AGENT-DIRECTED SIMULATION OF FLOUR SILO INSTALLATIONS
AS PLANNING TOOL FOR DECISION-MAKING

Alexander Ulbrich

Ralf Kraul

Christoph Tilke

Willibald A. Günthner

Buhler Ltd.
Uzwil, Switzerland
Description of a flour silo installation

State of the art

Modelling of the system

Example of a simulated system

Conclusions
• 49 employees, 36 scientific assistants
• Assisted by 100 auxiliary student assistants
• Some key aspects of the research activities at our institute:
  • RFID
  • Computer-integrated planning and logistics systems simulation
  • Flexible material-flow-systems for production
  • Technology of warehouse and material flow systems
Buhler Ltd.

- Annual turnover ca. US$ 1.9 billion
- 6500 employees active in 140 nations
- World-wide manufacturing and services network
- Technology and process partner for plant installation and services in many areas:
  - Grain processing (wheat, rice, animal feed,…)
  - Food processing (pasta, chocolate, …)
  - Advanced materials (die casting, coatings, …)
Introduction

grain → mill → basic flours in different qualities

recycling (Silo to Silo)

silos

continuous mixing → batch mixer

packing product → packing

bulk product

bulk product
Milling
• A combination of basic flours is produced and stored in the silos

Maturing of flours
• Ageing of the flour with different ageing times to get the right quality

Producing flours
• To fulfil an order: mixing of different flours specified by a mixing recipe

Continous mixing (blending)
• Mixing different flours using a conveyor

Batch mixing
• Mixing different flours using a batch mixer

Loading/packing
• Loading trucks with bulk flour / packing bags of flours

Recycling
• Transport flour from one silo to another (e.g. in order to enable blending on a specific conveyor)
Example layout of a silo installation
Planning and design is a difficult task:

• Estimation of performance is difficult
  - Lots of mutual blocking processes because of shared used connections between silos, mixers and loading sites
  - High variant diversity of the products
  - Different maturing times of the flours
  - Combined production of different flours in the mills: lots of eventually unwanted flours as byproduct

• Analytical methods
  - Rough key figures depending on static calculations
  - Dynamic correlations cannot be considered
  - Planning offers solutions to problems known from the on-going production
  - Planning relies on experience

Solution: Simulation of the dynamic processes of flour silo installations
How could simulation improve the planning process?

• planning is based on a substantially broader database
• dynamic dependencies between the individual components of the flour silo installation can be considered (e.g. blockades)
• detailed investigation of several versions
• better understanding of the production processes

• Increased transparency of the planning process
• Increased customer acceptance of the planned solution
Why is simulation not established yet?

- High complexity of milling systems
- High effort needed to build simulation
- Different layouts in every milling plant depending on the requirements and the number and type of products
- Lots of decisions made by humans based on the actual conditions

How can these problems be met?

- Efficient modelling is needed
- Configurable standard elements
- Adaptable milling layouts
- General implementation
- Abstract model for a broad market share
- Behaviour of the model has to be based on the actual conditions
- Decisions should be made on the same basis as in reality

Agent based simulation
Goals and approach of the project

Goals
• Develop an easy to use simulation framework
• Gain experience with simulation in this new field
• Facilitate the planning process of flour silo installations

Approach
• Develop the simulation components
• Experiment with demo scenarios
• Validate the model with data of a real flour silo installation
• Use the model in a planning projekt
Simulation system

**Used for simulation: eM-Plant**

- Discrete event simulator
- Widely used for material flow simulation
- Graphical user interface
- Object oriented programming using a built-in programming language
- Continuous flow is discretised by small unit loads

**Main reasons for using this software:**

- Short training period because of extensive experience with this tool
- Integrated powerful programming language
- Graphical user interface facilitates debugging and testing
General structure of the simulation

Simulation

Simulation infrastructure

Configuration

Simulation control

Reporting

Simulation of hardware

Mills
Silos
Conveyors
Batch-mixers
Loading sites

Simulation of control

Data manager

Supply agent
Order processing agent
Order processing agent for batch mixers
Recycling agent for continuous mixing
Recycling agent for supply
## Modeling of the system: Standard components

<table>
<thead>
<tr>
<th>Object</th>
<th>Symbol</th>
<th>Description/Specifics</th>
</tr>
</thead>
</table>
| Mills             | ![Mills Symbol](image) | • Production according to milling recipe  
• Different qualities are produced and have to be separately stored at the same time  
• Given capacity and changeover times |
| Conveyors         | ![Conveyors Symbol](image) | • Have a given capacity  
• Can or cannot mix continuously |
| Silos             | ![Silos Symbol](image) | • Have a given storage capacity  
• Have a given output capacity  
• Have to store layers of differently aged flour |
| Batch mixers      | ![Batch Mixers Symbol](image) | • Have a given capacity  
• Have a given number of pre bins  
• Have a given batch size |
| Loading sites     | ![Loading Sites Symbol](image) | • Can be packing or bulk loading  
• Have a given capacity  
• Can have one pre bin |
Agents are used to simulate the human decisions made in the real system.

**The agents consist of:**

- Goals of action
- Criteria and rules for decision making
- Memory
- Algorithms to develop alternative actions

**Implemented agents are:**

- Supply agent
- Order processing agent
- Recycling agent for continuous mixing
- Recycling agent for supply
- Order processing agent for batch mixers
Mode of operation

• Agents act when the system state changes
• Different alternative actions are generated using the memory and the state of the complete system
• Alternatives are evaluated in regard to the inbuilt criteria (which include the state of the system and the degree of performance)
• The best alternative is started

Notes

• All “intelligence” of simulation control is represented by the agents
• Even small changes of the decision criteria changes the total simulation performance drastically
Implemented agents (1)

Supply agent

Goals:
• Provide all flours needed for order fulfilment

Troubles:
• Different ageing times
• Limited capacity of storage
• Combined production of different flours

Order processing agent

Goals:
• Start orders in order to fulfil all the orders of the actual day
• Filling of the batch mixer pre bins

Troubles:
• All flour has to be aged
• The loading sites and batch mixers have to be utilised evenly
Recycling agent for supply

Goals:

• Provide space for milling

Troubles:

• Limited capacity of storage

Order processing agent for batch mixers

Goal:

• Start orders of the batch mixers
• Find silos for the mixed product

Recycling agent for continuous mixing

Goal:

• Enable the order processing agent to work by transferring flours to different silos

Troubles:

• All flours for a given order have to be connected to the same conveyor
Workflow using the simulation

Configuration

Test runs

Analysis of reports
Configuration of a layout

- definition of block layout (components)
- definition of the material flow (conveyor connections)
- automatic generation of the defined flour silo installation as material flow system
- definition of components capacities
Data input of the system load

- Definition of milling recipes
- Definition of production recipes
- Definition of customer orders
- Definition of restrictions
Example of a simulated system
Results (1)

Quantity of delayed orders per day

Average filling level of all silos
Results (2)

Silos: Percent of time active with intake and output [%]

Working times of batch mixer
Layout optimization
Results of the layout optimization

Quantity of delayed orders per day (initial situation)

Quantity of delayed orders per day (after layout optimization)
The road capability of the tool has been proved in cooperation with Bühler and their customers.

Currently there is no better way to evaluate different planning versions.

A large number of statistic data can be gathered (detailed information about capacity utilisation, distribution of filling levels, etc.).

Different layouts and system loads can be configured and simulated quickly.

Increased customer acceptance of the planned solution.

Only simulation is able to provide information about the dynamical behaviour of the system (e.g. blockades).

The simulation proved to be a very helpful tool for planning of silo installations.
Thank you for your attention!

Contact persons:

Lehrstuhl fml
Technische Universität München
Boltzmannstr. 15
D-85748 Garching
Germany

Dipl.-Inf. Alexander Ulbrich
+49 89 – 289 15972
ulbrich@fml.mw.tum.de

Buhler Management Ltd.
Corporate Technology
CH-9240 Uzwil
Switzerland

Dr. Mukul Agarwal
+41 71 – 955 3667
mukul.agarwal@buhlergroup.com