

MANUFACTURING SYSTEMS CONTROL WITH PETRI NET OBSERVERS

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This paper discusses the problem of controlling a Petri net whose marking cannot be measured. An observer is used to estimate the actual marking of the plant based on partial information of the initial marking and on event observation. This estimate is used to design a state feedback controller, that ensures that the plant in closed-loop evolves through a set of legal states. We present an efficient algorithm, that generalizes previous results, to design a safe observer-controller for legal states defined by linear constraint sets.

1. Introduction

In the classical approach of Ramadge and Wonham [12] to the supervisory control of discrete event systems, the *event-feedback* control scheme shown in Figure 1.a is adopted. Here the plant spontaneously generates events. The supervisor observes the word of events w generated and, given a set of legal words \mathcal{K} , computes at each step a suitable control pattern γ to ensure that no illegal word be generated.

Other authors have used a different *state-feedback* control scheme, shown in Figure 1.b. Here the supervisor observes the actual plant state M and, given a set of legal states \mathcal{L} , computes at each step a control pattern to ensure that no illegal state be reached. This scheme is particularly appealing when dealing with Petri net models of the plant [6], since the state of a net is given by an integer vector called *marking* and linear algebraic techniques may be used to solve the control problem.

A slightly different scheme is shown in Figure 1.c. Here the controller observes the word of events generated and, by means of an observer, it reconstructs the actual plant state M . The observer simply duplicates the plant model, and is driven by the observed events. If the structure (that is assumed to be deterministic) and the initial state M_0 of the plant are known, the knowledge of the word generated is sufficient to reconstruct the new state that each new firing yields.

In [4] a different scheme, shown in Figure 1.d, was considered and used in the context of Petri nets. In this scheme, the initial marking (state) M_0 is not completely specified, but is known to belong to a "macromarking", i.e., we know the token contents of subsets of places but not the exact token distribution. An algorithm was given for computing a marking estimate μ_w and error bound B_w . The estimate is always a lower bound of the actual marking.

In [4] a particular structure of the initial macromarking has been considered, i.e., it was assumed that the partition induced by the initial macromarking is disjoint. In this paper we extend the previous results to a more general case in which the initial macromarking is not completely disjoint: the presence of a single subset, whose intersection with all the others may be different from the empty set,

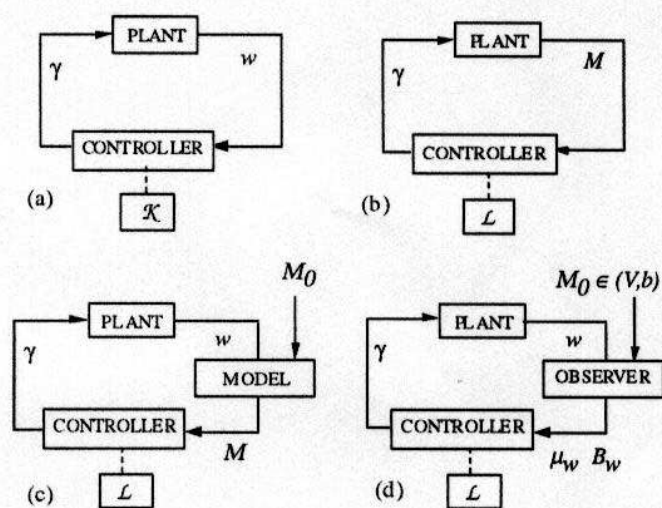


Figure 1: Different control schemes. (a) Event-feedback. (b) State-feedback. (c) State-feedback with event observer and initial marking. (d) State-feedback with event observer and initial macromarking.

is taken into account.

The system that computes the estimate is called an observer. It has been shown in [3] that a special net structure, called *observer net*, can be used to describe the observer: such a net has a set of places corresponding to the places of the plant whose marking is at each step μ_w , plus a set of bounding places (one for each place subset in the partition induced by initial macromarking) whose marking is B_w .

The special structure of Petri nets allows us to use a simple linear algebraic formalism for estimate and error computation. In particular, the set of markings consistent with an observed word, i.e., the set of marking in which the system may actually be given the observed word, can easily be characterized in terms of the observer marking.

Finally, we show how the estimate generated by the observer may be used to design a state feedback controller, that ensures that the controlled system never enters a set of forbidden states. We consider a special class of specifications that limit the weighted sum of markings in subset

