Simulation Software Selection to Methodological Approach to Manufacturing

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Abstract:

A comprehensive evaluation framework has been developed to facilitate selection of simulation software for modelling manufacturing systems. Different hierarchies of evaluation criteria have been established for different software purposes. In particular, the criteria that have to be satisfied for users in education differ from those for users in industry. A survey has also been conducted involving a number of users of software for manufacturing simulation. The purpose of the survey was to investigate users' opinions about simulation software, and the features that they desire to be incorporated in simulation software. A methodology for simulation software selection is also derived. It consists of guidelines related to the actions to be taken and factors to be considered during the evaluation and selection of simulation software. On the basis of all the findings, proposals on how manufacturing simulators can he improved are made, both for use in education and in industry. These software improvements should result in a reduction in the amount of time and effort needed for simulation.

Keywords:-Manufacturing Methodology, Simulation Software

1. Introduction

This thesis addresses the issues related to evaluation, selection and possible ways of improving manufacturing simulators. Several manufacturing simulators are evaluated on the basis of a case study carried out in a real manufacturing environment. A comprehensive evaluation framework is developed in order to assist selection of software for manufacturing simulation. A methodology for simulation software selection is derived as well as proposals for the improvement of manufacturing simulators.

1.1 Simulation and Manufacturing

Simulation modeling is the process of designing a model of a real system and conducting experiments with this model for the purpose of either understanding the behaviour of the system or of evaluating various operating strategies of the system. Although simulation can be done manually, it is usually referred to as computer simulation, because not many reasonable simulation studies can be carried out without the use of computers. In this context, specifies the basic principles of computer simulation: "The analyst builds a model of the system of interest, writes computer programs which embody the model and uses a computer to imitate the system's behavior when subject to a variety of operating policies. Thus, the most desirable policy may be selected".

The main types of simulation can be distinguished on the basis of changing the state of the system through time. The state of the system can be changed at discrete time points (discrete event simulation), it can be changed continuously (continuous simulation), or it can combine both discrete and continuous changes (combined discrete/continuous simulation). In practice the simulation process is dynamic and iterative. Individual stages provide feedback information to other stages.

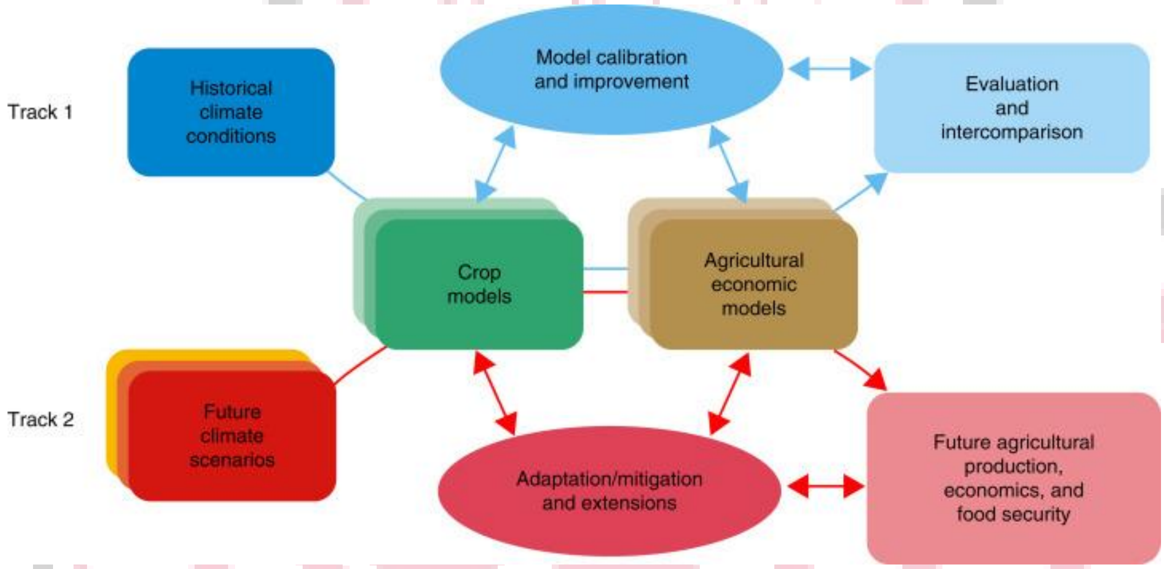

Fig.1 Compression of the purpose of simulation performed by survey participants

1.3 Classification of Simulation Software

There are many different ways of classifying simulation software. Pidd classifies simulation software in seven groups: general purpose languages (eg. FORTRAN, Pascal and C), pre-written libraries (eg. GASP, SIMON and FORSSIGHT), simulation programming languages.

1.3.1 Rapid Prototyping

Before commencement of a batch production of a product, a sample or prototype is often required as part of the design cycle to enable demonstration, evaluation or testing of the proposed product. Traditional prototyping requires considerable skilled labour, time and expense, typically applied to cutting, bending, shaping and assembling parts from standard stock material. The procedure was often iterative, with a series of prototypes to be made to test at various options. For many applications, this process has been revolutionised by a relatively recent technology known as Rapid Prototyping (RP), in which a part of an arbitrary shape can be produced in a process by adding successive layers of material. Many different RP processes have now been developed, using an increasing range of materials. The parts produced have been of steadily in increasing size, durability and the quality has improved. RP is being used more and more frequently to fabricate the parts both for production tools and functional prototypes.

RP is a technique used to quickly fabricate a model of a part or assembly using Three Dimensional (3D) Computer Aided Design (CAD) data. It allows parts of completely arbitrary 3D geometry to be fabricated, offering designers a new freedom to shape parts optimally without the constraints imposed by forming, machining or joining. It therefore allows a manufacturing cycle with a seamless transition through the computer design, simulation, and modeling and fabrication procedures. In addition, the profiles used by the fabrication process are straight forward for the designers and customers to understand, thus facilitating technical communications.

RP has also been referred to as Solid Free Form (SFF) manufacturing, Additive Manufacturing (AM), Computer Automated Manufacturing and Layered Manufacturing (LM). RP has obvious use as a vehicle for visualization. In addition, RP models can be used for testing, such as when an aerofoil shape is put into a wind tunnel. RP models can be used to create male models for tooling, such as silicone rubber moulds and investment casts. In some cases, the RP part can be the final part. RP is suitable for highly convoluted shapes including parts nested within parts.

RP improves product development by enabling better communication in a concurrent engineering environment. The trends in manufacturing industries continue to emphasis the following:

- Increasing number of variants of products.
- Increasing product complexity.
- Decreasing product lifetime before obsolescence.
- Decreasing delivery time.

1.3.2 Methodology of RP

The basic methodology for all current RP techniques can be summarised as follows:

A CAD model is constructed and then converted to STL format. The resolution can be set to minimize stair stepping. Part orientation partially determines the amount of time required to build the model. Placing the shortest dimension in the Z - direction reduces the number of layers, thereby shortening build time.

- The RP machine processes the .STL file by creating sliced layers of the model.
- If necessary, support structure is created which supports the overhanging features of the part during fabrication.

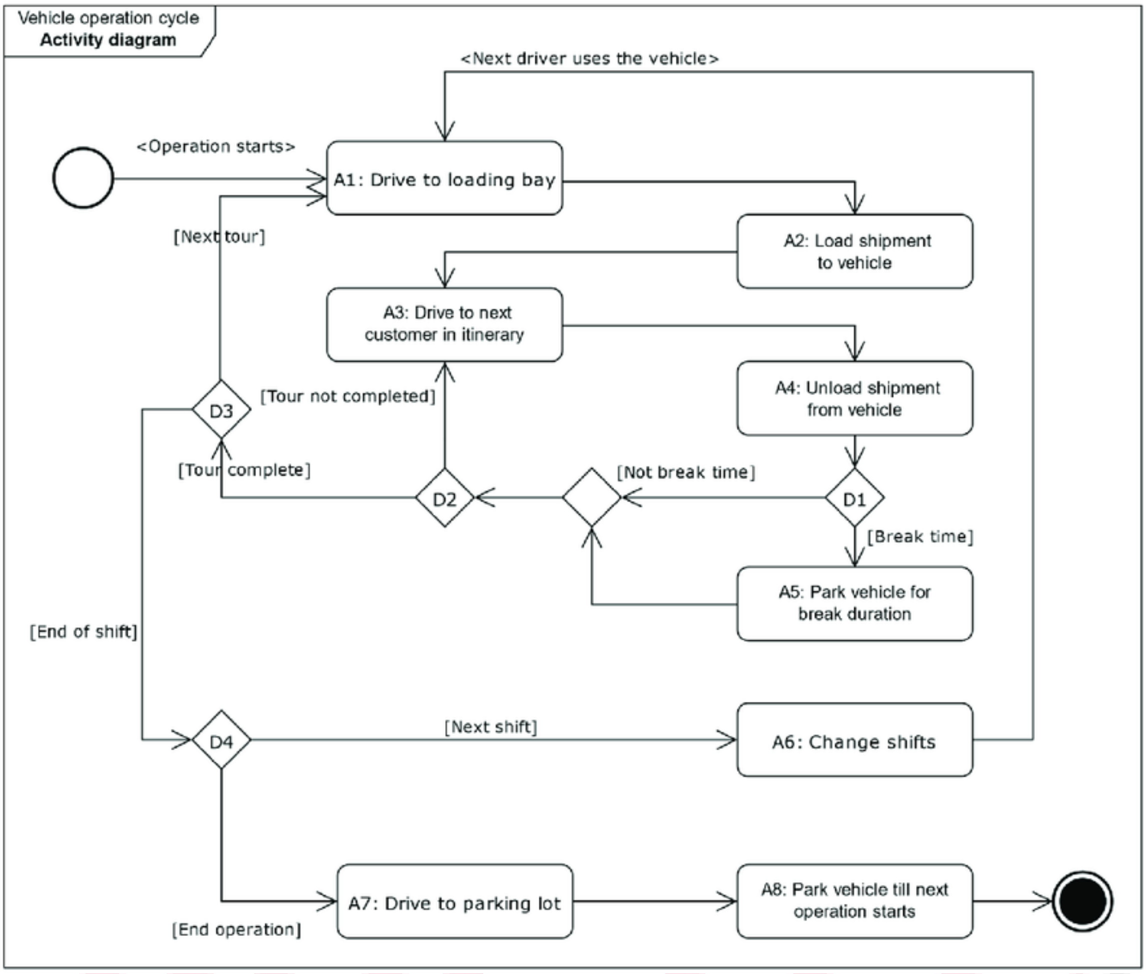

Fig. 2 Activity Cycle diagram for Loading and unloading

- Once all the above parameters were set, the tool path or scanning path was generated.
- The first layer of the physical model is created. The model is then lowered by the thickness of the next layer, and the process is repeated until completion of the model.
- The model and any supports used are removed. The surface of the model is then post processed and cleaned.

2. Simulation in Advanced Manufacturing Environments

The number of simulation applications in advanced manufacturing environments is constantly increasing. Evidence can be found in literature both in descriptions of specific case studies and in surveys of manufacturing simulation studies.

Some of these studies analyze some other aspects such as mathematical or computer modeling of manufacturing systems, using artificial intelligence techniques in addressing management problems etc. Kochhar and Ma (2015a) depict the major characteristics of simulation studies carried out in order to make decisions relating to production management problems and to assess the resulting benefits. Simulation applications are classified according to the control level of the manufacturing system (management control or production control), or according to the types of manufacturing systems being simulated (flexible manufacturing systems or just-in-time manufacturing systems). O'Grady and Menon (2016) present a review of flexible manufacturing systems and FMS literature. Part of this paper relates to a description of solving FMS planning and control problems using one of the following techniques: simulation, queuing theory, integer programming or heuristic algorithms. The authors propose that the purpose of simulation modelling has been one of the following: to establish the viability of a given FMS configuration of machine and transport devices, to assist the system design process with respect to hardware choices, or test operational planning and control strategies. Singhal et al (2017) discuss how models can play a major role in design and control of complex automated manufacturing systems. They describe publications related to the applications of various operational research methods for solving problems in automated manufacturing systems. Such as system design, production planning, scheduling and control, steady state operations and system improvements. Methods described include queuing network theory, simulation and artificial intelligence techniques. Several survey papers describe simulation research in production scheduling. Kiran and Smith (2017) report on numerous simulation studies carried out for production scheduling purposes. They classify all studies in two categories: studies comparing and/or developing scheduling rules which will give good performance under a given set of criteria, and studies investigating the sensitivity of manufacturing performance to changing of production parameters under a given set of scheduling rules. Ramasesh (2017) provides a state-of-the-art survey of simulation-based research on dynamic job shop scheduling. A number of different simulation studies are described with a focus in their findings on the job shop performance measures such as time-based measures, work-in-process measures, due-date related measures or cost-based measures. In the context of current and future issues concerning FMS scheduling, Hutchison (2018) discusses several simulation studies which were used in order to improve the performance of flexible manufacturing systems. A classification framework is provided that facilitates the identification of FMS types and types of scheduling strategies, as well as explaining interactions between these categories. The above survey publications are chosen as an illustration of the extensive use of simulation as an analysis tool in the design and operation of manufacturing systems. With the increasing use of simulation, the number of simulation software tools is also

- Increasing. As a consequence of this, the number of research studies related to analysis, evaluation and selection of simulation software is also growing, which is addressed in the next section.

3. Requirements for Simulation Software, and Improving Manufacturing Simulators

Machines are used in the model to represent physical equipment; specific operations performed by labour, and were also used for dummy activities used due to the software requirements. Whilst the quantity of machines representing production equipment corresponds to the number in the real system, the number of machines used to represent operations was chosen according to the amount of labour of a certain type available for specific operation. Spraying booths are modeled as single machines, because they spray only one flight bar at a time. The manual finish of specific batches coated automatically is performed on separate single machines using labour, to enable conditional routing of batches after automatic coating (either to a station for a manual finish or to a conveyor). Jigging of the parts and their loading on flight bars is modelled by three assembling machines, which take (using labour) a number of pans according to the attribute representing the number of pans per flight bar for a particular batch, and produce one pan which represents jigged parts to be loaded on the flight bar. On the other hand, the unloading activity is modelled by two production machines which take each pan from the conveyor after the last processing stage, and produce as many pans as are loaded on the flight bar.

The masking operation is modelled using five batch machines which mean that each batch to be masked is equally divided into five groups, and each worker has to mask one pan of the batch. Preemption rules are used here, thus although some workers may be busy with masking, they should leave the masking stations and participate in loading or unloading when required. Finally, there are some dummy machines, used to handle the logic related to masking. For example, when a batch to be masked is moved to the front of the buffer, dummy machines are used to pull this batch from the buffer and to push it to the masking.

3.1 Conveyors the system being modelled consists of a closed overhead conveyor chain.

Separate conveyors were defined for various sections in the chain. Whilst the length of separate conveyors varies according to the number of flight bars in the sections of the conveyor chain which these conveyors represent, the speed of all conveyors is the same as well as the breakdown pattern. The approach of modelling separate conveyors was taken for several reasons. First of all, WITNESS does not allow branching of conveyors. They can be defined with a fixed size and represented by a linear display. In addition, there are several points in the chain where a batch can be routed in different directions, depending on part attributes. Such conditional routing was possible to model only by using separate conveyors. In that case, the routing condition was programmed as an output rule for one conveyor, which determines where the batch will be pushed next The final reason for using a relatively large number of smaller conveyors to model the conveyor chain was to obtain a more realistic graphical display of the model. This has been done in order to improve communication with managers and production engineers and their awareness of the model and simulation in general.

Fig. 3 Cumulative deviation from Maximum Values of rates proposed for the group of criteria

(i) Parts Several different part types have been used in the model. One type relates to the raw materials which represents parts to be coated arriving in the buffer (storage area). After coating, parts are changed to 'painted', and after baking they are changed to 'finished', which means that the process of coating is completely finished and the parts represent final products. A special type of parts is used to represent gaps between different batches, with zero parts per flight bar.

(ii) Different types of labour were modelled, according to the type of work in which they can participate. One worker is dedicated only to painting. Several other participate in jigging and loading of parts. Some of the workers are assigned to unloading of parts from flight bars after the last processing stage. Finally, 'floating' workers can participate in any activity, depending on the current situation in the system. All types of labour can participate in the masking activity, system maintenance or equipment repair in the case of breakdowns.

(iii) Buffers Only two buffers have been used in the model. One to represent a storage area where parts wait to be loaded on a conveyor and another to temporarily store parts that have been masked until a complete batch is masked and pushed to the storage area to wait for loading.

(iv) Functions A variety of functions were written in order to handle the special logical features of the system. For example, for each attribute a separate function was written in order to assign the same values of the attributes to all parts within one batch. Otherwise, each part within the batch would have different values of the same attribute, or the values of attributes could be fixed, which means that all batches will have exactly the same values of attributes. Some other examples of the use of functions are as follows. Functions were used to determine the capacity and cycle times of loading and unloading stations, and to decide when a new batch can be pulled for loading. Functions were written to decide when parts can be loaded on the first conveyor, and when and how many gaps should be placed on this conveyor.

Several functions were used to handle the logic relating to the capacity of masking stations, routing of batches that require masking to different destinations in order to avoid

(i) Attributes A number of attributes have been defined for parts in order to describe different characteristics of different part types. The main feature of the system being modelled is a large variety (more than two thousand) of different part types with different characteristics. Attributes were also needed in order to enable conditional routing of batches. Attributes defined in the model relate to the batch number.

(ii) Variables Many variables have been used in the model. They were either used as global variables to monitor the changes in the system (eg. the number of colour changes), or as local variables used in functions. For each function. Separate variables have been defined in order to avoid logical errors. The display of some variables was very useful for model verification. For example, the number of flight bars to be loaded by a particular batch was displayed on the screen and it was easy to check whether the model behaved correctly. Some of the attribute values have been assigned to variables displayed, which was especially useful for testing conditional routing. Another example of the use of variables is a control of the random number streams. The model comprises more than twenty random variables. Each random number stream was assigned to a different variable.

(iii) Breaks at different time for different groups of labour, and to include weekly, monthly and yearly maintenance during which the system does not operate. This has resulted in a number of different sub-shifts and main shifts, which were modelled hierarchically to represent daily, weekly, monthly, and half-yearly performance of the system.

(iv) Time series several time series have been defined in order to display the performance of the System dynamically. These time series, very useful for model verification, showed the total throughput of the system during simulation, labour utilization and utilization of painting booths.

(v) User-defined distributions User defined distributions have been used for a small percentage of special part types in order to provide values for the batch size and the number of parts per flight bar. These parts represent small screws, where five hundred of them are jigged together and loaded on one flight bar. This special type of part was defined because it was not possible to fit such extreme values properly into theoretical distributions together with other values.

(vi) Files Several files were specified into which specific reports were written. The standard written report provided by WITNESS is lengthy and not very understandable.

Conclusion

Activity cycle diagrams were chosen m this study for simulation model development for the following reasons:

(a) A small number of different graphical symbols enable a simple presentation of systems.

(b) Manufacturing systems are systems that include numerous serving and queuing places (eg. parts waiting to be loaded on conveyor or painted on the booth).

(c) Conceptual models developed using this method can be used as a basis for Subsequent development of the computer models with any software package. Many features which were assumed to have an influence on the performance of the system being modelled were included in the model. The model developed is obviously only an approximation of the real system.

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