LRE Partner +
WP3: Variants and Extensions of Higher-Dimensional Automata

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LRE, EPITA

ANR CHAAT KickOff



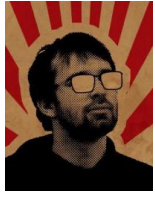
Laboratoire de Recherche de l'EPITA

- EPITA is a French graduate school specializing in computer science and software engineering.
- Its engineering degree is accredited by the French Commission des Titres d'Ingénieur (CTI).
- The EPITA Research Laboratory (LRE) is organized into five research groups:
  - AI
  - Security and Systems
  - Image Processing
  - Digital Humanities
  - **Automata and Applications**

LRE CHAAT Members



Amazigh Amrane
Automata Theory,
Concurrency
WP1, WP3, WP4
WP1, **WP3**, WP4



Hugo Bazille
Formal Methods,
Concurrency
WP1, WP3, WP4



Laetitia Laversa
Formal Methods,
Distributed Systems
WP3



Adrien Pommellet
Formal Methods,
Automata Learning
WP1, WP4



Enzo Erlich
Automata, Logic
Concurrency
WP1

WP3 at a Glance

WP3: Variants and Extensions of Higher-Dimensional Automata
Participants: LMF, LRE, IRIF, SMV

- **WP3.1 – Variants of HDAs**
  Amazigh Amrane, Hugo Bazille, Jérémy Dubut, Uli Fahrenberg, Jérémy Ledent, Noam Zeilberger.
- **WP3.2 – Higher-Dimensional Timed and Hybrid Automata**
  Amazigh Amrane, Hugo Bazille, Thomas Chatain, Emily Clément, Jérémy Dubut, Uli Fahrenberg, Benjamin Thibaut, Sven Dziadek, Philipp Schlehuber-Caissier.
- **WP3.3 – HDAs as Semantics for Concurrent Formalisms**
  Amazigh Amrane, Hugo Bazille, Benedikt Bollig, Thomas Chatain, Emily Clément, Uli Fahrenberg, Marie Fortin, Laetitia Laversa, Jérémy Ledent, Philipp Schlehuber-Caissier.

Precubical sets and higher dimensional automata

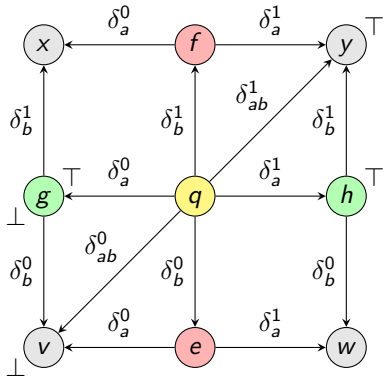
A conclist (concurrency list) is a finite, totally ordered and Σ-labelled set. (a list of events)

A precubical set X consists of:

- A set of cells X
- Every cell $x \in X$ has a conclist $\mathrm{ev}(x)$ (list of events active in x)
- We write $X[U] = \{x \in X \mid \mathrm{ev}(x) = U\}$ for an conclist U (cells of type U)
- For every conclist U and $A \subseteq U$ there are:
  upper face map $\delta^1_A : X[U] \to X[U - A]$ (terminating events A)
  lower face map $\delta^0_A : X[U] \to X[U - A]$ ("unstarting" events A)
- Precubical identities: $\delta^\mu_A \delta^\nu_B = \delta^\nu_B \delta^\mu_A$ for $A \cap B = \emptyset$ and $\mu, \nu \in \{0, 1\}$

A higher dimensional automaton (HDA) is a finite precubical set X with start cells $\bot \subseteq X$ and accept cells $\top \subseteq X$ (not necessarily vertices)

Example



$X[\emptyset] = \{v, w, x, y\}$

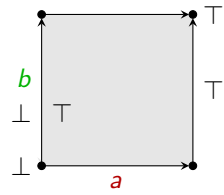
$X[a] = \{e, f\}$

$X[b] = \{g, h\}$

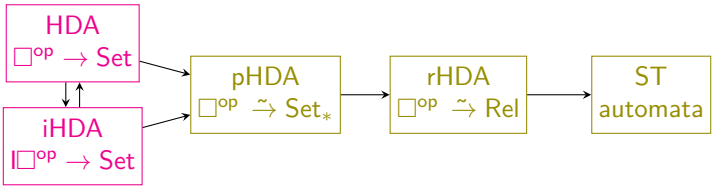
$X[[\begin{smallmatrix} a \\ b \end{smallmatrix}]] = \{q\}$

$\bot_X = \{v, g\}$

$\top_X = \{h, y, g\}$



WP3.1: Variants of HDAs [1]



Results

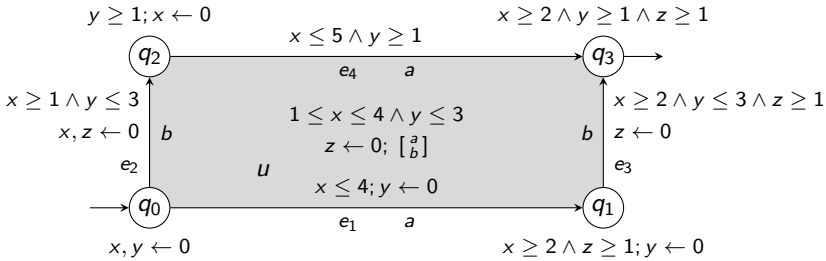
- Partial HDAs are determinizable.
- Simpler Kleene Theorem for pHDAs (à-la Thomson) using $\not\perp \sqsubseteq$ rat op.
- Language-wise $\downarrow \sqsubseteq$ and $\not\perp \sqsubseteq$.
- Material for WP1.

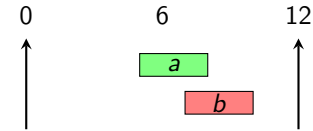
Open Questions

- MN, Büchi, Kamp Theorems?
- Which variant for ω-ipomsets
  - Büchi $\subseteq$ Muller $\subseteq$ ω-rational for ω-HDAs
- Why event order ?

[1] HB, JD, UF, KZ. *Variants of Higher-Dimensional Automata*, ICTAC'26.

WP3.2: Higher-Dimensional Timed and Hybrid Automata [2] [3]





Results

- Accepts pomsets with physical intervals
- Untimed languages of HDTAs are $\not\perp \sqsubseteq$

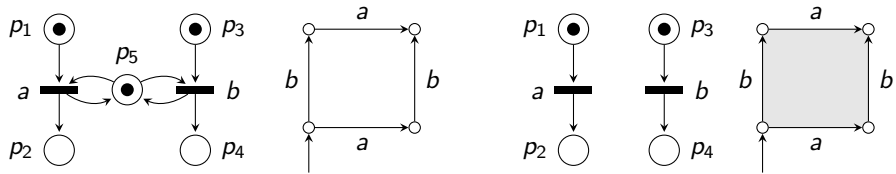
Open Questions

- Distances, Robustness?
- Relations of tipomsets with signals?

[2] UF. Higher-dimensional timed and hybrid automata. LITES'22
[3] AA, HB, EC, UF. Languages of Higher-Dimensional Timed Automata. PN'24

WP3.3: HDAs as Semantics for Concurrent Formalisms[4]

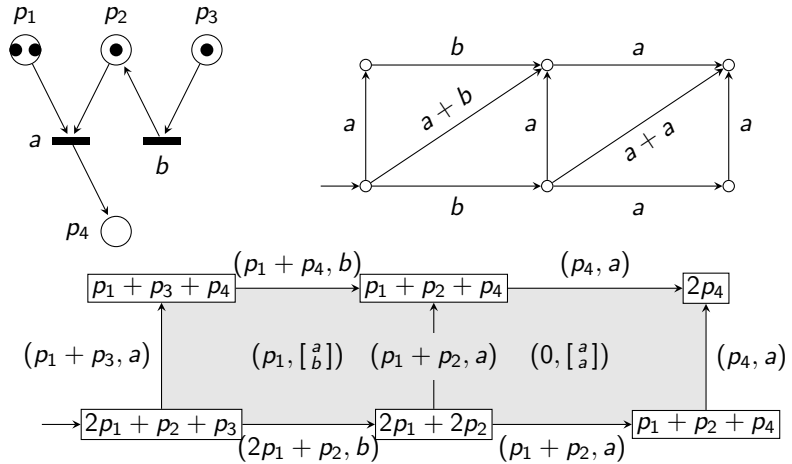
HDAs as an operational semantics of Petri Nets



[4] AA, HB, UF, LH, PSC. Petri nets and HDAs. PN'25

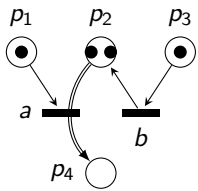
WP3.3: HDAs as Semantics for Concurrent Formalisms

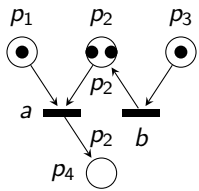
HDAs have a richer semantics

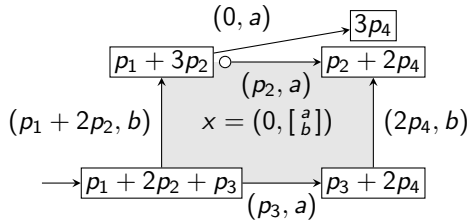


WP3.3: HDAs as Semantics for Concurrent Formalisms

Variants of HDAs are needed for some Petri Nets semantics







Open Questions

- What about other Petri Net semantics?
- What about timed Petri Nets?
- What about communicating automata?