

*AI4REASON:
Artificial Intelligence for Large-Scale
Computer-Assisted Reasoning*

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AI4REASON Goals

- Breakthrough in a hard problem in AI and reasoning:
automatically proving theorems in complex theories
- Produce AI systems that combine learning and reasoning
- Thus help with automating verification of:
 - advanced mathematics and big proofs (Kepler conjecture)
 - software and hardware designs (seL4 OS microkernel)
 - advanced systems and designs (finance, industry, science)

Example: The Kepler conjecture

- **Jan Kepler** (1611, Prague): The most compact way of stacking balls of the same size in space is a pyramid.

$$V = \frac{\pi}{\sqrt{18}} \approx 74\%$$



- The proof takes 300 pages + computations (**Tom Hales**, 1998)
- Formal verification took **20 – 30 person-years** (**Hales et al.**, 2014)
- Our AI methods can automate **40%** of the proofs (2014)
- Similar verification efforts needed to produce bug-free compilers, operating systems, hardware, etc.
- Good automation of reasoning is essential

What Is Needed: The AI4REASON Plan of Attack

WP1 AI for finding relevant knowledge in large formal corpora:

- How to capture similarity and analogy of ideas?
- How to learn from proofs, counter-examples and theories?

WP2 AI-based guiding methods for reasoning tools:

- How to efficiently apply the learned guidance?
- How to automatically learn the best reasoning strategies?

WP3 AI for suggesting plausible conjectures and concepts:

- What makes a good conjecture for a given problem?
- What concepts are good for a given problem?

WP4 Self-improving AI interleaving learning and deduction:

- How to explore easier problems to learn for harder ones?
- How to develop theories and gain most useful knowledge?

WP5 Deployment and Cross-Corpora Reuse:

- Deploy the methods as strong online services
- Develop AI methods for aligning different corpora

Team and Resources

- 6 people, 1.5M EUR (incl. overheads), 2 large servers
- JU, Dr. Chad Brown, Dr. Jan Jakubův, Bartosz Piotrowski, Zarathustra Goertzel, Shawn Wang
- Nucleus of **Prague Automated Reasoning Group** (2003):
- A group of young talented scientists in Prague/abroad
- **External scientific advisors**
 - Prof. Stephan Schulz (Autom. reasoning, DHBW Stuttgart)
 - Prof. Robert Veroff (Autom. reasoning, U. of New Mexico)
 - Prof. Tom Heskes (AI, Radboud U. Nijmegen)

Further Collaborations

- Dr. Cezary Kaliszyk, U. of Innsbruck (ERC in 2016)
- Dr. Jasmin Blanchette, VU Amsterdam (ERC in 2016)
- Prof. Larry Paulson, U. of Cambridge (ERC in 2017)
- Prof. Geoff Sutcliffe, U. of Miami
- Dr. Christian Szegedy, Google Research
- Prof. Herman Geuvers, Radboud U. Nijmegen
- ... and more ...
- over 20 research visits so far
- joint funding proposals, etc.

Some Highlights

- Dr. Brown: won the 2016 and 2017 reasoning competitions in his category
- Dr. Jakubův: Significant improvement of the best open provers by machine-learning guidance
- First implementations of deep-learning based provers (with Google Research)
- First Monte-Carlo provers (with U. of Innsbruck)
- ... and more ...
- Several invited talks by Dr. Urban (Fields Inst., ISAIM'16,..)
- Invited talk at ITP'17 by Dr. Kaliszyk about our joint work
- 2016 Google Research Award for JU
- new conference series started: aitp-conference.org
- new group at Google Research

Institutional Support

- Great support from the CIIRC team headed by V. Mařík
- Competent administrators at CIIRC (comparable to NL)
- Active CIIRC support for new large projects
- Not all perfect, but people are seriously trying
- EURAXESS - support for work visa for non-EU foreigners
- In 2016 we employed Dr. Chad Brown (US, PhD from CMU) – world's top expert in higher-order theorem proving
- Four international PhD students in 2017 – US, JP, PL, NL