The Holy Grail of Quantum Artificial Intelligence

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Machine Learning

1. Random Initialization
2. Update
3. Decision Model
4. Execution/Test
5. Reward/Loss
6. Result
3 AI and the Compute Method

1) “AI researchers have often tried to build knowledge into their agents,

2) this always helps in the short term, and is personally satisfying to the researcher, but

3) in the long run it plateaus and even inhibits further progress, and

4) breakthrough progress eventually arrives by an opposing approach based on scaling computation by search and learning.”
AI and the Compute Method

1) “AI researchers have often tried to build knowledge into their agents,
2) this always helps in the short term, and is personally satisfying to the researcher, but
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4) breakthrough progress eventually arrives by an opposing approach based on scaling computation by search and learning.”

“The biggest lesson that can be read from 70 years of AI research is that general methods that leverage computation are ultimately the most effective, and by a large margin.”

Rich Sutton.
The Bitter Lesson.
www.incompleteideas.net/InclIdeas/BitterLesson.html
The Power of Compute

Dario Amodei and Danny Hernandez. AI and Compute. openai.com/blog/ai-and-compute/
“Since 2012, the amount of compute used in the largest AI training runs has been increasing exponentially with a 3.5 month doubling time (by comparison, Moore’s Law had an 18 month doubling period).”
Options for the Future of AI

- Progress in AI research slows down.
- AI research becomes exponentially more expensive.
- New AI algorithms using less resources are developed.
- New sources of computation power are discovered.
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9 The Power of Efficiency

“Compared to 2012, it now takes 44 times less compute to train a neural network to the level of AlexNet (by contrast, Moore’s Law would yield an 11x cost improvement over this period). Our results suggest that for AI tasks with high levels of recent investment, algorithmic progress has yielded more gains than classical hardware efficiency.”

Published this May!

Danny Hernandez and Tom Brown. AI and Efficiency. openai.com/blog/ai-and-efficiency/
Options for the Future of AI

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Quantum Computing and AI

Quantum Computing
- could provide more computing power
- noisy for the foreseeable future
- can perform stochastic search (quantum annealing or QAOA)
- circuits are hard to construct for new algorithms
- operates on a multitude of possibilities to return a relatively short answer

Artificial Intelligence
- always needs more computing power
- needs randomness
- uses stochastic search
- can invent creative solutions for well-defined goals
Quantum Machine Learning

Random Initialization → Decision Model

Update → Execution/Test

Reward/Loss → Clustering/SVMs/

QAOA → Quantum Annealing

Quantum RNG → QBM

Quantum-Enhanced RL
Quantum Machine Learning

Random Initialization → Update → Decision Model → Execution/Test → Result

- Quantum RNG
- QAOA
- Quantum Annealing
- QBM
- Clustering/SVMs/
- Feedback Loop
- Quantum-Enhanced RL
- Reward/Loss

13
Quantum Machine Learning

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Update -> Execution/Test
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The Holy Grail of Quantum AI
Challenges for Quantum AI

The Feedback Loop

Replace the feedback loop around training entirely with a quantum algorithm.
The Amount of Data

**Earlier Today**
Challenges for Quantum AI

The Feedback Loop

Replace the feedback loop around training entirely with a quantum algorithm.

The Training Data

Provide means to process (the essence of) large amounts of data on quantum computers.
A Full Stack of Knowledge

- **QAI concepts**
- **QAI algorithms**
- **QAI applications**

Packaged solution

- Search & Order
- Implementation
- Analysis Standardization

Users
- Developers
- Specialists community

www.planqk.de
20 Challenges for Quantum AI

The Feedback Loop
Replace the feedback loop around training entirely with a quantum algorithm.

The Training Data
Provide means to process (the essence of) large amounts of data on quantum computers.

The Interfaces
Provide standardized interfaces that allow for dynamic combination of QAI components and (by extension) for experts of different fields to collaborate on QAI algorithms.
21 The Best Quantum Algorithm?

1. Employ a dozen algorithmically trained physicists and (physically trained??) programmers.

2. They will find a better algorithm than the one you wrote that one night in total desparation.

3. That algorithm may not actually need to use any quantum hardware.

Prof. Dr. Wolfgang Mauerer (earlier talk today)

“It’s in the journey!”
Challenges for Quantum AI

- **The Feedback Loop**: Replace the feedback loop around training entirely with a quantum algorithm.

- **The Training Data**: Provide means to process (the essence of) large amounts of data on quantum computers.

- **The Interfaces**: Provide standardized interfaces that allow for dynamic combination of QAI components and (by extension) for experts of different fields to collaborate on QAI algorithms.

- **The Real Reason**: Keep track of the source of observed improvements and use it wisely.
The Training Data

Provide means to process (the essence of) large amounts of data on quantum computers.

The Interfaces

Provide standardized interfaces that allow for dynamic combination of QAI components and (by extension) for experts of different fields to collaborate on QAI algorithms.

The Real Reason

Keep track of the source of observed improvements and use it wisely.

The Feedback Loop

Replace the feedback loop around training entirely with a quantum algorithm.

Thank You!
The Holy Grail of Quantum Artificial Intelligence
Thomas Gabor (QAR-Lab, LMU Munich)

Paper available!

Image Sources
• https://www.boredpanda.com/jumping-cats/
• https://kinder.wdr.de/tv/wissen-macht-ah/bibliothek/kuriosah/bibliothek-daumen-hoch-100.html
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