Simulation for Project Administration

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Abstract- Project plans and information about the current state of ongoing projects can be stored in a project database. The information in the database can be used to generate Simulation net models of these projects. Simulation nets are extended Petri nets. Such a Simulation net can be executed and the future progress of the projects can in this way be be simulated.

1. INTRODUCTION

A complete toolkit offering an integrated project and database management tool, communication and progress management and an intelligent decision support system (DSS) is desirable for efficient and well-founded management of projects. There is a wide variety of project management tools and database systems available. However these do not offer the desired integrated environment. The different products available are not designed for the high level of integration desired and are therefore hard to combine.

The SuperVision project strives to create such an integrated environment designed to operate within the computing environment of Wärtsilä Diesel Oy, Diesel Power Plants (WDFI-P) through the integration of existing components and by developing the missing links and components [Ekl94].

A local computer system, called ProVison, has been built to maintain and provide access to the project database. The project database contains the project plans, information about the subcontractors, suppliers and the current state of the projects. In the database projects are divided into activities which in turn are assigned one or several checkpoints, see Figure 1.

Progress control is executed through a confirm/approve protocol. When a work related to a checkpoint is complete the responsible person confirms it. However, the checkpoint is not considered as reached until it has been approved by the project manager. An activity is finished when the last checkpoint is reached. The reporting is done electronically in order to keep the database as up to date as possible by using the ProgressView software, developed in the SuperVision project.

Having both the project plans and a fresh snapshot of the current state in the database it would be of interest for the project manager to go beyond the current state and take a peak at the likely progress of the project. The ability of simulating the future of the project is of interest not only in the planning phase but also during the time the project runs.

It is possible to generate a simulation model of the project in the current state and to run the model from the current state on. There is a clear advantage of building the model so that it corresponds to the current situation thus eliminating simulation of events of which outcome we have knowledge. The more that is known the less there has to be simulated.

Output of the simulation can alert management on impending or potential problems. The advance alert will facilitate better management decisions. The project manager can use the simulation results as basis for decisions on which control actions to take in order to steer the project in an optimal way.

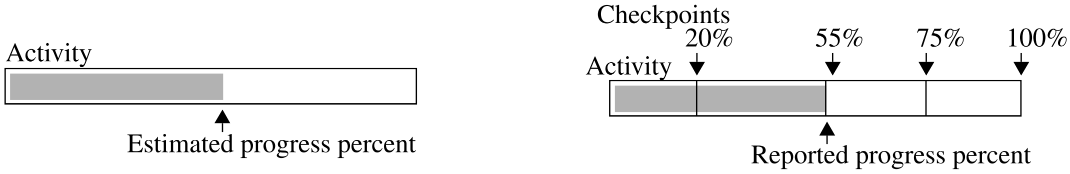

Figure 1: Traditional progress control and progress control using checkpoints.

2. CREATING THE MODEL

The simulation model is created based on the original project plan created by the project manager. The project manager often uses a conventional project planning tool for creating the plan. Several of the tools are capable of displaying the plan as a PERT-network. In the SuperVision case the PERT-network describing the project plan is placed into the project database. The project plan and the information about the current state is taken from the project database and rewritten in a form that can be red by a simulation package. In the SuperVision case this format is the XSimNet file format [Gus94].

On the highest level in the Simulation net model we have resources and subnets containing the different ongoing projects. All the ongoing projects are part of the same simulation model since they might use the same resources. Therefore a delay in one project can have impact on the progress of some other project. These interdependences between the different projects can be hard to notice without such a tool if the company has a large number of parallel projects.

In practice it might be possible to find disjoint sets of projects that do not share any common resource. It is then possible to limit the model to contain only those projects belonging to the set in which the project that is the primary target for the simulation is a member.

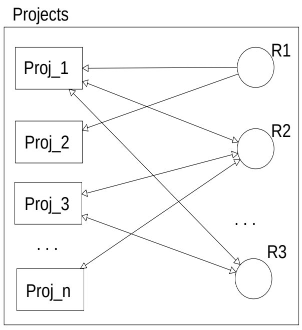

Figure 2: High level model of the projects and the resources.

Since Simulation nets are stochastic there is a need for running the model several times to collect statistics about the behaviour of the model. A construction for running the simulation a specific number of times can also be built into the model on the highest level.

In the subnets describing the different projects every activity in the PERT-network is described as a transition or a construction containing several transitions. The type of relationship between the current activity and its predecessors and successors, i.e. finish to start, start to start etc., is reflected in the way the activity is modelled. These different types of relationships has to be build into the simulation model. The ways the different relations are modelled are shown below.

2.1. Finish to start

The most basic case of relation between two activities A and B is finish to start. This relation describes situations where the completion of A is a necessary condition for B to start. The activity A can be modelled using a single transition, that models the duration of A, connected to B via an intermediate place, see Figure 3.

2.2. Start to start

If the relationship between the activities A and B is start to start, A has to start in order for B to start. To model this A is split into two parts, one transition describing the starting of A with a zero duration and another modelling the actual duration of activity A. The transition describing the starting of A enables B, see Figure 4.

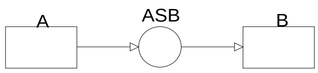

Figure 3: Finish to start.

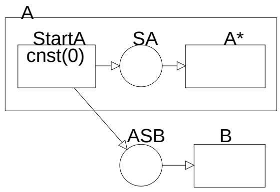

Figure 4: Start to start

2.3. Start to finish

If the starting of A is a necessary condition for B to finish, both A and B are split into two parts, one part modelling the starting or finishing of the activity and the other part the duration of the activity. The starting of A enables the finishing of B, see Figure 5.

2.4. Finish to finish

The finish to finish relation means that A has to finish in order for B to finish. This is modelled in a similar manner as the start to finish. Here A however does not need to be split, see Figure 6.

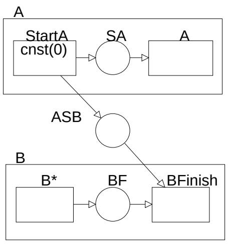

Figure 5: Start to finish

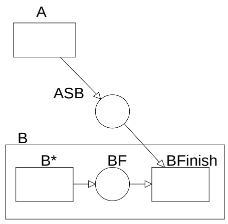

Figure 6: Finish to finish

2.5. Lag

The situation when B can start at the earliest *n* time units after the completion of A can be modelled by adding a lag transition with duration *n* between A and B, see Figure 7.

2.6. Lead

The lead relation expresses the situation where B can start *n* time units before the completion of A. This is modelled by splitting A into three parts. The first part, with zero duration, calculates the duration of A and the duration of A-*n*. The information about the durations is carried to the two other parts using coloured tokens. The two remaining transitions use the received information as durations. The transition with the duration A-*n* will enable transition B, see Figure 8.

2.7. Transition times

The duration of the activity is estimated by the project manager and entered into the project plan as three values describing the optimistic, most likely and pessimistic duration of the activity. Several probability density functions have been proposed for the modelling of nondeterministic activity times. These include the normal distribution, uniform distribution, logonormal distribution and beta distribution. The beta distribution is by far the most used for representing the probabilistic nature of activity times. A beta distribution can easily be fitted for the three given time estimates [Bai91].

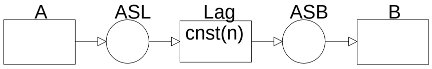

Figure 7: Lag

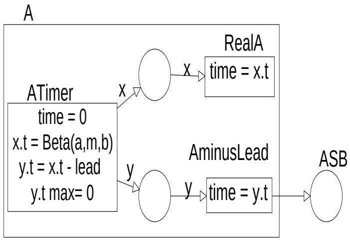

Figure 8: Lead

3. RESOURCES

When transforming the pert network into a simulation model also resources have to be taken into account. The availability of resources needed will influence the starting of activities. With limited resources available there can arise situations where an activity cannot start even though all its predecessors have reached their needed states. This will of course have impact on the completion time of the project. Such situations can be hard to foresee when using ordinary evaluation techniques such as PERT-networks or CPM. This is specially true if the resources are used by some other project. It would be necessary for the project manager to check all the other ongoing projects to see if there is a possibility of one of them influencing the completion of the project at hand. In a big company with several project managers running projects in parallel to find out this can be a very time consuming task.

When generating the model the resources will be represented by places in the high level net. There will be one place for each type of resource. The number of resources available is described by the initial marking of these places. The information about how many resources that are currently available is taken from the project database when the model is generated.

The resources can be of two different types; reusable and non-reusable. If the resource is of a reusable type the individual activities will upon completion return the resource that they have used during their execution to the resource pool.

If the number of resources available is known to change during the time period that is simulated due to some external event, e.g. delivery of more raw material, a construction to describe this event has to be added to the model.

4. UPDATING THE MODEL

Once the project has started simulating from the current time t_c onward the simulation model is not generated based only on the project plan. Additional information about the outcome of activities will be available. This information can be used to create a model that more accurately corresponds to the situation at time t_c.

All the activities that have already finished can be removed from the model since the simulation only involves future events and PERT-networks do not contain loops. The duration of all ongoing activities has to be updated to contain only the remaining part of the activity.

One possible way to update the duration of the activity would be altering the time estimates t_0+a (optimistic), t_0+m (most likely) and t_0+b (pessimistic). Given a, m, b and c (the percentage of the activity completed) the new estimates a' and b' can be calculated as $a'=(1-c)*a$, $b'=(1-c)*b$.

For calculating m' one more piece of information $t=t_c-t_0$ (the number of time units since the activity started t_0) is needed. t_0+t/c tells us when the activity would be ready if it would continue to advance at the same speed as up to now. Assuming that this is the right trend then it would be natural to move m towards t_0+t/c. To avoid over steering the correction will be $\alpha*(t/c-m)$, where α could be 0.5. The new m value could thus be calculated as $m'=(1-c)*(m+\alpha*((t/c)-m))$. In case of $t/c<a$ the value of m' can be calculated as: $m'=(1-c)*(m+\alpha*(m-a))$ and respectively if $t/c>b$ as $m'=(1-c)*(m+\alpha*(b-m))$.

All the ongoing transitions are connected to the starter transition. The rest of the uncompleted transitions are generated as described earlier.

It is important to make sure that the simulation starts in a way that corresponds to the situation at t_c. Several transitions besides the once known to be ongoing can be initially enabled in the generated model. If the activities need resources of a limited type in order to start, the starting of a transition can change the state of some other transition from enabled to disabled, i.e. there might not be enough resources available to start all the transitions that were initially enabled in the model. In Simulation nets the choice between which of the enabled transitions to start first is done arbitrarily. It is therefore important to make sure that all the transitions that are known to be ongoing in the real world are fired before any other transitions when the execution of the model starts. This can be done by giving the ongoing transitions a higher priority.

There will not be any conflicts between the activities with higher priority, there will be enough resources available for all the ongoing transitions to start, if the project database is consistent.

5. AN EXAMPLE

The scenario of the example starts when the project manger creates the initial project plan in the form of a PERT-network. This network can be seen in Figure 9.

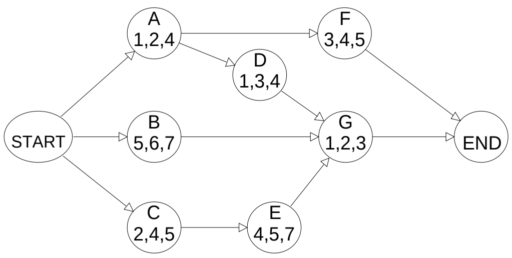

Figure 9: The initial project created by the project manager shown as a PERT-network.

Activity	Nr. of resources required	Type
A	3	R
B	5	R
C	4	R
D	2	R
E	4	R
F	2	R
G	6	R

Table 1: The number of resources needed for the different activities.

In the initial project plan all the activities can start when their predecessors have ended except for F which can start at the earliest one time unit after the completion of A (lag 1) and E which can start one time unit before the completion of C (lead 1).

The activities in the project only need resources of one type, namely R. The activity will start only if all the needed resources are available. The number of resources needed for the activities are given in Table 1. The total number of resources available of type R is known to be seven.

The first time the model is generated the project has yet not started. The Simulation net representation of the model can be seen in Figure 10. All the activities are still in the model and the activity times are computed directly from the time estimates in the project plan.

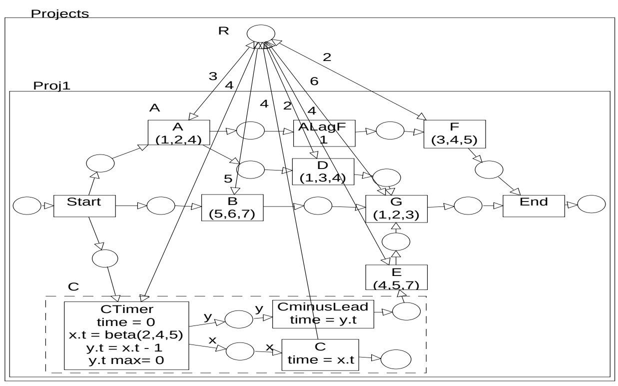

Figure 10: The initial Simulation net model at time 0.

At time t_c=3, a Simulation net model is again generated. At this point we can see from the project database that activity A was completed at time 2.25. The transition A can therefore be removed from the model. The transition describing the lag between A and B has been running for 0.75 time units. The new time for the lag will therefore be adjusted to 0.25.

We also see that the checkpoint telling us that 80% of activity C has been reached at time 3. The time estimates for C has been updated to a'=(1-0.80)*2=0.4, b'=(1-0.80)*5=1 and m'=(1-0.80)*(4+0.5*((3/0.8)-4))=0.775. None of the other activities has started. The Simulation net model describing the project at time 3 can be seen in Figure 11.

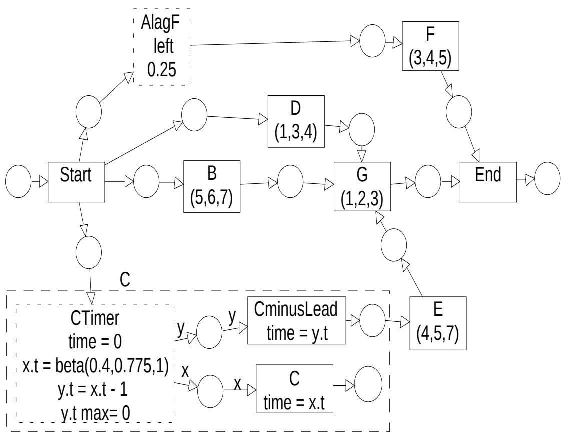

Figure 11: The Simulation net model generated at time 3.

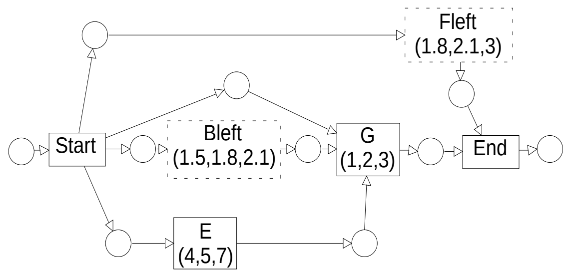

Figure 12: The Simulation net model generated at time 8.

The resources have been omitted from the figures in order to keep the figures tidy. The transitions with a higher priority are shown with a dotted outline.

At time 8, a new model is generated. At this point the activities A, C and D have finished and activity B has been completed to 80% and F to 40%. The activities E and G has yet not started, see Figure 12. The generated models have been executed using XSimNet.

6. CONCLUSIONS

Automatic generation of Simulation net models of the project will give the project manager a possibility to forecast potential problems and test different solutions. Since the models can be automatically generated the project manager does not need to learn to use Simulation nets for modelling.

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