A Quantum Enhanced Learning Algorithm for Maze Problems

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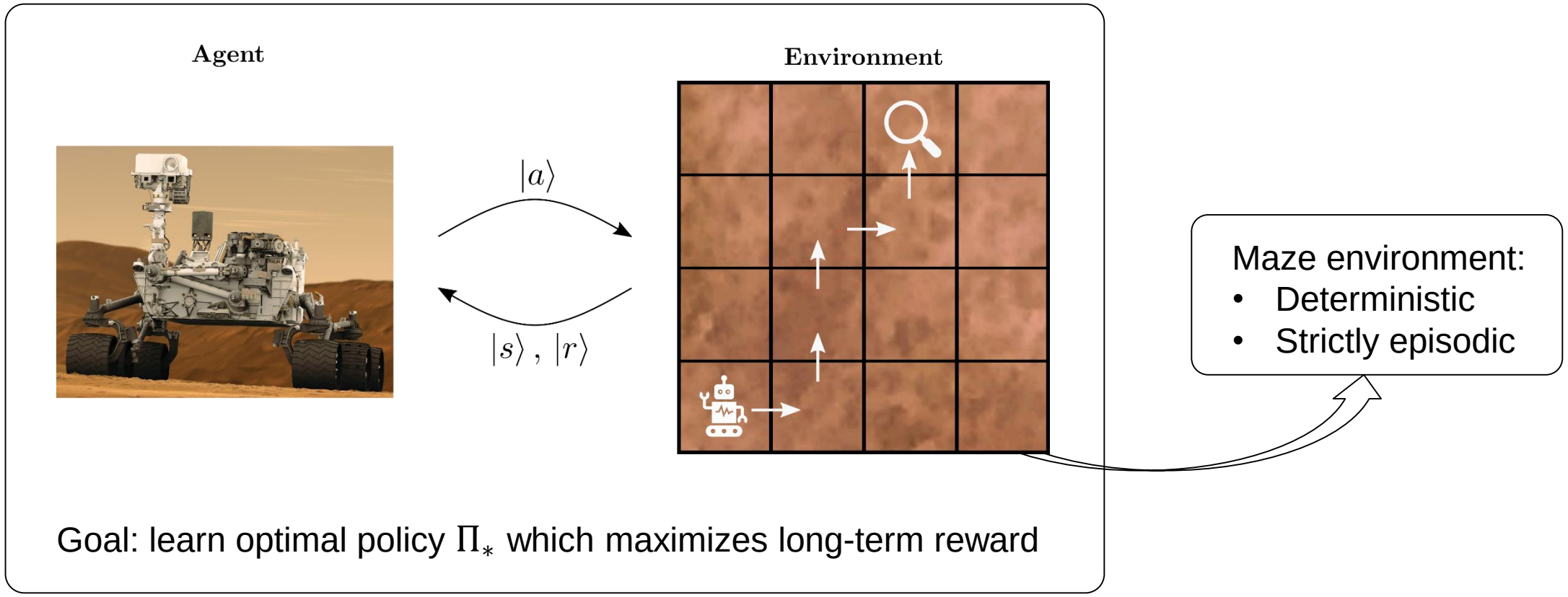
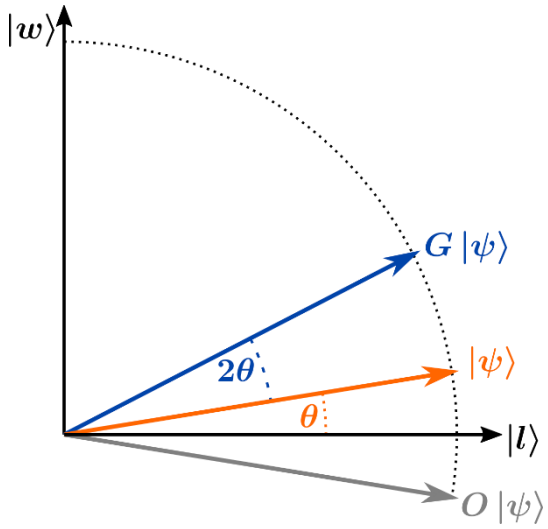
Reinforcement Learning



Find rewarded actions „quicker“ using amplitude amplification!

Quantum Amplitude Amplification



Environment unitary U_{Env}:

$$U_{\mathrm{Env}} |\vec{a}\rangle_A |0\rangle_S |0\rangle_R = |\vec{a}\rangle_A |\vec{s}(\vec{a})\rangle_S |r(\vec{a})\rangle_R$$

Phase kick-back oracle[1] O_{Env}:

$$O_{\mathrm{Env}} |\vec{a}\rangle_A |0\rangle_S |-\rangle_R = (-1)^{r(\vec{a})} |\vec{a}\rangle_A |0\rangle_S |-\rangle_R$$

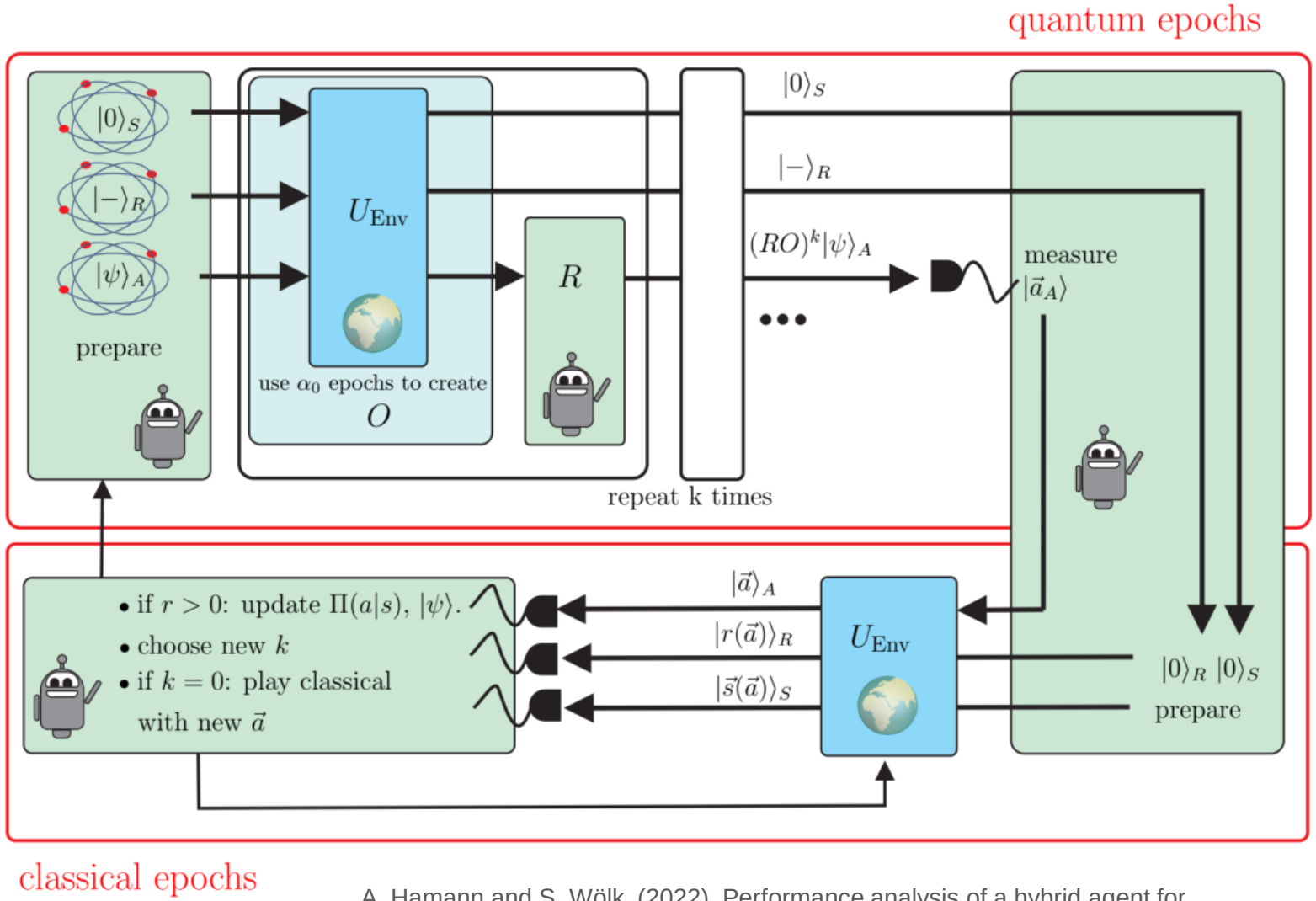
Grover operator:

$$G = (I - 2|\psi\rangle_A\langle\psi|)O_{\mathrm{Env}} \qquad \text{with} \qquad |\psi\rangle_A = \sum_{\{\vec{a}\}} \sqrt{\Pi(\vec{a})}\, |\vec{a}\rangle_A$$

$$G(p_{\mathrm{init}}, k) = \sin^2\left[(2k+1)\arcsin(\sqrt{p_{\mathrm{init}}})\right]$$

[1] V. Dunjko, J. M. Taylor, and H. J. Briegel. (2016). Quantum-enhanced machine learning. *Physical review letters*, 117(13):130501.

Quantum Enhanced Learning Algorithm



Quadratic speed-up in learning time:

$$\langle T\rangle_q \leq 9/4\sqrt{\langle J\rangle\langle T\rangle_{cl}}$$

Quantum advantage up to threshold probability

Experimental Proof of Concept:

V. Saggio et al. (2021). Experimental quantum speed-up in reinforcement learning agents. *Nature*, 591(7849):229–233.

A. Hamann and S. Wölk. (2022). Performance analysis of a hybrid agent for quantum-accessible reinforcement learning. *New Journal of Physics*, 24(3):033044.

The Search Length Dilemma

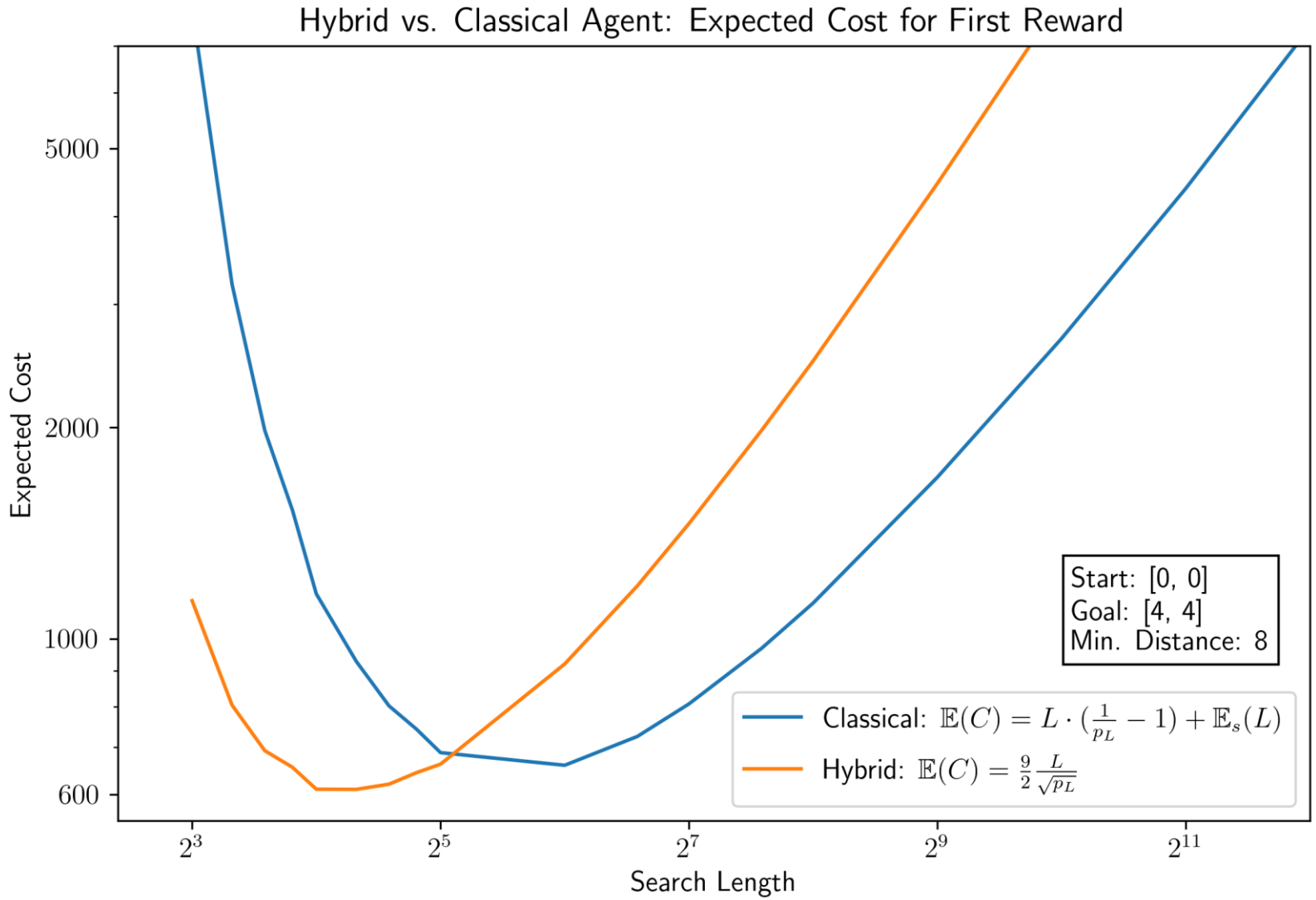
Restriction: fixed *search length L*

Cost $= N_{\text{queries}} * L = N_{\text{steps}}$

Minimal *search length* $\not\Rightarrow$ minimal *cost*

Minimal distance possibly unknown

Search length selection strategy required!



Thank You!

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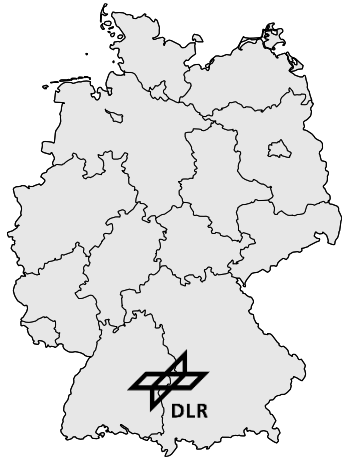
Key Points:

Quantum enhanced RL algorithm:
- View finding rewarded actions as quantum search problem
- Find rewards quadratically faster to speed up RL

Next step:
- Search length selection strategy for unknown goal distances



PS: we have open positions! Contact us for more details.