GESOS : a genetic based tool to aid project managers

*Claude BARON, *Samuel Rochet, **Daniel ESTEVE

*LESIA, INSA, 135 av. de Rangueil, 31077 Toulouse cedex 04, France
**LAAS, CNRS, 7 avenue du colonel Roche, 31077 Toulouse cedex 04, France

Abstract : Project managers have a difficult issue to deal with : identify tasks to plan during project management, with their technical and non-technical parameters, determine a goal to reach, and effectively reach it without deviating too much to avoid financial penalties… Our motivation is to help them to chose a project skeleton, called scenario, at the launching of the project, but also during its management, in order to quickly react in case of the occurrence of any perturbation (lack of a component, strike, cost reduction, etc.). We adopt the genetic approach to solve the problem of the selection and the optimization of scenarios to offer the project manager a panel of best potential solutions. This paper shows the benefits that result from this approach and the perspectives of larger applications we envisage thanks to the tool that supports it, GESOS.

Key-Words: multi-objective evolutionary algorithms, Heuristic Algorithms for Optimization, Prediction and Model Identification, system design, Simulation in project management, Multi-criteria Decision Making

1 Introduction

We situate our work in the problematic of the development of methodologies for project management. The originality of our approach is to couple these problems with that of the system design. In a simplified way, the question is to succeed in making evolve simultaneously the organization of the project and the organization of the design considering a shared model and a data base common to both steps. We think that would facilitate the construction of architecture of project planning and the optimization of it according to methods that we propose to develop. We associate with the process of project management some mechanisms of robustness and adaptability related to external disturbances, of a technical nature, either social or economic, while respecting the laid down objectives.

In a more general way, the study that we carry out is thus included in a context of management of shared risks between project management and product development processes. Initially, the question is to identify the risks likely to occur for better anticipating (out-of-stock condition, bankruptcy supplier, insufficient formation of the manpower, etc). At each risk will be associated an alternative, suggested to the project leader to help it to choose a new organization at the time when the incident occurs. Among the several possible scenarios, the project manager will have to select one, or some, which will make it possible to achieve the goals without too much deviation, in case of the occurrence of a risk disrupting the progress of the design and/or project management processes.

The problem thus comes to a minimization of the distance between the objective effectively achieved by the scenario (in terms of costs, times, quality…) and of the initial laid down objective. However the choice of the various tasks to be carried out during a project is a complex optimization problem. Only some heuristic methods can enable us to find a solution close to the optimum in a reasonable time, like the evolutionary algorithms. Indeed, considering this problem, we could note that such methods seem best adapted because these research algorithms allow taking into account multiple parameters of which they seek many combinations simultaneously. We validated our approach using a tool based on the use of the genetic algorithms, GESOS.

Section 2 exposes the views we shared on the two considered processes, product design and project management. In section 3 we justify our choice of evolutionary computation to manipulate scenarios and detail how the genetic mechanism operates in our case on an example. Then we conclude on our results and perspectives.
2 A shared view on two joint processes

2.1 Presentation of the concept

The accelerated development of technologies offers a wide range of materials, components, production modes… to the engineer. This is useful to design and sell products which life is short : either products are destined to be consumables, either they become old-fashioned in front of more innovative products. Manufacturers, in this very concurrent international context, must be very reactive to their client needs and very efficient to shorten the time to market. Once product specifications are established, manufacturers have to simultaneously master both the product design methodology and project management. The two processes of this shared problem are usually separately conducted and dispose of separated tools: CAD tools, economic planning tools, financial tools…. This practice presents risks of incoherence and lengthening delays for at least two reasons:

• the innovation process is not correlated enough to economical requirements, and enough introduced into the company life,
• project management is conducted on an insufficient knowledge of technical difficulties.

Obviously, these risks could be reduced if all technical, administrative and financial decisions relied on a shared model between partners.

Now, as it appears on figure 1, the originality of our research work is that we consider that both processes can be associated during the “preliminary design” and the “task definition” steps because on one side, the “design” one, the identification of technical options for the product (choice of components considering their performances, or reliability), will participate to the definition of tasks on the other side, the “project management” one, with their own specific parameters (resources, costs, suppliers, ..).

Our ambition thus is to link both processes at this level, from a methodological point of view, but also a practical point of view (that means that the method must be supported by tools to be applicable).

We will call this our “shared model”.

2.2 The tool platform in Toulouse

On this project, we collaborate with several research groups from the LAAS-CNRS, the French National Center of Scientific Research, and are now in the phase of connecting the different developed tools, as exposed on figure 2 (static view): HILES, an SART based tool, to describe the functional architecture of the product at a system level, TINA, a validation tool based on Petri nets to verify the design, LORA, that allows the tasks definition and planning, and GESOS, that proceeds to the selection and optimization of scenarios. Specifications of all tools are established using the UML language ; UML is also used to describe the product specifications. The use of XML is considered as a convenient tool to share and exchange data; finally, VHDL/AMS is used to simulate the product prototype.

![Relations between existing tools of the platform](image.png)

Fig.2 Relations between existing tools of the platform

2.3 The selection and optimization of scenarios

At the beginning of the project indeed, one can imagine an approach in which the project manager and the design engineer jointly define a global architecture for the project process as a whole: technological, financial … choices. This step consists in precisely estimating, scheduling, and anticipating the best general organization for the project. Then, during the project, regular adjustments will be necessary to take into account events that have occurred and which present new risks: longer delays, supplier bankruptcy, new security requirements on the product, insufficient performance…

The intersection between task’s content and the technical and non-technical objectives lead to establish several possibilities for the project
organization which are coherent with general specifications of products, as illustrated on figure 2; we call them scenarios.

![Diagram of scenario generation](image)

Fig.3 Generation of scenarios from tasks options

Scenarios are deduced from the options attached to each task. They correspond to global solutions respecting both technical specifications and strategic project requirements.

**Generation of multiple options**

Scenarios are thus deduced from initial options that only the project management team can determine under the form of a systematic questionnaire. The criteria used to validate an option can simply be the tests of whether this option verifies the technical specifications and the non-functional requirements. Acceptable scenarios will thus result from a compromise between compatible options.

One way to generate multiple options relies on architectural variants that can be imagined by the designer to answer non-functional requirements such as tolerance allocation, reliability, functional risks, and other “project” risks… A special accent can be put on risk analysis during this preliminary phase [4]. This is a first way to generate multiple scenarios; they can also be classified according to criteria based on non-functional aspects, using several algorithms that will be exposed in section 3.

**Options selection**

The selection of new options, and thus of alternative scenarios, will be done according to a new choice of functional (new technical performances) or non-functional (restricted budget) criteria. The question will thus be how to generate a set of possible solutions from the current state of the project that integrate new constraints; these solutions must also be close enough to the initial one in order to induce a minimum of perturbations into the different aspects of the project (financial, human, technical …).

These solutions are acceptable from only one point of view of their conformance to the modified project architecture. They will be submitted to the decision-maker and he will select a set of solutions that best satisfy a multi-criteria compromise (for example, global low costs and delays, but man-power increase).

**Optimization**

To improve the process and provide a better help to the decision-maker, these different scenarios can then be optimized, hierarchically arranged and selected on the basis of complex compromise criteria associating technical and non-technical considerations.

Our contribution in this context will precisely consist in helping the decision-maker to select an optimal project organization among the different scenarios.

3 **GESOS : Genetic algorithms for the Evaluation, Selection and Optimization of Scenarios – method and tool**

The process previously described offers the designer such elements as:

- A unique description: project tasks and steps, different options by tasks, multiple scenarios that conform to specifications and formulated requirements.
- These scenarios can be classified on the base of:
  - technical optimization criteria of potential performances by the examination of precise technological questions,
  - more complex optimization criteria dealing with technico-economical compromises (quality and cost for example),
  - economical profitability criteria by the anticipation of production and industrial exploitation phases...

Optimization will lead to different hierarchies of scenarios that the decision-maker will arbitrate.

Evolutionary Algorithms (EA) can be used to select particular scenarios among multiple scenarios.

3.1 **Justification of the use of genetic algorithms**

The choice of the various project's tasks is an optimization problem for which one no exact polynomial algorithm is known. The use of an exact method of optimization is then not very realistic for large-sized problems. However some heuristics like evolutionary algorithms can allow solving this problem. We chose it for mainly two reasons. First, these research algorithms are well adapted to multiple parameters. Second, they use a very simple criterion
of evaluation by allocating a note to each individual according to its performance, which avoids using more complex mathematic tools, which can be not easily usable in a similar problem.

3.2 Application of genetic algorithms to manipulate scenarios : the GESOS tool

3.2.1 Motivations and requirements
What motivates this tool comes from industrial solicitations: a project manager needs to be quickly guided towards a valid and optimal choice of project organization among the numerous possible solutions. He needs this help at the launching of the project, to define an initial planning of tasks, but also during the project, to be able to react when an incident occurs that leads the manager to adjust his organization. To efficiently help him, the tool must provide him a choice of selected scenarios corresponding to a selected complex criteria defined by the manager, with the largest diversity possible, and also evaluate the scenarios with a multi-criteria evaluation, according to several considerations:
- technical: performances
- economical: costs, time constraints
- subjective: quality, security, risk, etc.

The generation of scenarios is processed from the different options of figure 3; the generated scenarios are already validated and optimized from a functional point of view. Here is how the genetic mechanisms proceed.

3.2.2 Genetic procedure implemented by GESOS
A task, as defined on figure 1, is defined with three main parameters in a list approximation: cost, duration and prerequisites, and some additive informative categories.

A scenario is build as a combination of chosen options (an array) at each step. Options are also stocked into arrays at each step. A scenario contains the following pieces of information: total cost, total duration, fitness and some additive informative elements. The cost is calculated with simple addition operations and duration by PERT method.

Initialization. An initial population (an array) of scenarios is then randomly or quasi-randomly generated with alls their non-functional characteristics. An individual is represented by a chain of genes, each one representing either a task or a branch in node of choice (figure 4). Three parameters are associated to the population: best individual fitness, best scenario and average fitness. At the beginning of the project, one must fix the objectives in terms of cost and delays before generate the different options.

The genetic engine then makes this population evolve in order to obtain either the best valid and optimal scenario, or a set of optimized scenarios. The evolution of different scenarios is shown on figure 5.

Evaluation. Scenarios are then evaluated according to criteria related to the project management domain. The evaluation proceeds in three steps: removal of inactive tasks and nodes, calculation of duration and cost associated to the scenario, fitness calculation.

A selection of individuals is then made among the population of candidates in order to favor “good” individuals according to the selected evaluation criteria; however, as a certain diversity has to be respected into the population, a few individuals, less adapted, must survive too. What has been chosen for the moment is to apply the roulette principle.

Reproduction. Selected individuals are then crossed and mutated in different percentages, often empirically determined, in order to constitute the next population. For the moment, only a single point crossover is implemented, the objective being to validate the principle of use of the genetic algorithm.
The algorithm proceeds in this way until the solution(s) is obtained, which means that one or more scenario(s) that is functionally satisfactory and corresponds to other technico-economical non-functional constraints have finally been obtained. This stop criterion could be improved further in the next or future versions of the tool... When no optimal solution is reached, the algorithm can help the decision-maker to select the best approximated compromise...

3.2.3 GESOS: Results and Perspectives
The use of the evolutionary algorithms in this type of application is recent because until now they were used in problems of scheduling where tasks are known but not the order in which they must be followed (problems type flow shop, job shop or open shop). Here, the problem is the opposite, the general order of the tasks is predetermined and we try to find which chain of tasks would lead us as close as possible to our objectives. It is thus a new problem that is posed and that justifies why we chose to apply this method.

Thanks to the tool, we obtained encouraging results that validate our approach on scholar examples. In particular, we shown that, when the genetic parameters are well-adjusted, convergence is obtained within a few seconds, for quite complex problems (100 tasks with 100 options each, see results on figure 6).

![Fig.6 GESOS performances on a quite complex example](image)

Of course, the tool deserves to be improved, on several aspects which can be either:

- relative to the management and design processes:
  - by taking into account more task parameters (quality, risks, economical environment, choice of different fitness with regard to the enterprise politics...)
  - by processing a multi-objectives optimization
  - by processing a multi-modal optimization, to support the diversity of selected scenarios
- relative to the genetic procedure:
  - more sophisticated stop criteria to elaborate, selection procedure...
  - multiple cut points
  - precise adjustment of the mutation and crossover rates
  - introduction of a memory
  - etc.

To enforce and validate the choice of genetic algorithms, it would be useful to compare this approach with the ants colonies one for example, that also could reveal to be appropriated in our case...

4 Conclusion

Nowadays, project management is basically funded onto tasks scheduling and resources (human and financial) management considerations. It supervises product design tasks in the way that the decisions made determine the allocation of resources. This situation is not totally satisfactory because it induces misunderstandings, as the project manager can be very far from technical requirements, and reciprocally the product designer can be unaware of financial constraints.

The main contribution of this paper is to submit a first exploration of an organization more closely associating project management and product design. This proposition consists of three recommendations:

- First: a shared model to describe technical design tasks and project management steps similarly at a high level. Our hypothesis is that this model is founded on top down systems design steps: specification, preliminary design, virtual prototyping, optimization, material prototyping.
- Second: proceed to a model exploration by associating options at the task level, and by generating multiple scenarios at the project level. The generation of options and scenarios must be systematically based on possible technological variants, on risks analyses and on financial and administrative variants.
- Third: process selection and optimization treatments in order to select the most effective scenarios. These treatments must be activated at the beginning of the project, then regularly during the project. According to technical or financial criteria, choices could highlight some incompatibilities that decision-makers will have to arbitrate.

In this paper, we focused on the third step, the selection and optimization methods and tools that can be envisaged. The paper showed that genetic techniques can be employed to reduce computation delays in order to help the project manager to quickly react to any kind of event during the management process. What motivated this work is to help him to decide; this corresponds to a real industrial need. We exposed our strategy, justified its choice and
presented the benefits that can be obtained on the case of a complex example, though our approach still merits improvements. In conclusion, GESOS seems to be a well-adapted tool for decision makers to manage their projects. Considering the whole project, we determined ambitious objectives, and we are now in the phase of integrating the several research tools developed by our partners. We are now contemplating the possibility to use this platform and test it on real complex industrial applications.

5 References