

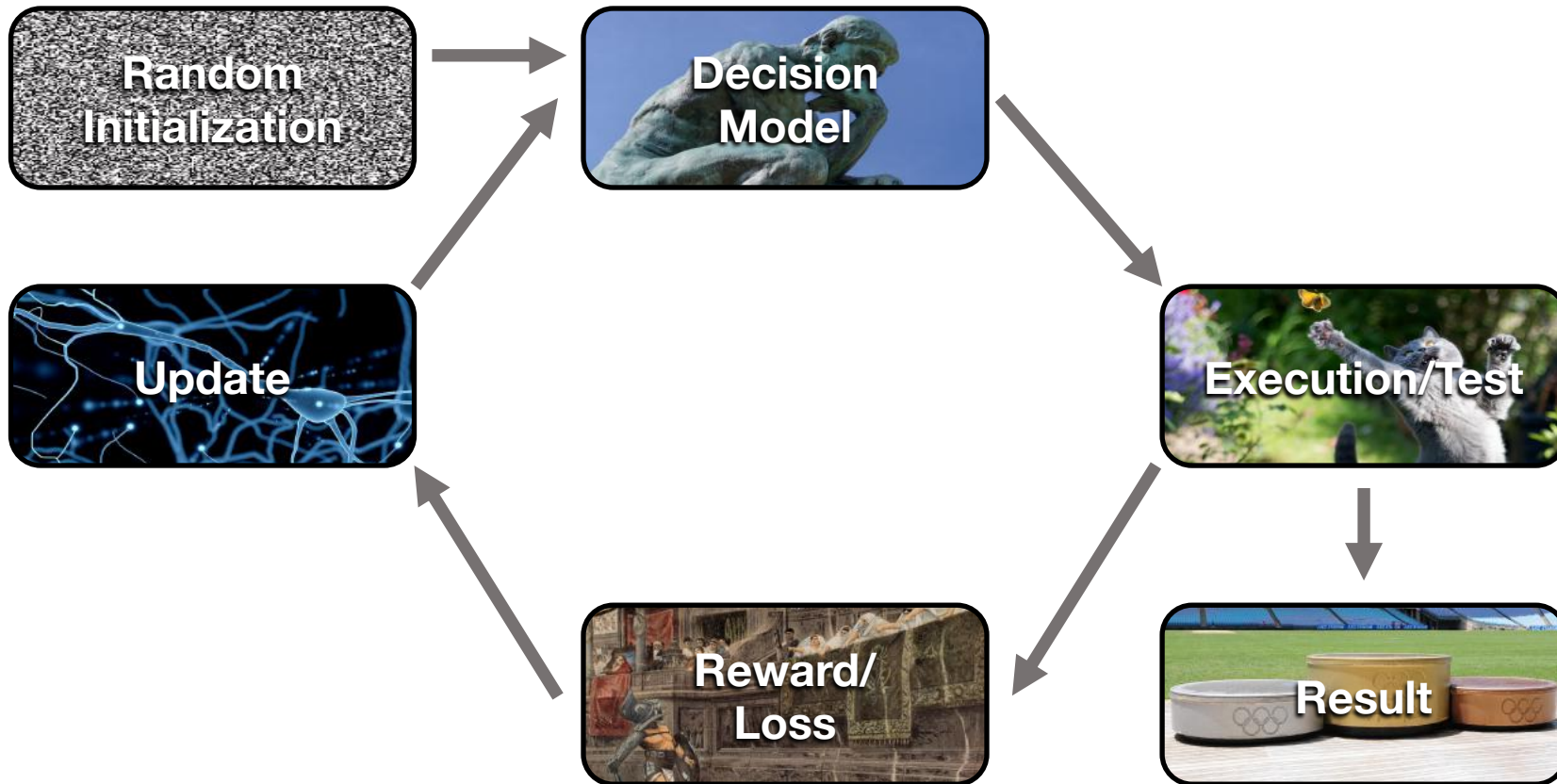
# The Holy Grail of Quantum Artificial Intelligence

Thomas Gabor

QAR-Lab, LMU Munich



## 2 Machine Learning



### 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.**”

Rich Sutton.  
The Bitter Lesson.  
[www.incompleteideas.net/  
InIdeas/BitterLesson.html](http://www.incompleteideas.net/InIdeas/BitterLesson.html)

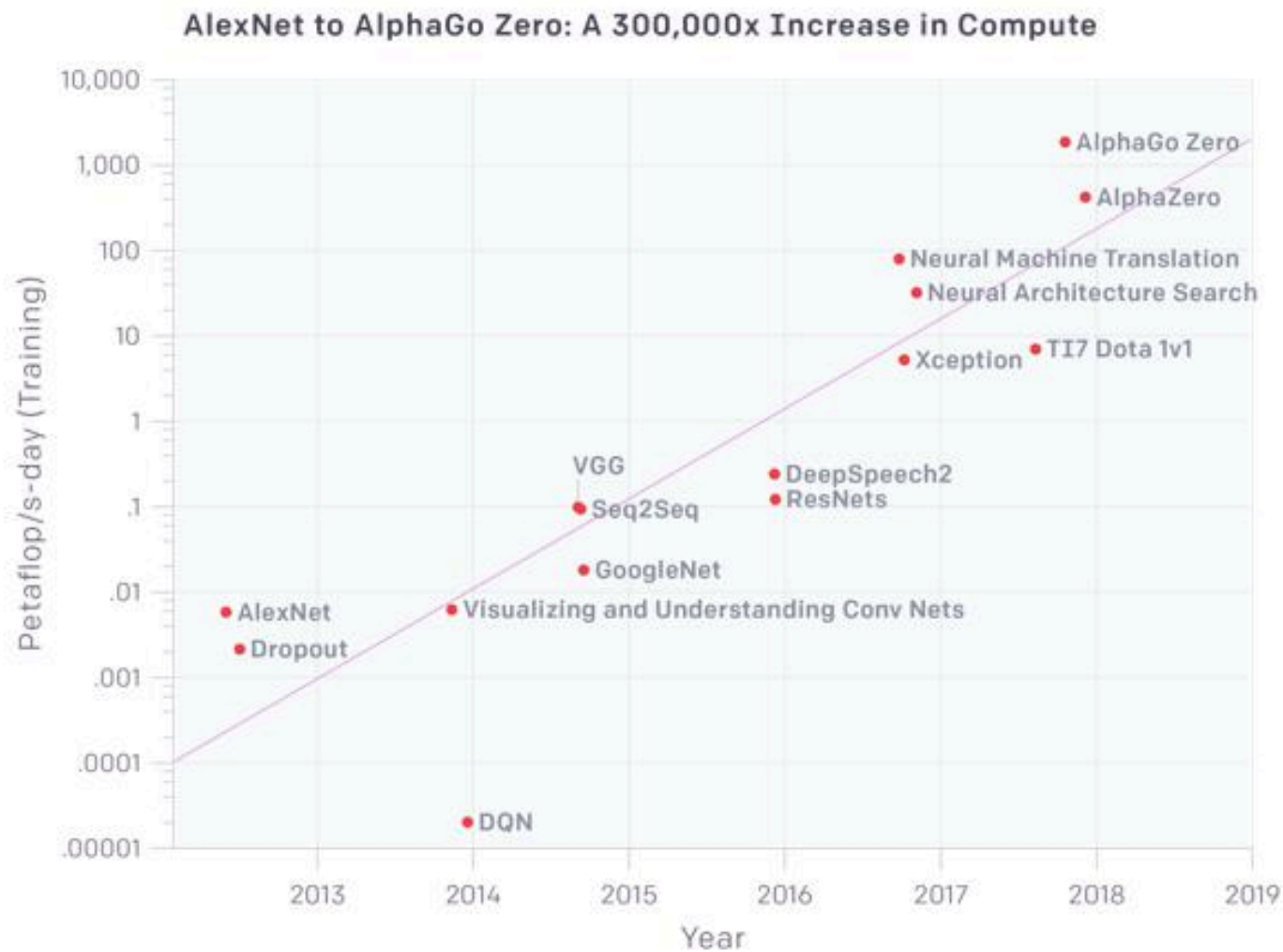
# 4 AI and the Compute Method

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“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.”

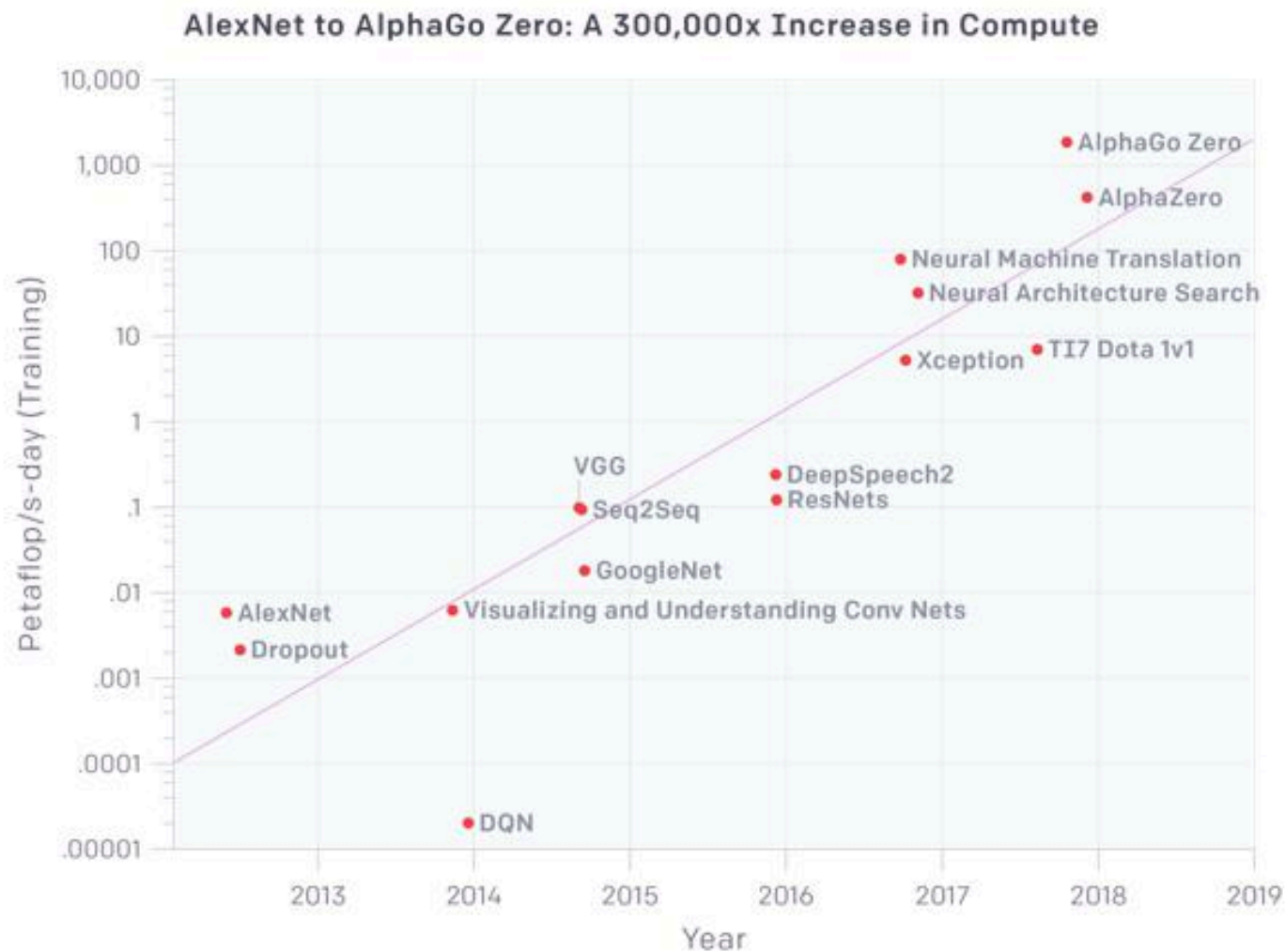
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# 5 The Power of Compute



Dario Amodei and Danny Hernandez.  
AI and Compute.  
[openai.com/blog/ai-and-compute/](https://openai.com/blog/ai-and-compute/)

# 6 The Power of 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).”

Dario Amodei and Danny Hernandez.  
AI and Compute.  
[openai.com/blog/ai-and-compute/](https://openai.com/blog/ai-and-compute/)

# 7 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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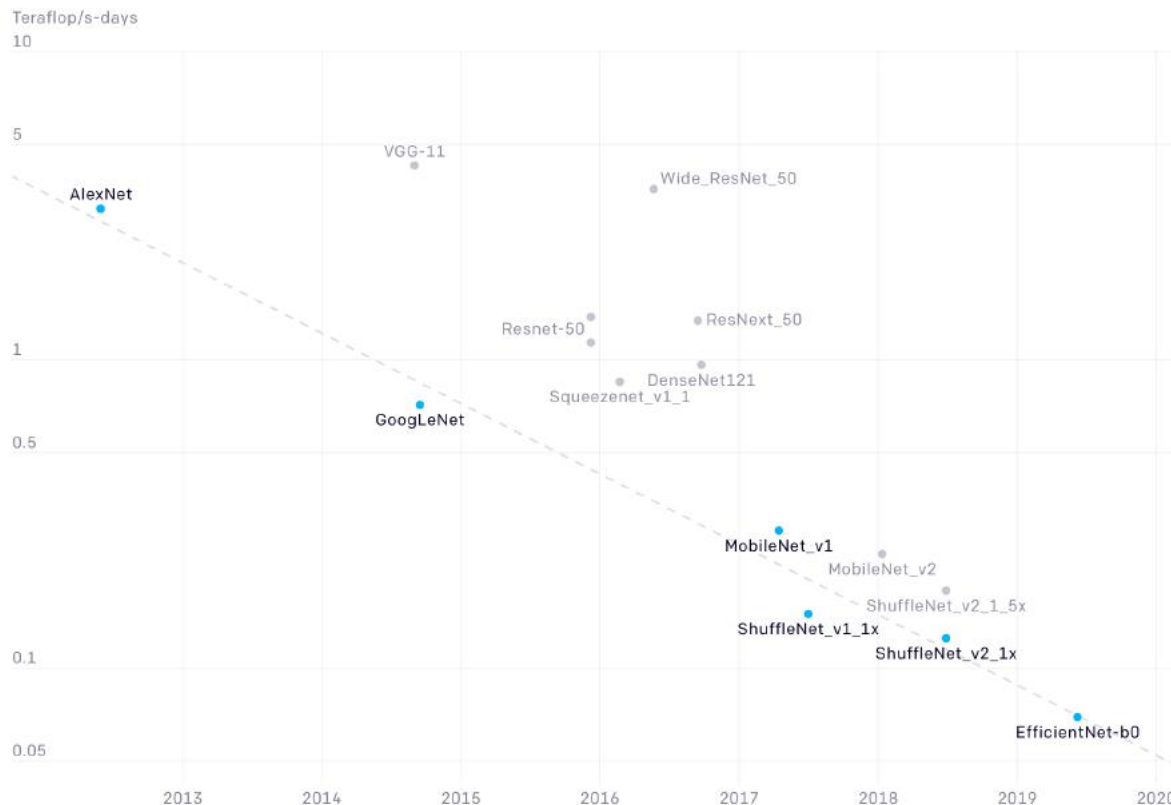
New AI algorithms using less resources are developed.

New sources of computation power are discovered.



# 9 The Power of Efficiency

44x less compute required to get to AlexNet performance 7 years later (log scale)



“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/](https://openai.com/blog/ai-and-efficiency/)

# <sup>10</sup> Options for the Future of AI

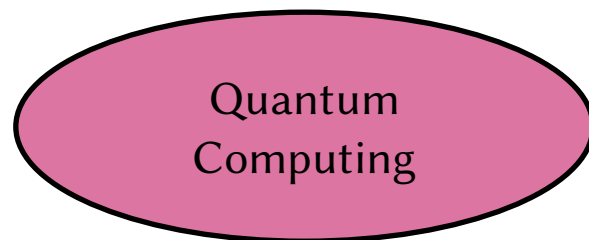
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# 11 Quantum Computing and AI



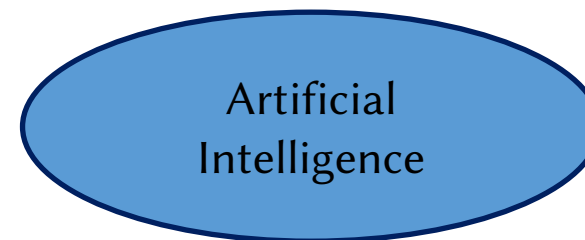
Quantum  
Computing

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



Artificial  
Intelligence

always needs more  
computing power

needs randomness

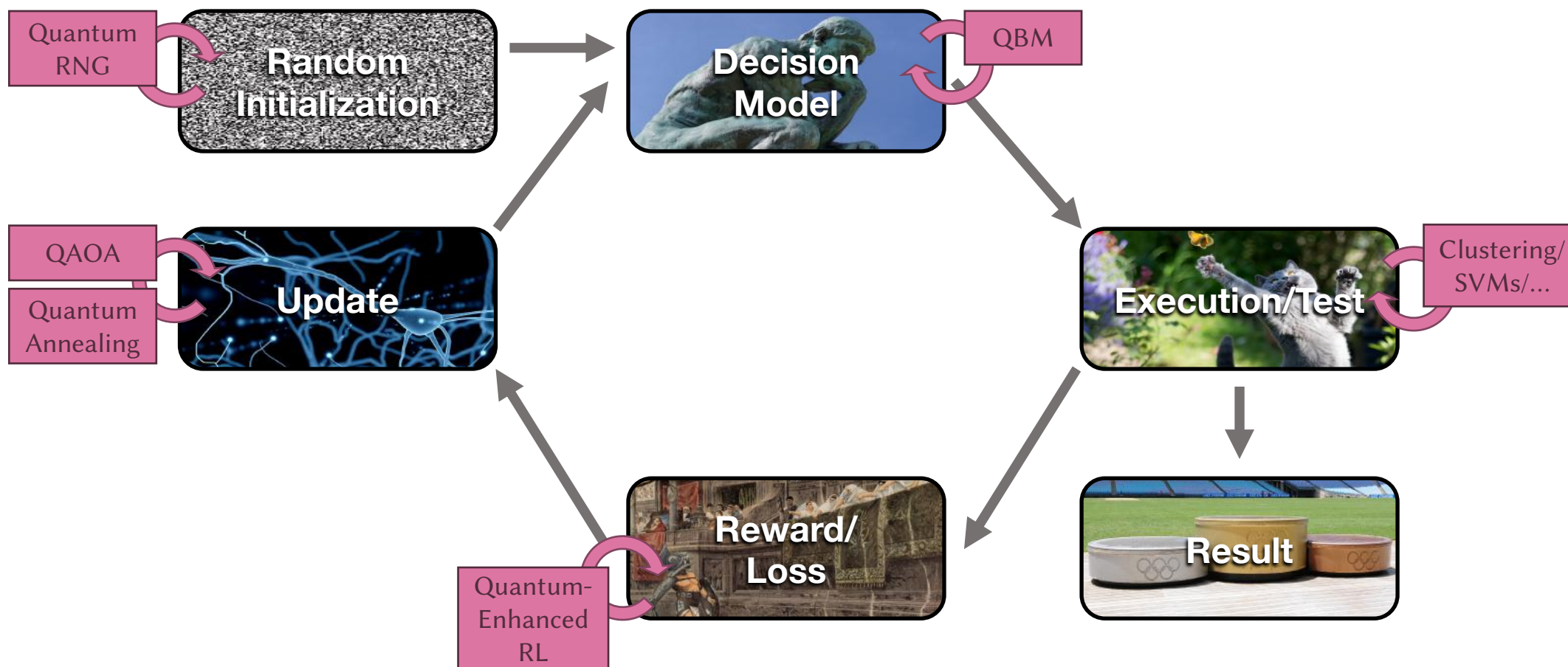
uses stochastic search

can invent creative solutions  
for well-defined goals

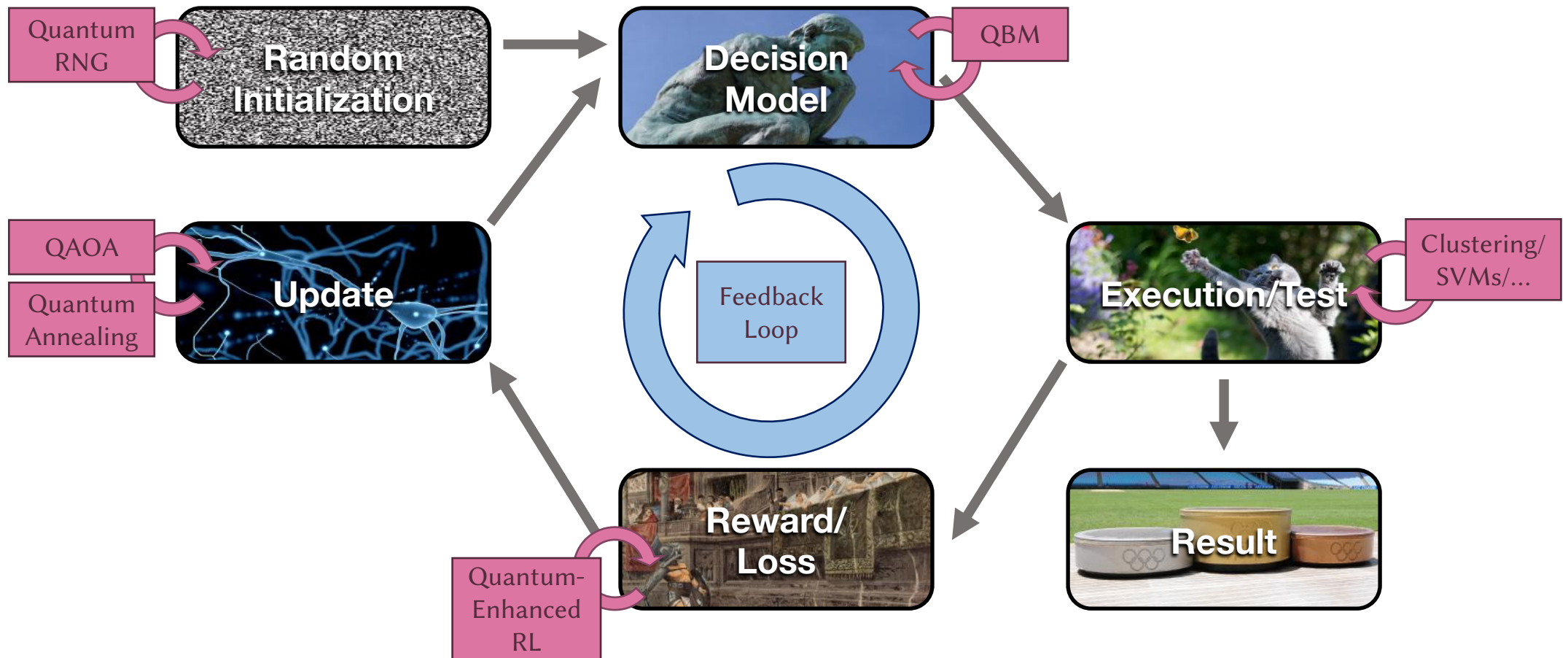


operates on a multitude of possibilities to  
return a relatively short answer

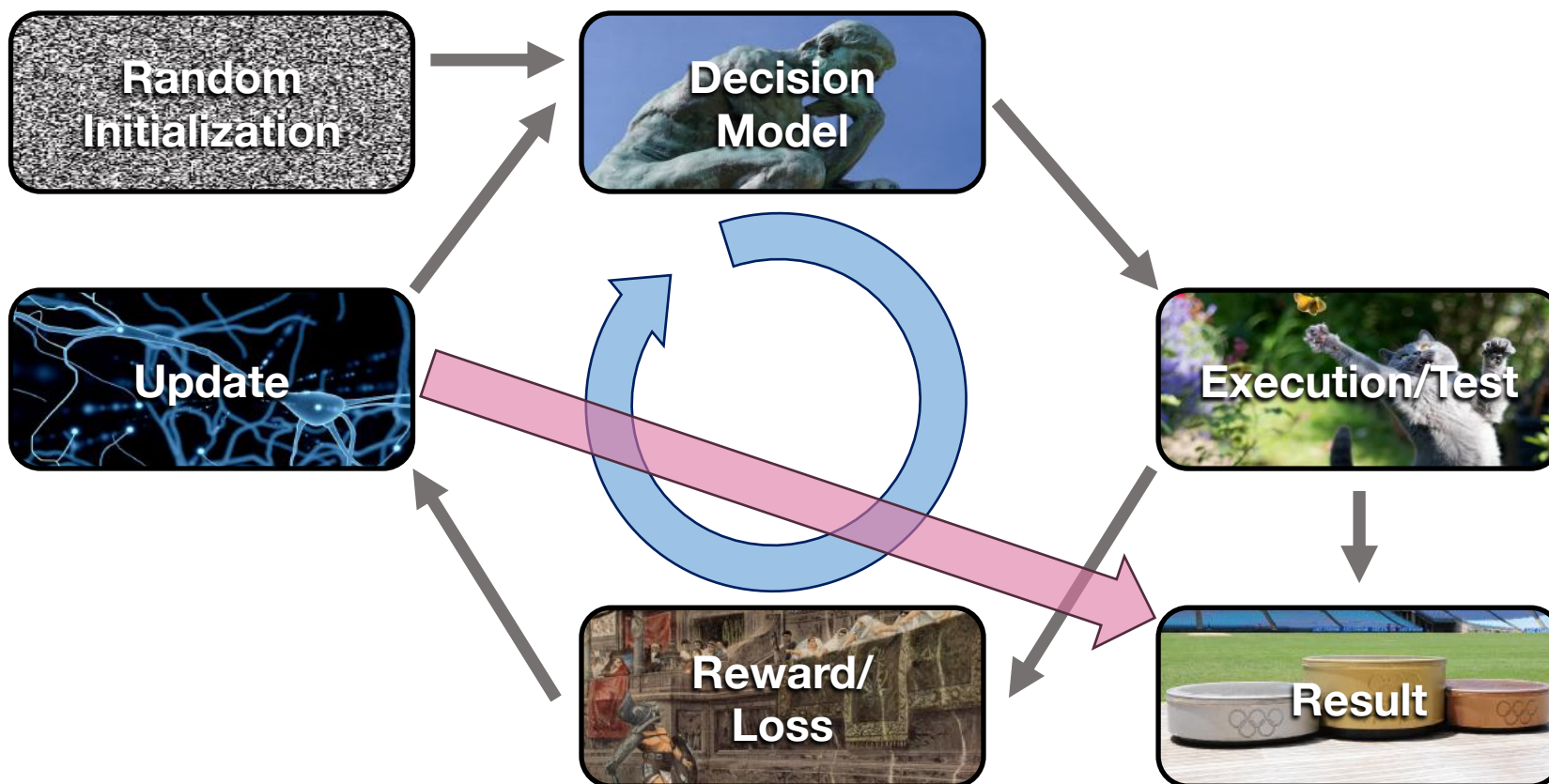
# 12 Quantum Machine Learning



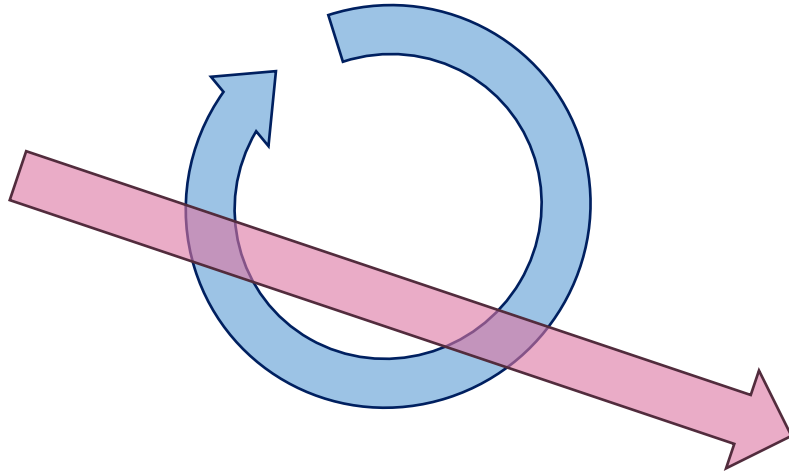
# 13 Quantum Machine Learning



# 14 Quantum Machine Learning



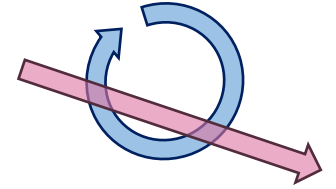
# The Holy Grail of Quantum AI



# 16 Challenges for Quantum AI

The  
Feedback Loop


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





# 17 The Amount of Data

## Relevant System Sizes

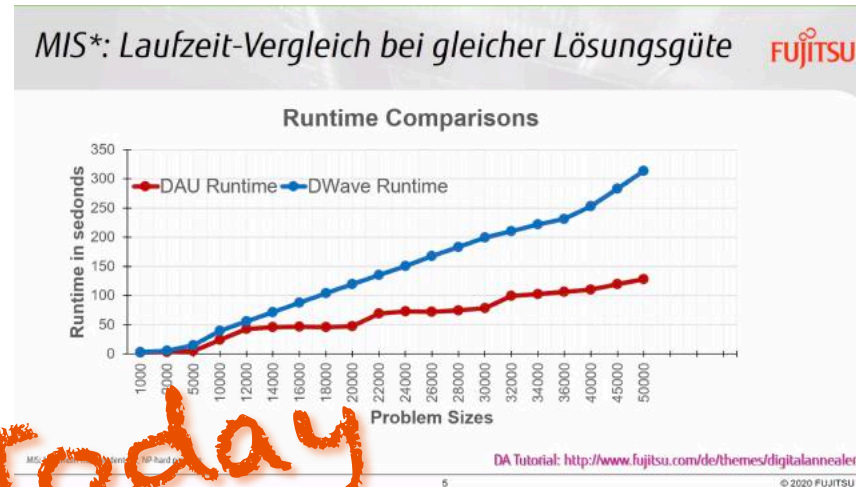


Quantum co-processor: augmenting, not replacing, traditional HPC systems

**Brute Force Limit**

- ~50+ Qubits: **Proof of concept**
  - Computational power exceeds supercomputers
  - Learning test bed for quantum "system"
- ~1000+ Qubits: **Small problems**
  - Limited error correction
  - Chemistry, materials design
  - Optimization
- ~1M+ Qubits: **Commercial scale**
  - Fault tolerant operation
  - Cryptography
  - Machine Learning

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Earlier Today

## Quantenoptimierung

Eingesetzte Quantenhardware

**QUBOs** können mit Quanten-Annealern sowie Gate-basierten Quantencomputer gelöst werden:



2048 Qubits



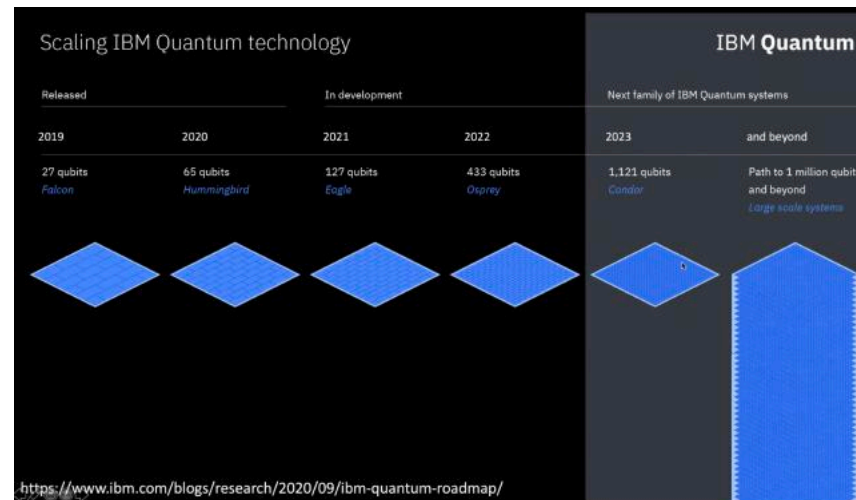
64 Qubits

Fujitsus Digital Annealer kann hierbei als Brückentechnologie dienen:



8192 komplett gekoppelte Bits

DB Systel | Manfred Rieck, VP Individual Solution Development 9



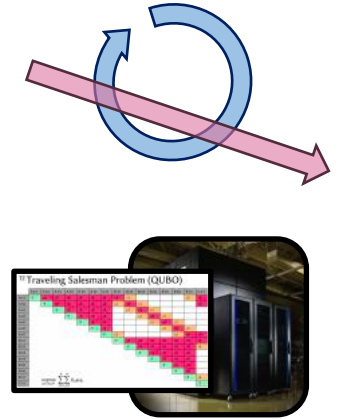
# 18 Challenges for Quantum AI

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.



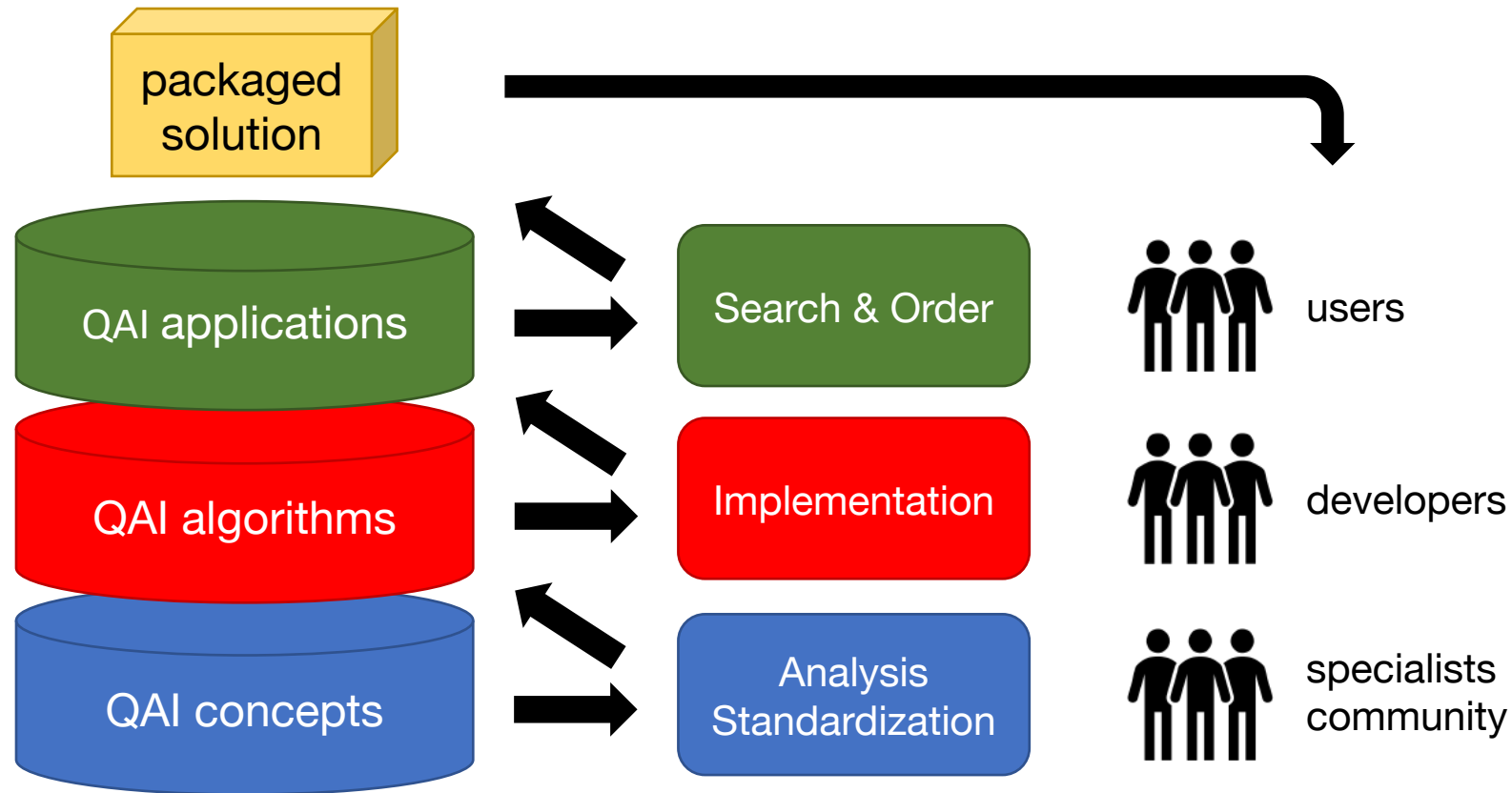
# 19 A Full Stack of Knowledge



**PlanQK**

[**'plan**ʌk]

[www.planqk.de](http://www.planqk.de)



# 20 Challenges for Quantum AI

The  
Feedback Loop

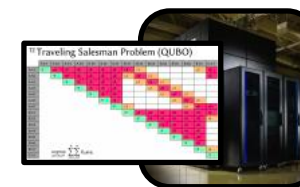
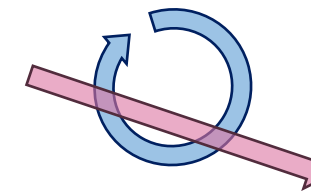
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The  
Interfaces

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



Domain Analysis

AI Algorithms

Quantum Platform

# 2<sup>1</sup> 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 desperation.

3

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



Prof. Dr. Wolfgang Maurer  
(earlier talk today)

*"It's in the  
journey!"*

# 22 Challenges for Quantum AI

The Feedback Loop

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

The Training Data

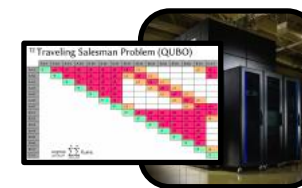
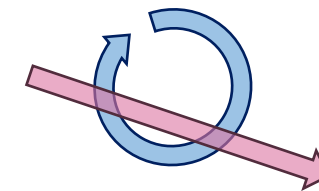
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The Real Reason

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



Domain Analysis

AI Algorithms

Quantum Platform

1 Employ a dozen algorithmically

2 They will find a better algorithm

3 That algorithm may not

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Thomas Gabor (QAR-Lab, LMU Munich)

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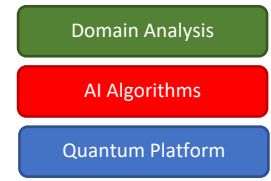
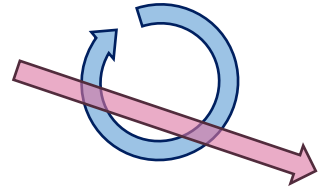
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THANK YOU!

# The Holy Grail of Quantum Artificial Intelligence

## Thomas Gabor (QAR-Lab, LMU Munich)

Paper available!

- <https://arxiv.org/pdf/2004.14035.pdf>

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The Bitter Lesson.  
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- <https://www.bostonmagazine.com/news/2015/07/30/boston-2024-winners-losers>
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