THE USE OF PROJECT MANAGEMENT METHODOLOGY AND TOOLS TO IMPROVE MODEL ASSESSMENT IN SIMULATION STUDIES

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ABSTRACT

The simulation model assessment comprises the design of experiments and model output analysis and it is a difficult task to be accomplished in simulation studies. The design of experiments is usually directed towards the identification of the bottlenecks and alternative strategies for model execution, by adding some more resources or modifying the way some components behave, with the resulting model changes being assessed individually. Many cross effects, nevertheless, may appear if more than one factor is applied and they make it difficult to determine the benefits of local changes to the overall performance of a complete production process or sub process. This suggests that the analysis could be directed towards sequences of repetitive tasks grouped together in process segments (production phases), representing partial/complete construction or assembling operations, which could be studied and improved in terms of completion time and operation costs, and would therefore enhance overall system's performance. This work proposes the use of project management methodologies and tools, based on time and cost management with the use of PERT-like networks, in the identification and analysis of these process segments, for improvement of model assessment in simulation studies. The problem class it addresses is that of discrete event models of serial production processes.

INTRODUCTION

The results presented and discussed in this work are of a preliminary and conceptual nature and they have been produced in order to set the basis for a more ambitious ongoing research project. The general goal of the main research project is to develop a comprehensive methodology, and to design and implement its supporting tools, aiming at the conduction of simulation studies based on an integrated approach, originated from a merge of both process simulation and project management techniques.

The proposed approach can be thought of as having two distinct viewpoints: the first one is related with the use of project management techniques as an auxiliary tool for modelling and analysis of a problem typical of the process simulation study area; and the second one is related with the use of process simulation techniques as an auxiliary tool for modelling and analysis of a problem typical of the project management study area.

The methodology, nevertheless, exists only as whole, and it is based on a modelling concept created by the first author and denominated Unified Simulation Modelling Diagrams (USMD). USMD is a modified version of Project Evaluation and Review Technique (PERT) diagrams, originated from a mix of both Activity Cycle Diagrams (ACD) and PERT networks. USMD diagrams can be used for modelling problems that belong to either of the domain classes of the two study areas mentioned above.

This work is focussed on the first viewpoint of the approach, as implied by its title above, but it does it solely as a result from the class of problem chosen to illustrate the creation of USMD, which is an example of a serial production process, typical of the simulation study area. Another example of a house construction process, typical of the project management study area, has also been made and studied separately as a simulation problem, but it will not be presented here for lack of space.

The following sections have been devised to explain the conceptual framework of the proposed methodology and were divided into: fundamentals of the methodology; its domain of applicability and limits, a comparison with other existing methodologies in both study areas, benefits of the integrated methodology and its tools, and the actual state of the research. The work concludes with a summary on the experience gained with the approach and points out to future research to be carried on the subject.

FUNDAMENTALS OF THE METHODOLOGY

The problem chosen for exemplification of the proposed approach is that of a hypothetical steelworks, commonly used as a course project for teaching simulation skills to post graduation students. Figure 1 shows the layout of the steelworks, as described in [Kienbaum and Paul 1994].

The Steelworks Problem

The main elements involved in the problem are: blast furnaces, torpedoes, cranes, steel furnaces and a railway system for the torpedoes to travel on, interconnecting the other static elements of the system. One of the tasks associated with the problem is that of identifying the minimum number of torpedoes for the system to generate minimum amount of waste (if the number of torpedoes in front of the blast furnaces is not enough to carry the molten iron blown by them, the molten iron is spilled on a waste area at their side, otherwise the blast furnaces would be damaged). Other requests regarding the correct operation of the system must be followed, and the number of cranes and steel furnaces is left variable, to allow for the existence of different strategies for running the system.

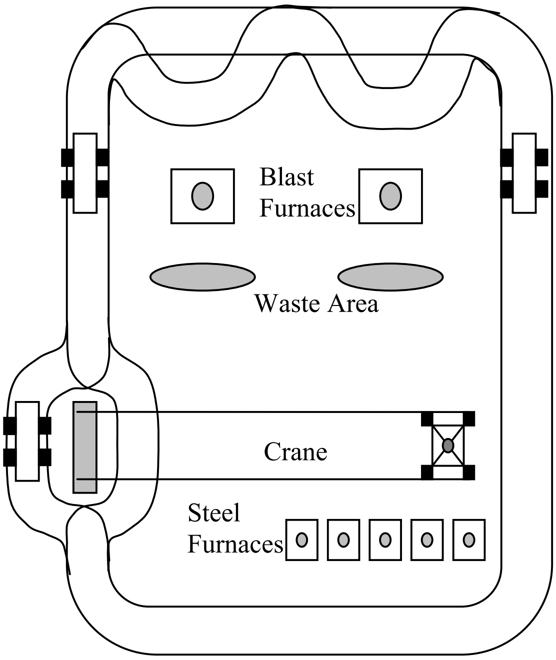

Figure 1. Steelworks' Layout

Activity Cycle Diagrams and their Transformation into PERT-like Diagrams

Activity Cycle Diagrams (ACD) is a very ease and intuitive form of graphical representation for models of discrete event systems, as described in [Pidd 1992]. Rectangles and circles are used to depict the active states and the idle states of the entities, respectively, and these states are linked by arrows, which show the direction of the life cycle followed by the entities in the model and their dynamic interrelationship. ACDs are communicative models, which may be used to discuss the main logical aspects among all participants of a simulation study. Figure 2 shows the ACD for the steelworks problem described above.

The ACD of any simulation problem can further be transformed into another graphical form of representation created by the first author and denominated Unified Simulation Modelling Diagrams (USMDs). In USMDs the network of activities is linked by their time of execution and their dependence in relation to the conclusion of previous activities, in the same way it is done in traditional PERT diagrams. The start of the process is depicted by an activity symbol that represents the generation of the successive process instances (generation of the casts for the blast furnaces in the steelworks model), as well as the generation and the allocation of the permanent entities, which is done only once, at the beginning of the simulation run. The symbol consisting of two concentric circles represents the resource pools, which are the storage places for idle permanent entities. The full lines represent that part of the ACD that links alternated activity and queue symbols and indicates the life cycle of the permanent entities inside the system and their engagement to perform the activities in the model.

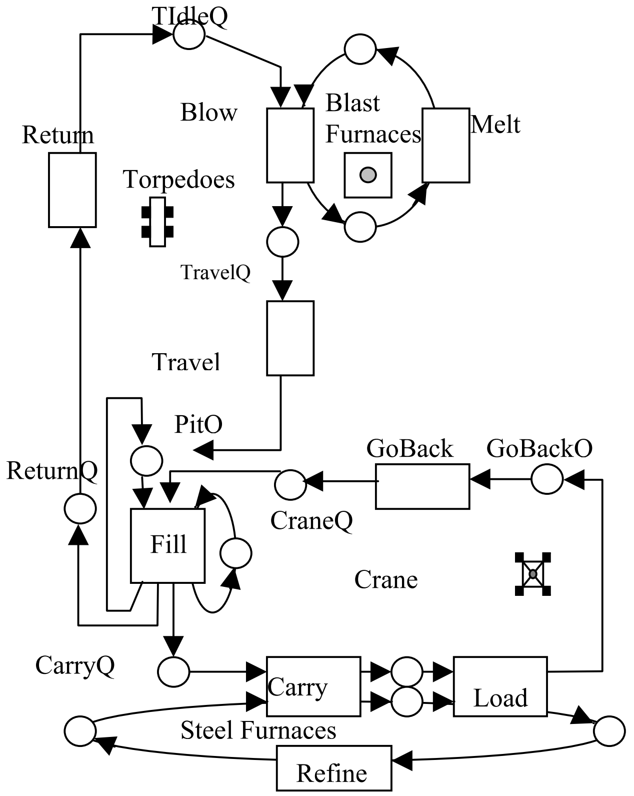

Figure 2: Steelworks' ACD

The process of transformation comprises the identification of the paths of the component processes of the model (corresponding to the temporal execution of the sequences of activities in the system). These paths are represented by dashed lines. In the example the path of the molten iron can be used as a guide to find out the main process, although the molten iron is not itself an entity of the system (entities in ACDs are countable items). Two ramifications are also identified, corresponding to activities that can be executed in parallel with the main path, such as the repositioning of the torpedoes and cranes after they have released their loads. The paths of the permanent entities of the system are indicated by full lines and arrows, connecting the resource pools (concentric circles), where they are initialised as idle elements, to the activities and queues formed by their life cycle in the system, in the same way they are depicted in ACD representations. These permanent entities or resources have the goal of blocking the progress of some other main entities or transactions (or the flow of control of the program), according to their availability or not, in the moment an activity in the flow of control or the path of the main entity is due for execution. Figure 3 shows the resulting graphical form of the USMD diagram for the steelworks problem.

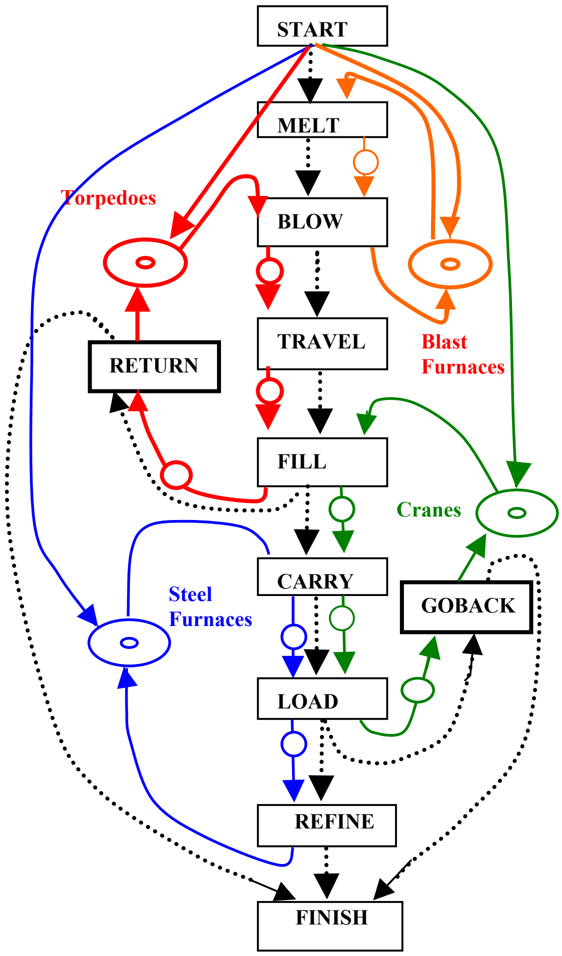

Figure 3: USMD Graphical Representation for the Steelworks Problem.

DOMAIN OF APPLICABILITY AND LIMITS OF THE APPROACH

The domain of applicability of the proposed methodology is that of the discrete event systems which can adequately be represented by ACD diagrams or by any PERT-like network of activities. This problem class tends to be very large because a network of activities, as well as its particular form known as ACDs, is a good representation of discrete event systems in general.

The choice of a problem based on an ACD representation has the advantage to show that a PERT-like network that needs to be traversed only once may represent even discrete event systems with a cyclical nature, such as a serial production process. This transformation is possible even in the case of several entities with complex interactions existing in the system, since the main path and its ramifications does not need to correspond to one of the real entities processed by the model. It might be described by a virtual entity "execution order" that splits for branches that are executed in parallel, as it is the case in the steelworks model shown in the diagram of Figure 3.

The breaking up of ACD cycles is done by using the concept designated as resource pools or repositories, and positioning the activities of a single cycle accordingly to what effectively happens in the real system (for example, one has to decide if RETURN of torpedoes is an activity that precedes BLOW or that succeeds FILL, the last case being the one represented in the diagram of Figure 3).

The application of the methodology and tools derived from the project management area is based on the idea that the complete production process or its segment currently under analysis can be seen as a single project. The successive cycles representing the different batches of products are dealt with by replicating the basic process, which might be restarted any number of times, with or without a time delay, creating a network of activities whose graphical representation is drawn and executed sequentially from left to right or top to bottom as in the case of Figure 3.

Serialized production processes are therefore represented as equivalent to a complex process/project of a multi-process nature, made of several instances of the single process, each instance initialised with a different start time.

There is no need to consider multi-projects with a high number of identical processes, because the finish time of the first process would limit the number of total processes which would be simultaneously active in the system. The system's steady state behaviour would thus depend only on the number of simultaneous processes being carried out in it at any one moment.

In some cases it might be necessary to repeat some parts of a process to create its complete graphical representation, if the same entity needs to repeat a sequence of activities for a fixed number of times, differently of the treatment described above for cycles that are originated from the processing of successive entities.

A problem arises when the number of times a segment must be repeated is dependent on a variable attribute for different instances of a class of entities being processed in the model. In this case the process cannot be described in this level of detail as a fixed PERT-like network of activities that needs to be traversed only once by that entity class or transaction existing in the model.

In these cases the problem may only be described as a PERT-like network of activities if the level of detail is reduced, that is, if the problem is modelled in a higher hierarchical form, with some details being encapsulated into a macro activity that has to be considered as a single activity for the purpose of complementary time and cost analysis proposed by the approach.

COMPARISON WITH OTHER METHODOLOGIES

Process simulation methodology and tools are used for analysis of system's performance, for example in the identification of production bottlenecks, and to set and evaluate different strategies for system's operation. These tools are quite good when one is addressing the representation of the structural complexity of system's model components and the interaction of their entities. The same holds for the description of the operations that occur inside the activities or services that make up the network traversed by the entities or transactions along the simulated time.

Simulation systems were not created, however, aiming at their application for the following up or analysis of projects of engineering or managerial nature, mainly concerned with execution deadlines and costs fulfilment. Even in typical process simulation studies these aspects are only dealt with as an analysis refinement for cost evaluation or optimisation purposes, and not as an integral part of the experimentation phase of all models. The reason for that is the lack of adequate pre-built mechanisms that would allow this kind of analysis to be performed independently of the specific model of the system being studied.

On the other hand, in project management and control study area, the tools used for analysis generally consider these aspects as the most relevant subjects of the analysis and control the process is undergoing. According to [Prado 1984], however, a project is traditionally seen as "a single enterprise, of limited time duration, formally organized, which aggregates and applies resources aiming at the fulfilment of precisely pre-established objectives". This "single enterprise" way of viewing projects might be the reason why projects have been traditionally treated in the literature of the area and by computer systems developers as a matter completely dissociated from industrial serial processes.

The traditional way to describe a project is by representing it as a sequenced network of activities, by means of diagrams known as Program Evaluation Review Technique - PERT, a renowned and well documented technique, used for management of engineering projects, be it of a service or industrial nature, aiming at their planning and execution control [Prado 1984].

PERT diagrams need, sometimes, to be reviewed during project execution, to keep a realistic view of the project during its execution, in order to remain an important element of assistance for decision taking by management personnel. These revisions are made to adequate the activities network in case of unexpected delay in their execution or to contemplate an alternative way to execute one or some of project's phases or sub processes. These changes may even require the revision of the whole project's PERT diagrams, but the final structure of the project's network of activities and their duration are based on judgements and believes which have to be established prior to project's start. In the determination of these parameters they are also not subjected to a closer modelling and analysis of its descriptive dynamical process, or to some kinds of experimentation, results analysis or animation in the way it is performed in typical simulation studies.

The analogies between the two kind of problems become evident, however, when one considers a project not as a single process, but as a serial one or, equivalently, when one looks at it as a multi-project, made by the repetition, in parallel and possibly with some delay between each start, of its basic single process. The objective of a project management study could then be seen as the determination of the ideal basic process descriptive of the project, corresponding to the optimised distribution of all allocated resources to achieve the best performance both in terms of total process time and cost through all stages or phases of the project execution.

The analogies identified above between process simulation and project management have not yet been explored consistently, as far as the author is aware, aiming at an integration of their concepts and the development of a unified methodology for their simultaneous and integrated application. These methodologies and their supporting tools have remained conceptually very divergent and self contained in their respective knowledge and application domains, showing almost no communication between them, even taking in account the most recent developments made in these areas.

The most recent advances identified in the literature towards the integration of process simulation with project management and control objectives can be attributed to software developers of simulation applications. This is the case of the use of spreadsheets or even project management systems, which were adapted or expanded to make use of random variables and of a simple iteration mechanism [Palisade 2002]. These systems allow the execution of Monte Carlo simulation over some aspects of interest in project management studies, such as the duration of the activities.

The availability of these additional facilities in project management application programs, nevertheless, does not alter the true nature of this kind of software. They continue to be used in a very different context, essentially dissociated from process simulation, unlike the tools that target simulation as their main objective of study. An exception is the SIMPROCESS [CACI 1996] simulation system, which is being considered as a platform to develop the hybrid environment proposed here, by means of the addition of new libraries to the system.

BENEFITS OF THE METHODOLOGY AND ITS TOOLS

The idea is to take advantage from the application of project management techniques to the simulation model analysis and vice versa in order to benefit from the complementary aspects for which each kind of technique is especially stronger.

One of the results expected, from the simulation modeller standpoint, is to keep track of the complete map of dependences and sequencing of all activities, and of the use of the resources involved in the model. Experimentation and simulation model assessment will be improved and productivity will be enhanced in some segments or in the overall descriptive process of the model, through the optimisation of resources allocation and the minimisation of completion times, subject to costs constraints.

This result can be achieved by creating pre built mechanisms that are independent from the specific model under consideration, allowing model assessment for productivity improvement to become part of the normal objectives of a simulation study. These model independent mechanisms may be developed by using existing functionalities, or may be newly created if these functionalities are still not available, in an integrated simulation environment.

On the other hand, from the project management modeller standpoint, it is expected that the application of simulation for project management might turn into a rich research and application area on its own, one with great relevance to complement any study performed using the project management technique. Problems that have so far been treated as being of a static nature could benefit enormously from the use of process simulation. The analysis, using simulation, of the multi-project created will produce a better understanding of the single project or process and allow the increase of its productivity, by optimising resources allocation and shortening complete or partial process execution times, while keeping control of activities costs.

The optimisation will be based on the dissociation of the time delay incurred by the permanent entities in the queues in front of each activity from the duration of these activities, what is treated as an aggregated estimation in the project management current studies, based on conservative estimative. The reduction of these waiting times by increasing the number of resources allocated, keeping control of their relative costs for each level of execution time reduction, shall produce on its own a major gain of productivity in the execution of single projects.

The gain in productivity will be even greater when one considers the scaling factor, existing in systems in which real multi-projects or multi-processes need to be carried out, with their start time shifted only by a certain delay and their processes being executed in parallel, by big work teams divided in classes by their specialities.

The lack of this kind of analysis in project management studies actually performed is explained by the fact that the existing software tools used in this study area have no capabilities for experimentation of alternative forms for the modelling of their processes, for the animation of the passage of time, and for the testing of its dynamical resources allocation in the case of multi-projects. These are clear deficiencies of these systems, when they are compared to the existing simulation systems. These mechanisms will be an essential part of the hybrid simulation environment here proposed.

Model assessment in both cases will be made by a combination of the normal procedures used in simulation studies with the addition of the techniques derived from project management of a multi-project nature, with the aim of enhancing the understanding of the experimental factors and strategies which significantly affect system's productivity.

ACTUAL STATE OF THE RESEARCH

The USMD model of the steelworks was implemented both in MICROSAINT [Micro Analysis and Design 1992] and in MS Project 2000 and the same kind of dual implementation has been done with a USMD model of a house construction problem. Both models were represented as if they were single assembling processes (or projects), that is, the models contemplate only one go of the production processes.

These implementations were conducted by groups of research students as final simulation course projects. The choice of the application systems above was made solely due to their availability as course material, but any existing process simulation and project management software available in the market can be used for this exploratory phase.

Concepts such as critical paths and completion time for a segment of the process, typical of project management technique, were applied in the simulation study of the steelworks USMD model to yield greater productivity and a thorougher analysis of possible strategies for system's operation. Concepts such as the identification of idle times of entities staying in queues in front of activities and dynamical resources allocation via the use of simulation were applied on its turn to reduce segments or overall process completion times and costs in the house construction model.

As expected, the systems showed their deficiencies too in dealing with some aspects of the modelling, such as replicating the processes and allowing the conduction of experiments with multiple processes in the case of simulation and with making activity duration dependent upon the quantity of resources of each class allocated to the model, in the case of the project management tool.

CONCLUSIONS

The integrated use of standard model assessment and project management techniques in simulation studies reveals that they have a complementary nature, the first group of procedures allowing for the analysis of the dynamics of the process, including optimisation of resources allocation, and the second one allowing for a better evaluation of activities completion time of partial or complete production cycles, as well as their cost assessment.

The application of the existing software tools interchangeably in each of these study areas can already improve the simulation model assessment and the multi-projects management tasks. The combination of these two techniques is therefore very promising, but its advantages cannot be entirely exploited through the separate use of the actual existing software tools of the individual types in studies of the other area, because they have been designed with different purposes, which do not take into account their complementary nature.

The full benefits of a unified methodology shall only be achieved if one undertakes the design and the construction of a hybrid simulation environment to deal simultaneously with all the issues involved in both study areas. A hybrid simulation environment based on an integrated approach will allow the modelling and analysis a production process or a management project in a similar way to that of a multi-project made of several identical processes. With such tools it will be possible to increase productivity, reducing segment or full process completion time, subjected to resources and costs constraints, by shifting and analysing the start of successive production cycles or single projects.

The full methodology and tools will derive from the addition of the functionalities of the project management type to a simulation environment based on unified modelling conceptual framework, rather than by the addition of simulation functionalities to project management software, because these last ones generally lack on functionalities already existing in simulation systems, such as the capability for dynamical analysis and for multi-processes handling.

This initial work addresses the identification of the similarities and differences between the model representation forms and the application of process simulation and of project management as individual techniques, and the formulation of concepts and procedures for their integration and the exploitation of their relative advantages in a unified methodology. A conceptual framework has been devised which will lead to the development of a full methodology and its supporting tools to deal with the issue of model assessment described.

The proposed methodology presents a innovative character, being able to be applied to a large problem class, with special interest focused on applications in serial processes and in multi-projects of an identical single project nature, whose execution share common resources and occur in parallel. The full development and application of the methodology will require the use of existing simulation and project management systems to perform several case studies, as well as the creation of a new hybrid simulation environment, which on its turn will require quite a lot of software application and development time.

Further research is planned to make use of the SIMPROCESS [CACI 1996] simulation system as a development platform for the hybrid simulation environment proposed. This research project is ongoing and the conclusions obtained will be included in future publications of the work, as new progresses are made.

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BIOGRAPHY

GERMANO DE SOUZA KIENBAUM, PhD, was born in Recife (PE), Brazil, in 1957, and has both the Brazilian and the German nationalities. He graduated in Aeronautical Engineering at the Technological Institute of Aeronautics (ITA/Brazil) in 1983. In 1985 he joined the Laboratory for Applied Computing and Mathematics (LAC) of the National Space Research Institute (INPE/Brazil) in the research group Operations Research and Systems Simulation. He finished MSc in Systems Analysis and Applications at INPE in 1989. As a research assistant and student he went to Passau University, Germany (1991-1992), and Brunel University, United Kingdom (1992-1995), where he obtained his PhD degree in 1995. Since then he resumed his researching and teaching activities in the research Group Operations Research and Systems Simulation at LAC/INPE and the post-graduation program in Applied Computing (CAP/INPE). His main research interests are software engineering and systems modelling methodologies for use with simulation. He conducted several simulation studies, both continuous and discrete, in fields as different as air-to-air missile tracking, airport planning and operation, production plants and business systems. He took part in the development of several types of simulation model building tools, such as program generators and graphical user interfaces for simulation modelling. During his eighteen years carrier in the field he has also done consulting services for several companies and governmental agencies, among them the Civil Aviation Department (Brazil), Parity Plc (UK) and CACI Company (USA).