Prediction and diagnosis of emergence for independent agents operating in a shared environment

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Background

In recent years, there has been an increasing effort to enhance the control systems by applying the extensible approaches such as component-based and agent-based architectures. For example IntelliGrow and Controleum are two component-based climate control systems used in greenhouses. The controversy of this issue is highlighted in the case that the intelligent control system should deal with the synergies arise from the emerging behavior of independent agents and components operating in a shared environment. Corfixen introduced the independent components of the system as features. A feature is described by a set (R, S, W) of related system specifications S together with domain properties W that entails a set of related requirements R. The entailment relation states that a feature satisfies its requirements R if its specifications S combined with domain properties W hold. The logical entailment relation is as follows $\boldsymbol{S}, \boldsymbol{W} \vdash \boldsymbol{R}$. Feature interactions occur when parallel features shared properties in which the entailment relationship is not true. Although, the system behavior analysis is a hard task due to the complexity and dynamic changes in the system. However, far too little attention has been paid to evaluation of objectives′ optimality for understanding the future behavior of a system, especially regarding to extensibility. For instance, extensible multi-agent systems in dynamic shared environment have the problem of analyzing the system behavior based on the agents′ behavior over time. Armstrong indicated that among all reasons leading the interactions and emergence behavior, the shared context (which is known as shared environment and shared resources in our problem domain) is in the center. Rely on this evidence, one possible research area is to analyze and evaluate the environment characteristics over time beside analysis and evaluation of the Pareto-optimality. These potential cases may lead us to the notion of prediction and diagnosis of emerging behavior in the aforementioned systems, which recently addresses as a challenge in this concept. In addition, current studies do not take account of the diagnosis model for the future emergence happens in concurrent operation of independent agents.

Problem statement

Engineering of emergence for independent agents operating in a shared environment is difficult due to the uncertainties and unpredictable situations in which the system cannot have the desired behavior. This is more highlighted when the system is composed of independent agents and environment characteristics change dynamically, which has the direct influence on system behavior. Considering a system composed of independent agents operating in a shared environment, we address the problem of predicting and detecting the future emergent behavior of the system and consequently, we are facing the problem of assessing whether the observed emergent behavior of the system is correct. To the best of our knowledge, combining independent agents in a shared environment may lead the system to face with the feature interactions. But in the case that any feature interaction is not seen, emergence may happen. In different conditions emergence may or may not happen in the system: We expect not to have the emergence when:

- Feature interactions lead the system to the condition that the system
- would not be able to find any satisficing solution. Entailment relation is broken for a set of basic behaviors having compatible pre-conditions and post-conditions.

By this definition, we define the emergence using the entailment relation. Considering a systemic requirements Rs: $\boldsymbol{Rs} \Longleftrightarrow \boldsymbol{R2} \wedge \boldsymbol{R1}$ emerge when:

- $\boldsymbol{S1} \parallel \boldsymbol{S2}, \boldsymbol{Ws} \vdash \boldsymbol{R2} \wedge \boldsymbol{R1}$; or
- $\boldsymbol{S1} \parallel \boldsymbol{S2}, \boldsymbol{Ws} \vdash \boldsymbol{R2} \wedge \boldsymbol{R1} \Longleftrightarrow \boldsymbol{R}$

Where Ws represents the shared domain properties, $\parallel$ is the operator representing the parallel composition and $\vdash$ is the entailment relation.

Emergence in Smart Grids

Figure beloew indicates the emergence behaviour in smart energy solutions such