Types in Computation and Communication

Silvia Ghilezan
University of Novi Sad
Serbia

ELTE , Budapest, 27/02/2014

University of Novi Sad

Faculty of Technical Sciences

Some figures

University of Novi Sad 

- 14 faculties (Science, Engineering, Medicine, Law, Arts)
- 45.000 students

Faculty of Technical Sciences - FTN 

- 12.000 students
- 11 departments (Electrical, Mechanical, Civil, Traffic, Architecture, Environmental, Computer Sciences)
- BSc, MSc, PhD
- 1 general department: Mathematics (35) and Physics (15)
- MSc, PhD

Mathematical Institute SASA, Belgrade 

Our research group

Computation, Concurrency, Logic and Reasoning - Co^2LoR

- Silvia Ghilezan, Professor,
- Jovanka Pantović, Professor
- Jelena Ivetić, Assistant Professor
- Svetlana Jaksić, Teaching Assistant, PhD student
- Jelena Čolić, Teaching Assistant, PhD student
- Andrijana Stamenković, PhD student
- Jovana Obradović, PhD student
- Jovana Radenović, PhD student
- Nenad Savić, PhD student
- Dragiša Zunić, Assistant Professor, (PhD, ENS-Lyon)

Group members abroad / former group members

- Petar Maksimović, INRIA Rennes (PhD cotutelle UNS, University of Nice)
- Silvia Likavec, U. Torino, (PhD cotutelle U. Torino, ENS-Lyon)
- Viktor Kunčak, EPFL Lausanne, (PhD MIT)

Projects

Accomplished projects:

- FP6 TYPES - Types for Proofs and Programs, (2004-2008)
- Tempus DEUKS - Doctoral School towards European Knowledge Society (2007- 2009)
- COST Rich-Model Toolkit - An Infrastructure for Reliable Computer Systems (2009-2013)
- Bilateral with CNRS TLIT - Types and Logic in Information Technologies (2007-2010)
- Bilateral with Slovenia: Distance learning in the area of computer supported mathematical education (2006-2007)

Projects

Ongoing Projects:

- COST BETTY - Behavioural Types for Reliable Large-Scale Software Systems
- COST COSCH: Colour and Space in Cultural Heritage
- SEMACODE - INRIA associated team
- Bilateral with France Logic and Types in Foundation of Information Technologies
- Bilateral with Italy DART Dynamically and Autonomously Reconfigurable Types

Activities

- Summer School FIT 2009 - Foundations of Information Technologies
- Conference RDP 2011
  - RTA 2011 - Rewriting Techniques and Applications
  - TLCA 2011 - Typed Lambda Calculi and Applications
  - workshops:
    - Compilers by Rewriting, Automated (COBRA)
    - Higher Dimensional Type Theory (HDTT)
    - Theory and Practice of Delimited Continuations (TPDC)
    - Two Faces of Complexity (2FC)
    - Reduction Strategies in Rewriting and Programming (WRS)
    - IFIP Working Group 1.6 Term Rewriting
- Workshops
- Seminars
- Working groups

Types in computation

Duality of Computation
- Delimited continuation

Types in communication
- Linked documents
- Linked data

Types in computation

Duality of Computation
- Delimited continuation

Types in communication
- Linked documents
- Linked data

Curry - Howard - Lambek - de Bruijn

INTUITIONISTIC LOGIC	TERM CALCULUS
Axiomatic system	Combinatory Logic
Natural Deduction	λ-calculus
Sequent system	???

- 1950s Curry
- 1968 (1980) Howard formulae-as-types
- 1970s Lambek - CCC Cartesian Closed Categories
- 1970s de Bruijn AUTOMATH

intuitionistic logic vs term calculus

$$\vdash A \quad \Leftrightarrow \quad \vdash t : A$$

Curry-Howard correspondence

$$\vdash A \quad \Leftrightarrow \quad \vdash t : A$$

formulae –as– types

proofs – as – terms
proofs –as– programs

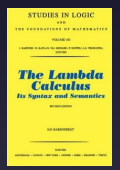
proof normalisation –as– term reduction
cut elimination –as– term reduction

Pierce's law not inhabited

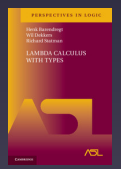
More types

- Barendregt's cube consists of 8 calculi:
  - $\lambda\rightarrow$, $\lambda 2$, $\lambda\omega$, $\lambda\underline{\omega}$, PL: Haskell, Clean
  - λP, $\lambda P2$, $\lambda P\omega$, $\lambda P\underline{\omega}$ PL: Agda, Coq
- recursive types
- intersection types PL: Forsythe
- variants of λ-calculus: λLJ, $\overline{\lambda}$, $\lambda^{Gentzen}$, $\lambda_{\circledR}$...

References:



H.P. Barendregt.
Lambda Calculus: Its syntax and Semantics.
North Holland 1984.



H.P. Barendregt, W. Dekkers, R. Statman.
Lambda Calculus with Types.
Cambridge University Press 2013.

Publications

S. Ghilezan, J. Ivetić, P. Lescanne, and S. Likavec.

Intersection types for the resource control lambda calculi.

ICTAC 2011, LNCS 6916: 116-134 (2011)

J. Espírito Santo, S. Ghilezan, J. Ivetić.

Characterizing strongly normalising intuitionistic sequent terms.

TYPES 2007, Lecture Notes in Computer Science 4941: 85-99 (2007)

S. Ghilezan, S. Likavec.

Reducibility: a ubiquitous method in lambda calculus with intersection types.

ITRS 2002, ENTCS 70 (2003)

S. Ghilezan, V. Kunčak.

Confluence of Untyped Lambda Calculus via Simple Types.

ICTCS 2000, LNCS 2202: 38-49 (2001)

H. P. Barendregt, S. Ghilezan.

Lambda terms for natural deduction, sequent calculus and cut-elimination.

Journal of Functional Programming 10(1): 121-134 (2000)

Computational interpretations of classical logic

- Griffin 1990

  formulae-as-types notion of control (axiomatic)
- Parigot 1992

  $\lambda\mu$ *algorithmic interpretation of classical logic (natural deduction)*
- Barbanera, Berardi 1996

  Symmetric lambda calculus - classical program extraction (sequent)
- Curien, Herbelin 2000

  $\bar{\lambda}\mu\tilde{\mu}$ *symmetric lambda calculus - duality of computation (sequent)*
- Wadler 2003

  Dual calculus (all connectives) - duality of computation (sequent)
- Urban 2000

  X *symmetric lambda calculus - cut elimination in classical logic (sequent)*
- Lescanne, van Bakel 2005

  X^* *symmetric lambda calculus - diagramatic calculus functional calculus (sequent)*

Duality of computation: Call-by-value, Call-by-name

Curien, Herbelin $\overline{\lambda}\mu\widetilde{\mu}$-calculus (sequent)
Non-confluent due to a critical pair.
Cut-elimination in classical logic is not confluent.
Two confluent subsystems of $\overline{\lambda}\mu\widetilde{\mu}_{CBV}$ and $\overline{\lambda}\mu\widetilde{\mu}_{CBN}$.

- Strong normalization of CBV and CBN: CPS translations of *overline*$\lambda\mu\widetilde{\mu}_{CBV}$ and $\overline{\lambda}\mu\widetilde{\mu}_{CBN}$ into simply-typed λ-calculus
- SN of free reduction?
- Characterization of SN with intersection types?
- Pierce's law inhabited - $\mathrm{call/cc}$!

$$\lambda x.\mu\alpha.\langle x \parallel (\lambda y.\mu\beta.\langle y \parallel \alpha\rangle) \bullet \alpha\rangle : ((A \to B) \to A) \to A$$

Delimited continuation

- $\lambda\mu$: call-by-name Parigot, de Groote classical natural deduction
- Böhm separability and the maximality of equality $\lambda\mu$ versus $\Lambda\mu$
- $\Lambda\mu$ with a top-level dynamic continuation: a calculus for call-by-name delimited continuations
- Shift and reset (Danvy and Filinski), control and prompt (Felleisen: F, $\sharp$)
- $\overline{\lambda}\mu\widetilde{\mu}$ calculus: classical sequent calculus - uniform framework for CBN and CBV delimited continuation - ongoing work

Publications

H. Herbelin and S. Ghilezan.

An approach to call-by-name delimited continuations.

POPL 2008 383-394.

D. Dougherty, S. Ghilezan and P. Lescanne.

Characterizing strong normalization in the Curien-Herbelin symmetric lambda calculus: extending the Coppo-Dezani heritage.

Theoretical Computer Science 398: 114-128 (2008).

D. Dougherty, S. Ghilezan, P. Lescanne, S. Likavec.

Strong normalization of the Dual classical calculus.

LPAR 2005, Lecture Notes in Computer Science 3835: 169-183 (2005).

D. Dougherty, S. Ghilezan and P. Lescanne.

Characterizing strong normalization in a language with control operators.

PPDP 2004 155-166.

Curry-Howard paradigm extended

COMPUTATION	COMMUNICATION
determinism	non-determinism
term	process
sequential composition	concurrency
computational behaviour	interactional behaviour
λ calculus	π calculus

Curry-Howard paradigm:

formulae – as – types
proofs – as – terms
proofs – as – programs
proofs – as – processes

Linked documents: $Xd\pi$ calculus

- π*calculus*: Process calculus (R. Milner)
- $d\pi$*calculus*: distributed process calculus with locations (M. Hennesy)
- $Xd\pi$*calculus*: distributed process calculus with XML documents (Ph. Gardner, S. Mefais)

Type system for $Xd\pi$*calculus*

- The proposed type system for $Xd\pi$*calculus* enjoys subject reduction
- As a consequence, several security properties for handling web documents are obtained.

Linked data

- WWW
  Setting hyperlinks between Web documents.
  Standards: URIs, HTTP protocols, HTML language.

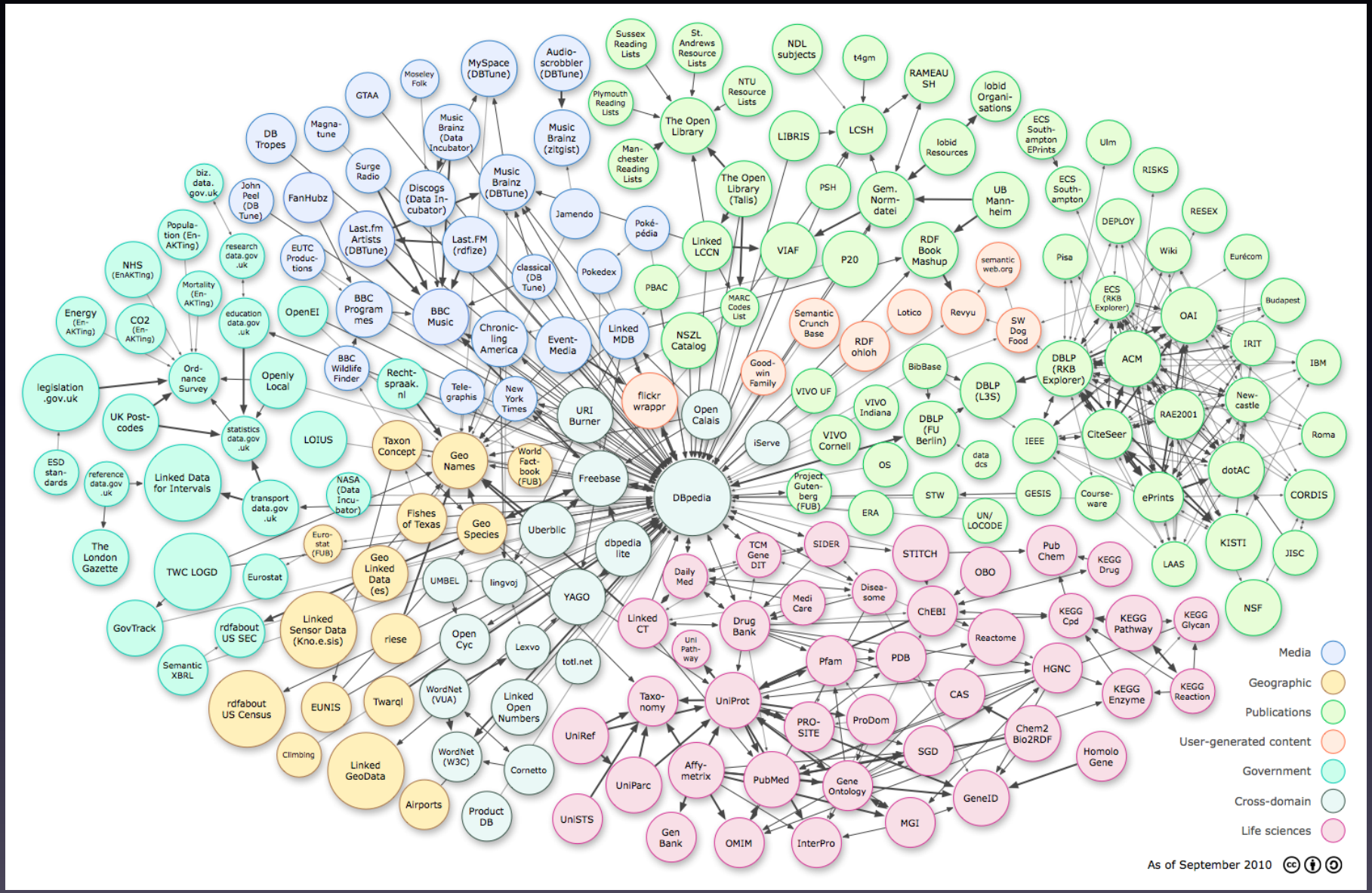
- Web of Linked Data
  Google, Yahoo, Amazon, eBay... provided access to data bases through different Web APIs (Application programming interfaces).

- Technologies: URIs (Uniform Resource Identifiers), RDF (Resource Description Framework), SPARQL, Marbel (linked data web browser) ...

- W3C project: Semantic Web
  http://www.w3.org/standards/semanticweb/

- Published Data: media, publications, life sciences, geographic data, DBpedia, e-government, user-generated content including profiles from social networks and blogs ...

Linked Data Cloud



Privacy

- Linked Data Calculus, C. Bizer, T.Heath T. Berners-Lee
  - Safety
  - Security
  - Privacy
- Privacy may not include just private status of some data but also significance or non significance of data for some group and the ability of users to understand the data properly.

Types as tools for safety, security and privacy:

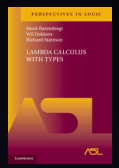
- The types system is sound w.r.t. the reduction rules (subject reduction).
- As a consequence, several privacy properties are preserved along the computation

Publications

- S. Ghilezan, S. Jakšić, J. Pantović, M. Dezani-Ciancaglini:
  Types and Roles for Web Security.
  Transactions on Advanced Research, 8:16-21 (2012).
- M. Dezani-Ciancaglini, S. Ghilezan, S. Jaksić, J. Pantović.
  Types for Role-based Access Control of Dynamic Web Data.
  WFLP'10 - Functional and Constraint Logic Programming, LNCS 6559: 1-29 (2011).
- M. Dezani-Ciancaglini, S. Ghilezan, J. Pantović, and D. Varacca.
  Security types for dynamic web data.
  Theor. Comput. Sci., 402(2-3):156–171 (2008).
- M. Dezani-Ciancaglini, S. Ghilezan, J. Pantović
  Security types for dynamic web data.
  TGC'06- Thrustworthy Global Computing, LNCS 4661: 263-280 (2006).
- S. Ghilezan, S. Jakšić, J. Pantović:
  Privacy for Linked Data.
  submitted.

Joint work with

- Henk Barendregt, *Radboud University, Nijmegen, The Netherlands*
- Mariangiola Dezani-Ciancaglini, *University of Torino, Italy*
- Daniel Dougherty, *Worcester Polytechnic Institute, USA*
- Jose Espírito Santo, *University of Minho, Braga, Portugal*
- Hugo Herbelin, *INRIA, Paris, France*
- Jelena Ivetić, *UNS*
- Svetlana Jaksić, *UNS*
- Viktor Kunčak, *EPFL Lausanne, Switzerland*
- Pierre Lescanne, *ENS Lyon, France*
- Silvia Likavec, *University of Torino, Italy*
- Jovanka Pantović, *UNS*
- Daniel Varacca, *Université Paris 7, France*
- Betty Venneri, *University of Florence, Italy*
- Dragiša Žunić, *UNS*
- Joviša Žunić, *University of Exeter, UK*



H.P. Barendregt, W. Dekkers, R. Statman.
Lambda Calculus with Types.
contributors F. Alessi, H, Barendregt, M. Bezem, F. Cardone, M. Coppo, W. Dekkers, M. Dezani-Ciancaglini, G Dowek, S. Ghilezan, F. Honsell, M. Moortgat, P. Severi, R. Statman, P. Urzyczyn.
Cambridge University Press 2013.

S. Vilani.
Živa teorema
translation from French of the book by Cédric Villani: Le theorem vivant.
2013

S. Ghilezan, L. Paolini.
Intersection Types and Related Systems.
Fundamenta Informaticae 2012.

Acknowledgments

- Magyar Tudományos Akadémia Domus Hungarica ösztöndij 2014
  Host: Zoltán Horváth
  Tibor Lukity

- ICFP 2013, Boston
  Zoltán Horváth, Gergely Devai

Announcements

- LAP 2014, Dubrovnik, Croatia, September 22-26, 2014

  SD 2012, LAP 2013 http://imft.ftn.uns.ac.rs/math/cms/LAP2013
- BEAT 2014, Rome, Italy, September 1, 2014
  collocated with CONCUR 2014

  http://beat2014.behavioural-types.eu/