A Repository of Simulation Models for Interactive Support of Teaching Material Flow Systems

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Abstract

This paper considers using simulation models in teaching material flow systems. Features of such systems that can be efficiently illustrated by simulation models are characterized. A set of specialized simulation models is presented that provide an interactive animated support for teaching material flow related courses. An example model is described in more details. The models illustrate important dynamical properties of logistics and manufacturing systems and allow interactive parameter adjustment and guided real time experiments.

Keywords

Simulation-based learning, discrete event simulation, engineering education.

Introduction

The ability to analyze and understand the underlying properties of industrial systems is of great importance for future professionals. Real industrial scenarios and interactions of different system elements should be integrated into the study process. Simulation, as an imitation of key characteristics of real events, situations or procedures (Girod et al, 2008), can be used to replace real experiences with guided computer experiments. Simulation-based learning (Lateef, 2010), incorporating an interactive simulation-based representation of system properties, increases the effectiveness of learning. Simulation is applicable in the scope of various approaches, such as constructivist learning, through learning-by-doing or improving higher order thinking by applying various teaching models (Baek, 2009). A taxonomy of embedded tutorials and demo models in simulation tools is proposed in (Koischubajew and Weber, 2015). Special aspects of using simulation in teaching statistical distributions are considered in (Grascht and Lavrov, 2018).

In this paper, we give some general considerations on using simulation models in engineering education and present several examples and recommendations. Some important system properties are listed and the corresponding model repository is characterized. Then, an example model - of a one machine queuing system - is explained. In order to retrace the effective application of models in a lecture, a six-step workflow of model usage in a lesson is described.

Model Repository: Illustrating System Properties and Behavioral Phenomena

Pure mathematical examples, in particular – of queuing systems, as a central model for logistics and manufacturing systems - are usually not easy to understand by engineer students. Therefore, a real time animation, for example, of rapidly growing queues in service systems, would be very helpful.

Analogous, the importance of a proper choice of pre- and re-ordering mechanisms in logistics and production systems can be better understood via interacting with parameterisable simulations.

Table 1 contains a list of selected models from the developed repository, together with a brief characterization of the properties and phenomena of material flow systems they illustrate.

Model	Illustrated system properties and effects
OMQS (One Machine Queuing System)	Queue length and order waiting times depending on system utilization
APTV (Arrival and Processing Time Variation)	Order processing characteristics depending on the variation of the arrival and processing times
OSD (Order Structure Diversity)	Impact of the order diversity on system performance
PRT (Priority Rules Test-Bench)	Cycle time and other time characteristics depending on the order processing discipline (sequencing)
ASRSOC (AS/RS Online Control)	Stacker crane and shuttle control strategies
TOM (Tour Optimization Model)	Effects of different routing heuristics
IAP (Item Assignment Policies)	Influence of various item assignment policies in a storage on the overall system performance
BESC (Bullwhip Effect in Supply Chain)	Emergence and development of a bullwhip effect in a simple supply chain
KCPL (Kanban control of a product line)	Illustrating the logic of kanban control in a manufacturing system
BCR (Buffer capacity under rejects)	Input buffer dimensioning under different reject rates

Table 1: Selected models from the repository

Model Example: Representing a One Machine Queuing System

As explained in the previous section, queuing systems play an essential role in logistics and manufacturing system analysis. The presented model makes it easy to show the principles and relationships of queues. The following scenario is used (Figure 1): goods flow into the system via a source with exponentially distributed arrival times; they reach a workplace with the aid of a conveyor belt; having been processed by the workstation, the goods proceed to a sink via another conveyor belt.

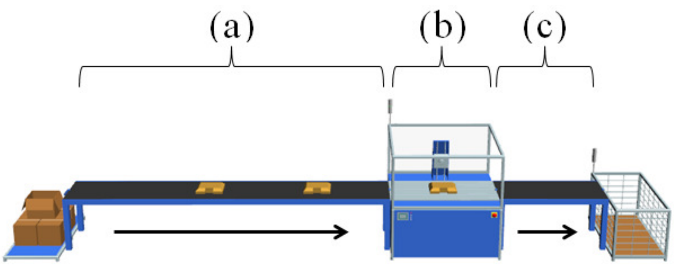

Figure 1: One Machine Queuing System Model

The main system parameters can be changed using a user interface. In particular, via a dialog box as in Figure 2, one can adjust the arrival rate of the conveyed goods, the processing time of the working station (in relation to the arrival frequency or as an absolute value), the total duration of the simulation run, etc. The main parameters are initially set to their default values which are most appropriate for illustrative purposes.

To illustrate effects of the queuing theory in a simple and understandable way, a grows of the queue can be observed on a long conveyor belt (Figure 3). First, the simulation has just begun, the belt is empty and the flow to the workstation is unhindered (Figure 3, a). Depending on the current system parameter values, the queue may gradually grow. When the complete conveyor belt is filled, the maximum queue length is reached (Figure 3, b). In this way, the “evolution” of the queue can be easily tracked.

Furthermore, it is important to record the results of the various simulation runs, in order to be able to make comparisons and, as a consequence, to derive the optimal parameter settings. During the simulation run, data regarding the queue length and waiting times are collected over the pre-defined time period.

Upon the simulation run, the data processing module calculates the resulting mean queue length and further statistics and transfers them to the output tables (Figure 4, a). A diagram (Figure 4, b) shows the outputs of the different simulation runs side by side. Another menu can be used to show or hide these results or to reset the data base.

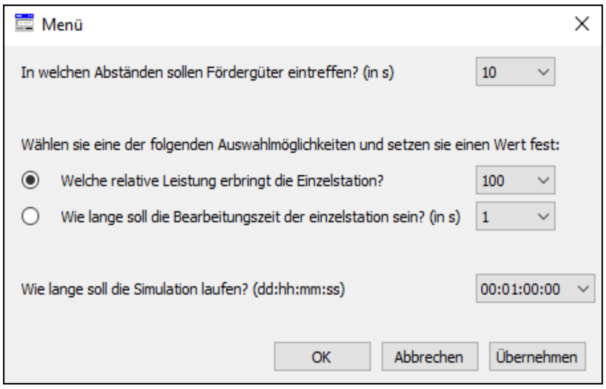

Figure 2: User Dialog

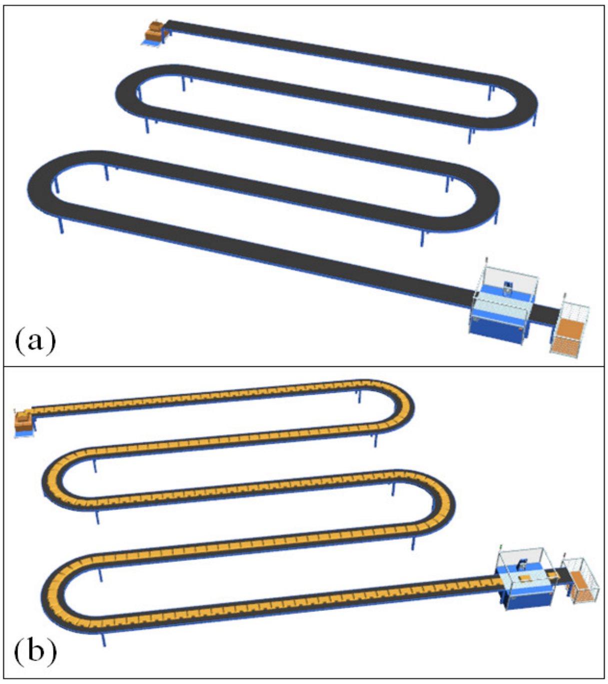

Figure 3: Illustrating a queue length: (a) initial state – no queue, and (b) growing queue with higher utilization

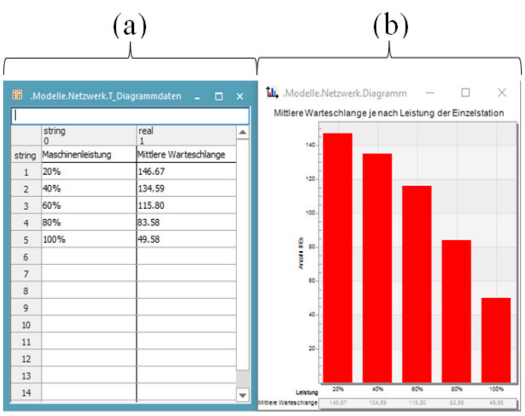

Figure 4: Data table and comparison chart

Model Application in a Lecture: Principles and Practical Advices

Experience shows that the results of a simulation-based learning can become disappointing if proper explanation and guidance are missing (Swaak and de Jong, 2001). In addition, a continuous alternation of theory and practice, especially in engineering courses, is very useful to close the gap between the university theory and the real life setup (Gilliot and Rouvrais, 2004).

In order to effectively and sustainably integrate a simulation model in a lecture, it is important that this model

- is simple enough,
- allows an intuitive usage, possesses a comfortable menu: everyone should be able to serve it,
- can be directly and individually used by students,
- relates to the corresponding theoretical part of the lesson in a natural way,
- focuses on a concrete, preferably single, problem statement ("one model – one problem").

For the effective usage of a simulation model in a lecture, the following generic workflow, using an example of a queuing system, can be recommended (Figure 5):

First, the very basics of the queuing theory should be delivered (Figure 5, step 1); this provides students with the first impression of the topic. The second step is a "transfer" of the theory into a simple visualization, using a simulation program; for this purpose, the model described in the previous section (Figure 1) can be used (Figure 5, step 2).

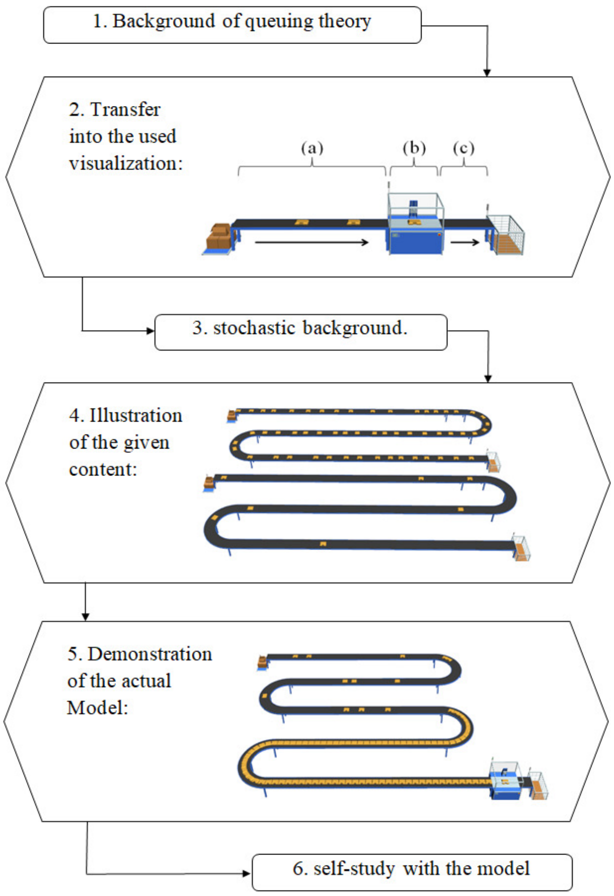

Figure 5: Worflow of simulation application

Then, it is necessary to provide a more thorough theoretical insight into the relevant stochastics properties; this is an important factor, e.g., for considering the arrivals of the conveyed goods and their processing (Figure 5, step 3). On the basis of another, compact simulation model, this theory is then directly illustrated by the arrival frequency of the units on the conveyor belt with different standard deviations and different mean intervals (Figure 5, step 4). After that, the complete simulation model can be demonstrated, showing how it operates and which results are produced (Figure 5, step 5). The final step is the individual work of students, including the usage of the corresponding simulation model, given to their disposal (Figure 5, step 6). In this way, through the simulation-based learning, the students can call up and directly apply their knowledge gained in the theoretical part (Jonassen et al, 2000), (Luo et al. 2014).

Conclusions

Interactive visual simulation-based support of study enhances the teaching process and increases the quality of solutions of industrial and practical problems. Students can consolidate the theory they have learned during their studies through simulation-based applications. The "Pack and Go" function of the used simulation software makes the models autonomous and executable everywhere, since no license is required. In addition, they are designed to be highly interactive, so that the target group can work with it in the most efficient way. The developed repository includes models which allow to study the impact of parameter settings of queuing system, of arrival and processing time variation, of order structure diversity, of item assignment policies, and so forth.

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