

About use of Everett's interpretation of quantum mechanics in decision making

ver. 0.1

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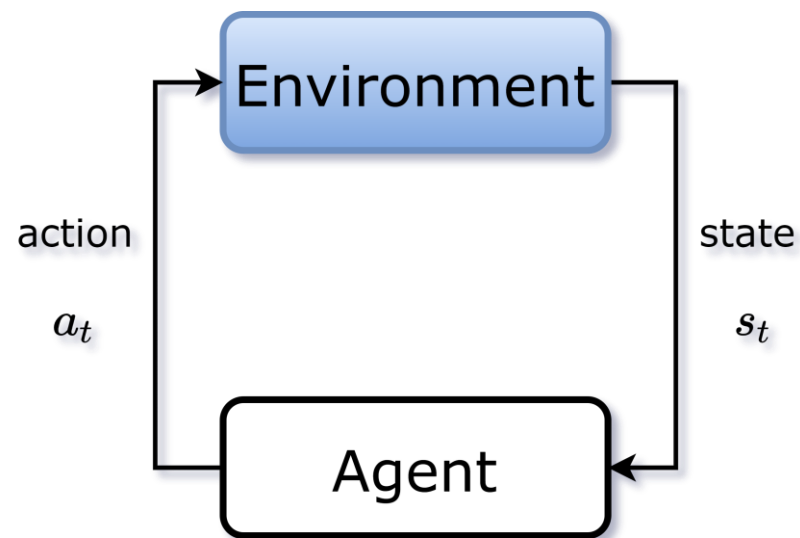
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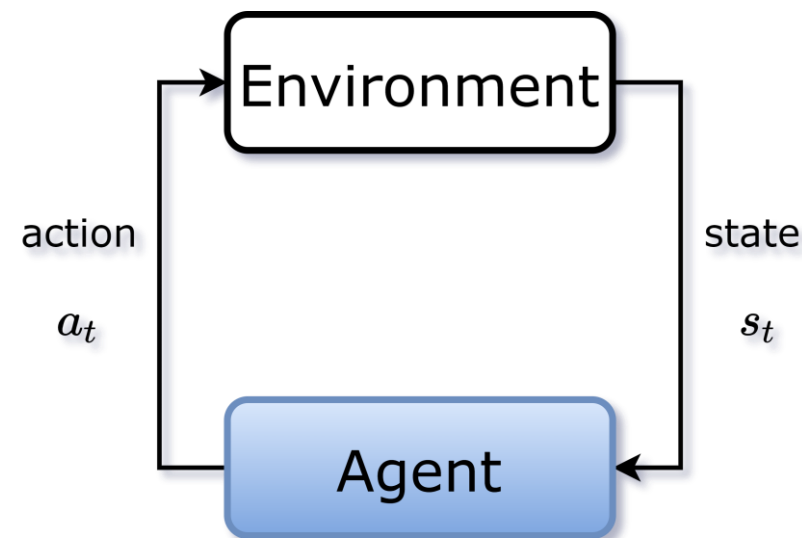
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Recall: closed loop is (almost) everywhere



- **Agent's aim:**
to *influence the environment* behavior
- **Examples:** control; automation; autonomic systems;
- **Applications:** autonomous cars; IoT; (smart) robotics, etc.

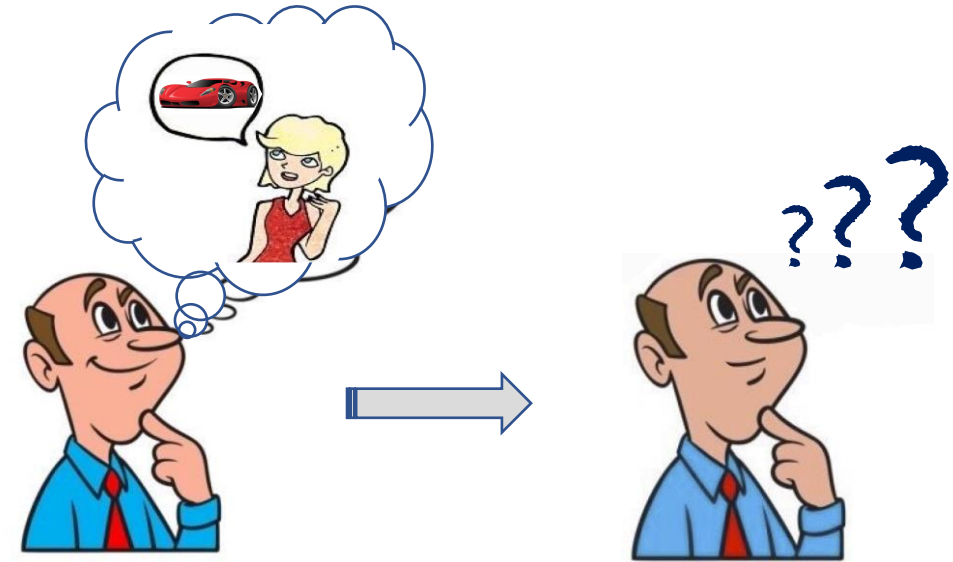
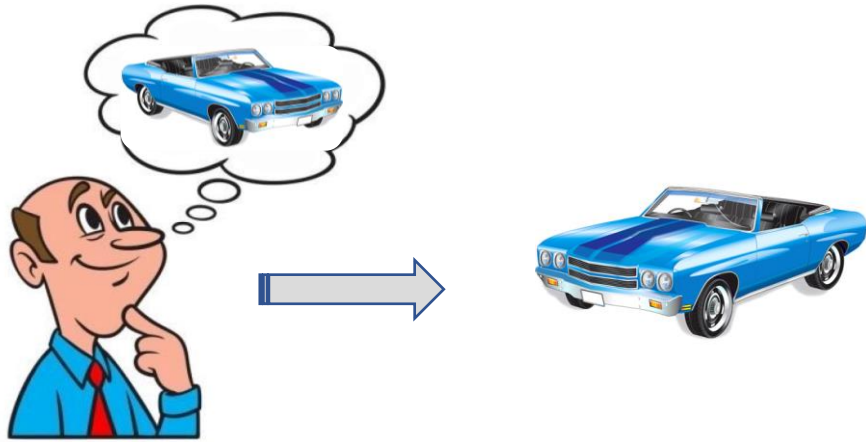


- **Agent's aim:**
 - to *influence/improve the agent's knowledge* about the environment (model, reward function, ...)
- **Examples:** reinforcement learning, prediction.
- **Applications:** forecasting; DL; non-invasive examinations (e.g. medical one); language and image processing, etc.

Consumer choice example:



or



Even a *question* about his wife's preferences *disturbs* and introduces uncertainty about his own preferences.

It is impossible to be in a definite state wrt two different questions because a definite state for one question is indefinite state (superposition) for another.

(Busemeyer & Bruza, 2014)

CPT-based DM: what is missed?

CPT-based DM contradicts findings in psychology and cognition:

- Judgements are based on *indefinite states* (aka superposition states allowing all definite states).
- Judgements disturb each other and introduce uncertainty => *order matters*.
- Judgements *do not obey Boolean logic* => classic probability theory (**CPT**) is not enough
 - Boolean logic is a base of contemporary probabilistic DM as Kolmogorov axioms assign probabilities to events defined by sets. Its important feature is distributive axiom.
 - Quantum probability uses von Neumann axioms assigning probabilities to events as *subspaces* of a vector space, i.e. a superposition state can be any point at a vector space => logic of subspaces:
 - i. does not obey Boolean distributive axiom;
 - ii. does not obey a law of total probability

Classic DM using quantum probability proved to solve the problems above => it is time for **quantum FPD!**

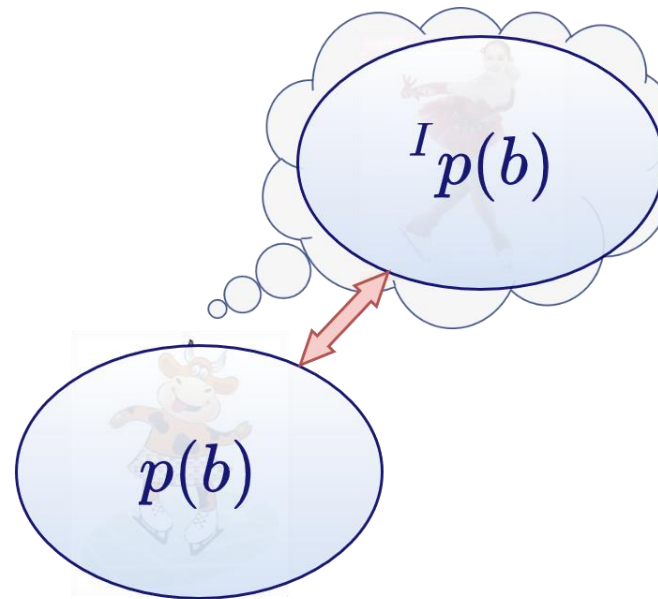
What is Fully Probabilistic Design (FPD)?



real behaviour
that the agent
has

DM task:

Which sequence of actions
should the agent chose to
make real behavior close to
the preferred one.



Optimal FPD strategy:

$$p^{opt}(a_t | s_t) = \operatorname{argmin}_{\{p(a_t | s_t)\}} D(p(b) || I p(b))$$

What is good about FPD and why do we care?

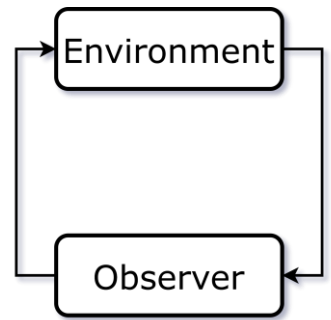
Advantages of FPD:

- each task solved by classic DM can be also solved by FPD
- implicitly solves problem of exploration (FPD provides inherent exploration)
- beliefs and preferences are described with same mathematical structure (pdf vs. utility function)

It motivates us to search for Quantum FPD.

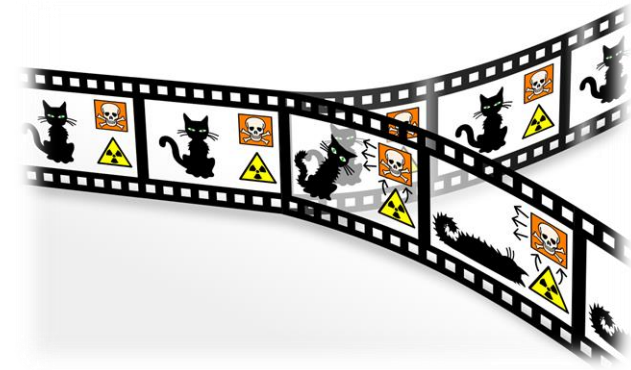
But: It is hard.

Quantum world by Everett



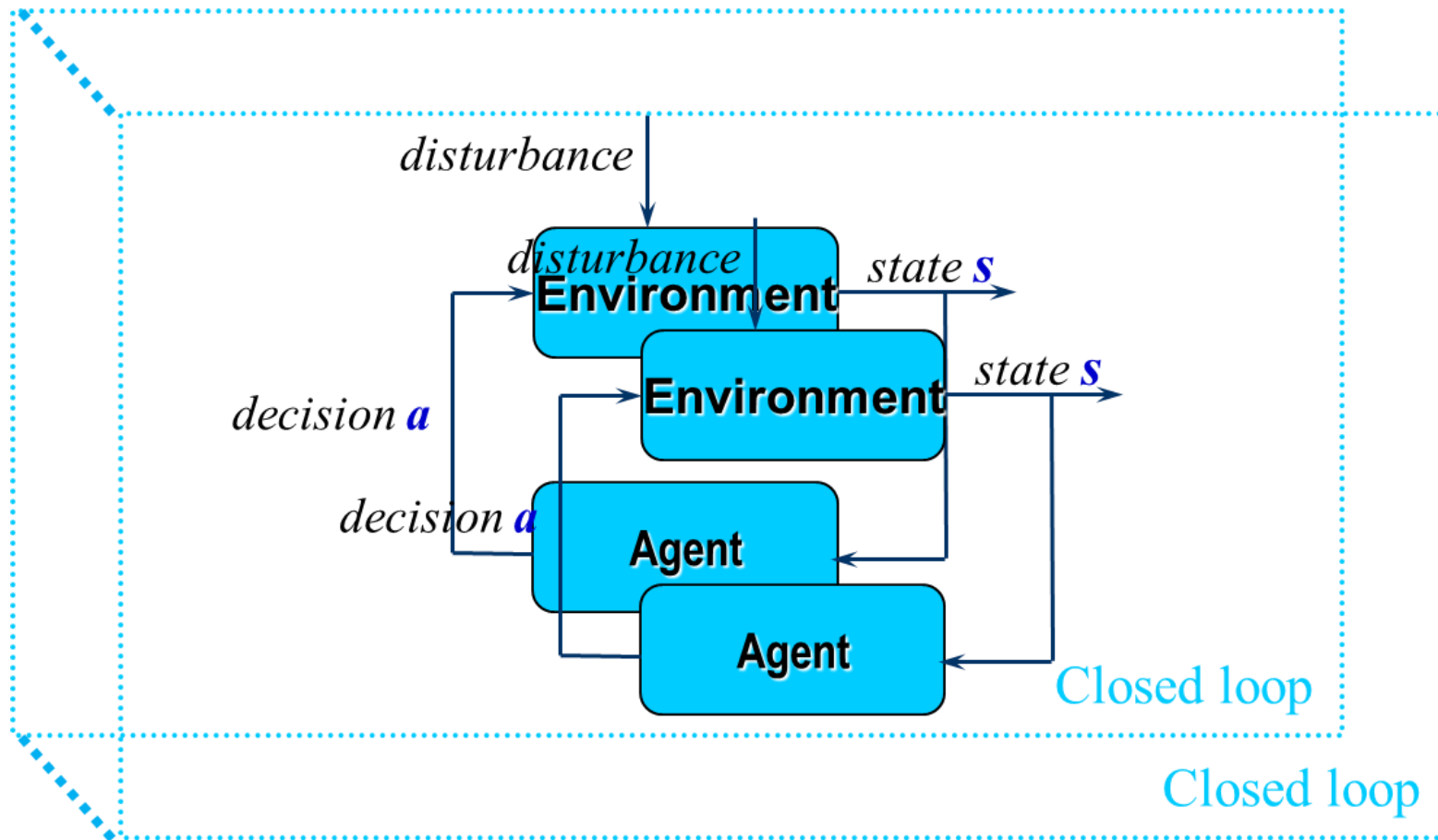
Many-worlds interpretation can describe compound systems and is chosen by us as it:

- shares the concept of closed loop (agent=observer, interaction=observation);
- treats an observer as a part of the compound system (cf. closed-loop);
- models consequences of observations;
- models micro- and macro- world similarly;
- describes subjective experience via the observer's memory;
- can define relative state (=conditional probability);
- takes the state of the closed loop as an element in Hilbert space.



Many-worlds:

Alive and dead cats are in *different* worlds that are equally real, but which do *not* interact with each other.



Conclusions

Quantum FPD

- is a new approach with DM inspired by physical formalism
- provides better modelling and reasoning at micro and macro level
- considers human-like judgement (e.g. zooming) and cognition
- opens a way for general human AI
- may bring interesting mathematics to those who are interested in

Thank you for your attention!