SOFTWARE INDUSTRY AND TELECOMMUNICATION NETWORKS

THEMATIC EXCELLENCE PROGRAM 2019
INDUSTRY AND DIGITALISATION APPLICATION DOMAIN SPECIFIC HIGHLY RELIABLE IT SOLUTIONS

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NATIONAL RESEARCH, DEVELOPMENT AND INNOVATION OFFICE HUNGARY

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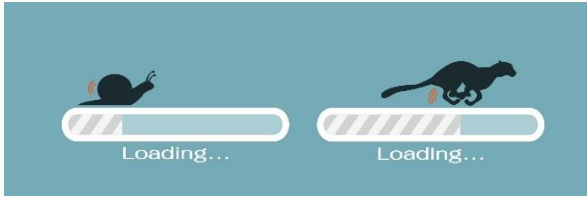
Software industry and telecommunication networks

- Huge complexity of software systems

- Checking reliability and correct behaviour

- Other requirements such as performance, scalability, energy-consumption, etc.



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Software industry and telecommunication networks

- ~~Dedicated hardware for specific tasks~~
  - ~~Expensive, rigid, scalability issues~~

- Network function as software (VNF)
  - Cheap, flexible, scalable, performance limitation
  - Running on commodity servers (x86, ARM)

- Programmable switches
  - Not so expensive, flexible, scalable, high performance
  - Network prog. language: P4, pipeline computing model, many restriction and contraints

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Research Group








- Erzsébet Csuhaj-Varjú (DSc)
  - Investigation of reaction systems
- Ambrus Kaposi (PhD)
  - Quotient inductive types in Martin-Löf type theory
- Dániel Horpácsi (PhD)
  - High assurance refactoring
- Melinda Tóth (PhD), István Bozó (PhD)
  - Static source code analysis and transformation for Erlang
- Sándor Laki (PhD), Gergő Gombos (PhD), Péter Vörös (PhD)
  - Deeply programmable networks and their applications
  - Future Internet transport and in-network Quality of Service
  - Resource management in next generation heterogeneous networks

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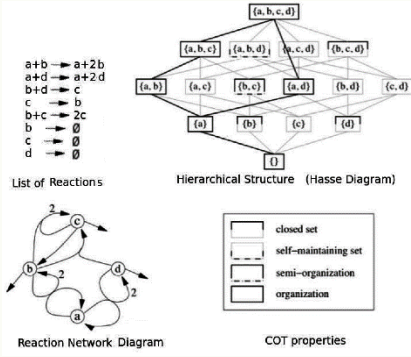
Reaction Systems Theory

- A **new, dynamically evolving field** of **unconventional computing**
- It allows for a **better understanding** of certain **biochemical phenomena** and **intermolecular** processes
- It can also be used for **modeling complex distributed systems**



- We described the reversible processes of reaction systems and examined how to interpret known reversible computational models in the terminology of reversible reaction systems.

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Type Theory-based Program Verification

- Industrial software systems are **extremely complicated**
  - and are **riddled with errors**
- Programming languages **don't enforce writing correct programs**
- We **develop a programming language** in which arbitrary **properties** of a program can be **expressed and proved**
  - **correctness of programs is ensured by the language**

- We developed the **theoretical foundations** for our language
  - called **setoid type theory**
- We showed that the new language can **describe programming languages and formalize their properties**.

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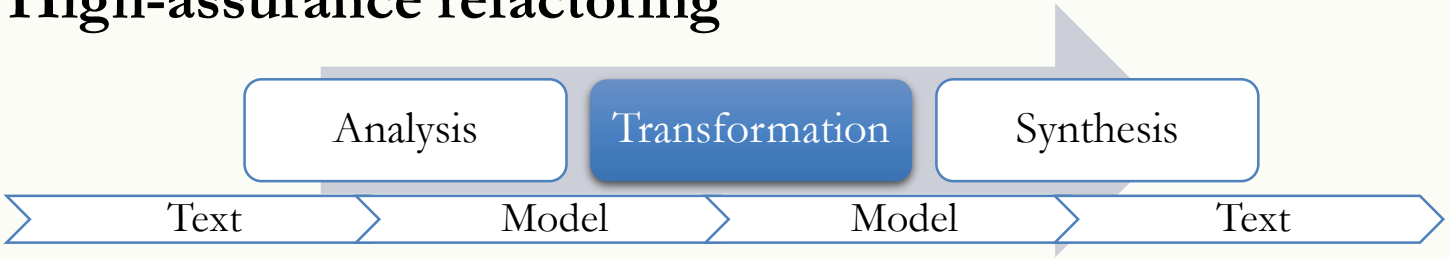
High-assurance refactoring



- Refactoring: **program transformations to optimize the code**
- High-level **refactoring specification language**
- Semi-automatic formal **verification for correctness**
  - **static verification of the transformation definition**

- **Formalization** of Core Erlang and Applicative Matching logic, eq. proofs
- **Prototype** implementation
  - https://github.com/harp-project

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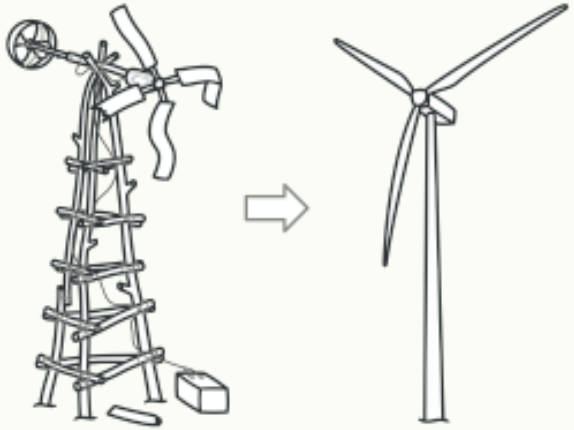
Static source code analysis and transformation for Erlang

- Static program analysis and transformation
  - **secure and reliable software**
- Different refactoring **objectives**
  - including **energy efficiency, performance**
- Mainly for the Erlang programming language,
  - with possibility of **adaptation to other languages**



- Tools for supporting **secure coding and measuring software reliability**
- **Industrial quality** refactoring tool called RefactorErl
  - Applied by industrial partners

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Future Internet Transport and In-Network Quality of Service

- **Revolution in the area of Internet data transport**
  - New protocols resulting in **significant unfairness**
- **Require admission control** of network resources to ensure fairness
- In addition to bandwidth sharing, **ultra low latency** is also important
  - Not only non-queue-building traffic
    - DNS, gaming, voice, SSH, ACKs, HTTP requests, etc
  - **Capacity-seeking traffic as well**
    - TCP, QUIC, RMCAT for WebRTC, HD video conferencing, interactive video, cloudrendered, virtual reality, augmented reality, remote presence, remote control, interactive light-field experiences,...

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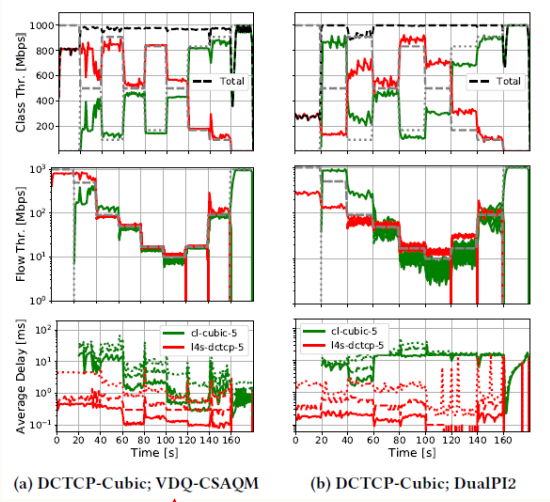
L4S achieves ultra-low queuing delay over the public Internet

- **L4S = Low Latency, Low Loss and Scalable Throughput**
- Design goals:
  - Isolation of L4S service from Classic.
  - Coexistence between L4S and Classic flows.
- Current „state-of-the-art” proposal:
  - DualQ AQM – DualQ-PI2 AQM
  - It still not able to handle different aggressiveness of„scalable” TCPs
- **We developed a method with in-network admission control**
  - **Ensuring fair resouce allocation and ultra low-latency**



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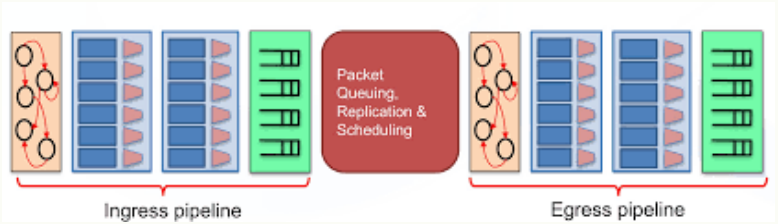
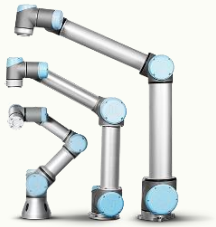
Deeply programmable networks and their applications

- P4 language for **programming network devices**
- Switches can perform **complex computations**
  - **Pipeline computational model**
  - **Limitations**
  - **High throughput and ultra low latency**
- **Moving computations from servers to the network**
  - **data processing, caching and real-time control tasks**





- We developed a method for **fast sensor data processing and real-time control in the network**
  - Extremally faster reaction time – real-time robot control
- We work on a **complex event processing method**
  - Logical rules in tables of the switch

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RG in numbers

- Journal papers:
  - **Accepted: Q1: 1, Q2: 4** --- Under review: D1: 1, OTH: 6
- Conference papers:
  - **Accepted: 10** --- Under review: 8
- Number of supervised students: **22 (BSc/MSc), 9 (PhD)**
- Project proposals:
  - 2 COST Action proposal as secondary and main proposers
    - **1 Accepted**, 1 Rejected
  - 1 ERC Starting Grant – Rejected
  - 1 OTKA FK_20 – Under evaluation
  - Further proposal submission planned in June

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Cooperation

- Strong cooperation between RG members
  - Focus on the various programming languages and their behavior
- **Joint work with Mathematics and Optimization RG**
  - Theoretical analysis of the developed network QoS framework
- **Active international cooperation**
  - University of Nottingham (UK), University of Gothenurg (Sweden), University of Nantes (France), Karlstad University (Sweden), University of Campinas (Brasil), University of Kent (UK), University of Tuebingen (Germany), University of Novi Sad (Serbia)
  - Others through the COST Actions…
- **Industrial connections**
  - Ericsson and OTP Bank
- **Standardization and international efforts**
  - IETF/IRTF, ONF (P4.ORG), DPDK

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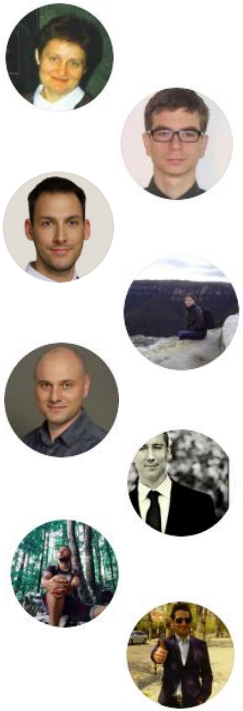
Future plans in nutshell



- **Formal analysis and verification**
  - Research towards the applicability of reaction systems to **describe distributed systems**
  - Further analysis of type theory-based program verification and the proposed prog. language
  - New language elements needed for **representing interactive programs**
  - **Industry strength implementations**
- **Refactoring**
  - Complete the formalization of the **refactoring primitives** and prove some extensive transformations correct in the Coq proof assistant
  - **Industrial applicability and prototype development**
  - Investigation of **other programming languages**
  - Methodologies to measure **energy efficiency** for **code optimization**
- **Programmable networks**
  - Extensions to our QoS framework to supporting network **slices in 5G and 6G networks**
  - Methodology for **policy design and policy-based practical load balancing**
  - **Prototype implementation** of QoS framework in P4 language, **promotion in IETF, MWC**
  - More complex in-network industrial control scenarios, promotion in IETF
  - Extended memory for prog. switches needed for **industrial UCs**

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communication networks laboratory

Eötvös Loránd University

THANK YOU!

HTTPS://BIT.LY/ELTE-TKP-2019

Project no. ED_18-1-2019-0030 (Application-specific highly reliable IT solutions) has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the Thematic Excellence Programme funding scheme.

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