Research project offer

Location: ISAE SUPAERO, Toulouse, France **Department**: Department of Complex Systems Engineering (DISC) **Research group**: SysCo (Connected Systems) [redacted]	
OFFER DESCRIPTION	
Title: Design and development of a tool for the modeling of socio-technical systems **Proposed duration and period**: May 2024 to August 2024	
Context	Anticipating technical developments and innovations and foreseeing obsolescence problems are key issues for public and private organizations working in the field of dual innovation. Not only is this a vital question of competitiveness and sovereignty, but it is also a financial problem of prime importance. Planning and directions to follow in terms of investment in research and development are central issues for organizations in the field of dual innovations. <u>Qualitative and Quantitative Technological Anticipation</u> To be the best, companies need to identify and understand future trends before others. Many companies rely on both the intuition of experts and tools and methods such as technological and scientific monitoring. The strategic departments and/or general management are then responsible for analyzing potential scenarios and thus make it possible to feed but above all to inform strategic decision-making. A certain number of quantitative methods of technological anticipation are based on the analysis of historical data and are designed to enable decision-makers to identify a certain number of typical developments. As such, we naturally think of methods for extrapolating trends. These methods have, in fact, an important advantage compared to purely qualitative methods of anticipation: they are free from subjective bias. Furthermore, since these methods can be modeled mathematically, they can be the subject of automated tools within the reach of non-scientific decision-makers. <u>Limitations of quantitative methods generally used</u> Although particularly developed in the industrial and defense fields, these methods encounter a certain number of limits which are more important as we face a phenomenon of accelerating technological developments. The main disadvantage of this type of method lies in its simplicity. First, there is always the (very strong) risk of the emergence of unknown events which have the consequence of profoundly changing the phenomena of technological developments (disruptive innovations, economic crises, etc.). However, these events are ignored when automating the purely quantitative models described above. The solution, by necessity, is then human intervention to adjust the mathematical model. This introduces, at the same time, new biases… Furthermore, traditional methods for extrapolating trends focus on models where a technology or system will be evaluated mainly by a Figure of Merit (FoM). Evaluating the performance of a technology or system cannot be limited to a FoM. <u>Multi-dimensional optimization</u> In engineering, design issues and problems are often formulated as optimization problems, where design choices are encoded as evaluations of decision variables and the relative merits of each choice are expressed via a utility/cost function in function of the decision variables. In most real-world optimization situations, however, this cost function

	is multidimensional. Multi-criteria or multi-objective optimization problems have been the subject of methods, some of which have met with some success. One approach is to define a one-dimensional aggregate cost/utility function by taking a weighted sum of the different costs. Each choice of a set of coefficients for this sum leads to an optimal solution for the one-dimensional problem which is a Pareto solution for the initial problem. Other models are based on heuristic search and in particular genetic/evolutionary algorithms. The main problem with these models is the difficulty in finding meaningful measurement elements to evaluate the solutions they propose to provide. <u>Forecasting methods and game theory</u> Forecasting methods (we use here the term anticipation as the holistic approach to strategic anticipation and forecasting as the quantitative methods and tools making it possible to obtain results to guide strategic anticipation) are the subject of research in different fields. Here we place ourselves in project management and show how to optimize results using more efficient methods that are close to industrial realities. The work of Heidenberger and Stummer (1999) provides an overview of quantitative methods for R&D project selection and resource allocation. They describe the approaches of game theory as those which are the most optimal for understanding an organization in a strategic ecosystem where competitors co-act and have, by the very fact of their actions to survive and/or win, an effect on themselves, on the ecosystems and therefore their competitors. However, there remains a significant gap between the complexity of real-life decision-making and this model. In 2017, Xiong and his colleagues proposed a model that combines game theory and the network model to understand strategic decision-making in weapon system of systems (WSoS). Indeed, with the development of armaments, planning in terms of weapon systems evolves in an environment of competition with what is called competitive co-evolution. In the vocabulary of game theory, we consider that there is no single optimal solution but rather that there exists a set of efficient solutions or Pareto solutions which are characterized by the fact that their cost cannot be improved in one dimension without being degraded in another. The set of all Pareto solutions, the Pareto front, represents the trade-offs of the problem. A new approach in applied mathematics is proposed to management, based on the stochastic estimation of the evolution of Pareto efficient frontiers in n dimensions. With a combination of approaches based on stochastic optimization and artificial intelligence, we will be able to obtain optimal results. Innovative modeling considers interactions stimulated by inter-organization competition in a targeted strategic environment. We take as a main example forecasting for innovation in the strategic ecosystems of the aeronautics industry. We are thus targeting an ecosystem with which we have worked and with dual technologies that we know. Closer to operational and industrial expectations, we propose a dynamic model considering the full complexity of a strategic ecosystem fundamental to French sovereignty. The interdisciplinary method is placed in the field of project management and the tools associated with it.
Possibility to continue with a PhD (Yes/No): Yes	
REQUIRED APPLICANT PROFILE AND SKILLS	
Study Level	X Undergraduate students (3rd or 4th year) X Master students (1st year) ☐ PhD students

Objectives and work

Within the framework of this internship, a contribution will be made to a bigger project that covers the problem described in the section "Context".

The topic of game theory is the central topic of this internship. The intern is expected to first reproduce previous results, so that proper functioning of the software can be ensured. Then, the approach will be extended, by bringing in other artificial intelligence techniques. This latter part, the adoption of "knowledge-based" techniques and methods to address the identified needs, which will make it possible to propose and implement improvements to previously studied approaches. Such integration of these methods with mathematical approaches will open new opportunities. To make this a reality, the impact of these solutions on systems engineering practices will be addressed.

The work required, to be refined with the student upon arrival, will mainly concern the realization of the game-theory-based solution, the verification with respect to earlier results and the investigation of "knowledge-based" techniques and methods to enhance the approach.

The missions entrusted to the intern can be refined at the initiation of the project, and in an iterative manner during the project. This will mainly be:

- become familiar with the context, the objectives, and the systemic approach,
- carry out a state of the art on game theory and its application to the concerned domain,
- development of the game theory software,
- verification with respect to earlier results, and
- if time permits, investigation into "knowledge-based" techniques and methods.

This research initiation project requires very good programming skills.

References

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Required profile and skills

Programming knowledge

Other useful information