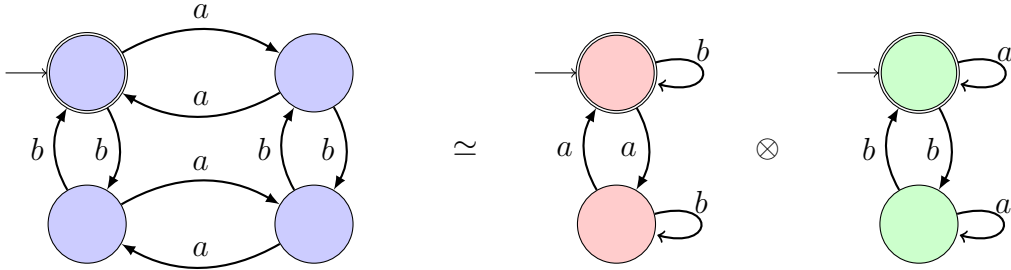# Finite State Automata Decomposition

proposed by
PIERRE-CYRILLE HÉAM et ISMAËL JECKER

1   Scientific Context and Objectives

The aim of formal methods is to develop reliable systems, i.e., systems that comply with their specifications. Many techniques and approaches have been developed to achieve this goal, and this work lies at the intersection of model-checking and system synthesis, also called realisability in this context.

In model-checking, the objective is to verify that a pre-designed system meets all specifications. This approach, which is effective for relatively small systems such as electronic components or protocols, quickly encounters high complexity and, in some cases, undecidability issues.

In realisability, the approach is dual: it starts from the specifications and attempts to automatically generate a system that satisfies all of them. However, as with model-checking, theoretical complexity makes this approach challenging for complex specifications.

Whether in model-checking or synthesis, finite automata-based models are frequently used, as they offer a good balance between expressiveness and algorithmic properties.

This thesis aims to study the decomposition of (possibly extended) finite automata to reduce problem complexity. By breaking down a specification into a conjunction of smaller properties, the model-checking problem naturally decomposes into multiple simpler subproblems. For synthesis, recent studies suggest that such decompositions could also be beneficial.

The problem of determining how to decompose an automaton into a product of smaller automata is a current research topic that has been studied in [5, 3, 4, 7, 6, 2, 1].

2   PhD Work

The proposed PhD work includes both theoretical and experimental aspects. Depending on the profile of the recruited student, it will be possible to focus more on one direction or explore both.

The key topics to be addressed during the PhD may include (but not restricted to):

- Review of the state of the art,

- Identifying subclasses of regular languages that are (efficiently) decomposable,
- Developing heuristics for decomposition,
- Studying the decomposition problem for more complex specifications, such as those based on logics,
- Developing approximation techniques for practical casess,
- Implementing techniques to empirically evaluate the effectiveness of the proposed approaches.

3   Work Environment

The PhD will be supervised by Pierre-Cyrille Héam and Ismaël Jecker.

Pierre-Cyrille Héam is a professor at Université Marie et Louis Pasteur (formerly Université de Franche-Comté) and specializes in algorithmic problems, particularly in finite automata theory. He has supervised eight doctoral students and currently has no PhD students.

Ismaël Jecker is associate professor at Université Marie et Louis Pasteur and specializes in finite automata for system verification. He is not currently supervising any PhD students.

A third supervisor, an assistant professor, may be recruited depending on ongoing hiring at Université Marie et Louis Pasteur.

The PhD will be conducted at DISC[1] (Department of Computer Science at the Femto-ST Institute[2]), CNRS.

An ANR-JCJC project (currently in second phase) may support the work.

Thesis students are paid the official salary for doctorates funded by the Ministry of Higher Education and Research, i.e. 2,200 euros gross per month[3] (approximately 1,800 euros net per month). Besançon is a fairly cheap city for France, where you can find decent accommodation for around 500 euros a month.

4   Application

Interested students should send an e-mail to the supervisors **before 20 May 2025** attaching

- a curriculum vitae
- grades obtained in the last two years (including those for the current year)
- if possible, a letter of recommendation or the name of a referee.

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As the subject may take a highly theoretical or more experimental direction, the profiles sought may be

- theoretical computer scientist
- a computer scientist with an interest in algorithmic issues and programming skills
- mathematicians (algebra, combinatorics, discrete mathematics) with an interest in fundamental computer science issues and basic programming skills

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[1] https://www.femto-st.fr/en/Research-departments/DISC/Presentation
[2] https://www.femto-st.fr/en
[3] https://www.enseignementsup-recherche.gouv.fr/fr/le-financement-doctoral-46472

It is required to speak either french or english.

Important points.

The thesis is due to start on 01 October 2025 but may be postponed.

It is not possible to start the thesis if the master's degree has not been completed, but it is possible to apply earlier.

The Femto-ST laboratory is at the heart of the Marie et Louis Pasteur University in Besançon, but is under the ZRR (restrictive area) regime. Any application accepted must be validated by the Ministry of Defence, independently of the University. This is an administrative formality (we currently have doctoral students from all over the world, including Africa, the Middle East and South America) that can take between two weeks and three months and may delay the start of the contract. This is a mandatory step.

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