Comments on “Bisimilarity Enforcement for Discrete Event Systems Using Deterministic Control”: Extension to Decentralized Setting

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Abstract—An article on bisimilarity enforcement for discrete event systems using deterministic monolithic control was published recently in 2011, Issue 12, Volume 56, pages 2986-2992, of IEEE Transactions on Automatic Control [6]. This note shows how the results straightforwardly extend to the case when the control is decentralized. Only the language requirement of “observability” gets replaced by “coobservability”; no new constraint on the branching structure is required.

I. INTRODUCTION

The following result was reported in [6, Theorem 1] that provides a necessary and sufficient condition for the existence of a bisimilarity enforcing deterministic control while plant and control-specification are nondeterministic, modeled as nondeterministic automata. Here we will assume familiarity with the standard notions of controllability, observability and coobservability (see for example [1]).

Theorem 1: [6] Given nondeterministic plant G and nondeterministic specification R, set of uncontrollable events Σu and an event-observation mask M, there exists a deterministic (Σu, M)-compatible controller S such that G||S ≃ R if and only if L(R) is controllable and observable, and G||det(R) ≃ R.

Here (Σu, M)-compatibility means that the controlled language L(G||S) is controllable and observable (so no uncontrollable events are disabled, and identical control-actions are issued following indistinguishable traces).

II. EXTENSION TO DECENTRALIZED DETERMINISTIC CONTROL

Theorem 1 can be straightforwardly generalized to decentralized setting, simply by replacing “observability” with “coobservability” [5].

Theorem 2: Consider a nondeterministic plant G, a nondeterministic specification R, a set of uncontrollable events and observation mask pairs \{ (Σui, Mi), i ∈ I \} (where I is an index set of controllers). Then for each i ∈ I, there exists a deterministic (Σui, Mi)-compatible controller Si such that G||iSi ≃ R if and only if L(R) is controllable and coobservable, and G||det(R) ≃ R.

Proof: For necessity, suppose such controllers \{ Si, i ∈ I \} exist. Then from hypothesis, since G||iSi ≃ R, it follows that L(G||iSi) = L(R). Then from necessity of language-enforcing decentralized control, L(R) is controllable and coobservable [5]. Further by considering S := ||iSi as a monolithic supervisor, it follows from the necessity part of the proof of Theorem 1 (see [6]) that G||det(R) ≃ R.

Now for sufficiency, choose for each i ∈ I, Si = det(\( \inf_P PC_{\Sigma_u} OM(L(R)) \)), namely, the deterministic generator of infimal prefix-closed, Σui-observable and Mi-observable superlanguage of R. (Existence of such a language is known in literature, see for example, [1].) Then it follows that each Si is (Σui, Mi)-compatible. Let S := \( \|iSi \) so that L(S) = L(\( \|iSi \)) = \( \bigcap_i L(S_i) = \bigcap_i \inf_P PC_{\Sigma_u} OM_{\Sigma u}(L(R)) = \inf_P PC_{\Sigma u} OM_{\Sigma u}(L(R)) \), where the last term denotes the infimal prefix-closed, controllable and coobservable superlanguage, and the last equality was established in [2, Theorem 3]. By hypothesis, L(R) is controllable and coobservable, and so \( \inf_P PC_{\Sigma u} OM_{\Sigma u}(L(R)) = L(R) \). Thus L(S) = L(\( \|iSi \)) = L(R).

Since each Si is deterministic by definition, so is S = \( \|iSi \), and since L(S) = L(R), it follows that S = det(R). Finally since by hypothesis, we have G||det(R) ≃ R, where as we showed det(R) = S, it follows that G||S = G||det(R) ≃ R, or equivalently, G||iSi ≃ R as desired.

III. CONCLUSION

Theorem 2 shows that, fundamental to the existence of a bisimilarity enforcing deterministic control, is the requirement G||det(R) ≃ R, requiring that the portion of the plant that only executes the traces allowed by the specification, has the same branching structure (i.e., nondeterminism) as the specification. This is a fundamental requirement since this requirement stays constant as one moves from centralized to decentralized setting (only the language-level requirement changes from observability to coobservability). It follows that analogous results can be derived even when a more general architecture for decentralized control is employed. For example if an inferencing-based decentralized control architecture is used, then the coobservability in Theorem 2 will be replaced by inference-observability, introduced in [3]. On the other hand, if modular control architecture is employed, then the coobservability in Theorem 2 will be replaced by the

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separable-controllability, introduced in [7]. Finally since the
tests for the language properties of interest already exist in lit-
erature, the existence test for enforcing bisimilarity enforcing
deterministic control boils down to checking the fundamental
property $G \parallel \det(R) \simeq R$. A test for the same was reported in
[6], and an test based on an equivalent notion of simulation-
based controllability was presented in [4].

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