Contribution To A Methodology Of Mechatronic System Design : MODEL INVERSION AND UNCERTAINTY PROCESSING

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***Abstract*— This thesis aims to provide a systematic method for uncertainty processing in mechatronic systems design and furthermore, for tolerance synthesis.**

The problem of system design, in general, and/or the problem of sizing, in particular, aims to response the question: What system/component do we have to choose to satisfy the given specifications. For example, in a hoist engine, we desire to move the masse with a certain velocity, what motor do we have to use, and how should we adjust its parameters? In engineering, the system design problem is considered in the V cycle, which consists of 2 phases: from the client's specifications to the virtual prototype and from the virtual prototype to the production of real system.

In the process of system design, there are always uncertainties and imprecisions in the specifications and measures. Moreover, the produced components are usually not exactly the desired value, due to variations in the fabrication process. As consequence, we need to take into consideration the uncertainties, both in design process and in fabrication process, in order to improve the performance and robustness of system.

***Résumé*—**

I. CONTEXT AND PROBLEMATIC OF THE THESIS:

A. Context:

This thesis takes part in the European project ITEA2 OPENPROD: "Open model driven whole-product Development and simulation environment". The project is composed of 27 partners (laboratories and industrial companies) from 5 countries (France, Germany, Sweden, Switzerland and Finland). The project aims to develop an environment for modeling and simulation, which integrates Eclipse with the open-source tools of OpenModelica.

This thesis is in the theory study part of the project. Its works concern the mechatronic systems design with consideration of uncertainties.

B. Problematic:

The problem of system design, in general, and/or the problem of sizing, in particular, aims to response the question: What system/component do we have to choose to satisfy the given specifications. For example, in a hoist engine, we desire to move the masse with a certain velocity, what motor do we have to use, and how should we adjust its parameters?

In engineering, the system design problem is considered in the V cycle, which consists of 2 phases: from the client's specifications to the virtual prototype and from the virtual prototype to the production of real system.

In Ampère laboratory, a design methodology based on model inversion has been being developed for about 15 years. This methodology has proven its interest, compared with the direct method, in term of design time and real system performance.

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order to improve the performance and robustness of system.

This thesis aims to provide a systematic method for uncertainty processing in mechatronic systems design and furthermore, for tolerance synthesis.

II. Approach taken and justification from the literature:

A. For modeling: Bond graph

Justification: Bond graph is a multidiscipline language for modeling. Based on the concept of effort and flux, it can model an entire mechatronic system, which consists of several physic domains, in only 1 graph. The tools for model structure analysis and model inversion are already available in the works of JARDIN and EL FEKI.

For sizing: The system design methodology based on model inversion.

Justification: The methodology based on model inversion has proven its interest, compared to the direct method (try – error - correction), both in term of design time and real system performance. The criteria of inversibility and inversion procedures are well developed in the work of NGWOMPO and JARDIN, as well as some others in Ampère laboratory.

B. For uncertainty processing: Probability theory and fuzzy logic.

Justification: Uncertainties in a mechatronic system are classified into 2 classes: aleatory uncertainty, which is associated to the variability of a size, and epistemic uncertainty associated to the ignorance on a size. These 2 types of uncertainty have their respected tools for processing. The fuzzy logic considers the satisfaction level of a system performance, with respect to the desired performance. On the other hand, the probability theory treats the variability of real value of components in the fabrication, and hence the quality of production process. The result of fuzzy logic approach is used in quality control of a unit while the result on probability approach is used for the industrial massive production. These 2 approaches are therefore complementary and can be combined for a systematic process of uncertainty treatment in mechatronic system.

III. The work actualized:

- Research on the uncertainty processing in a mechatronic system design, using model inversion, probability theory and fuzzy logic.
- Proposition a designing methodology with consideration of uncertainty, which is attached to the V design cycle.
- The proposed methodology is applied on an example of sizing a continuous courant motor.
- The methodology is based on both probability theory and fuzzy logic, in the aim for a complete uncertainty processing in mechatronic system design. The comportment of system is considered in stationary state and dynamic regime, to consider also the system performance and constraint in transitive regime.
- The obtained result is not always ready for production (for example, not in the form of a normal law, which is demanded by the manufacturer, or there is a constraint to respect…). Therefore, we proposed an adaptation phase in order to modify the obtained result, for production.
- The result of probabilistic approach is used to determine the fabrication tolerance, whereas the result of fuzzy logic approach is used for system performance evaluation.
- Participating and presenting the research results at the meeting/seminars of project OPENPROD and group SEEDS.

IV. Conclusion and outlook:

A. Conclusion:

- The work of this thesis has taken into account the uncertainty in the methodology of mechatronic system design.
- The interest of designing by model inversion and the adaptation phase is proven.

B. Outlook:

- Formulation of the adaptation method, using a combination of probability theory and fuzzy logic
- Considering the results of multi variables case. We are also heading for an aleatory process
- Research for other mean of uncertainty propagation.