AERES Evaluation

MExICo

Modelling and Exploitation of Interaction and Concurrency
MExICo: Created in 2009

ENS Cachan

Thomas Chatain
MdC

Paul Gastin
Head of CS Dept

Serge Haddad
Professor

CNRS

Benedikt Bollig
CR

INRIA

Stefan Haar
CR
MExICo: 2013

ENS Cachan

Thomas Chatain
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Paul Gastin
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Serge Haddad
Professor

Stefan Schwoon
MdC
INRIA Chair 2009

Claudine Picaronny
MdC
(Temp\textsuperscript{2013} \rightarrow MExICo)

CNRS

Benedikt Bollig
CR

INRIA

Stefan Haar
DR

Alban Linard
Research Engineer

Visitor 2009-2011

Marc Zeitoun
Pr. Univ. Bordeaux (LABRI)
### Past PhD student

<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
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<tbody>
<tr>
<td>Tali Sznajder</td>
<td>2009</td>
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<tr>
<td>Akshay S.</td>
<td>2010</td>
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<tr>
<td>Hilal Djafri</td>
<td>2012</td>
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<td>Sandie Balaguer</td>
<td>2012</td>
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<td>Benjamin Monmege</td>
<td>2013</td>
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### Current PhD students

<table>
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<tr>
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<tr>
<td>César Rodríguez</td>
<td>12/12/2013</td>
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<td>Aiswarya Cyriac</td>
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<td>Benoît Barbot</td>
<td>2014</td>
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<td>Hernán Ponce de León</td>
<td>2014</td>
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<td>Simon Theissing</td>
<td>2016</td>
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Mexico (Tenochtitlán), ca. 1524
MExICo, since 2009

Partial Orders
Partial Observation
Concurrency
Recursivity
Real Time
Quantities
Focus I: Partial orders

Concurrent and distributed systems need *partial orders*

- conceptually: exhibit *causal* dependencies
- computationally: fight *state space explosion*

Focus

- Distributed Synthesis
- Unfolding Semantics
Highlight: Distributed Synthesis

**Two problems**

- Decide the existence of a distributed program such that their joint behavior $P_1 || P_2 || P_3 || P_4 || E$ satisfies $\varphi$, for all $E$.
- Synthesis: If it exists, compute such a distributed program.
Highlight: Distributed Synthesis

Synchronous semantics: Introduced by Pnueli/Rosner 1990

- At each tick of a global clock, all processes and the environment output their new value
- DS Undecidable with global specifications
- DS Undecidable with constraints on internal channels
- DS Undecidable with bandwidth constraints

Asynchronous Semantics: Gastin, Lerman, Zeitoun

- Processes evolve asynchronously for local actions
- Synchronize by signals
- Specifications over partial orders

Positive Results

Synthesis problem is decidable for

- strongly-connected architectures,
- disjoint unions of decidable architectures.
Partial order unfoldings

The State Space Explosion Problem

- Need to explore behavior of concurrent systems:
  - Verification, Diagnosis, Control, Test, ...
- State graph size prohibitive

Therefore:

Use occurrence net unfoldings
Improving Unfoldings

**Contextual Petri Nets**
- Extension by **read arcs**
- Allow for independent concurrent **read actions**
- Contextual unfolding **up to exp-smaller**
- Implemented in **CUNF tool**

**Other improvements**
- **Merged processes**
- **Reveals** Relations: Implication between events, contraction
Focus II: Partial Observation

- Active Diagnosis
- Weak Diagnosis
- Test
Partially observable Systems and Diagnosis

Assumptions

- Possible behaviours well-known
- Current execution only partially visible

Goal:

- Determine, from partial observations, whether a certain event (fault) has happened in the past.
Active Diagnosis

A system with an *ambiguous* pair of runs is not diagnosable

In that case: Compute *control*

- based on past observations
- so that faults manifest themselves through observations

Our Results

- Memory Consumption down from $2^{O(n)}$ to
  - $2^{O(n^2)}$ with minimal diagnosis delay
  - $2^{O(n)}$ with *twice* the minimal delay

- Computational complexity shown *optimal*
Quick Tour 1: Quantities

- Stochastic Systems
- Weighted Systems
Quantities: Stochastic Systems

**Product Form** (Stochastic) Petri Nets: most open problems solved

- sound and complete set of rules to synthesize Petri net with invariant measure in *product form*
- complexity class of standard problems (liveness, reachability, coverability)
- Structurally characterized subclass with computable invariant measure
- Petri Nets (ICATPN) 2011 *outstanding paper award*

**Statistical and Rare Events Model Checking**

- Logic HASL: path behavior performance
- Tool COSMOS

**Active Probabilistic Diagnosis**

under way
**Quantities: Weighted Automata and Weighted Logics**

### Weighted Models
- Introduced **weighted** versions of MSO and CTL
- These weighted logics generalize boolean and probabilistic counterparts
- Allow to include additional quantities, e.g. energies and rewards

### Contributions
- Probabilistic Kleene Theorem
- Applications in XML query evaluation
- Further Extensions for MSO
  - ... to pebble models
  - ... to infinite alphabets
Quick Tour 2: Recursivity

Concurrent Recursive Systems
- Unifying framework: partial orders with nesting
- Model checking \textit{decidable} in elementary time for \textit{any} temporal logic
- \textit{Decidability} for MSO model checking of Multi-Pushdown Systems under bounded split width
Quick Tour 3: Real Time

- Interplay: Concurrency ↔ timing
- Distributed Timed Systems
Real Time: Timed Systems and Concurrency

Interplay concurrency ↔ timing

- Networks of TA versus TPN: Concurrency-preserving translation
- Interactions between TAs: when can clock sharing be avoided?

Distributed Timed Systems

- Distributed timed automata with *independently* evolving clocks
- Natural semantics: existential/universal/game-based
- Model-checking problems:
  - Decidable for safety properties
  - Undecidable for liveness properties
  - Decidable for liveness properties wrt. under-approximation
**Publications**

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<th></th>
<th>'13</th>
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**Platform COSYVERIF (→ MeFoSyLoMa group), includes:**

- COSMOS for stochastic model checking
- CUNF for unfolding of contextual nets
- 2 outstanding paper awards: Petri nets (ICATPN) 2011 + 2013
- Tutorials ICATPN, WATA; Invited Talks: DCFS, CIAA, DLT, ...
- Co-organization of CONCUR 2010
- Co-direction of CNRS international lab (LIA) INFORMEL with CMI, India
- Several PCs, SCs, Editorial boards
- Teaching: ENS, MPRI and more
Major Partners

Île de France
- MeFoSyLoMa and more: LIP 6, LIAFA, LIPN.

France
- Rennes (SUMO, IRISA)
- Bordeaux (LABRI)
- Nancy (VERIDIS, LORIA)

Europe
- Germany: München, Lübeck, Aachen
- Italy: Padova, Torino, Milano
- Spain: Zaragoza
- UK: Newcastle

Beyond
- India
- Chile, Argentina
### Projects completed or under way

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<th>FP 7 UNIVERSELF</th>
<th>Self-aware networks</th>
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<td><strong>NoE Hycon2</strong></td>
<td>Highly complex and networked control systems</td>
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<td><strong>ANR</strong></td>
<td><strong>IMPRO</strong>: Robustness and implementability of timed systems</td>
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<td><strong>DIGITEO</strong></td>
<td><strong>COCHAT</strong>: Covered channels in Timed Systems</td>
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<td><strong>LOCOREPS</strong>: Recursive concurrent logics</td>
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<td><strong>TECSTES</strong>: Conformance testing using event structures</td>
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Into the Future I: Some New Paths

**Distributed Algorithms**
- Variable number of entities, variable topologies
- Parametrized verification

**Exploration: new application fields**
- *Supervision in multi-modal transport systems*
  IRT SystemX : (started 2013)
Into the Future II: Continuity

More on partially observed and concurrent systems

- Stochastic Diagnosis and Opacity over MDPs or partial orders
- Enhance unfoldings + reveals
- Address fairness

Partial Order Logics

- Identify relevant, tractable fragments
- Develop efficient and distributed verification algorithms

Weighted Models

Based on semi-ring models, develop general quantitative verification techniques
Thanks!