the stack height for different filling degrees and a 30 by 30 grid size:



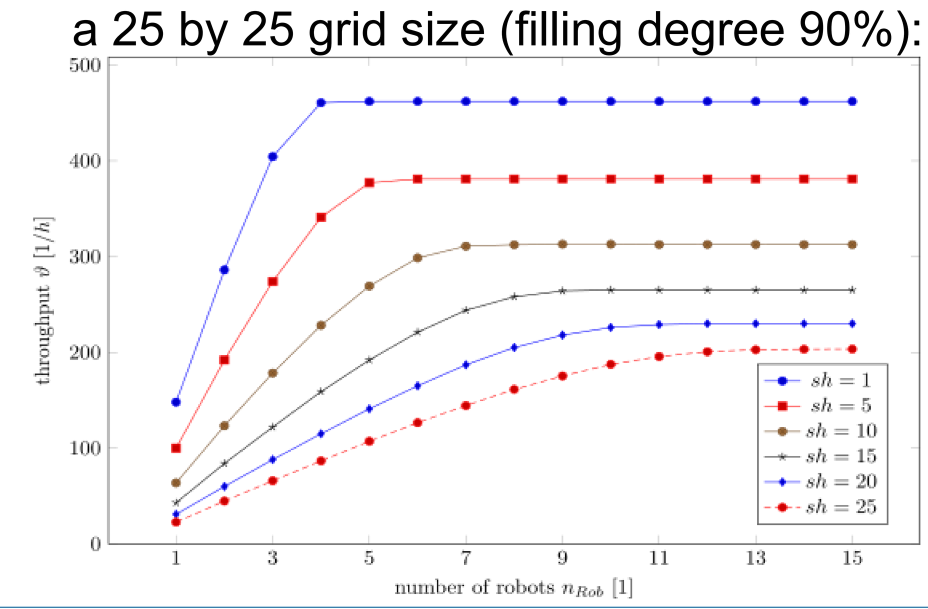

- Throughput depending on the number of stacks for different filling degrees and a stack height of 16:




- Throughput depending on the stack height for different quadratic grid sizes and a 90% filling degree:

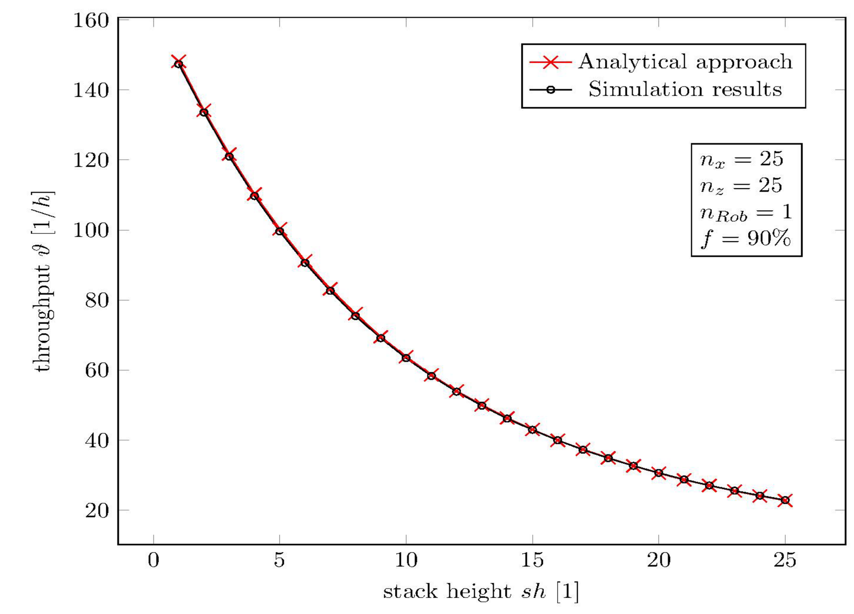


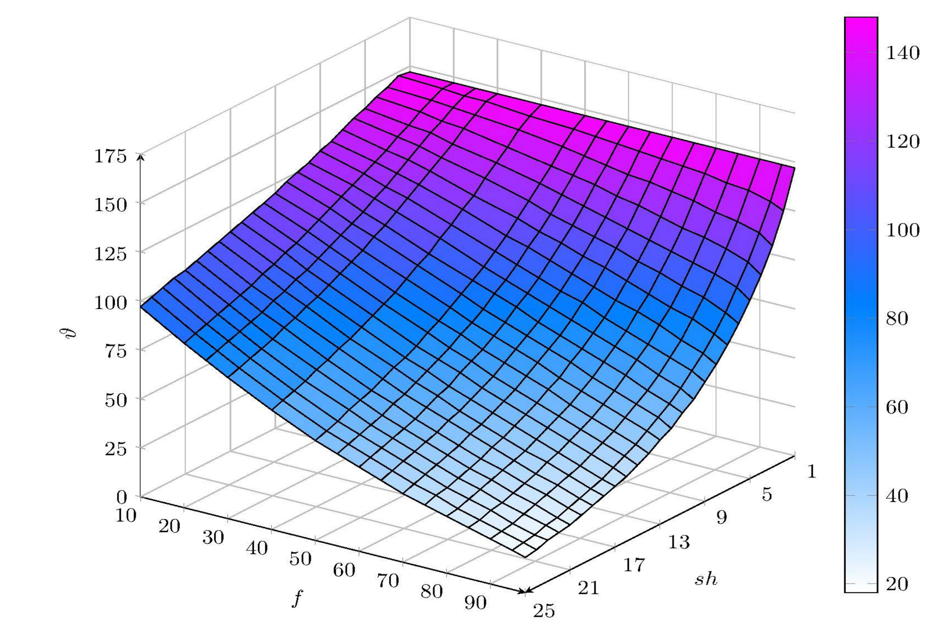

- Throughput depending on the number of robots for different stack heights and a 25 by 25 grid size (filling degree 90%):




## (5) Analytical approach

Besides the numerical simulation, an analytical approach was developed to calculate the system's performance using a cycle time model. The left figure depicts the throughput depending on the stack height of an RCS/RS with a 90% filling degree and a 25 by 25 grid with one operating robot and compares the results from the analytical approach with those from the simulation. The right figure shows the throughput depending on the stack height and the filling degree for a 25 by 25 grid:



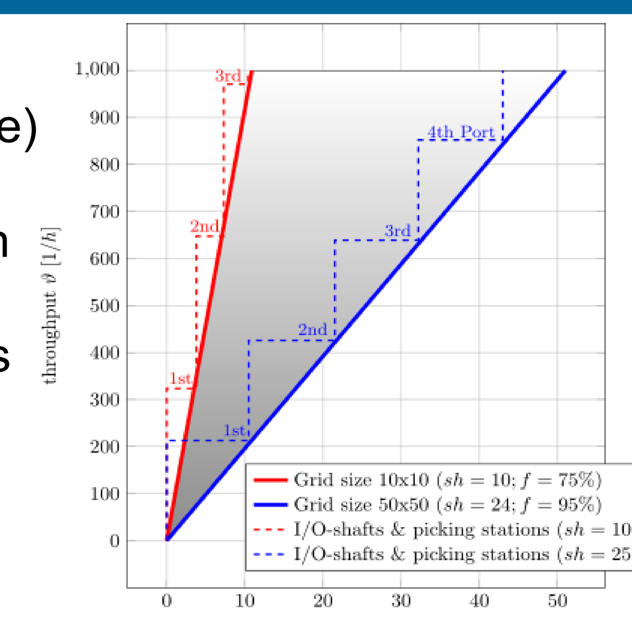

## (5) Conclusion and further research

**Conclusion:**

- Simulation of large systems (up to a 50 by 50 grid size)
- Analytical approach for one operating robot
- Validation of the analytical approach by the simulation

**Further research:**

- Simulation with more picking stations along the edges (forecast application field - right figure)
- Analytical approach with several robots and picking stations (queuing theory)
- Applying a class-based article distribution (e.g. ABC)




16th International Material Handling Research Colloquium
Dresden, Saxony, Germany, June 20-23, 2023

CICMHE
COLLEGE-INDUSTRY COUNCIL ON MATERIAL HANDLING EDUCATION

MHI
THE INDUSTRY THAT MAKES SUPPLY CHAINS WORK™