Title: Optimisation and invention within the factory 4.0.

Under supervision of professor Roland DE GUIO

Table of content

1 Summary in English :

The research topic takes place in the context of inventive design where the best solutions resulting from the optimization of existing systems cannot meet the objectives. In this case, the problem solving purpose is to find new ways of solving problems based on inventive principles, which are leading to solutions that meet the specifications of the problem. These so-called "inventive" problems are addressed through an approach that allows the problem to be formulated and represented in a canonical form thanks to the contradictions encountered when trying to solve the problem based on existing system models.

The thesis will focus on improving the automatic or semi-automatic identification and extraction of contradictions systems resulting from multi-objective optimizations of production systems. The applications will focus on the optimization and design of production systems with a cyber-physical system, and new products designed for the Internet of Things.

The PhD will be performed within the frame of the VIRTFAct project.

Keywords : TRIZ, industry 4.0, factory of future, optimisation, inventive design, simulation, IoT

2 Summary in Chinese 摘要

摘要：

本课题在创造性设计的背景下进行，其中最佳解决方案源于现有系统的优化。在这种情况下，解决问题的方式是找到基于发明原理解决问题的新方法，这些新方法用来规范解决方案。这些所谓的“创造性”的问题是通过允许问题制定，以规范的形式表示。出发点是矛盾。

博士课题将重点关注通过生成系统的多目标优化来改进矛盾的自动或半自动识别和提取。这些应用程序将侧重于使用网络物理系统优化和设计生产系统，以及为物联网设计的新产品。博士学位是在VIRTFAct项目的框架内进行的。

关键词: TRIZ, 工业4.0，未来工厂，优化，创新设计，仿真，物联网

3 Detailed description of the research

Digitization of the Simulation-Optimization- Problem Solving - Inventive design for industry 4.0 loop

3.1 Introduction: the loop and its application in our context

The purpose of this section is to introduce the links between design, optimization, simulation and performance improvements before providing the scientific context and issues we want to address in the next section.

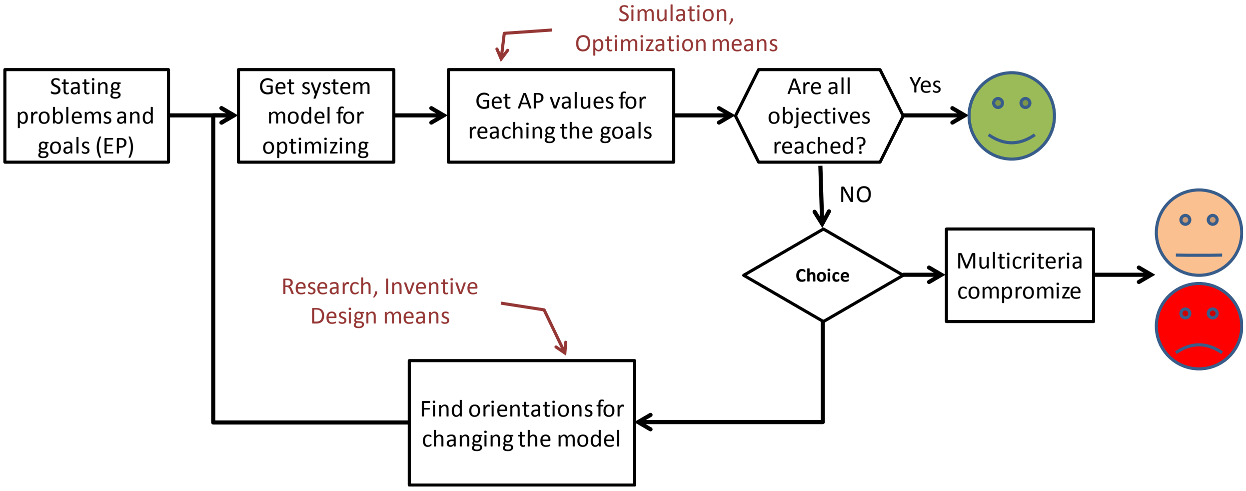

Figure 2 : Simulation loop optimization and inventive design

The problem of improving a production system is usually triggered by new performance expectations. After being stated, the problem must be modeled so that it can be addressed by simulators and optimization algorithms. In this type of problem, the parameters are separated into two main groups: (1) performance evaluation parameters (PE) that facilitate the evaluation of system performance and (2) action parameters (PA) that allow designers or optimization algorithms to seek a solution that meets the objectives. When the objectives are achieved, the problem is solved. Usually, there are several objectives. When resolving these objectives leads to a dilemma, a classic approach is to define a compromise between optimal Pareto solutions, none of which meets all the objectives. These solutions are the best solutions that can be found with the systems modeled in optimization algorithms and simulators. In the event of a dilemma, the only way to achieve a solution that meets the objectives is to change the existing system model to a new one that achieves the desired results.

The TRIZ methodologies make it possible to achieve this objective by qualitatively analysing, on the one hand, the correlations between the PEs to define dilemmas of objectives (DO) called technical contradictions (TCs) in the TRIZ and, on the other hand, to identify the PAs parameters at the origin of the technical contradictions. PAs reflect a design dilemma (DC) called physical contradiction (CP) in the TRIZ. Previous work has shown that it is possible to take advantage of the digital data generated during the optimization process to identify contradictions and improve the efficiency of the optimization process. It was also pointed out that the effectiveness of the so-called initial situation analysis phase could be improved by the use of data analysis tools. In addition, the use of TRIZ databases can speed up the resolution process.
In the context of the evolution of production systems, most problems have many parameters of action and multiple objectives. The advent of new technologies and the Internet of Things (IoT) will, on the one hand, create the need to evolve systems for many companies and, on the other hand, change ways of thinking and designing production systems and accelerate the frequency of

reconfigurations. We also wish to be able to use these tools to conduct our research on new system structures induced by the evolutions mentioned above, including energy, green and human issues in the context of industry 4.0.

3.2 Scientific context and research issues

The relevance and feasibility of this approach and tools have been evaluated in previous work and are promising [1-8]. Nevertheless, this work has also shown a problem that we will address in this project in order to facilitate the processing of cases with many parameters and to speed up the problem formulation process.
The link between multi-objective optimization and TRIZ has been shown. This contribution demonstrated the limitations of the TRIZ's contradiction model. In order to deal with this situation, the generalized system of contradictions was proposed. Subsequently, various researchers analyzed the problem of identifying generalized contradictions (association between objective dilemmas and associated design dilemmas) from the data and various techniques were proposed.

To date, the identification of objective dilemmas (DOs) is sufficiently effective for use in projects. On the other hand, the identification of design dilemmas (DCs) that cause objective dilemmas is not yet fully resolved. Indeed, the available algorithm is a brute force search algorithm with two disadvantages. The first of them is related to the calculation time. The search for all DCs is recognized as a difficult NP problem; in particular, the search time of the brute force algorithm increases exponentially with the number of PEs of the problem. Thus, this algorithm cannot be used when there are more than 13 PAs with 2 levels per parameter. The second problem is that there are often many DCs; the practical question is how to select the most interesting one or ones? In response to this question, it was proposed to use discriminant analysis techniques based on automatic learning methods (AML) to identify the parameters and values participating in the AMLs without knowing the AMLs, thus reducing the amount of data to be processed by the brute force algorithm. Tests of this approach on real cases have taught us that the joint use of data analysis methods and optimization methods can help to provide DCs. However, the practical disadvantage of this method is that it requires discrete optimization skills and data analysis skills that are not easily gathered during a reconfiguration project. The purpose of this research is therefore to build a method or heuristic so that DCs can be quickly obtained by engineers usually in charge of a reconfiguration project without additional resources.

The next step will be to evaluate and integrate these tools into production system design projects. It should be noted that these tools can also be applied in product design. They are also expected to be tested for the analysis of simulation results of multi-physical systems as part of the design of new meta-materials. These explorations contribute to an identified need for the design of innovative products for the plant of the future.

References :

1. Lin L, Rasovska I, de Guio R, Dubois S (2017) Optimization Methods for Inventive Design, chapter 7. In: Cavallucci D (ed) TRIZ – Theory Inven. Probl. Solving. Cavallucci, Denis, pp 151–185
2. Ben Moussa FZ, Rasovska I, Dubois S, De Guio R, Benmoussa R (2017) Reviewing the use of the theory of inventive problem solving (TRIZ) in green supply chain problems. J Clean Prod 142:2677–2692. doi: https://doi.org/10.1016/j.jclepro.2016.11.008
3. Dubois S, Maranzana N, Gartiser N, de Guio R (2017) A global approach to manage the performance of the problem solving process in innovative design. Int J Interact Des Manuf 11:351–363. doi: 10.1007/s12008-016-0357-9
4. Bach S, De Guio R, Nathalie G (2017) Combining discrete event simulation, data analysis, and TRIZ for fleet optimization. J Eur TRIZ Assoc Innov 4:47–61. 1.
5. Dubois S, de Guio R, Rasovska I,_Ben Moussa F, Benmoussa R (2017) From simulation to inventive problem resolution, a global method. In: Int. Conf. Eng. Des. ICED'17. pp 503–512
6. Lin L, Dubois S, de Guio R, Rasovska I_(2015) An exact algorithm to extract the generalized physical contradiction. Int J Interact Des Manuf 9:185–191. doi: 10.1007/s12008-014-0250-3
7. Dubois S, Rasovska I, de Guio R (2009) Towards an automatic extraction of Generalized System of Contradictions out of solutionless Design of Experiments. 3nd IFIP Work. Conf. Comput. Aided Innov. Growth Dev. CAI
8. Dubois S, Eltzer T, de Guio R (2009) A dialectical based model coherent with inventive and optimization problems. Comput Ind 60:575–583.

Candidate profile :

- Background in combinatorial and statistical optimization and/or computer science and mathematics.
- Ability to work in a multidisciplinary team