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

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ABSTRACT
In this paper we discuss the approach of using simulation for the planning process of flour silo installations. After a brief introduction in the topic the usual performed planning process is presented. Advantages of using simulation as support tool, the requirements for the acceptance and the establishment of simulation during the planning process are described; the modeling of such a planning tool especially as agent simulation tool is discussed and a usual workflow of using the planning tool is illustrated. After that some possible results are shown and the applied validation techniques are briefly discussed. Last but not least an outlook is given.

Keywords: flour silo installation, planning tool, agent simulation, decision support system

1. INTRODUCTION

Flour silo installations assure the supply of a great number of various flours. On the one hand in these systems the basic flours are received from the flour mills and these flours are stored in large silos and are aged over several days. On the other hand there are produced a lot of further products through mixing of different basic flours. For instance depending on the production program there can be produced up to about 200 mixing products from about 20-30 basic flours. There are two different types of realizing the mixing process. One opportunity is mixing by mechanical conveyors. This was state of the art in former times because long-winded transport processes by pneumatic conveyors were too energy-intensive rather too expensive (Eberle 2009). Certainly for the mixing process by mechanical conveyors additional rearrangements of flour become necessary because all the flours to be mixed need to have access to the same mixing conveyor. Furthermore in this case of process the blending of small flour portion is only possible by mixing the product in multiple steps. A simplification of the production processes can be achieved by using batch mixers for the mixing process (Strauch 2003). This offers a more flexible, short time and faster order processing, so that normally a smaller number of silos are needed in case of producing mixing products only in the moment of order execution without any intermediate storage. Moreover the sanitation requirements of flour silo installations become more and more important so that nowadays in new planning, restructuring and enlargements pneumatic conveyors are widely assembled instead of mechanical conveyors (Eberle 2009).

2. STATE OF THE ART

The planning of flour silo installation and mainly the identification of the expected capacity is a very complex challenge due to the scores of requirements and mutual blocking processes through the use of shared connection paths between silos, mixers and loading stations. Because static analytical methods of calculation provide only quite rough key figures, since dynamical correlations cannot be considered, the planner of such an installation normally relies mainly on his experience and offers solutions to problems which are known from the on-going production. To increase transparency of the planning process and therewith to assure the solution and increase the customer acceptance the Institute of Material Handlings, Material Flow and Logistics (fml) of the Technische Universität München in collaboration with the Bühler Management AG company developed a planning tool. This planning tool offers the agent simulation of flour silo installations with its complex dynamic processes.

3. ADVANTAGES OF USING SIMULATION

Using simulation for planning of flour silo installations brings along the following important advantages:

- planning is based on a substantially broader database
- dynamic dependencies in particular interactions between the individual components of the flour silo installation can be considered
- detailed investigation of several versions
- better understanding of the production processes

Simulation offers the possibility to consider changes in the system load and to compare several layout versions against each other. In flour silo installations a big number of jobs cannot be executed at the same time because they need one or more of the same resources as other jobs or processes. Furthermore specific jobs depend on other jobs if premixing-processes are required. Also aging times of the flours have to be regarded. In our opinion it is not possible to consider these dynamic dependencies by other means than simulation. Another great advantage is the larger detail of data output by simulation which allows the detailed investigation of several versions. Moreover the simulation analysis leads to a better understanding of the production processes.

4. REQUIREMENTS ON SIMULATION

First of all the main reason for the lack of use of simulation during the planning of flour silo installation is the high complexity of these systems and the high effort needed to built simulation. Due to this efficient modeling of such systems is needed for simulation. This can be achieved by using configurable standard components and general implementation. The implementation of the standard elements has to be so abstract that a broad market share is covered and finally almost all flour silo installations easily can be simulated by configuration.

In the same way the modeled processes of a milling plant have to be applicable for various layouts.

Because the succession of jobs is depending on the state of the silo installation no fixed succession is assumed. Therefore the approach is seen in agent simulation. An agent decides based on the state of the silo installation which process has to be performed next and how.

To increase the acceptance of the tool the planner has to be able to use the planning tool without or with less additional knowledge about simulation. Therefore all parameters and components have to be configurable through centralized tables.

Because this investigation needs no information about the flow characteristic of flour, the use of a material flow simulation environment as e.g. PlantSimulation (eM-Plant) is suitable. Therefore the bulk good has to be discretized to small piece goods.

5. MODELING OF THE SYSTEM

In the next paragraph we want to illustrate which elements have to be modeled for a planning tool used to design flour silo installations. First standard components and their attributes have to be identified and implemented so that the layout can be built up (section 5.1). For the control of the system agents with different goals have to be modeled (section 5.2). Additionally an automatic flow-path finder is needed to find possible conveyor combinations from source to sink to ensure operability with any layout (section 5.3) and a versions manager for different configurations is desirable (section 5.4).

5.1. Standard Components

The components of a flour silo installation are straightforward after increasing the level of abstraction. Besides mills for the flour supply, there are silos, conveyors, loading stations and batch mixers. Important attributes of mills are the number of different flours (vary in quality) and the capacity for each flour. Silos attributes for instance are the output capacity and the volume. Additionally every silo has to save the information of different layers in case of differently aged flour. The conveyors main attributes are the capacity and the variable mixable or not. Mixable in this context means mainly if the conveyor is mechanical and if mixing on it is allowed or not. Loading stations differ mainly in bulk and packing loading stations, have pre-bins or not and the capacity. Last but not least the batch mixers have a number of pre-bins and attributes for the batch size and the capacity.

5.2. Agents

For the control agents with different goals are necessary. In our planning tool an agent is defined as illustrated in figure 1.

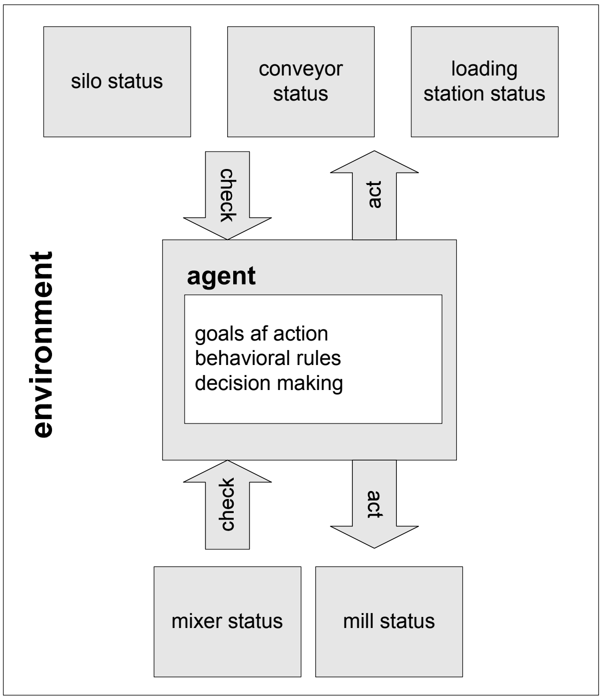

Figure 1: conceptual model of an agent

Every agent has goals depending on their tasks and observes the environment state (Macal 2008). The environment state in flour silo installation is mainly given through the status of silos, conveyors, loading stations, mixers, mills, material, jobs and orders. With knowledge of the abovementioned status an agent determines possible actions and evaluates them according to behavioral rules. In our planning tool there are four different agents identified and distinguished.

The first agent has to arrange that the mills have enough space/silos to produce at any time. Therefore it must recycle the flour of specific silos to other silos which are not connected with the corresponding mill. These silos are generally assigned for recycling. This action must take place in silo installations where the space in silos connected to the mills is not sufficient.

Moreover an agent has to arrange that products requiring mixing by mechanical conveyors are transferred to silos which are connected to the same conveyor. In installations with more than one mill and with mixing products consisting of flours from two or more mills, recycle jobs from specific silos to others are unavoidable. Due to this not each silo can be assigned fixed with a particular flour. The agent has to permit feasibility of all requested customer orders.

For the task of order dispatching the agents three and four are identified, because order dispatching can be distinguished in two sections. Agent number three's goal is to start requested orders. These can be the following tasks:

- flour from one silo to a loading station
- flour from several silos transported via mixing conveyor to a loading station
- flour from several silos transported via mixing conveyor to a silo
- starting orders mixed by batch mixers and initiating filling jobs for the batch mixers
- flour from one silo to a pre-bin of a batch mixer according to the requested filling jobs

The goal of the last agent is the order processing in the batch mixers. It has to check which jobs can be performed and which sequence should be chosen. The feasibility is depending on the availability of silos or loading stations, the availability of enough flour in the pre-bins and the availability of the batch mixer.

5.3. Automatic path-way finder

Due to the fact that conveyors sometimes have more than one in- or/and output stream there are a big number of possible path-ways from any source to any sink. Since the planner or user of the planning tool only defines the connections between all components via tabulations, an algorithm had to be implemented to identify every possible path-way. For this a list is generated and loaded with the gathered information. Therewith the agents can quickly identify possible path-ways.

5.4. Versions manager

During the work with the planning tool bottlenecks can be identified in the designed versions. Due to this often from initially two or three versions a big number of different versions grow up. But changes from version to version differ only in a small number of configuration variables. Hence it is desirable that the configuration is saved separately and can be reloaded into the actual release of our planning tool. Due to this the configuration tabulations are centralized and saving or loading is done by a versions manager.

6. WORKFLOW OF PLANNING

The workflow of planning with our tool can be divided in to layout configuration of the flour silo installation, specification of the material flow system, definition of data needed for the information system, the simulation test runs and finally the interpretation of results.

6.1. Layout configuration

According to figure 2 the planner has to carry out the following steps to configure the layout of the flour silo installation.

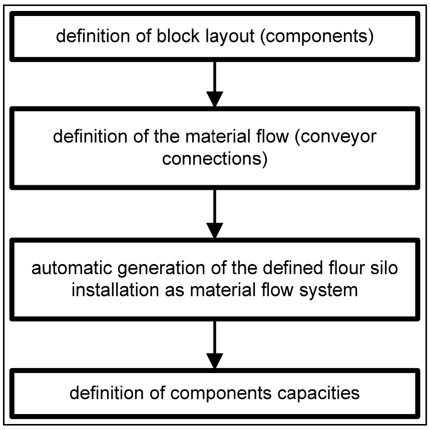

Figure 2: workflow of layout configuration

First of all the planner has to define the number of components needed to describe a layout version and the approximate placement inside a specified grid. This can be done by filling a table with key words. The result of this step is an unassociated scheme of the installation containing the defined number of mills, silos, loading stations, mixers and conveyors.

In the next step the connections between the several components have to be configured by definition of input and output streams of every conveyor. This step defines the whole material flow and a downstream algorithm can detect every possible pathway. Afterwards the whole material flow system is drawn and components capacities can additionally be defined in centralized configuration lists.

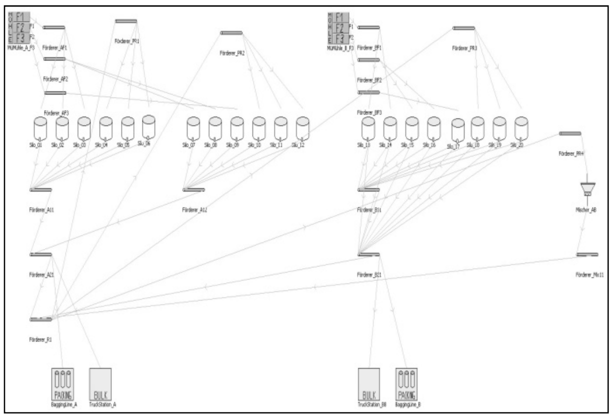

Figure 3: example of a configured layout

In figure 3 an example for the configuration of a flour silo installation is illustrated.

6.2. Data input

The workflow for defining the information system of a flour silo installation is illustrated in figure 4.

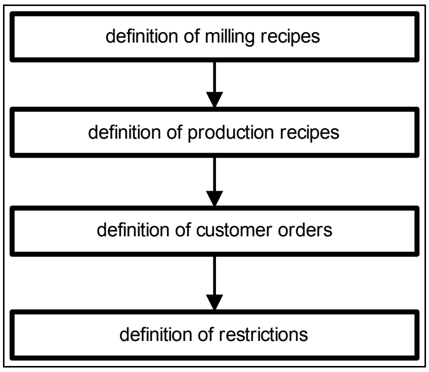

Figure 4: configuration of the information system

There are several data lists needed to describe the information system of a flour silo installation. Besides the customer orders the recipes for mixing production, the milling recipes for the basic flours, the dependencies between basic flours, the assignments of basic flours to mills and some additional restrictions are needed. Usually the planner performs the data input according to figure 4. Restrictions can be that some mixture recipes can only be performed on special components (e.g. mixers).

6.3. Test runs

After configuration is made by the abovementioned steps the simulation test runs are performed automatically and several time stamps are collected. By running the simulation slowly the planner can inspect the correctness of processes by animation of the material flow streams. Simulation of a big flour silo installation with more than 100 Silos, several loading stations and 2-4 mixers takes about an hour runtime for a customer order list containing all work of a month.

6.4. Outputs

Finally there are a big number of possible key figures. Some of them are shown below. In figure 5 for instance the layout of the flour silo installation is illustrated in style of a sankey diagram. Often used connections are marked according to the quantity of material flow.

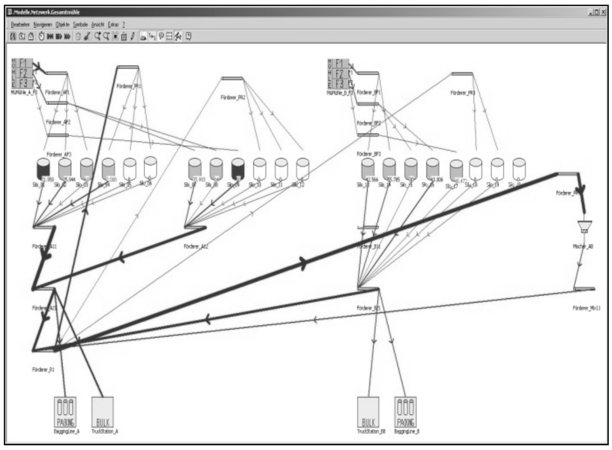

Figure 5: visualization after a test run

Because the number of orders differs from day to day, the workload per day is illustrated in another diagram. Figure 6 illustrates the quantity of completed orders per day of an example installation.

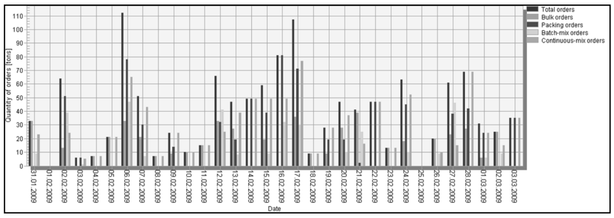

Figure 6: quantity of completed orders per day

Often the aging-time is another quality benchmark of the planning results. Normally there is a minimum time (hard requirement) for which the flour must be aged and a desired time (soft requirement) for which it should ideally be aged. Figure 7 shows the aging time of the completed orders of an example.

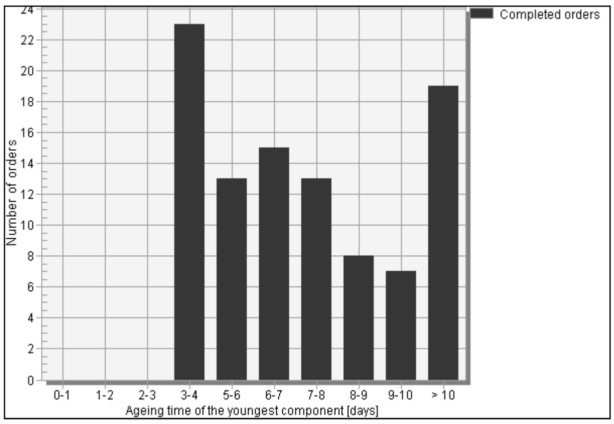

Figure 7: ageing time of completed orders

Furthermore a focus on recycling activities in flour silo installations is applied. This is on the one hand to save energy costs and on the other hand to free silos and conveyors by saving recycling jobs. The number and quantity of recycling jobs depends mainly on the layout and the preferred mixing technique. To visualize these processes another diagram in Figure 8 shows the quantities of flour transfers from and to silos.

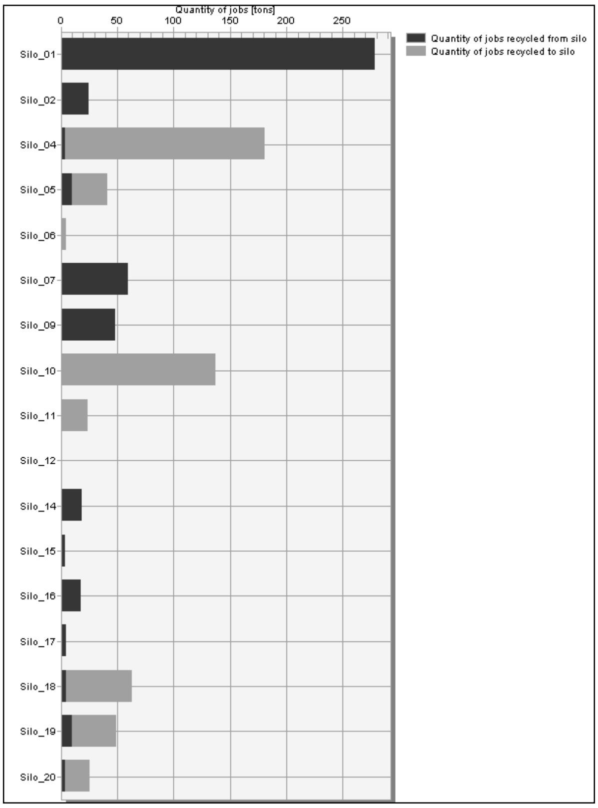

Figure 8: quantity of recycled jobs from/to each silo

7. VERIFICATION AND VALIDATION

There are several approaches discussed in literature to decide whether a simulation model is valid or not (Sargent 2007, Schlesinger 1979). Three of these are applied for this model. The first one is subjective and performed by ourselves. Therefore we observed some different customer orders if they are performed as desired and evaluated the results. In the next step, the validity of the simulation model had to be decided by the model users. Another approach used to decide the validity was to compare the results of our planning tool with the results of an existing silo installation in the same time period. Therefore data of a customer of Bühler AG were used and a big model was configured. The results achieved by the simulation could then be compared to recorded data from the real installation.

All performed approaches were successful and affirmed the validity of the simulation model.

8. CONCLUSION AND OUTLOOK

By the agent simulation of flour silo installations the planning of such systems becomes more transparent and the acceptance by the client is increased. Till now there is no better way to evaluate different planning versions. The requirements of these systems can be considered and the versions can be compared to each other.

In future it is no more imaginable for us to plan a flour silo installation without using such a planning tool. Moreover the simulation tool can be used in other branches as e.g. the animal-food industry (Kersten, Rohde and Nef 2005).

REFERENCES

Eberle, S., 2009. Mehl mischen oder homogenisieren - Umbau von vorhandenen Silo- bzw. Mischereianlagen. In *Mühle + Mischfutter, 146. Jahrgang. Volume 3*. February 2009, pp. 73-81, ISSN 0027-2949. Moritz Schäfer Verlag, Detmold, Germany. (in German)

Macal, C., North, M. 2008. Agent-based modeling and simulation: ABMS examples. *Proceedings of the 2008 Winter Simulation Conference*, pp. 101-112. December 7-10, Miami, Florida, USA.

Kersten, J., Rohde, H.R., Nef, E., 2005. Mischfutterherstellung: Rohware, Prozesse, Technologie. AgriMedia, Clenze, Germany. (in German)

Sargent, R.C., 2007. Verification and validation of simulation models. In *Proceedings of the 2007 Winter Simulation Conference*, pp. 124-137. December 9-12, Washington D.C., USA.

Schlesinger, et al. 1979. Terminology for model credibility. *Simulation* 32 (3). pp. 103-104.

Strauch, W., 2003. Marktübersicht Feststoffmischer. In *Mühle + Mischfutter, 140. Jahrgang. Volume 24*. November 2003, pp. 721-725, Moritz Schäfer Verlag, Detmold, Germany. (in German)

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