Using Subjective Logic to Estimate Uncertainty in Multi-Armed Bandit Problems

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Problem setting

We want to solve a **multi-armed bandit problem** [2].

We use **subjective logic** (SL) [1] to quantify:

- *Aleatoric uncertainty*
- *Epistemic uncertainty*

SL Opinions

A *multinomial opinion* over a discrete countable set of elements i is a tuple[3]:

$$\omega = (\boldsymbol{b}, u, \boldsymbol{a})$$

where:

- b_i is the belief in element i (*How likely is element i?*)
- u is global uncertainty (*How likely is the modelling of beliefs?*)
- a_i is the base-rate probability of element i (*What is the a priori probability of element i?*)

SL multinomial opinions may be mapped to/from *Dirichlet-categorical* models.

[3] with some constraints. See paper.

SL Bandit Algorithms

In a *bandit problem*, we use a *multinomial opinion* to capture the opinion of an agent on which lever is the best.

We define an algorithm(s) based on:

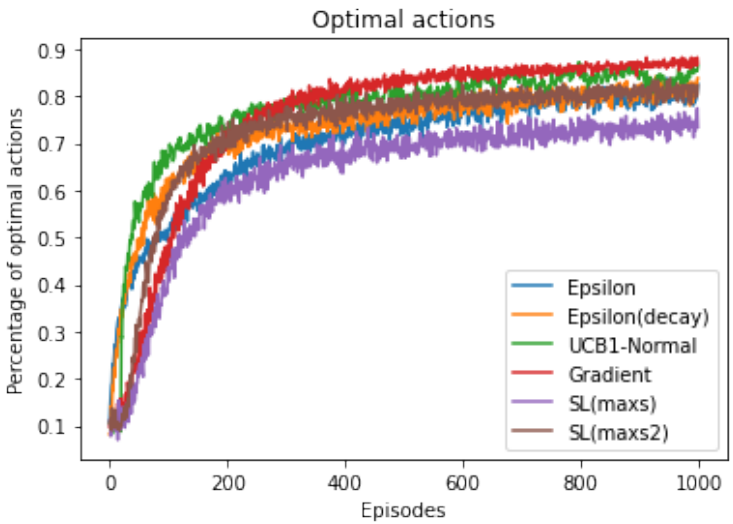
- *Estimating probability of actions from SL opinion*
- *Updating SL opinions based on evidence after action*

During learning, we track uncertainties:

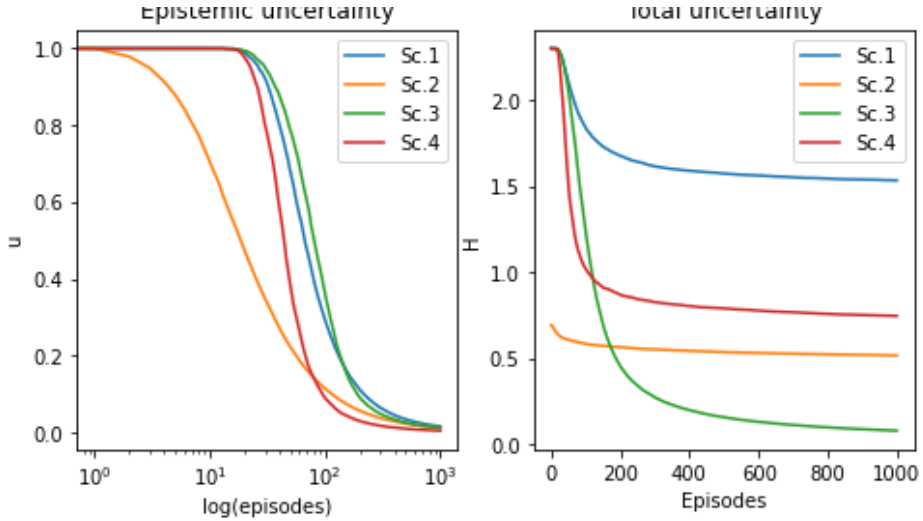
- *Epistemic uncertainty:* uncertainty u
- *Aleatoric uncertainty:* entropy in the Dirichlet-categorical model

Preliminary Simulations

Comparison with other bandit algorithms



Evaluation on uncertainty on different scenarios



Conclusions

- SL may provide a intuitive way to assess uncertainties
- Information on uncertainty may be used to improve learning

- Theoretic analysis and grounding of the dynamics of uncertainty evolution is in order.

Thanks

Thank you for listening!

References I

[1] A. Jøsang. *Subjective Logic: A Formalism for Reasoning Under Uncertainty*. Artificial Intelligence: Foundations, Theory, and Algorithms. Springer International Publishing, 2016.

[2] Tor Lattimore and Csaba Szepesvári. Bandit algorithms. *preprint*, page 28, 2018.