Towards a Framework for Predicting Opportunism in Multi-agent Systems

(Extended Abstract)

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ABSTRACT

Opportunism is a behavior that takes advantage of knowledge asymmetry and results in promoting agents' own value and demoting others' value. We propose a framework to reason about agents' opportunistic propensity and characterize the situation where agents will perform opportunistic behavior.

Keywords

Opportunism, Propensity, Logic, Reasoning, Decision Theory

1. INTRODUCTION

Let us first consider an example scenario. A seller sells a cup to a buyer and it is known by the seller beforehand that the cup is actually broken. The buyer buys the cup without knowing it is broken. The seller exploits the knowledge asymmetry about the transaction to achieve his own gain at the expense of the buyer. Such behavior which is intentionally performed by the seller was named opportunistic behavior (or opportunism) by economist Williamson [4]. Opportunism is a selfish behavior that takes advantage of relevant knowledge asymmetry and which results in promoting one's own value and demoting others' value [2]. In the context of multi-agent systems, it is normal that knowledge is distributed among participating agents in the system, which creates the ability for the agents to behave opportunistically. We want to constrain such a selfish behavior, as it has undesirable results for other agents in the system. Evidently, not every agent is likely to be opportunistic. So it is needed to investigate the interesting issues concerning opportunistic propensity, such as which kinds of agents are likely to perform opportunistic behavior and under what circumstances, so that the appropriate amount of monitoring [3] and constraint mechanisms can be put in place. An agent will perform opportunistic behavior when he knows he can do it and he prefers doing it. Those are the two issues that we consider in this paper. Based on this assumption, we propose a model of transition systems in which agents are assumed to have their own knowledge and value systems, which are related to the ability and the desire of being opportunistic respectively.

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2. FRAMEWORK

We use Kripke structures as our basic semantic models of multi-agent systems. A Kripke structure $\mathcal{M}$ is a directed graph whose nodes represent the possible states of the system and whose edges represent accessibility relations. Within those edges, equivalence relation $\mathcal{K}(\cdot) \subseteq S \times S$ represents agents' epistemic relation, while relation $\mathcal{R} \subseteq S \times Act \times S$ captures the possible transitions of the system that are caused by agents' actions. It is important to note that, because in this paper we only consider opportunistic behavior as an action performed by an agent, we do not model concurrent actions. We require that for all $s \in S$ there exists an action $a \in Act$ and one state $s' \in S$ such that $(s, a, s') \in \mathcal{R}$. Since we assume actions are deterministic, sometimes we denote state s' as $s\langle a \rangle$ for which it holds that $(s, a, s\langle a \rangle) \in \mathcal{R}$. The set of an agent's epistemically accessible states from state s is called the knowledge set of the agent. We also use $Ac(s)$ to denote the available actions in state s. The language $\mathcal{L}_{\text{KA}}$ we use is propositional logic extended with knowledge modality and action modality.

3. VALUE SYSTEM AND RATIONAL ALTERNATIVE

Given several (possibly opportunistic) actions available to an agent, it is the agent's decision to perform opportunistic behavior. One important feature of opportunism is that it promotes one agent's own value but demotes the other agent's value. A value can be seen as an abstract standard according to which agents define their preferences over states. For instance, if we have a value denoting *equality*, we prefer the states where equal sharing or equal rewarding hold. Because of the abstract feature of a value, it is usually interpreted in more detail as a state property, which is represented as a formula in our language. We then define a value system as a strict total order over a set of values, representing the degree of importance of something, which is inspired by the way of defining agents' preference in [1].

Definition 1 (Value System). *A value system* $V = (\text{Val}, \prec)$ *is a tuple consisting of a finite set* $\text{Val} = \{v, ..., v'\} \subseteq \mathcal{L}_{\text{KA}}$ *of values together with a strict total ordering* $\prec$ *over* Val. *When* $v \prec v'$, *we say that value* v' *is more important than value* v. *We say that a value* v *is promoted by an action* a *if and only if action* a *brings about* v *from* $\neg v$, *denoted as*

promoted(v, a), *and we say that* v *is demoted by an action* a *if and only if action* a *brings about* $\neg v$ *from* v, *denoted as* demoted(v, a).

Given two states, an agent defines his preference over these two states with his value system by looking at the most important value among all the values that are changed. We use a binary relation "$\precsim$" over states to represent agents' preferences. Agent i weakly prefers state s' to state s, denoted as $s \precsim_i s'$, if and only if his most important value does not get demoted (either stays the same or gets promoted). In other words, assuming v^* is the most important value that agent i looks at when comparing state s and state s', $s \precsim_i s'$ if and only if $s \models \neg v^*$ and $s' \models v^*$, or, the truth value of v^* stays the same in both state s and state s'.

Before choosing an action to perform, an agent must think about which actions are available to him. We have already seen that for a given state s, the set of available actions is $Ac(s)$. However, since an agent only has partial knowledge about the state, we argue that the actions that an agent knows to be available is only part of the actions that are physically available to him in a state. For example, an agent can call a person if he knows the number of the person; without this knowledge, he is not able to do it, even though he is holding a phone. Given an agent's partial knowledge about a state as a precondition, an agent's subjectively available actions is denoted as $Ac(i, s)$, which is the intersection of the sets of actions physically available in the states in this knowledge set. Based on an agent's rationality assumptions, he will never perform an action which is strictly worse than another action. We call the relation *dominance* between actions in this paper. This notion gives rise to the following definition:

Definition 2 (Rational Alternatives). *Given a state* s *and an agent* i, *the set of* rational alternatives *for agent* i *in state* s *is given by the function* $a_i^* : S \to 2^{Act}$, *which is defined as follows:*

$$a_i^*(s) = \{a \in Ac(i, s) \mid \neg\exists a' \in Ac(i, s) : a \neq a' \text{ and } a' \text{ dominates } a \text{ for agent } i \text{ in state } s\}.$$

The set $a_i^*(s)$ are all the actions for agent i in state s which are available to him and are not dominated by another action which is available to him. In other words, it contains all the actions which are rational alternatives for agent i. We can see that the actions that are available to an agent not only depend on the physical state, but also depend on his knowledge about the state. The more he knows, the better he can judge what his rational alternatives are. In other words, agents try to make the best choice based on their value systems and incomplete knowledge about the state.

4. DEFINING OPPORTUNISM

Opportunism is a social behavior that takes advantage of relevant knowledge asymmetry and results in promoting one's own value and demoting others' value [2]. We firstly use KnowAsym(i, j, ϕ) to represent the context where there is knowledge asymmetry between agent i and agent j, and then we define opportunism as follow:

Definition 3 (Opportunism). *Given a multi-agent system* $\mathcal{M}$, *a state* s *and two agents* i *and* j, *the assertion* Opportunism(i, j, a) *that action* a *performed by agent* i *is opportunistic behavior is defined as:*

$$\text{Opportunism}(i, j, a) := \text{KnowAsym}(i, j, \text{promoted}(v^*, a) \wedge \text{demoted}(w^*, a))$$

where v^* *and* w^* *are the values that agent* i *and agent* j *most care about in the transition respectively.*

This definition shows that if the precondition KnowAsym is satisfied in state s then the performance of action a will be opportunistic behavior. Compared to the definition of opportunism in [2], Definition 3 focuses on the opportunistic propensity of an agent in a state, in the sense that the precondition of performing opportunistic behavior is modeled in an explicit way. As is stressed in [2], opportunistic behavior is performed by intent rather than by accident. Easily we can prove that opportunistic behavior results in value opposition for the agents involved, because v^* and w^* are what agent i and agent j most care about in the transition respectively. Therefore, we have $s \prec_i s\langle a\rangle$ and $s \succ_j s\langle a\rangle$.

5. REASONING ABOUT OPPORTUNISTIC PROPENSITY

Agents will perform opportunistic behavior when they have the ability and the desire of doing it. The ability of performing opportunistic behavior can be interpreted by its precondition: it can be performed whenever its precondition is fulfilled. Agents have desire to perform opportunistic behavior whenever it is a rational alternative. Given the asymmetric knowledge an agent has, there are several (possibly opportunistic) actions available to him, and he may choose to perform the action which is a rational alternative to him, regardless of the result for the other agents. Therefore, given a multi-agent system $\mathcal{M}$, a state s, two agents i and j and opportunistic behavior a, opportunistic behavior is a rational alternative for agent i in state s, formalized as $\exists a \in a_i^*(s) : \mathcal{M}, s \models \text{Opportunism}(i, j, a)$, iff

1. there is knowledge asymmetry between agent i and agent j about promoted$(v^*, a) \wedge$demoted(w^*, a) for enabling its performance, where v^* and w^* are the values that agent i and agent j most care about in the transition respectively;
2. $s \prec_i s\langle a\rangle$ and $s \succ_j s\langle a\rangle$, meaning that its performance can promote agent i's value but demote agent j's value;
3. it is not dominated by any actions in agent i's rational alternatives $Ac(i, s)$.

It is important to stress that the above statements never state that agents will for sure perform opportunistic behavior if the statements are satisfied. Instead, it shows opportunism is likely to happen because it is in the agent's rational alternatives.

6. CONCLUSION AND FUTURE WORK

In this paper, we argue that agents will behave opportunistically when they have the ability and the desire of doing it. With this idea, we developed a framework of multi-agent systems to reason about agents' opportunistic propensity and characterized the context where agents will perform opportunistic behavior. In the future, we would like to enrich our formalization of value system over different sets of values and to consider norms in our framework in addition to the ability and the desire of being opportunistic.

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