CRISTAL
(2009-2012)
Contrôle des Ressources par Interprétations Sémantiques et Théorie de la démonstrA tion Linéaire

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November 15, 2012
Cristal belongs to Implicit Computational Complexity (ICC) that aims at:

- Providing **machine independent** characterizations of complexity classes
- Studying **resource consumption** on several programming paradigms:
  - Functional
  - Imperative and object-oriented
  - Concurrent (multi-threaded) calculi
  - ...
Applications

- Programme
- Analyse statique
- Programme certifié

- space upper bounds (heap, stack, ...)
- time upper bounds (instructions, recursive calls, ...)
ICC Tools

- ICC uses distinct static analysis tools and methodologies:
  - Linear logic (Soft and Light logics)
  - Interpretations (abstract, quasi-and sup-interpretations)
  - Termination techniques for TRS
  - Type systems
  - Second order logic and function algebra

- Practical motivations:
  - Distributed systems have increased the need for program correctness and certification.
  - Certifying runtime properties is of central importance for small and mobile devices with bounded computational resources that receive programs to be executed.
Light logics
TRS based techniques
Light logics
TRS based techniques
Type systems
Light logics
TRS based techniques
Type systems
Abstract interpretations
- Light logics
- TRS based techniques
- Type systems
- Abstract interpretations
- Quasi and sup-interpretations
Light logics : Turin
TRS based techniques
Type systems
Abstract interpretations
Quasi and sup-interpretations : Nancy
Formal methods in computing, Dipartimento di informatica, Universita degli Studi di Torino:

- **Simona Ronchi Della Rocca**, PR, principal investigator
- **Luca Roversi**, assistant PR
- **Marco Gaboardi**, postdoc (now in U. Penn.)
- **Mauro Piccolo**, postdoc
- **Luca Vercelli**, PhD student (has left CRISTAL in 2010)
- **Maurizio Dominici**, PhD student since 09/2010
- **Erika De Benedetti**, PhD student since 09/2011
French participants

- EPI Carte, Inria Nancy Grand-Est and UL:
  - Romain Péchoux, assistant PR, principal investigator
  - Guillaume Bonfante, assistant PR
  - Jean-Yves Marion, PR, team leader
  - Hugo Féréé, PhD student since 9/2011
The collaboration has led us to several results:

1. Characterizations of complexity classes based on Lafont’s Soft Linear Logic (SLL)
2. Development and study of a resource lambda-calculus
3. Interpretations for studying stream complexity
4. Non-interference based type systems
1. SLL based characterizations

Linear Logic (LL) is a modal logic where premises are interpreted as physical resources having the same power as System F.

Soft Linear Logic (SLL) is a restriction to PTIME extended by:

- STA ≡ (F)PTIME [TYPES 08]
- ISTA ≡ (F)PTIME and SN with intersection types [ITRS12]
- PSTA ≡ NPTIME [LSFA 08]
- BSTA ≡ PSPACE [POPL 09, ACM TOCL 11]
2. Theoretical study of a resource lambda-calculus

Syntax introduced in [FOSSACS 10]:

\[ M, N, \ldots ::= x \mid \lambda x. M \mid (M \ P) \mid M + N \] (terms)

\[ P, Q, \ldots ::= [M_1, \ldots, M_n] \] (bags)

The \(\beta\)-rule becomes:

\[(\lambda x. M)[\ ] \rightarrow_\beta M\{0/x\} \quad (\lambda x. M)[N] \cdot P \rightarrow_\beta (\lambda x. M\langle N/x\rangle) P\]

- 0 is the neutral element of the sum
- \(\{0/x\}\) is the usual \(\lambda\)-calculus substitution
- \(\langle N/x\rangle\) i is the linear substitution, i.e., replacing one occurrence of \(x\) at a time.

This calculus has also been extended to a non-linear fragment.
3. Interpretations for studying stream complexity

Criteria based on interpretations ensuring:

- A local (global) upper bound \( F \) in [CSL 09], [I&C 2012]
- A synchrony upper bound \( G \) in [FOPARA 10]
- Characterization of type-2 polynomial time complexity (related to BFF) in [ISAAC 10]
The type system [LICS 10] captures FPtime on an imperative language using:

- Non-interference type system by Volpano and Smith
- Tiering techniques by Leivant-Marion and Bellantoni-Cook

The essence is as follows:

\[
\begin{align*}
X & : \alpha \\
E & : \beta \\
X & := E : \alpha \\
\alpha & \leq \beta
\end{align*}
\]

\[
\begin{align*}
E & : 1 \\
C & : \alpha \\
\text{while}(E) \text{do}\{C\} & : 1 \\
\alpha, \beta & \in \{0, 1\}
\end{align*}
\]

Extended to:

- FPspace with processes using fork/wait instructions
- Multi-threads working in polynomial time
Publications (2009-2012):

24 publications in ICC (16 conferences and 8 journals):

- **3 journal co-publications:**

- **3 conference co-publications:**
  - Global and local space properties of stream programs. In FOPARA 2010.
  - A Logical Account of PSPACE. In POPL 2009.

- **Good publication record in:**
  - conferences like POPL, LICS, ICFP, ESOP,...
  - journals like TCS, I&C, ACM TOCL, ...
Conclusion:

- An active community with two main annual events:
  - DICE, ETAPS affiliated workshop
  - LCC, LICS affiliated workshop
- In particular, the EA helped to:
  - fund and organize DICE 2011.
  - fund members travels and stays between distinct sites (Torino, Bologna, U. Penn. and Nancy).
  - fund PhD students (there were 5 students from 2009 to 2012).
Future?

Complexity of stream programs...