Recursive Immuno-Inspired Algorithm for Time Variant Discrete Multivariable Dynamic System State Space Identification

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ABSTRACT

In this paper a recursive immuno inspired algorithm is proposed to identify time variant discrete multivariable dynamic systems. The main contribution of this paper has as starting point the idea that a multivariable dynamic system state space model can be seen as a point in a space defined by all possible matrices quadruples that define a state space model. With this in mind, the time variant discrete multivariable dynamic system modeling is transformed in an optimization problem and this problem is solved with an immuno inspired algorithm. To do that the inputs given to the system and the resulting outputs are divided in small sets containing data from small time intervals. These sets are defined as time windows, and for each window an immuno inspired optimization algorithm is applied to find the state space model that better represents the system at that time interval. The initial candidate solutions of each time interval are the ones of the last interval. The immuno inspired algorithm proposed in this paper has some modifications to the original Opt-AINet algorithm to deal with the constraints that are natural from the system identification problem and these modifications are also contributions of this paper. The method proposed in this paper was applied to identify a time variant benchmark system, resulting in a time variant model. The outputs estimated with this model are closer to the benchmark system outputs than the outputs estimated with models obtained by other known identification methods. The Markov parameters of the variant benchmark system are also reproduced by the time variant model found with the new method.

Keywords: Evolutionary Algorithms, Immuno-Inspired Algorithms, Multivariable System Identification, State Space Identification, Time Variant System Identification

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INTRODUCTION

State space system identification is the name given to the techniques used to find a state space model that represents a dynamic system based only on system inputs and outputs. In other words it means to find a state space model that, when excited by known inputs, has outputs that are as near as possible to the known system outputs. The use of state space models instead of transfer functions models has the advantage that multivariable systems can be identified with no constraints regarding the number of elements on it.

Many state space system identification techniques have been developed to identify time invariant multivariable dynamic systems (Aguirre, 2004; Barreto, 2002; Cáceres, 2005; Verhaegen & Verdult, 2007; Young, 2011). Basically these techniques take into account all available system input and output samples, estimate the Markov parameters and from these parameters some algebraic manipulations are made to find the matrices of a linear time invariant model that has outputs similar to the system outputs when excited by the same input. Since these techniques are based on the whole set of samples available, only linear time invariant systems can be modeled correctly.

Recently a technique was developed to deal with the time variant multivariable system identification problem (Tamariz, 2005). This technique, known as MOESP-V AR algorithm, is based on splitting the data set in time windows and finding one model for each one of these windows separately. The method used to model each window is the Multivariable Output Error State Space (MOESP) (Verhaegen & Dewilde, 1992). This method requires the estimation of the Markov Parameters of the system and to do that a large amount of data is needed. Consequently the time windows must be large enough to the MOESP method work inside each one of them.

In other papers the authors have shown that an immuno inspired method can be applied to solve a problem similar to the system identification, that is the time series modeling (Giesbrecht & Bottura, 2011). The main advantage of this approach is that is not necessary to evaluate time series covariances and consequently any imprecision brought by a non-exact covariances estimation are eliminated. An idea similar to the one proposed in these papers is explored in this work to identify time variant dynamic systems without calculating the Markov parameters, that in the system identification have the same role that the covariance matrices have in the time series modeling.

In this paper a recursive immuno inspired method for time variant multivariable system state space identification is introduced. This method is based on applying an immuno inspired algorithm to update the matrices of a state space model that has a behavior similar to the time variant system behavior as long the time passes by.

Differently from the MOESP based methods, the immuno inspired system identification method proposed in this paper does not depend on Markov parameters estimation after the initialization and consequently the input and output windows needed to update the model matrices are smaller than would be if the Markov parameters calculation was needed. Consequently, faster system changes can be identified.

The algorithm proposed in this paper is defined as recursive in the same sense as the Recursive Least Squares Method, which means that the solutions obtained in one step are refined using the data presented in the next step of the algorithm.

Using the new proposed method a time variant system was identified with better results than the ones obtained with a pure time invariant identification algorithm and the ones obtained with the MOESP-V AR algorithm.

This paper has seven sections. In the following section some state space discrete system identification algorithms are discussed. In the third section is described how the immuno inspired algorithms can be used to solve optimization problems and the advantages of using this kind of algorithm are highlighted. In the fourth section is detailed how the multivariable time variant state space system identification...
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