Anxiety-Sensitive Planning
From Formal Foundations to Algorithms and Application

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Motivation

Anxiety is a huge social matter:

- most prominent source of psychological harm
- huge costs (USD 1 trillion (!) yearly productivity loss) [1]
- high prospect (mental health matters provide a 4x return of investment on health and productivity) [1]

Anxiety should be part of AI systems

- AI systems focusing on hard performance can create anxiety
- Towards human-centric AI

Will you get your plane? Short or quiet trip?

Two options:

- **black option**: fastest in average, but no certainty until the late minute on the outcome
- **blue option**: certain outcome from start

The blue options offer a much less straining trip to the airport. Would you prefer a quiet ride over some time to chill at the airport?
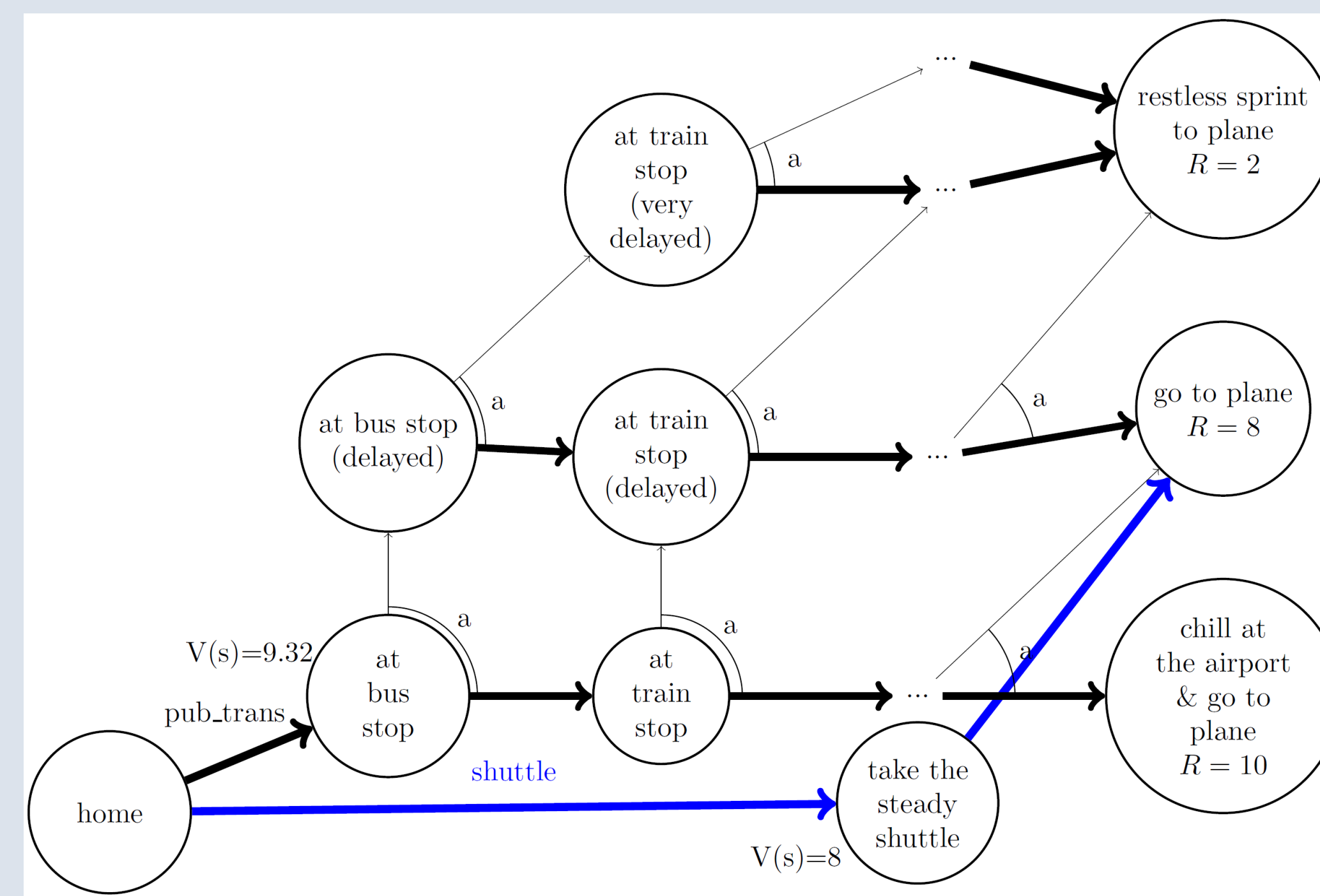
Theory of anxiety

Turning on the brains to anticipate danger
A negative emotion [2]:

- **Process**: stimulus, arousal, coping
- **Stimulus**: uncertainty (threatened stakes), highly future-oriented
- **Coping behaviors**:
  Problem-oriented: control (e.g. prepare, anticipate, remove ambiguity)
  Arousal-oriented (e.g. distract, look away)

Psychological damage

- Exhausting
- Too much or too long
- Damage from coping (e.g. self-sabotage, substance abuse)

Formal model of anxiety

From s, $argmin_\pi CumAnx(\pi, s)$; $\quad CumAnx(\pi, s) = InstAnx(\pi, s) + \sum_{s' \in S} T(s, \pi(s), s') \times InstAnx(\pi, s')$

$$InstAnx(\pi, s) = \sum_{i}^{t} FutUnc(\pi, s)$$

$$FutUnc(\pi, s) = AC(D(V^\pi(s)))$$

where $D(V^\pi(s))$ is a distribution over the reachable values from s following π and
AC is an anxiety cost, modelling the cost of dispersion (e.g. standard deviation).
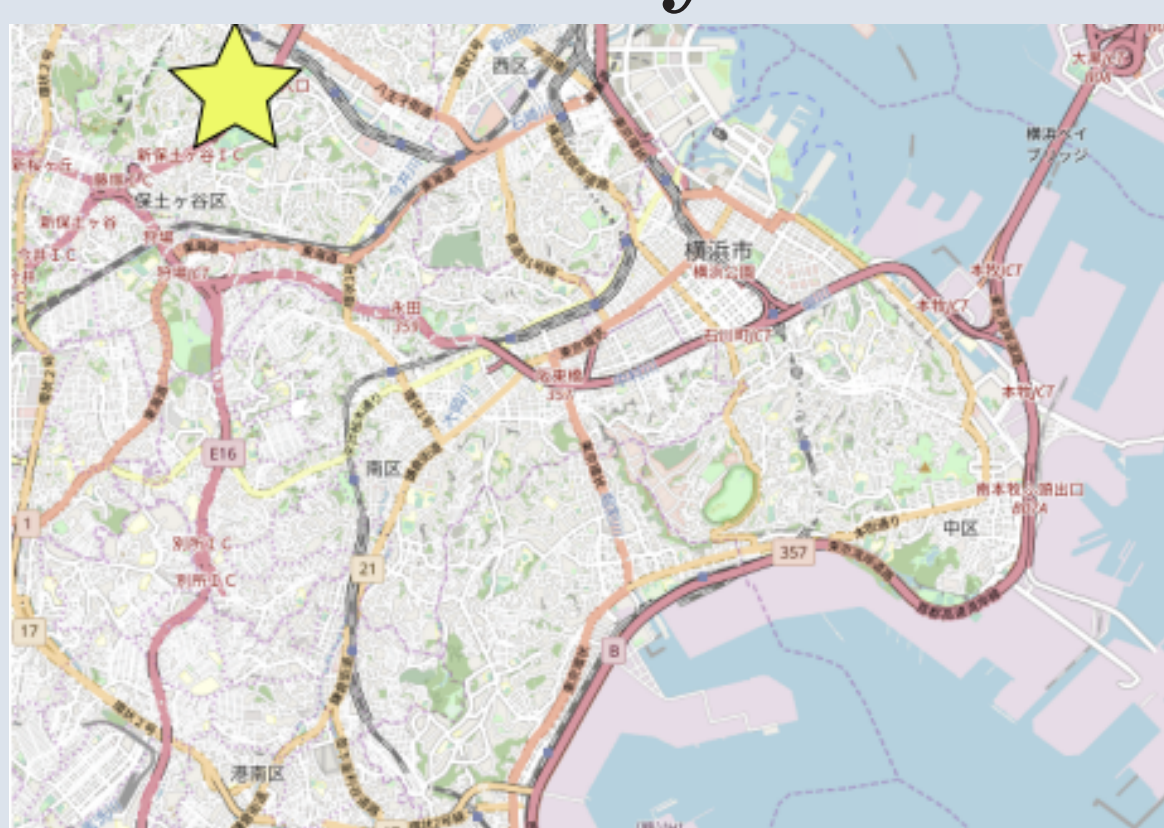Generalized model (AA-MDP) in the paper.
Algorithm: Value Iteration modified for back-propagating value distributions (instead of expected values), proven polynomial if the number of possible values is bounded.
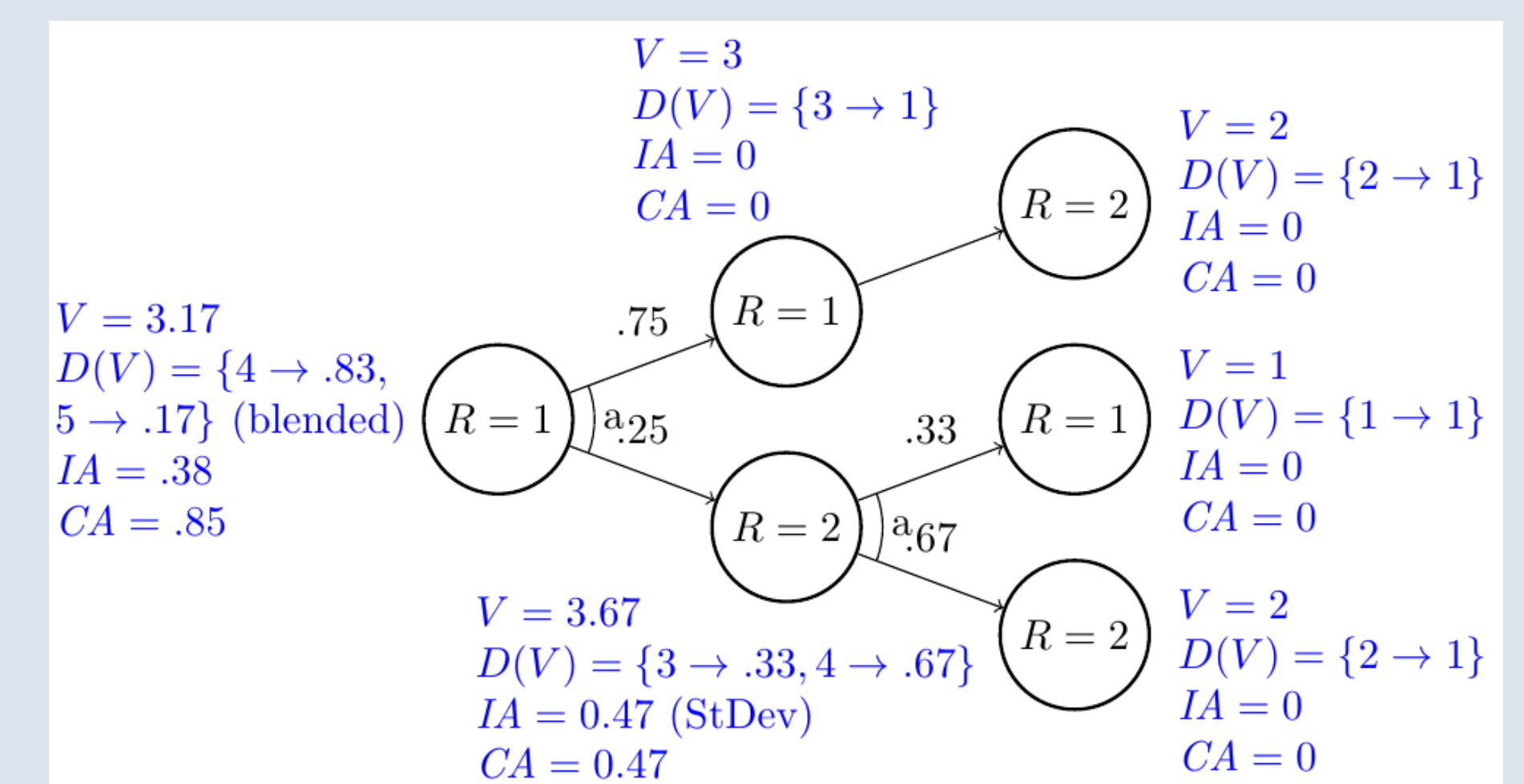
Results

AA-MDPs for anxiety-sensitive policies

Original map (red roads are assumed more prone to traffic jams but faster in average)
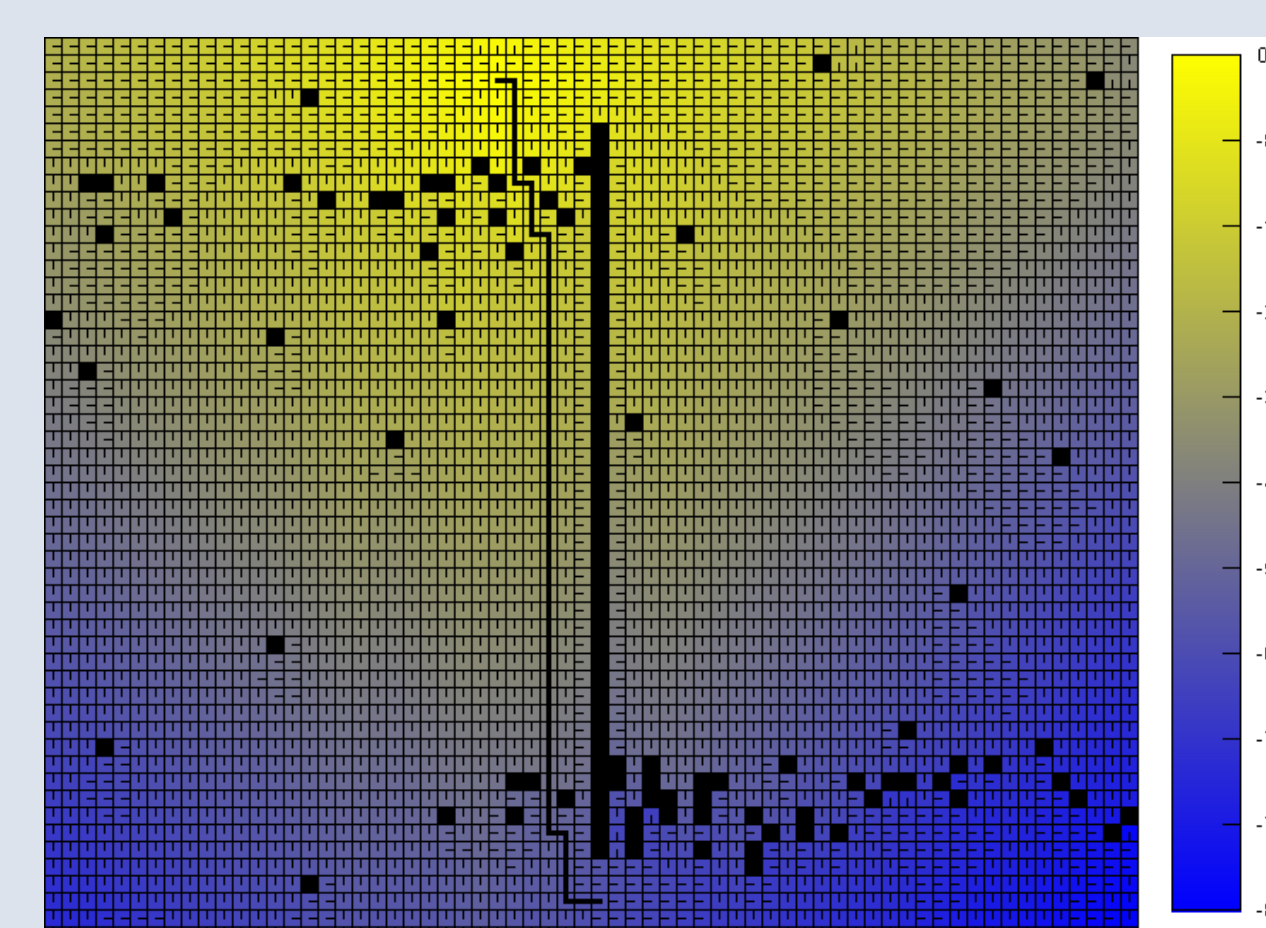

Optimal policy   Anxiety-sensitive policy

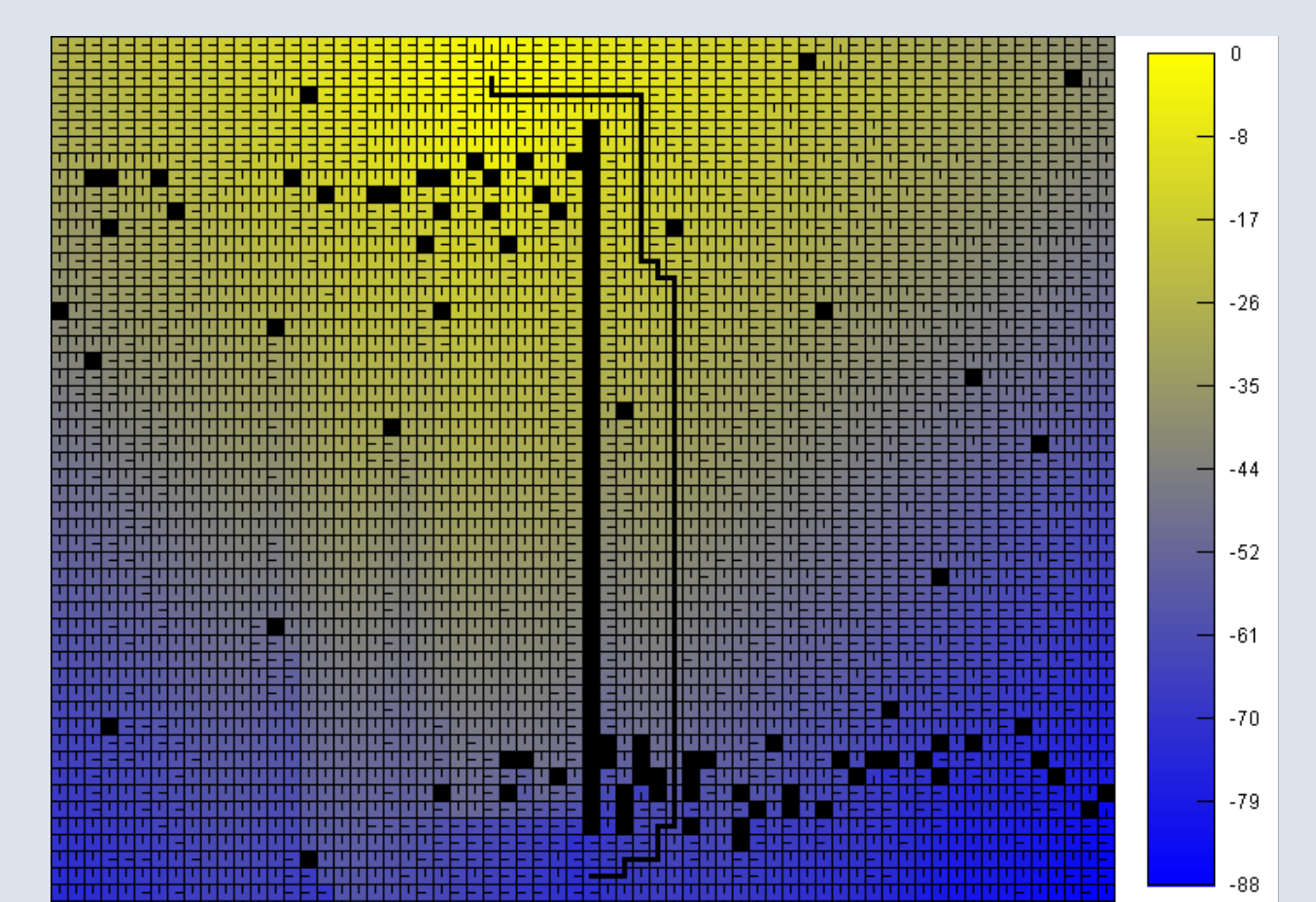**Pareto tradeoff**: 97% less anxiety for 17% lower reward
Psychology grounding: human follow similar strategies to lower their transportation anxiety
Off-the-shelf: can be directly deployed on any existing MDP setting the ratio reward/uncertainty W
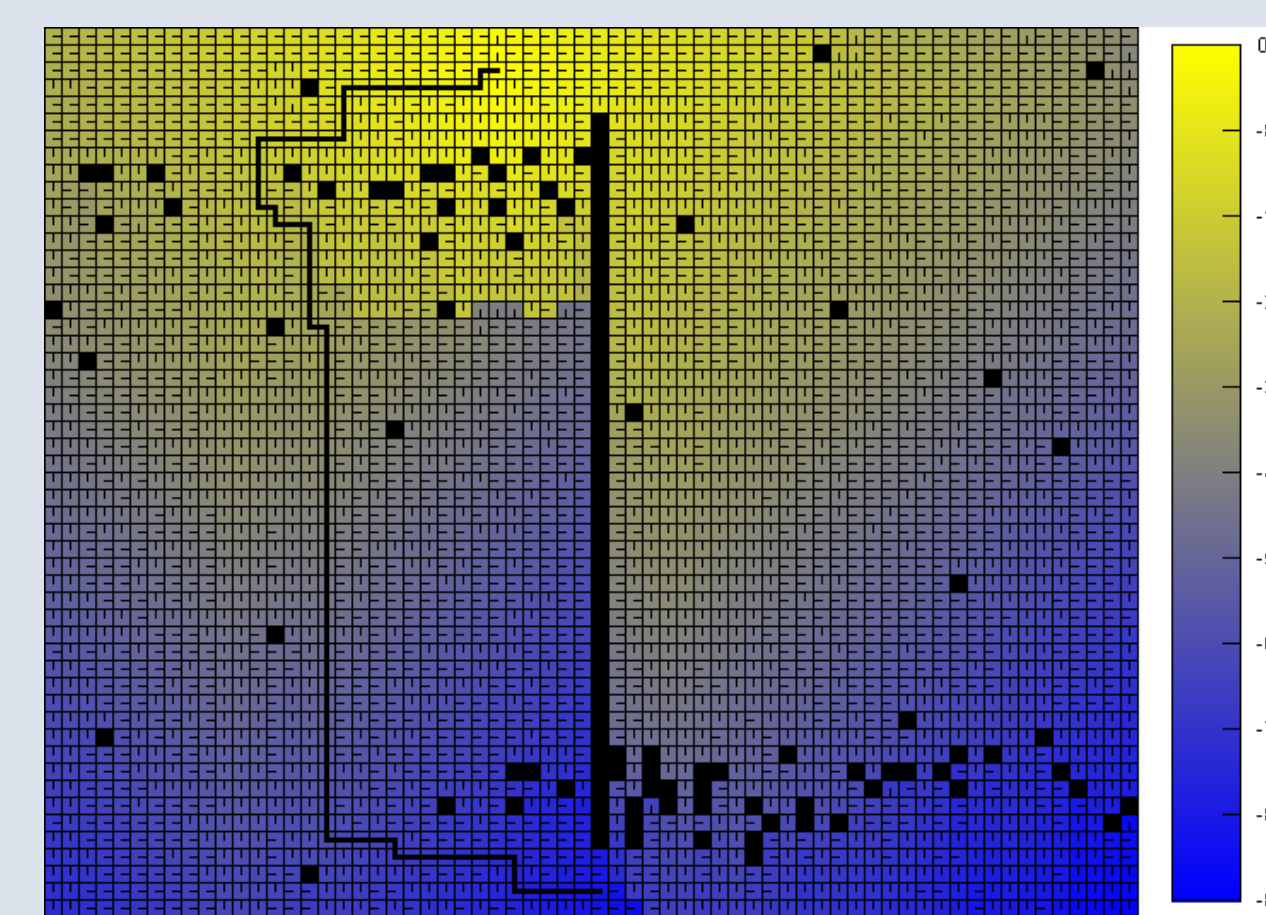
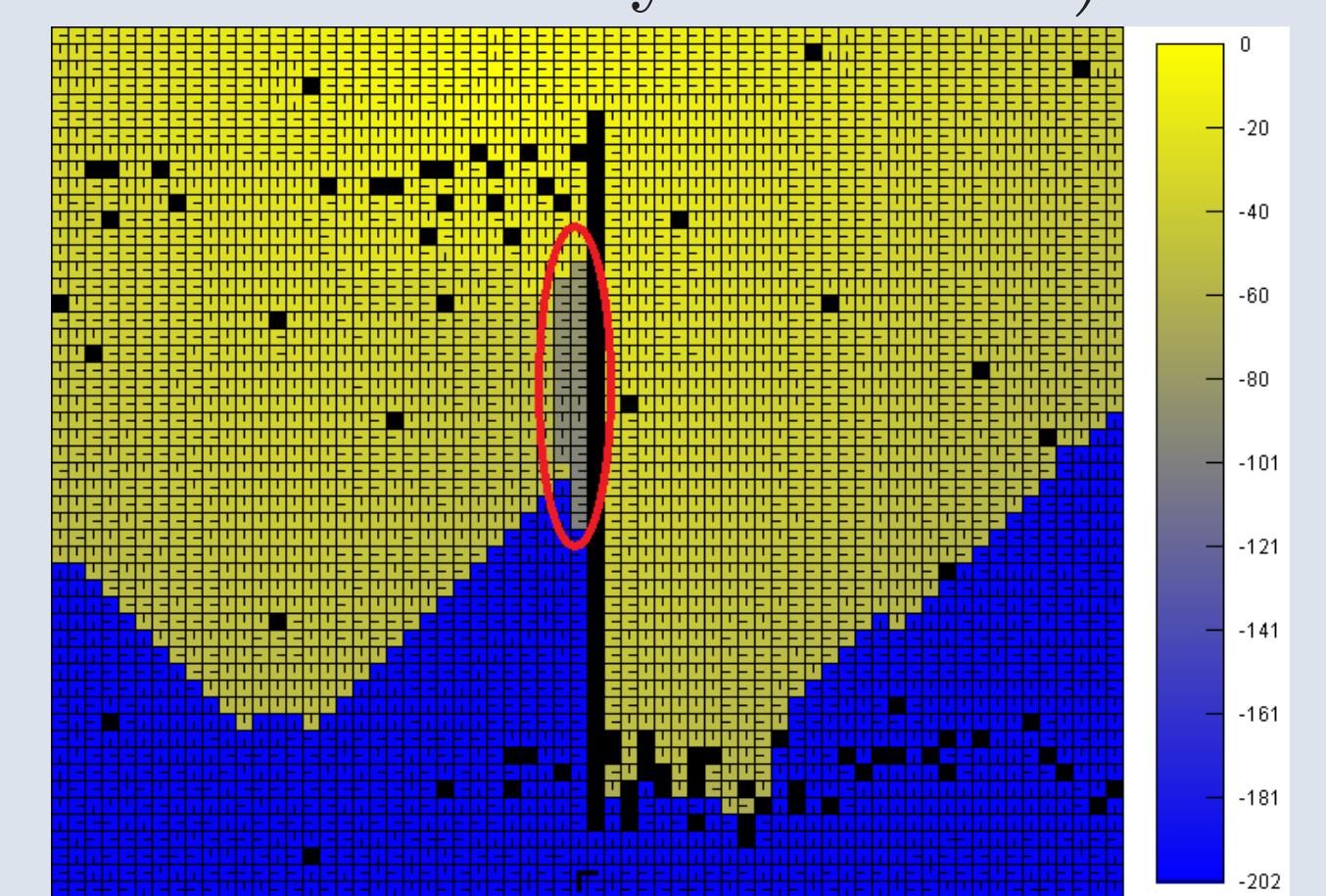### AA-MDPs for human-like behavior

Optimal policy (direct to goal)

Moderate (impatience, takes minor risk to reduce exposition of uncertainty over time)

Large (avoid hitting obstacle at all costs)

Pathological (give up trying due to the uncertainty to reach the goal, certain self-harm rather than uncertain risk)

References

[1] The Lancet Global Health, "Mental health matters," *The Lancet Global Health*, vol. 8, no. 11, e1352, 2020, ISSN: 2214-109X. DOI: https://doi.org/10.1016/S2214-109X(20)30432-0. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2214109X20304320.

[2] M. Miceli and C. Castelfranchi, "Anxiety as an "epistemic" emotion: An uncertainty theory of anxiety," *Anxiety, Stress, and Coping*, vol. 18, no. 4, pp. 291–319, 2005.