

Worker Simulation using HLA

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Abstract

One field in the wide area of simulation applications is the field of manufacturing systems. Within it the human factor is of growing interest. To increase the efficiency and productivity of a company besides investment in new technologies the introduction of alternative working structures becomes more and more important. For the modeling of working structures the modeling of workers is significant.

Most of the simulation systems available at the market offer elements for the modeling of workers in a more or less detailed way. Usually, the workers are implemented as a special resource with disposability and qualification. Worker elements in simulators are passive elements requested by a machine. In contrast, the worker elements in flexible working structures are active elements with many degrees of freedom in decision making. Because of the importance of the workers in the companies the modeling possibilities in the simulation systems have to be extended.

Therefore, we propose a specification for worker modeling to extend existing systems. The specification supports the user by providing information about system elements with their attributes, parameters, and relations. A formal specification is needed for processing by a computer. For monolithic simulations there exists no standard specification language. Just for distributed simulations there is a new standard available, the High Level Architecture for Modeling and Simulation (HLA) developed by the DoD. We have tested the applicability of HLA for monolithic simulations.

In our specification we have three components, the worker itself, the time model and a component for worker management. Every component represents a class with attributes, parameters and behavior. In a model several objects of each class, except the worker management class, can exist. This specification is simulator independent. Even though it is object-oriented, the implementation does not have to be. The components are extensible and adjustable. In the worker management some standard strategies are pre-defined, but special strategies can be supplemented. All information needed is in the worker management.

We used HLA to describe the relations between the components and the participating parameters. We cannot describe the behavior of a component. These parts of the system we specified informal. So the specification is appropriate to build a monolithic simulation model including extended worker elements. However, with our approach every worker can be implemented as

an autonomous entity. The material flow system, the worker management, the shift model, and every worker can interact in a distributed simulation system.

Summarizing we can say that HLA is able to specify the field of monolithical simulation in an object-oriented way. We can specify the attributes, parameters and interactions between components. The information about the behavior of the components has to be added.

1 Introduction

Due to restructuring of production, the role of workers in a company has increasingly changed over the past several years. A transition from the manufacturing system, organized by Taylor's principles, to flexible, self-organizing working structures took place in several domains. Different structures evolved, often in a company-specific fashion. To be able to estimate the effectiveness of these flexible systems, a simulation model has to be very detailed. It is necessary to gather additional input data and to include specific model components. Our approach integrates workers with existing models of logistic systems.

A worker specification was developed that describes the structure of modeling components, the required input data and the interfaces to other modeling components. The specification uses the HLA standard to specify the interfaces. This enables us to make the specification nearly simulator-independent. The stronger consideration of the workers in simulation models is denoted as worker-integrated resp. worker-oriented simulation. In worker-integrated simulation the main point is the evaluation of the logistic system, while in worker-oriented simulation special factors influencing the workers get analyzed [ZH97]. The increasing level of detail by worker modeling requires an increasing effort in the whole modeling process. In the following sections we will present methods and techniques helping to decrease the effort for worker-oriented simulation.

In the presented analysis particular thought was given to flexible working structures because of the large scope for development of the workers and the interdependence between disposition strategies and efficiency of the logistic system. One of the major problems in modeling flexible working structures is the description of disposition strategies. The possibilities range from simple, centrally coordinated worker pools to the decentralized, distributed approach of intelligent agents. Several publications (e.g. [BS97]) show that the effort of gathering strategies and implementing decentralized worker management is very high, even for rather small systems. Therefore, in our approach a central worker control is used. The condition for the integration of flexible working structures into simulation models is a comprehensive analysis of the general and company-specific properties.

2 Elements for Worker-Simulation

As mentioned before, we analyze workers in manufacturing systems. We do not analyze human models comprising a graphical presentation of the human body and proper to solve problems of workplace design. In models of manufacturing systems we model the decision-making when handle jobs.

2.1 Workers in Manufacturing Systems

Workers in manufacturing systems fulfill several tasks. The role of the workers depends on the existing working structure and range between the operation of a machine and organization of the work flow. When operating a machine we have to consider just the availability of a worker. In flexible working structures besides availability, ability and competence become important.

Flexible working structures are distinguished by four characteristics which can occur in different peculiarities [DES94]:

- Integration of Functions and Tasks,
- Cooperation and Communication,
- Autonomous Control and Inspection, and
- Integration of Qualification.

Due to the integration of functions and tasks the possible range of decisions and activities for the workers increases. Increased requirements of cooperation and communication arise when workers are organized in teams. These teams have to work autonomous with self-control. The integration of qualification means to assign certain tasks to less skilled workers for practice. The special values of these characteristics are unique in every individual company. So we have to specify an open system that has to be adjusted in the special case.

2.2 Workers in Simulation Models

The kind of simulation we will investigate is called *worker-oriented* simulation. Furthermore, there is *worker-integrated* simulation. These concepts are defined in a new VDI guideline which is under development. *Worker-integrated* simulation models represent logistic systems including the workers. The main focus is on solving economical problems. In *worker-oriented* simulation models the workers are represented in a higher degree of detail. The main focus here is on analyzing the impacts working structures have on the workers and the whole system. The main elements of worker-oriented simulation models are work-places, functions, and workers (see Fig. 1a).

To model the relations shown in Fig. 1a is very expensive. So we abstract from it to simplify the requirements to build a simulation model, but nevertheless consider all relations and elements. The first relation, ability and requirement, is modeled as worker qualification. Every worker got a qualification for every task. This is represented by a value between 0 and 1, in any desired graduation. The feasibility is included in our task definition. We presuppose that every task is unique, i.e., the same task at another machine is another task in this sense. The competence is inclusive thereby, because there is just one work-place to do the task and every worker who is competent to do the task, is competent to work at this work-place (see Fig. 1b).

To realize the requirements resulting from our definitions we need three system elements for worker simulation: the worker itself, the time management for the workers, and a controlling facility holding the disposition strategies and information. We specify these elements in Sec. 3.

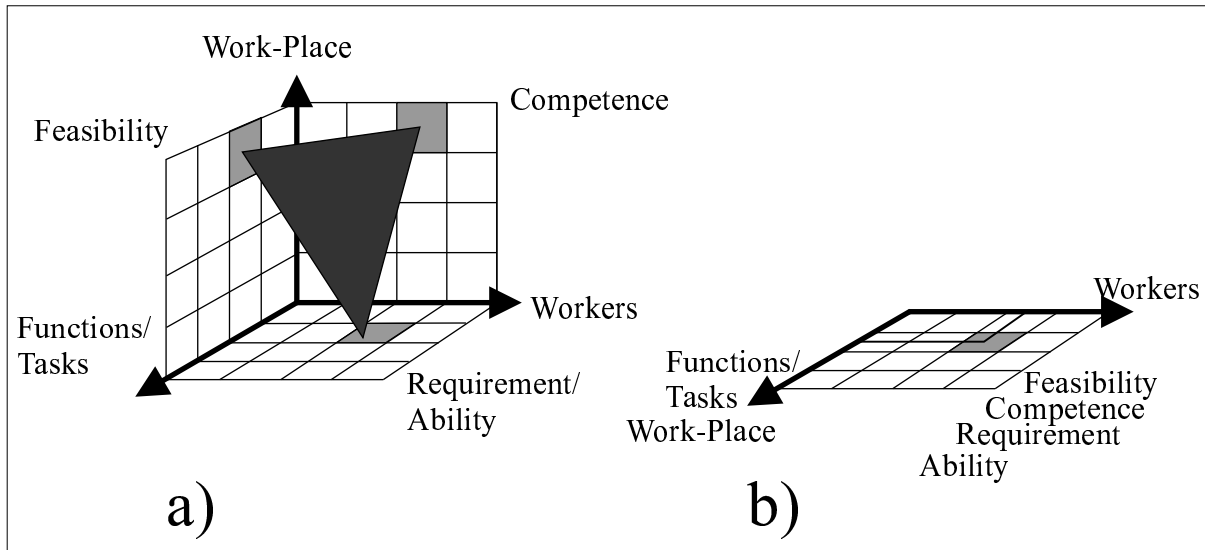


Figure 1: a) Relations in worker-oriented simulation [ZH97] b) Relations in our Worker Simulation

3 Using HLA for the Specification

The worker specification is a description of the data necessary for modeling workers and their mutual relations. It assists the modeler in gathering and preparing of the required input data as well as providing a form of documentation. There is no standard for specifying a monolithic simulation model, but for distributed model there is. So we analyzed the HLA (High Level Architecture) standard from the DoD with regard to its applicability for monolithic simulations.

HLA was developed in 1996 at the DoD to describe distributed simulation systems. The primary objective of HLA is to provide a basis for establishing interoperability among simulations of a federation and across functional communities and to facilitate reuse of simulation components ([Dep96]).

HLA describes the interaction of federates and the attributes and parameters used in the interaction. The individual federates are considered as a *black box*. A federate is a member of a HLA federation, a federation is used as a whole to achieve some specific objective. HLA provides interface definitions, object models, and time management. All information is described in tables. There is an Object Class Structure Table, an Object Interaction Table, an Attribute/Parameter Table, and the Enumerated and Complex Datatype Table. In addition, there is a lexicon to define objects, interactions, attributes, and parameters.

Now we have to specify the three elements for worker simulation. To use HLA we imagine these three elements like interacting federates and define all the attributes and parameters of the elements and the interaction between them. First we have to create the Object Class Structure Table. An HLA class structure is defined in terms of hierarchical relationships between classes of objects. We have just three classes (see Table1).

P means that the class can be published by a federate, *S* means that a federate is currently capable of utilizing and (potentially) reacting to information on objects in the specified class.

OBJECT CLASS STRUCTURE	
Type of Worker (P, S)	Worker
Time Model (P, S)	
Worker Management (P, S)	

Table 1: Object Class Structure Table

Next we create the Object Interaction Table for any interaction between instances of the classes defined in Table 1. There are listed the initiating and receiving objects, the interaction parameters and a column to categorize the current capabilities of an individual federate with respect to object interactions. In the Attribute/Parameter Table the attributes of the objects and the parameters of the interactions are listed with a set of characteristics like attribute name, data type or the accuracy. The tables for enumerated and complex data types shall be used if such a data type appears in the Attribute/Parameter Table. At last, we have the lexicon for the object classes, the object interactions, and the attributes and parameters. The attributes and parameters of the element *worker* are shown in Table 2. Like the worker, the time management and the worker management are defined.

ATTRIBUTE/PARAMETER DEFINITION		
Worker	Identification	unique identification of the individual worker
	Type of Worker	either the identification or a classification
	Qualification	value between 0 and 1 for every task
	Monotony	the last 10 tasks the worker has done
	Current Task	identification of the task the worker handles at the moment
	Current Part	identification of the part the worker handles at the moment
	Time Model	link to the worker's time model
	Worker Management	link to the Worker Management
	State	current state of the worker: at work, waiting, free, not available, pausing
	Task Schedule	link to the related task schedule of the current part
	Working Cycle	number of the current working cycle
	Break	date of the next break by the related time model
	Location	worker's current location in the system

Table 2: Attribute and Parameter Definition of the Element *Worker*

In our tables we defined the three elements with attributes, parameters and relations, but we did not define the internal behavior of the objects. HLA does not provide the possibilities to define internal structures, so we used an informal specification to describe the rest.

The workers do not have any internal behavior. The time model allows the implementation

of flextime while computing the actual starting time using underlying distributions. This is an internal behavior. The worker management includes many disposition strategies that are described informal (see [Fre97]). A couple of strategies are pre-defined, such as first-come-first-serve. Every strategy can be added because of the information available at the worker management.

4 Exemplary Implementation

We did an exemplary implementation using Simple++ and WITNESS. We modeled an assembly line with 5 workers. The layout of the model is shown in Fig. 2.

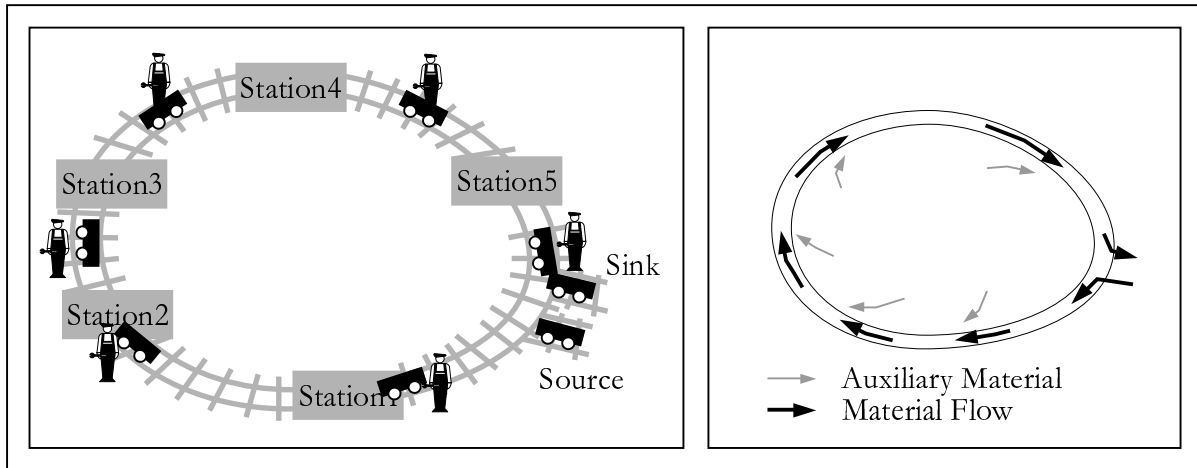


Figure 2: Layout of the Assembly Line

The assembly stations are connected via rails where assembly wagons will be moved by the workers. The wagons cannot overhaul each other. An experimental parameter is the qualification of the workers. In one scenario every worker has the qualification to work at one station only, another is when every worker is able to handle the whole assembly line. In the simulation the qualification influences the handling time, the error rate and the assignment of tasks to a worker. Conversely, the qualification is influenced during the simulation run. The effect of learning a job can change the qualification value. How often a worker has to iterate a job at a stretch to realize a learning effect depends on the specific system.

Before the simulation starts, an estimation of the available qualification for every task is possible (see Fig. 3). This enables the user in the planning phase to decide if the available qualification complies with the requirements of the planning. However, when there is insufficient qualification the simulation can be used to detect the required enhancement of qualification for the several tasks. We can detect the request on qualification by comparing the workload of every worker in the several scenarios. Then we can rate the costs for qualification in relation to the earning in the production.

Furthermore we can check several disposition strategies. The worker management contains all information about the current system state, (which helps us to consider it) to decide which

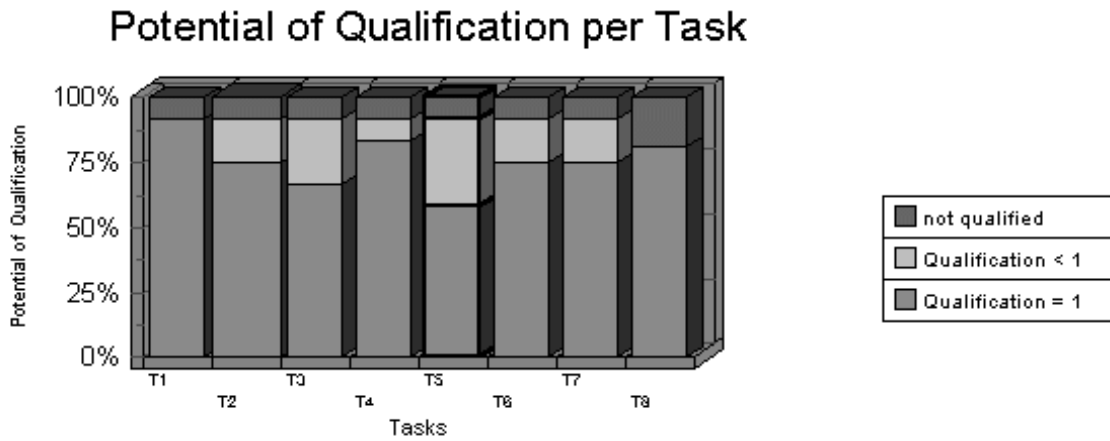


Figure 3: Available Qualification per Task

task the worker has to do. We can consider the monotony, the tasks' deadline, the appropriate qualification, and much more. The limits are caused by the difficulty to describe the behavior of a real system in an algorithmic way. Because of this problem we provide a trace-file to perform post-run analyses. We can depict the sequences of tasks for every worker (see Fig. 4).

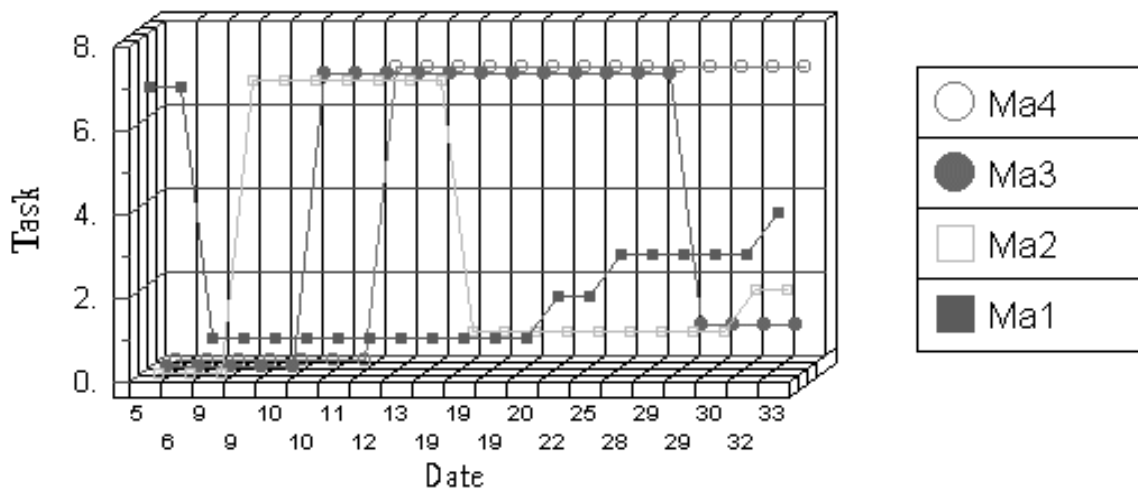


Figure 4: Analysis of workers activities

We can connect our trace-file with an application to explore the physical and psychical strain put on the workers. Therefore, it is necessary to gather characteristics related to every task, e.g., body movement, noise, clima, etc. Because of our task definition we can assign workplace-specific characteristics to a certain task. The noise value, for instance, can correctly be added because it is related to a certain workplace. When the simulation has ended we update the database related to the analysis tool to add the actual working times. Now we achieve a strain protocol for every worker for the simulated time (see Fig. 5).

5 Results and Conclusion

With our specification we provide support to integrate worker-oriented simulation requirements to existing simulators. All data needed and their relations are defined, further attributes and strategies may be added. Because of our definition that every task is separate from another we achieve additional analysis, e.g., strain analysis. However, this detailed simulation and analysis is leading to an increased effort in data gathering.

One special problem when modeling human behavior is the fact that it is impossible to describe it in algorithmic form. So we have to abstract and simplify from reality and have to consider this in our analysis. We are able to inspect the bottlenecks in our system for worker-related reasons. We can check the influence of special working structures on a system.

References

- [BS97] Willi Bernhard and Axel Schilling. Simulation of group work processes in manufacturing. In S. Andradóttir, K. J. Healy, D. H. Withers, and B. L. Nelson, editors, *Proceedings of the 1997 Winter Simulation Conference*, pages 888–891, 1997.
- [Dep96] Department of Defense. *High Level Architecture for Modeling an Simulation*, 1996.
- [DES94] Dr. Klaus Dieckhoff, Hildegard Eisenlauter, and Wolfgang Schröter. *Gruppenarbeit – Chancen und Probleme*. Deutsche Forschungsanstalt für Luft- und Raumfahrt e. V., Rostock, 1st edition, 1994.
- [Fre97] Rita Freudenberg. *Abbildungsmöglichkeiten von flexiblen Arbeitsstrukturen mit Simulationswerkzeugen*. Master’s thesis, Otto-von-Guericke University, 1997.
- [ZH97] Gert Zülch and Jochen Heel. Personalorientierte Simulation – Grundsätze und Anwendungsaspekte. In Axel Kuhn and Sigrid Wenzel, editors, *Fortschritte in der Simulationstechnik*, pages 57–66. Vieweg, November 1997.

Posture	██████████	██████████	██████████
Body Movement	██████████		
Lift/Bear/Move	██████████		
Dynamic Muscle Work	██████████	██████████	
Noise	██████████	██████████	
Vibration	██████████		
Clima-High Temperatures	██████████		
Clima-Low Temperatures	██████████		
Clima-Radiant Heat	██████████		
Drafty Air	██████████		
Weather Influence	██████████		
Wet Work	██████████		
Work Substances	██████████		
Dirt	██████████		
Lighting	██████████		
Glare	██████████		
Responsibility for Other Persons	██████████		
Responsibility for the Process	██████████	██████████	
Necessity of Immediate Decisions	██████████		
Requirements on Concentration	██████████		
Complexity of the Job	██████████		
Stress Due to Less Requirements	██████████		
Skillfulness	██████████		
Iterations of Job Sequences	██████████		
Connection to the Technical Process	██████████		
Contact to Cooperators	██████████		
Possible Industrial Injury due to Strange Influence	██████████		
Possible Industrial Injury due to Own Behavior	██████████		
Possible Industrial Injury due to Technical Facilities	██████████		
Stress due to Protection Equipment	██████████		

██████████ critical value
 ██████████ boundary value
 ██████████ noncritical value

Figure 5: Strain Protocol of Worker 1