AI can solve our research problems — *what next?*

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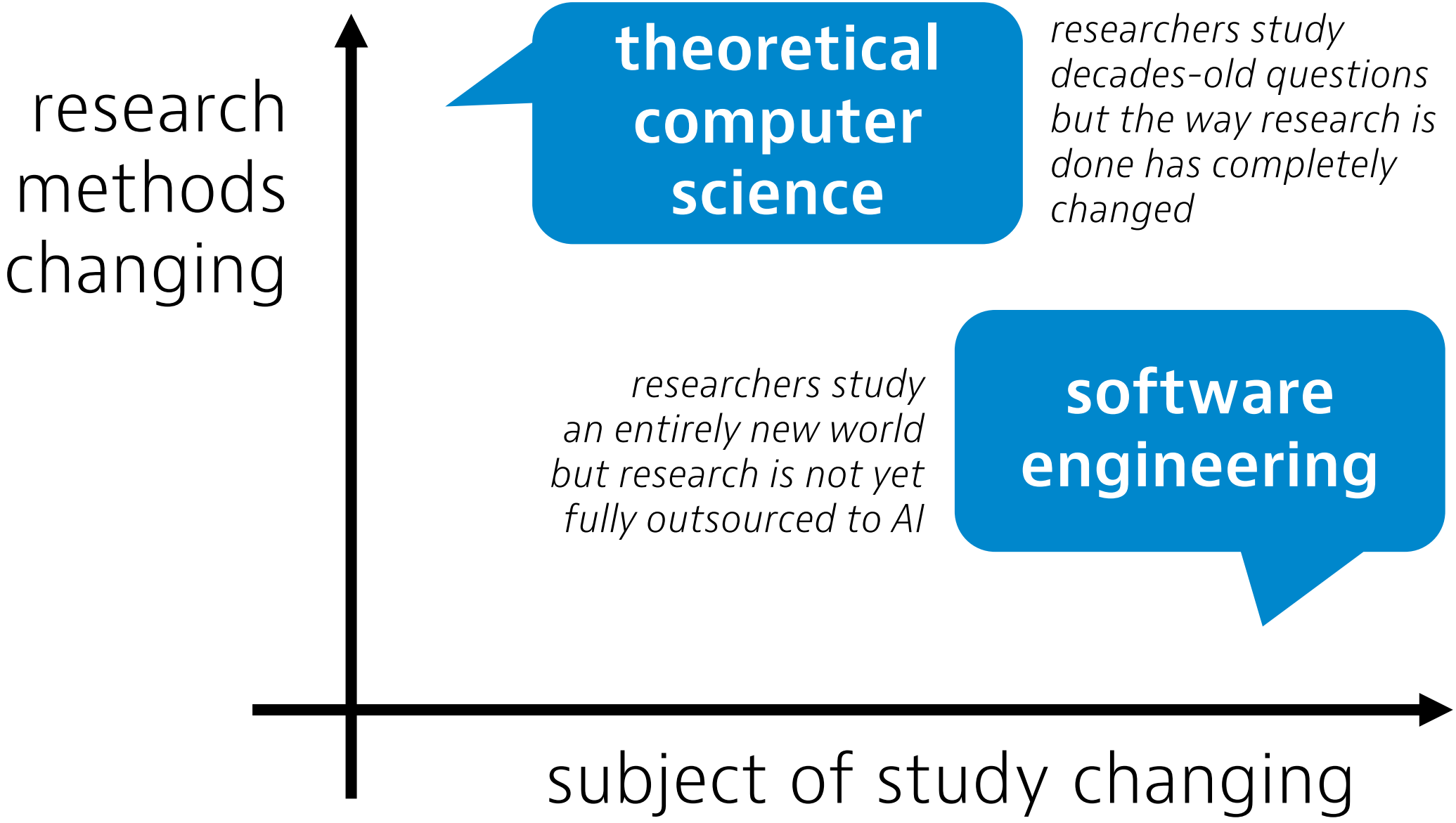
My own perspective

- I work in **theoretical computer science**
  - ***what can and cannot be computed efficiently?***
- At the intersection of **computer science** and **mathematics**…
- … and both fields have been dramatically impacted by AI

Computer science & AI

- Computer science is both the field that **brought** us AI and a field that has drastically **changed** thanks to AI
- But not all areas of CS are the same…


research methods changing
theoretical computer science
researchers study decades-old questions but the way research is done has completely changed
researchers study an entirely new world but research is not yet fully outsourced to AI
software engineering
subject of study changing

TCS research

Theorem: This-and-this computational task can be solved so-and-so fast.

Proof: …

- **Typical research result:**
  - a ***mathematical fact*** with a ***proof***
- **Traditional working methods:**
  - hiring smart students
  - ***thinking hard***
  - doodling on a whiteboard
  - hoping that you come up with something…

What AI can do in TCS

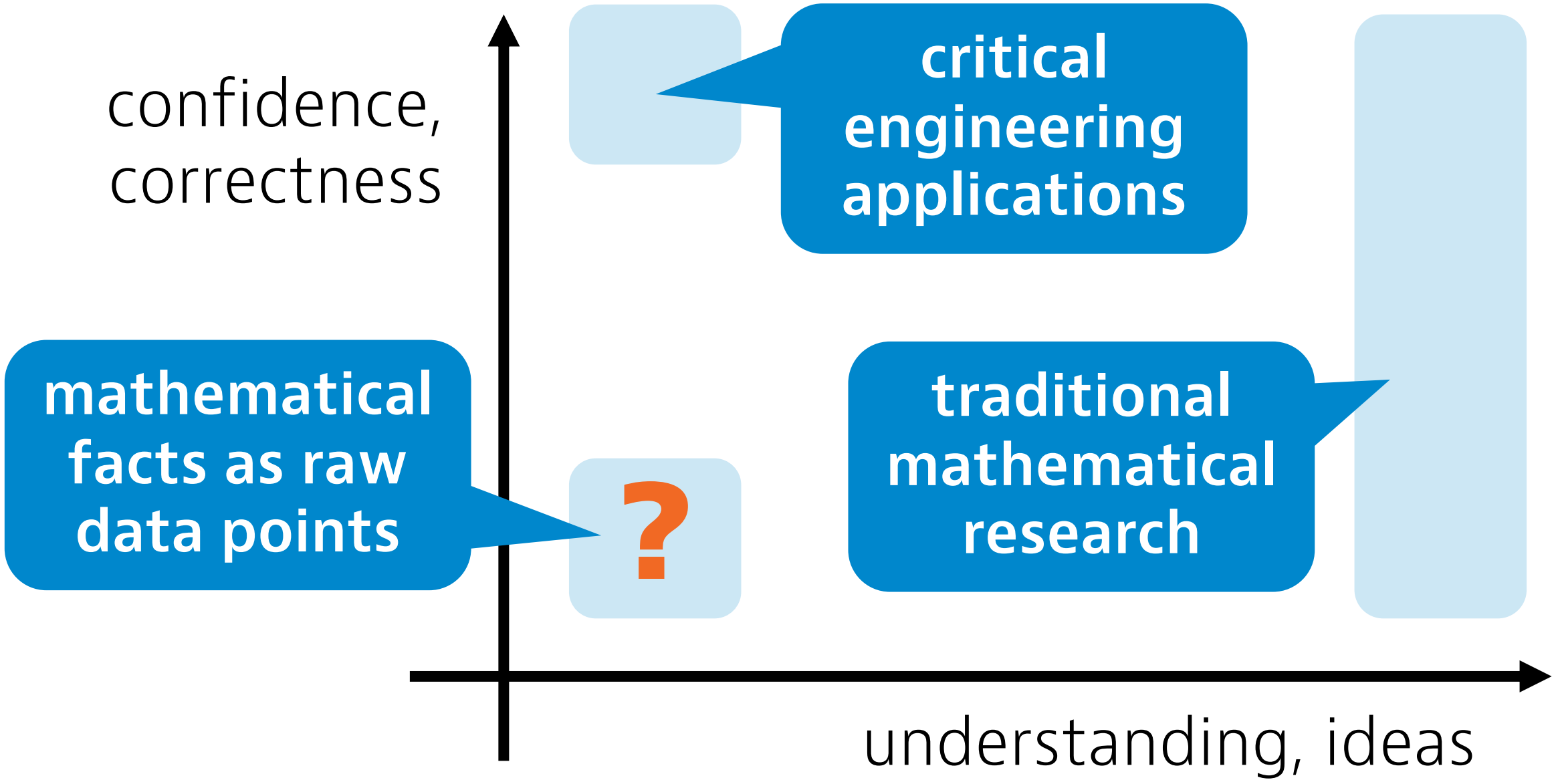
- **In theoretical computer science, modern AI tools can autonomously:**
  - find an interesting open research question
  - ***fully solve it***
  - write it up for submission to a conference
  - prepare the presentation slides …

What AI can do in TCS

- **Slop and hallucinations no longer a major issue:**
  - AI can write formal mathematical proofs in a computer-readable language
  - proof assistant tools (e.g. ***Lean***) can then automatically check them

Facts vs. understanding

- **Previously these were coupled:**
  - producing a mathematical ***fact***
  - gaining confidence that it is ***correct***
  - research community gaining ***understanding***
- **Now they are decoupled:**
  - theorems and proofs can be mass-produced
  - auto-formalization helps with correctness
  - ***human understanding lagging far behind***


confidence,
correctness
critical
engineering
applications
mathematical
facts as raw
data points
?
traditional
mathematical
research
understanding, ideas

Facts as raw data

- **A mathematical result used to be precious**
  - researchers spent months producing it
  - it better result in a paper or thesis…
- **What could we do if we could cheaply mass-produce thousands of results?**

Facts as raw data

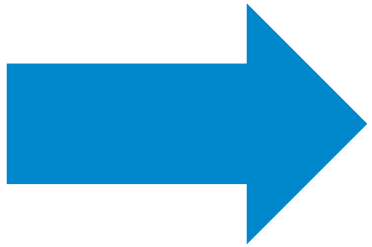
- **Compare with physics:**
  - run an experiment, produce a raw data point
  - individual data points are not that interesting
  - but we can analyze the whole data set and try to find interesting outliers or phenomena so far unexplained by existing theories…
- **We could start to do similar research also in theoretical computer science!**

Facts as raw data

- **What we could do:**
  - build a database of raw results
  - identify phenomena so far unexplained
  - formulate hypotheses, ***build new theories***…
- **Right focus for human understanding:**
  - ***understanding broadly-applicable theories***
  - without worrying too much about the details of individual raw data points?

Next level?

Problem-solving



Theory-building

largely solved?

plenty of room for interesting human–computer collaboration?

Challenges

*What if I actually **enjoy** problem-solving, doing it for living has been my lifelong **dream**, and I'm **bad** at theory-building?*

Am I going to spend the rest of my life just deciphering AI-generated proofs?

Do we soon reach the point where AI proofs are so advanced no human will ever understand them?

My own thoughts

- AI can invent ***delightfully simple and elegant*** algorithms and proofs
- I can enjoy ***learning*** about them
- I can enjoy ***teaching*** them

Reflections on AI in TCS

- **AI can mass-produce solutions to major open research questions**
  - new research methods, facts as ***raw data points***
- **Science is advancing very rapidly**
  - breakthroughs weekly and it is ***accelerating***
- **Our scientific community is struggling**
  - need to pay attention to our own ***wellbeing***