Application potential of Agent Based Simulation and Discrete Event Simulation in enterprise integration modelling concepts

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KEYWORD

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ABSTRACT

This paper aims to present the dilemma of simulation tool selection. Authors discuss the examples of methodologies of enterprises architectures (CIMOSA and GRAI) where agent approach is used to solve planning and managing problems. Actually simulation is widely used and practically only one tool which can enable verification of complex systems. Many companies face the problem, which simulation tool is appropriate to use for verification. Selected tools based on ABS and DES are presented. Some tools combining DES and ABS approaches are described. Authors give some recommendation on selection process.

1 Introduction

Nowadays companies are facing different economic and financial crises. In order to survive on the market and gain a competitive advantage the enterprises need to be prepared and well-organized. Enterprise modelling is one way for restructuring them in order to improve their performance and efficiency. Three methodologies are mainly used for modelling enterprises: PERA, CIMOSA and GRAI. Enterprise modelling involves not only global enterprise performance improvement but also local improvements. Authors use in their researches CIMOSA and GRAI methodologies. In this paper authors present examples of two multi-agents systems, which were elaborated to improve the enterprise's processes. In the case of CIMOSA it was agent system for planning process. For GRAI the research concerns a new tool which combined multi-agent systems with Case Based Reasoning (CBR). CBR remains widely used for the definition of the needs for the design and development of expert systems. The originality of this part is that it shows how the reasoning is combined with the theory of multi-Agent systems and Artificial Intelligence and metaphors of mind.

In both case the verification of developed methods is necessary. Actually simulation is widely used and it is practically only one tool which can enable verification of complex systems.

The both presented cases are regarding manufacturing and supply chain processes. The logic of the planning and design of expert tool allows the use of agent technology but the simulation of the processes of manufacturing and supply chain is not so obvious. In authors' opinion in order to continue the further research, it is necessary to use simulators that take into account both the requirements of the agent approach and the requirements of classical DES (Discrete Event Systems). In this paper both approaches are discussed. The authors present available commercial simulation tools and define the requirements from point of view of the potential users- engineers dealing with operations management and supply chain processes.

The paper presents brief theoretical introduction to the studies (Section 2). Section 3 describes the management using MAS and modelling of manufacturing and supply chain processes. The overview of tools for

Discrete Event Simulation DES is provided in Section 4. Discussion on the selected tools is presented in Section 5 and final conclusions are stated in Section 6.

2 VLPrograph - tool supporting CIMOSA

CIMOSA (Computer Integrated Manufacturing Open System Architecture) is a methodology used for designing CIM open system architecture, for defining a set of concepts and rules for facilitating the realization of future manufacturing systems and for aiding the reimplementation of existing systems. This methodology has been developed within the framework of the European strategic programme ESPRIT. It is architecture for describing enterprises by giving characteristics for modelling production systems on three levels: definition of requirements, design specification, and implementation description [CHEN, E. ET AL. 2008]. CIMOSA is a reference architecture which supports the description of the enterprise from the management level to the shop floor level (Fig.1). CIMOSA consists of an enterprise modelling framework, an enterprise modelling language and an integrated infrastructure. This methodology is useful for the improvement of enterprise performance at the local level.

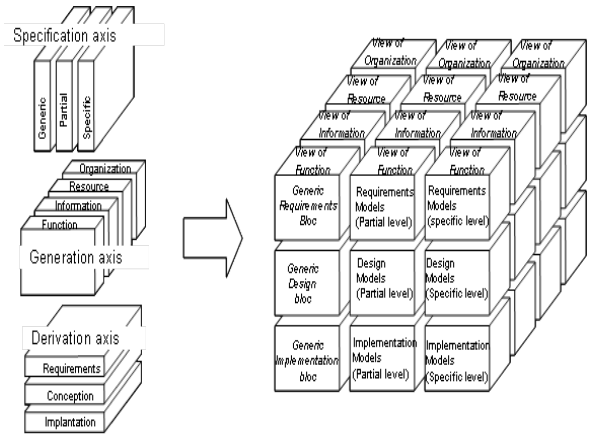


Fig. 1. Architecture of CIMOSA.

In our researches CIMOSA is used for improving enterprises locally. The results of the previous studies are presented in paper [PAWLEWSKI, P. 2011]. These results consisted in planning the process taking place in an enterprise characterized by the manufacture of complex products (machine building). The idea is based on the so-called domains of the CIMOSA concept which has been used for the modelling. A planning process based on the multi-agent architecture called VLPRO-GRAPH. Agent-based system is defined in the present section as a multi-agent system that acts as a support tool and utilizes the databases of main system (ERP system). Multi-agent system is a collection of heterogeneous, encapsulated applications (agents) that participate in the decision making process [PECHOUCEK, M.ET AL. 2003]. The architecture of the tool (VLPRO-GRAPH – Very Long Process Graph) is based on the assumption that the system will support the master production schedules (MPS) creation in ERP system and will be plugged in to ERP system database by for example java connector.

A production process based on CIMOSA domains is presented in figure 2 where domains are [PAWLEWSKI, P. 2011]:

- D1 – order and management planning,
- D2 – license documentation,
- D3 – loads planning
- D4 – Sales and production planning, scheduling for strategic machines,
- D6 – procurement,
- D7 – quality, process and costs control,
- D8 – production sub-process 1,
- D9 – production sub-process 2,
- D10 – production sub-process 3.

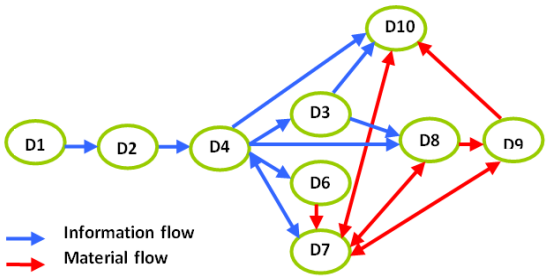


Fig. 2. Production process based on CIMOSA domains (based on [PAWLEWSKI, P. 2011].

This architecture was introduced in [6] and extended by a new agent, i.e. MR agent (movable resource agent). [PAWLEWSKI, P. & KAWA, A. 2010]. The task of this agent is integrated with the

planning process which is described at three layers (see Fig.3) reflecting to [PAWLEWSKI, P. 2011]:

- A – the whole process perspective, the so-called whole process planning;
- B – the entity level where the whole process plan is divided into sub-plans which are executed by each sub- process and being transformed for individual production schedule at the domain level and where local re-planning activities takes place;
- C - domain sub-layer where production control activities are executed and information about disturbances is gathered and passed to upper levels.

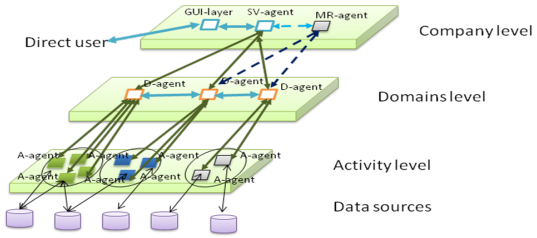


Fig. 3. Extended VLPRO-GRAPH agent model (based on [PAWLEWSKI, P. 2011]

The graphical user interface agent creates a graphical user interface (GUI) for the interaction of the MAS (Multi-Agent System) to production manager (direct users). The GUI-Agent is able to initialize and send behavior parameters and messages to the Super-Visor Agent (SV-Agent). The SV-Agent is exactly one in the system because the data from all the domain agents (D-Agent) are fused at this agent to generate re-planning schedules for the production. The SV-Agent is responsible for the control of the logic of all agents and creates the plans for the D-Agent. The SV-Agent starts the work of MR-Agent which checks the movable resources allocations and limits. According to the results of MR-agent work, the decision of plans execution is prepared. The planning process is presented in figure 4. D-Agents are initialized by the SV-Agent and they are responsible for the translation of the long process plan into detailed schedules. The agent is allowed to prepare the number of alternative (contingency) local plans as long as they do not conflict with long process MPS. The local re-planning activities are allowed as long as they don't influence the long process MPS. When re-planning activity affects the long process MPS, it has to be passed to the SV-Agent. The A-Agent is responsible for the control of plans execution within sub-process based on the given performance indicators. It reports to the D-Agent in the upper layer if production plans are executed according to given MPS.

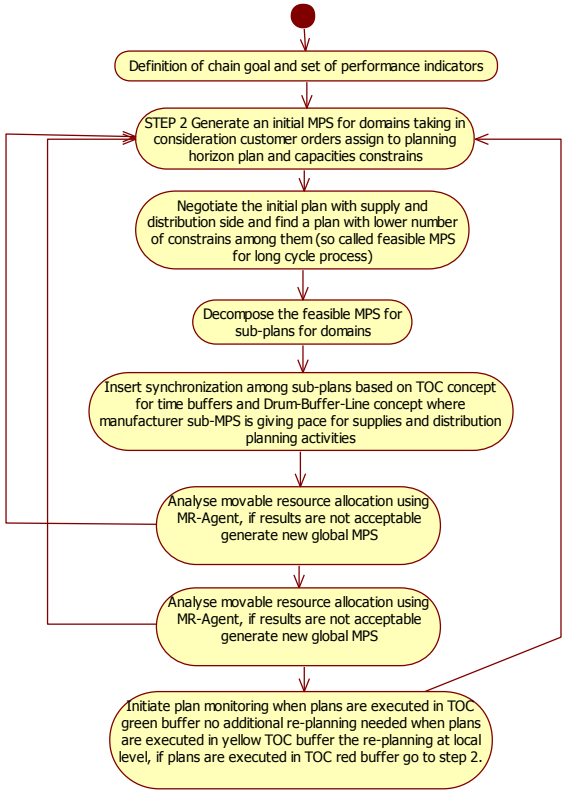


Fig. 4. Extended Planning algorithm for VLPRO-GRAPH agent model l (modified from [GOLINSKA, P. et al. 2007]

4 GRAIMOD – tool supporting GRAI methodology

GRAI Methodology is used for global performance improvements. GRAI Methodology is designed and defined for managing of this modelling. This method is used for example to choose and implement a computer tool (Supply Chain management and ERP) which meets the real market needs (globalization, relocation, capacity to be proactive, cost optimization, lead time, quality, flexibility, etc.).

GRAI approach is composed of four phases:

- An initialization phase to start the study,

- A modelling phase where the existing system is described,
- An analysis phase to detect the inconsistencies of the system studied,
- And a design phase during which the inconsistencies detected are corrected, and a new system proposed.

The GRAI methodological tree is composed of five domains as clearly shown in figure 5. Each domain contains modules used for modelling, analyzing and improving enterprises. GRAIPROGI and GRAI Quality can be translated in software forms, thereby, enabling enterprises to select the tools necessary for the optimization of the supply chain and to manage their approach to quality. Then GRAISUC and GRAIQUAL are being developed.

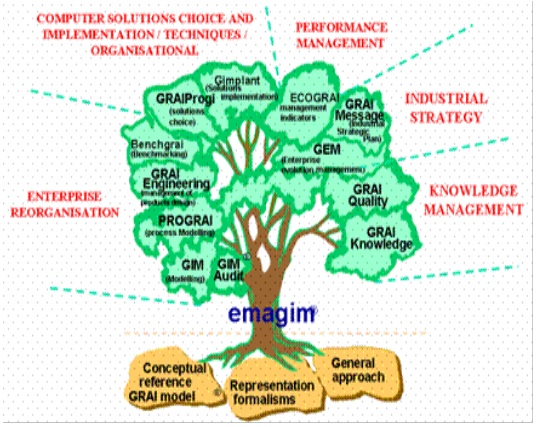


Fig. 5. GRAI Methodology tree

GRAIMOD is a tool being developed for supporting the methodology [DOSSOU, P. ET.AL 2011]. The general structure of the tool is based on Case Based Reasoning (CBR). According to CBR concepts the new case studied could be capitalized, but the parameters would also improve the reference model of the enterprise domain. Java is chosen for developing GRAIMOD. The Jade platform is being used in relation with FIPA-ACL for developing the different modules of GRAIMOD (GRAIQUAL for managing quality approach, GRAISUC for choosing and implementing an ERP or SCM tool in an enterprise and GRAIXPERT for managing reference models and rules used to improve enterprise performance).

The use of multi-agent systems will allow to facilitate the development of GRAIMOD. Some changes could be integrated according to the opinion of Jade specialists. Then CBR needs to be related to Multi-agents systems in order to satisfy user requirements. The reactive agents are not appropriate to our problem because they react only for the environment changes.

The global objective of this research is to be more efficient in the improvement of enterprises. The supply chain of each enterprise could be reorganized by using the concepts elaborated. The reorganization takes into account both the production typology and the supply chain in the modelling

For each enterprise, the supply chain is decomposed into different parts (sourcing, procurement, purchasing, production, distribution, sales, transport and logistics management). For each part GRAIQUAL is used and a quality approach is defined in order to improve this part. Indeed, the optimizing of each part is coherent with the other parts.

The importance of the CBR reasoning is evident because of the use of knowledge capitalization realized for each enterprise domain, for each part of the enterprise supply chain. But the necessity of multi-agent systems is to justify this choice. For instance, the implementation of SQA in enterprise needs the use of knowledge relating to this enterprise domain, but the system will also evolve during this implementation. The system both provides the new case with data and takes into account the particularity of this new case. The multi-agent system defined is well-suited to this kind of work: use and capitalization of knowledge [SEN, S. & WEISS, G.. 1999].

Multi-agent systems architecture also facilitates the communication between each different module of GRAIMOD by defining connections from each module to the others. The improvement of quality in the whole enterprise has a positive impact on cost and on delivery date.

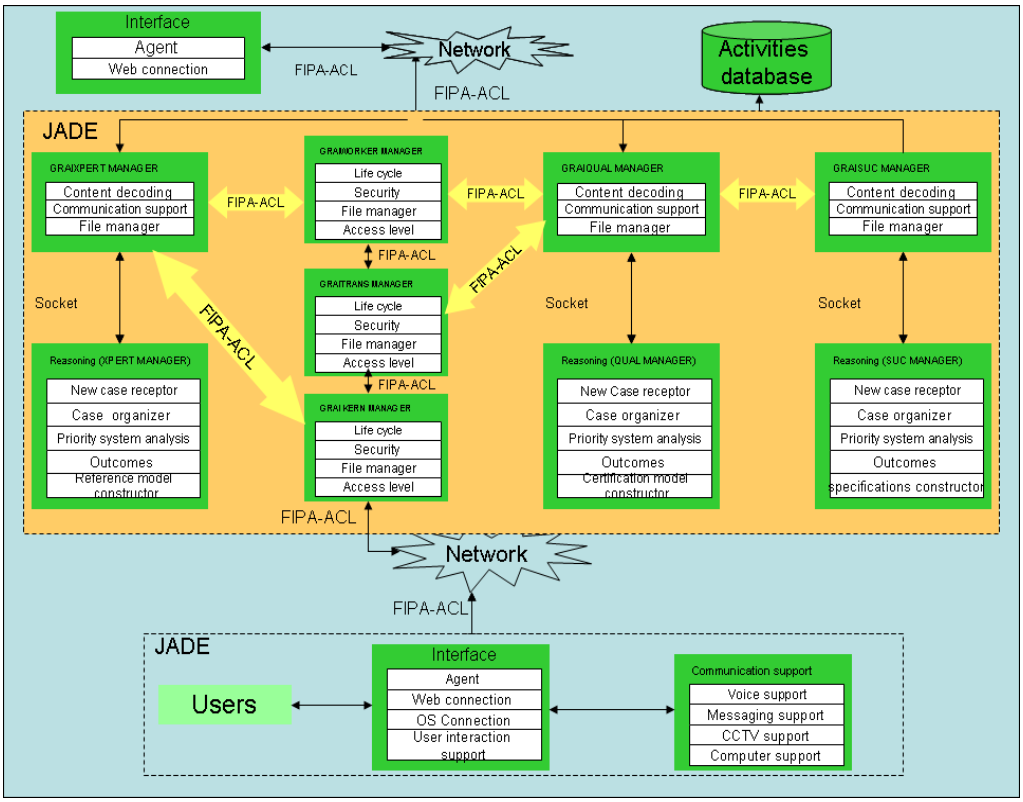


Fig. 6. Architecture of GRAIMOD in a Java environment

5 Process simulation – DES and ABS

For manufacturing and supply chain process simulation DES (Discrete-Event Simulation) has been mainstay for over 40 years. DES is useful for problems that consist of queuing simulations or complex network of queues, in which the processes can be well defined and their emphasis is on representing uncertainty through stochastic distributions [SIEBERS, P. ET.AL. 2010]. Many of these applications occur in manufacturing, supply chain and service industries as well as queuing situations.

DES models are characterized by [SIEBERS, P. ET.AL. 2010] process oriented approach (focus is on modelling the system in detail, not the entities). They are base on top down modelling approach and have one thread of control (centralized). They contain passive entities (i.e. something is done to the entities while they move through the system) and intelligence (e.g. decision making) is modeled as a part in the system. In DES queues are a key element; a flow of entities through a system is defined; macro behavior is modeled and input distributions are often based on collect/measured (objective) data. These attributes describe manufacturing and supply chain processes too. Typically DES simulation tools use a process driven approach where the flow of the parts between processes cause the demands on resources. That is to say a part moves to a machine and demands a resource to complete the operation. Whilst this methodology is fine for some applications in manufacturing and supply chain it does not allow for situations where the resources have tasks to complete which are not flow related – in this situation other approach is necessary.

ABS (Agent Based Simulation) help to better understand real-world systems in which the representation or modelling of many individuals is important and for which the individuals have autonomous behaviors [9]. ABS offers something novel, interesting and potentially highly applicable to manufacturing and supply chain. However, there is relatively little evidence that ABS is much used in the Operational Research community, there being few publications relating to its use in OR and OR-related simulation journal. Much greater volume of ABS papers is in journals from disciplines such as Computer Science, the Social Sciences and Economics.

Summarized ABS models are characterized by [SIEBERS, P. ET.AL. 2010]:

- Individual based (bottom up modelling approach); focus is on modelling the entities and interactions between them;
- Bottom up modelling approach;
- Each agent has its own thread of control (decentralised);
- Active entities, i.e. the entities themselves can take on the initiative to do something; intelligence is represented within each individual entity;
- No concept of queues;
- No concept of flows; macro behaviour is not modelled, it emerges from the micro decisions of the individual agents;
- Input distributions are often based on theories or subjective data;

These attributes doesn't describe manufacturing and supply chain processes but describe many aspect of management. But as mentioned some situations in manufacturing and supply chain where the resources have tasks to complete which are not flow related need other approach – task driven approach. Thinking in ABS paradigms gives potential to propose solution for these situations.

The emergence of ABS as a technique in Operational Research is timely. Globalised business is a highly complex management process, and making decisions in this environment is not well supported by the current set of tools, including DES [NORTH, M.J. & MACAL C.M. 2007].

In table 1 is presented list of selected agent systems. This list includes systems which originate really from agent based approach.

Apart from presented list there are available many systems based on Java like: iGen, ICARO-T, JABM, JAMEL, JANUS, JAS, JASA , JCA-Sim, Madkit, Mason, Moduleco, Sugarscape, VSEit. There is a number of excellent academically developed tools, the commercially available software is limited to AnyLogic (but Anylogic origins are from DES so we classified it as DES system which included ABS approach), and all of these products expect knowledge of object oriented programming techniques and the modeller needs to be comfortable with Java. It is difficult to find an agent system which has possibilities to combine agent based and DES.

Name	Description	www
Altreva Adaptive Modeler	software application for creating market simulation models for price forecasting of real-world stocks and other securities.	www.altreva.com
AgentBuilder	an integrated software toolkit to quickly develop intelligent software agents and agent-based applications	www.agentbuilder.com
AOR Simulation	AB discrete event sim.; special extensions for modelling cognitive agents (with beliefs and speech-act-based information exchange communication).	oxygen.informatik.tu-cottbus.de/aor/
Ascape	General-purpose agent-based models.	ascape.sourceforge.net
Brahms	Multi-agent env. for sim. organizational processes	www.agentisolutions.com
Construct	Multi-agent model of group and organizational behavior.	www.casos.cs.cmu.edu/projects/construct/index.php
FAMOJA	Resource flow management, theoretical systems science, applied systems, environmental analysis	www.usf.uos.de/projects/famoja/
JADE	Distrib applications composed of autonomous entities	jade.tilab.com/
NetLogo	Social and natural sciences; Help beginning users get started authoring models	ccl.northwestern.edu/netlogo/

Table 1 List of selected available agent systems.

Table 2 presents the list of selected DES systems. This list includes systems which really originate from discrete events approach.

Name	Description	O/C	www
PowerDEVS	an integrated tool for hybrid systems modeling and simulation based on the DEVS formalism.	O	www.fceia.unr.edu.ar/lsd/powerdevs/index.html
SimPy	an open source process-oriented discrete event simulation package implemented in Python.	O	simpy.sourceforge.net/
Tortuga	an open source software framework for discrete-event simulation in Java.	O	www.ohloh.net/p/tortugades
Facsimile	discrete-event simulation/emulation library	O	www.facsim.org/
Galatea	the product of two lines of research: simulation languages based on Zeigler's theory of simulation and logic-based agents.	O	galatea.sourceforge.net
MASON	fast discrete-event multiagent simulation library core in Java	O	cs.gmu.edu/~eclab/projects/mason/
AnyLogic	graphical general purpose simulation tool which supports discrete event (process-centric), system dynamics and agent-based modeling approaches	C	www.xjtek.com/
Arena	simulation and automation software developed by Rockwell Automation. It uses the SIMAN procesor and simulation language.	C	www.arenasimulation.com
Enterprise Dynamics	simulation platform developed by INCONTROL Simulation Software. Features include drag-and-drop modeling and instant 2D and 3D Animation	C	www.incontrolsim.com
ExtendSim	general purpose simulation software package	C	www.extendsim.com
Flexsim	discrete event simulation software which includes the basic and three product lines: distributed simulation system (DS), container terminal library (CT) and Healthcare Simulation (HC)	C	www.flexsim.com
Witness	A discrete event simulation environment, with graphical 2D & 3D and scripting interfaces, for modelling processes and experimentation	C	www.lanner.com
Plant Simulation	by Siemens PLM Software enables the simulation and optimization of production systems and processes	C	www.plm.automation.siemens.com
ProModel	discrete event simulation tools	C	www.promodel.com
Simio	tool for rapid modeling of discrete-event systems to give rapidly an accurate 3D animated models.	C	www.si mio.com

Table 2 List of selected DES systems available on market (O – Open Source, C – Commercial).

Some systems offer possibilities to combine DES with ABS. the first is AnyLogic. AnyLogic supports agents in a continuous or discrete environment and also supports sophisticated animation capabilities to visualize agent behaviours. It contains a graphical modelling language and also allows the user to extend simulation models with Java code. The Java nature of AnyLogic allows model extensions via Java coding as well as the creation of Java applets which can be opened with any standard browser. The second system is Simio. The Simio framework is a graphical object-oriented modelling framework as opposed to simply a set of classes in an object-oriented programming language that are useful for simulation modelling. The graphical modelling framework of Simio fully supports the core principles of object oriented modelling without requiring programming skills to add new objects to the system. Simio framework is domain neutral, and allows objects to be built that support many different application areas. The

Simio framework supports multiple modelling paradigms. The framework supports the modelling of both discrete and continuous systems, and supports an event, process, object, and agent modelling view. The third system is Flexsim. The Flexsim Simulation Software is a new generation of simulation software. The from the scratch own developed simulation kernel, the seamless integration of Microsoft C++ and the use of the newest OpenGL technology for unrivalled 3D animation in combination with the just as compact as practice-oriented library are the highlights of Flexsim. Flexsim is offered in following versions: GP (General Purpose Simulation), CT (Container Terminal Simulation), and HC (Healthcare Simulation). Flexsim GP is an object oriented simulation tool. Thereby is naturally well suited to ABS. It also possesses special features for modelling large volume systems, either through it's built in modelling constructs, or c++ for especially demanding agent based models.

6 Conclusions

Authors identify two main barriers for ABS implementation in area of manufacturing and supply chain. These barriers are on the different levels:

- features of manufacturing and supply chain processes - queuing simulations or complex network of queues, in which the processes can be well defined and their emphasis is on representing uncertainty through stochastic distributions,
- all of ABS products expect knowledge of object oriented programming techniques and the modeller needs to be comfortable with Java. These are not skills that the average manager has developed during his career. For this reason, ABS remains the domain of a relatively few skilled experts and academic researchers.

The first challenge is therefore for the software development community, working in collaboration with current users from manufacturing and supply chain areas to establish how and where software can simplify the more technical aspects of ABS and reduces this barrier to entry. Reducing the amount of java code to be written is a must [SIEBERS, P. ET.AL. 2010]:.

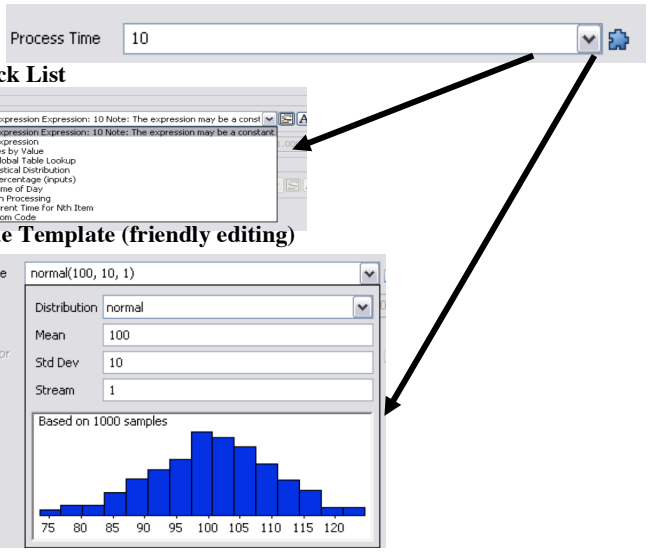
Based on our researches we decided to choose Flexsim as our main simulation tool for three reasons.

The first one is that in Flexsim the ability to combine any number of models together provides unlimited scalability, such that in principle, any size of agent model can be constructed. This can be especially important when agent based models have the possibility to become computationally intensive. Flexsim is able to represent agents with objects and can describe the state models of each agent object in it's own modelling language or c++. The 3D virtual reality environment of Flexsim allows the agents to operate in a detailed world where geometry, shapes and motion exist. Rapid development of agent models is facilitated through the built in flexscript language engine which does not require compilation steps, and if more simulation execution power is required, the same code can be promoted seamlessly to c++ for optimal performance.

Moreover in Flexsim is possible to mix process driven functionality (characteristic for DES) with task driven functionality. A task driven approach ensures that jobs can be undertaken in a realistic manner. For example an operator has the job of performing a set of inspections of idle equipment when not otherwise engaged in process work. The task based approach allows for the creation of activities for the operator which are totally independent of any processing activities and allows him to become engaged in a set of tasks which may require him to travel, acquire tools and remain “busy” for a period of time. Furthermore, using a task driven approach resources can incorporate their own ‘intelligence’ to decide what jobs to do and when – it is a paradigm of ABS approach. The task driven approach results the task executor methodology. According to this methodology the user has possibilities to create an ordered “Job list” of tasks which can be carried out in a specific sequence. The Task Executors can also work in partnership with other resources such that an operator can be given a job and part of the job may require the use of a Fork Lift Truck. The operator can then be tasked with becoming the driver of the fork truck in order to carry out part of the operation thus coordinating the travelling and transferring of parts between multiple task executors. Task Executor functionality includes the ability to model; Robots, Overhead Gantry Cranes, Fork Lift Trucks, AGV’s and Operators. According to ABS paradigms the communication between “agents” – simulation objects is necessary. Flexsim offers the use of message passing which allows one operation to send a message to another operation (this can be time delayed if the modeler wishes). Furthermore, on receipt of the message the receiving process

can chose to act on, ignore or further delay the message until a more appropriate time. This functionality is commonly used as it is a more natural way to model control logic but also makes the model more understandable for someone reviewing the model code and therefore improves the maintainability of the model. Note a factor of message passing is that the receiving object can act on the message irrespective of its state, i.e. it can close a connection to another element at the time the message arrived even if the process is currently idle.

Flexsim offers possibilities to work through the three levels of users: occasional, intermediate and advanced. According to these levels Flexsim propose to work using (see figure 7): the pick list, the code template (user friendly), logic builder, the code edit (access to Flexsript/C++).



The Code Edit (Access to Flexscript/C++)

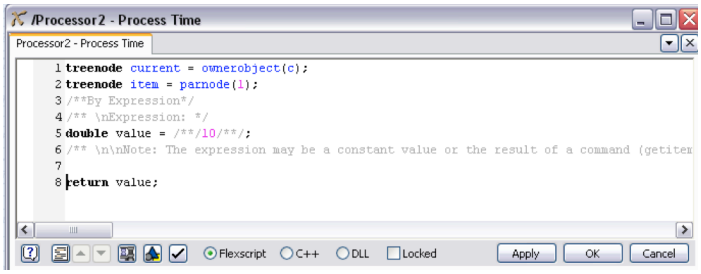


Fig. 7. Different level of user possibilities in Flexsim.

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