Petri Nets Identification Techniques for Automated Modelling of Discrete Event Processes

Edelma Rodriguez-Perez
CINVESTAV Unidad Guadalajara, Mexico

Ernesto Lopez-Mellado
CINVESTAV Unidad Guadalajara, Mexico

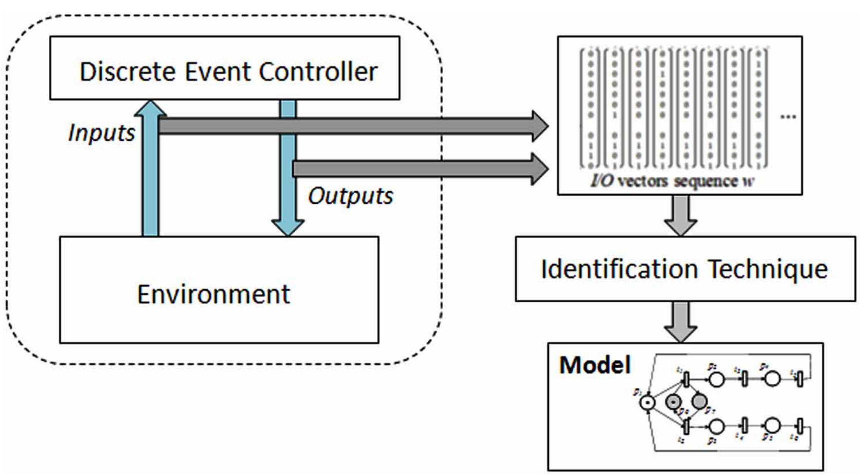
INTRODUCTION

Building Petri net models from system behaviour observations is a hard task when the system is large and complex; then, the use of computer-aided modelling tools is useful. Identification techniques have been useful for building systematically models involving events and states. Finite automata and Petri nets have been used as a formalism to describe the functioning of discrete event processes in operation.

Reactive systems are embedded within an environment interacting with other systems. We focus on systems that interact through binary signals, which is the case of discrete event processes. The behaviour of the system is then captured as sequences of vectors whose entries are the values of input-output signals; afterwards, the sequences are processed by an identification method to obtain the discrete event model. This is shown in Figure 1.

This chapter surveys relevant identification methods and overviews two approaches that generate models of different levels of abstraction; one that describes in detail the relationship between input events and outputs, and other that yields compact descriptions. Finally, current research problems and trends on discrete event process identification are discussed.

Figure 1.



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BACKGROUND

1. Identification Methods

1.1. Language Learning Methods

Pioneer works on identification methods can be found in computer science theory, where the problem of obtaining a language representation from sets of accepted words has been dealt since a long time. Such methods are generally referred as *language learning techniques*.

Gold´s method (Gold, 1967) for identification in the limit processes positive samples: an infinite sequence of examples such that the sequences contain all and only all the strings in the language to learn.

The Probably Approximately Correct (PAC) learning technique in (Valiant, 1984) learns from random examples and studies the effect of noise on learning from queries.

The query learning model proposed in (Angluin, 1988) considers a learning protocol based on a "minimally adequate teacher"; this teacher can answer two types of queries: membership query and equivalence query.

Several works adopted state machines as representation model, allowing describing the observed behaviour.

In (Booth, 1967) a method to model a language as Moore or Mealy machines is presented. The method proposed in (Kella, 1971) allows obtaining models representing Mealy machines from a single observed input-output sequence. In (Biermann & Feldman, 1972) a method to identify non deterministic Moore machines based on a set of input-output sequences is presented. The method presented in (Veelenturf, 1978) processes simultaneously a sample of sequences to produce stepwise convergent series of Mealy machines, such that the behaviour of every new machine includes the behaviour of the previous one. Later, in (Veelenturf, 1981) an algorithm to identify a unique Moore machine generating the behaviour observed during *m* sequences starting at the same initial state is proposed. This method is improved in (Richetin, Naranjo & Runeau, 1984); it proposes two algorithms to identify multiple systems.

Other works use as description formalism Petri net models. In (Hiraishi, 1992) an algorithm for synthesising Petri net models is presented. The proposed algorithm has two phases. In the first phase, the language of the target system is identified in the form of DFA. In the second phase, the algorithm guesses from the DFA the structure of a Petri net that accepts the obtained language.

1.2. Methods for Process Identification

In recent years, identification approaches (based on Petri net or automata) have been proposed for obtaining approximated models of Discrete event process whose behaviour is unknown or ill-known. In the context of manufacturing processes, identification methods can be complementary to established modelling techniques.

The incremental synthesis approach, proposed in (Meda, Ramirez & Lopez, 2000), (Meda & Lopez, 2001), (Meda & Lopez, 2003), deals with unknown partially measurable concurrent discrete event systems (DES) exhibiting cyclic behaviour. Several algorithms have been proposed allowing the on-line building of interpreted Petri net (IPN) models from the DES outputs. Although the techniques are efficient, the obtained models may represent more sequences than those observed.

In (Giua & Seatzu, 2005) a method to build a free labelled PN from a finite set of transitions strings is presented. This method is based on the resolution of an Integer Linear Programming (ILP) problem; the obtained PN generates exactly the observed language. Both the ILP statement and its solution are computationally demanding. This approach has been extended to other PN classes (Cabasino, Giua, & Seatzu, 2007; Dotoli, Fanti, & Mangini, 2008; Fanti & Seatzu, 2008; Dotoli et al., 2011); however, issues regarding applications to actual industrial DES have not yet been addressed in these works.