Languages of Higher-Dimensional Automata

Master Internship Proposal – IRIF, Université Paris Cité

Supervisors: Emily Clement, Jérémy Ledent

Prerequisites: The intern should be interested in one or several of the following areas: automata theory, concurrency, logic, verification. Knowledge of higher-dimensional geometry is not required.

Context. Higher Dimensional Automata (HDA) [6] are a model of concurrent programs that extends the notion of finite-state automata by allowing events to occur simultaneously. They model true concurrency: this means that we are not only interested in pairwise commutation of events (as in interleaving concurrency), but also n-ary relations representing n processes running in parallel.

Like finite-state automata, HDAs have states (dimension 0) and edges between them (dimension 1). But they also include higher-dimensional cells: squares, cubes, hypercubes. In general, a cell of dimension n indicates that n events can happen simultaneously. Thus, HDAs have a geometric flavor [5].

A new notion of language for HDAs was recently introduced [3, 1]. HDAs recognise languages of pomsets, rather than words. A pomset is a kind of generalised word, in which the letters are partially ordered. When two events/letters a and b are not ordered, this means that they occur simultaneously. The picture below shows three possible executions of the program ab || cd, and their representation as paths in an HDA, and as pomsets.
Objectives of the internship

Since the introduction of pomset languages of HDAs, several classic results of automata theory have already been adapted to the setting of HDAs, such as a Kleene theorem [2] and a Myhill-Nerode theorem [4]. Yet, many questions remain open, as this is a very young area of research.

The first goal of the internship will be for the intern to familiarise themselves with higher-dimensional automata and pomset languages, by studying one existing result in the literature. Then, the student will investigate one open question, depending on what he or she is interested in. Examples of topics include (but are not restricted to):

- a Kamp theorem for HDAs. Define a temporal logic on pomsets, and compare the class of pomset languages definable by a temporal logic formula, to the class of pomset languages recognizable by HDAs.
- $\omega$-HDA. Define HDA languages for infinite executions, and compare different acceptance conditions (Büchi, Muller, parity). Prove an equivalence between $\omega$-HDA and $\omega$-regular expressions on pomsets.
- Model-Checking for HDAs. Given an HDA and a property (specified by a temporal logic or MSO formula), find an algorithm that can decide if that property holds for that HDA.
- Implementation. For more practice-oriented students, it would be interesting to implement, in their language of choice, a prototype of some algorithm found in the literature. For instance, the translation between HDAs and pomset regular expressions described in [2].

Additional information: The internship may involve interactions with researchers of the LRE laboratory (EPITA): Amazigh Amrane, Hugo Bazille, Uli Fahrenberg. The internship could lead to a PhD thesis if the student wishes to continue working on this topic, co-supervised by Uli Fahrenberg and Jérémie Ledent.

References


