French Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes one of the PhD subjects proposed by the French Polytech network. The network is composed of 15 engineering schools/universities. The document also provides information about the supervisor. Please contact the PhD supervisor by email for further information regarding your application.

Supervisor information	
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PhD information	
Title	Relaible and Low-power Embedded System Design for embedded AI
Main topics regards to CSC list (3 topics at maximum)	Structure of new computer systems, IC Design, Techniques of simulation and application

Required skills in science and engineering	HDLs, Mathematics, Model-based approach, Reliability, Embedded system, programmation

Subject description (two pages maximum including biblio)

Nowadays, the digital revolution is driven by the creation and distribution of embedded systems in all application domains, as for embedded AI for example. The design and implementation of these electronic devices must meet several requirements:

- the implementation must guarantee the safety of the final product and its protection against failures which may be from accidental (reliability) or intentional (security) origin,
- for each service, the observed reactivity must improve both the provided service to the customer and reduce its production costs, supporting the required computation power,
- the object autonomy and its lifetime requirement must be satisfied.

The design and implementation of these connected and embedded systems while considering reliability and consumption are crucial multidisciplinary research themes. They are strongly constrained by development time requirements (”Time to Market” reduction), performance, cost and energy efficiency. A methodology framework is therefore needed to consider safety and energy consumption requirements from the upstream design phases.

Scientific problems

A major problem encountered during a system dependability study is the effectiveness and the realistic impact of ambitioned techniques on the system implementation while considering various dependencies. For example, how can we evaluate the impact of a reliability solution and its implementation on the energy consumption of the final system (multi-criteria problem). The design work must be based on a cost function to be defined and which produces a solution that achieve a trade off between the various expected properties. AI algorithms could be considered for this optimization process.

Another identified lock that will be considered, concerns the use of the adaptability properties of systems (dynamic reconfiguration). It is thus possible to introduce advanced reliability mechanisms by allowing the reconfiguration of the system in the event of failure of one sub part of it. This requirement results in the need of dynamic modeling for system characteristics in order to assess reliability, and a runtime management of the system under design.

Solving these 2 points requires the creation of models and methods which conduct to the design of embedded systems by taking into account operational safety [1], global energy consumption [2] and the possible reconfiguration of modern architectures. Another obstacle will then be to measure and be sure that the chosen formalism is suitable for the automation of the interpretation or the acquisition of these descriptions of feared situations.

The methodology therefore requires the implementation of a multi-criteria modeling [3] and an adequate methodology [4] to evaluate and mark the possible architecture to implement the embedded system. A multi-objective optimization algorithm (possibly AI-based) will also make it possible to search and find the optimal architecture without having to define the cost function of the system.

Goals and contributions

This thesis aims is to study the definition and the implementation of a model driven engineering methodology allowing the design of reliable and low-power embedded AI systems. The models will not only consider functionality, but also safety and security aspects on two key issues:

_ The adequacy between the risks (related to safety and security), effectively identified as likely in the system environment, and the measures implemented to control their impact,

_ The optimization of the product architecture and energy.

The research work will provide a methodology that :

_ is driven by models,

_ integrates operational safety requirements (reliability, security, safety),

_ takes into account models allowing the study of energy consumption,

_ optimizes the functional and physical architecture of such systems. This optimization should be carried out using a multi-objective approach (reliability, consumption) or from a cost function if available. Consideration of reconfiguration possibilities will also be integrated in the search for an optimized architecture.

The targeted application domain will mainly focus on embedded AI.

Context

The PhD will take place in Polytech'Nantes, but it is a join project with Polytech'Angers.

Preliminary bibliography

[1] Rausand, Marvin, and Arnljot Høyland. *System Reliability Theory: Models, Statistical Methods, and Applications*. 2nd ed. Wiley Series in Probability and Statistics. Hoboken, NJ: Wiley-Interscience, 2004.

[2] García-Martín, Eva, Crefeda Faviola Rodrigues, Graham Riley, and Håkan Grahn. "Estimation of Energy Consumption in Machine Learning." Journal of Parallel and Distributed Computing 134 (December 2019): 75–88. https://doi.org/10.1016/j.jpdc.2019.07.007.

[3] Snooke, Neal. "Model-Based Failure Modes and Effects Analysis of Software." (2004).

[4] Dubrova, Elena. Fault-Tolerant Design. New York: Springer, 2013.