

# Recursive Identification of Takagi-Sugeno Models in the Presence of Piecewise Polynomial Disturbances

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**Abstract** – The paper considers recursive identification of Takagi-Sugeno (TS) models. The TS models consist of finite collection of linear time invariant systems. It is supposed that real systems can be described with the Hammerstein model for which the reasonable approximation is TS model. The disturbance is piecewise polynomial. As identification algorithm the Kaczmarz algorithm is used. Special attention is paid for design of input signal for Hammerstein system and verification signal. Cluster analysis is based on Gustafson-Kessel algorithm. From this analysis it follows determination of membership functions. As a result, the recursive algorithm has structure similar to instrumental variable method. Simulations cover the practical behaviour of algorithm.

**Key words:** Takagi-Sugeno model, Kaczmarz algorithm, Gustafson-Kessel algorithm, piecewise polynomial disturbance

## I. INTRODUCTION

Fuzzy models well approximate nonlinear systems. This particularly refers to TS models where it is used linearization of nonlinear systems in fuzzy regions of the state space [1]. Input space is decomposed into a finite collection of fuzzy regions. The consequent function describes system behavioural in those regions.

In this paper, it is considered modelling of Hammerstein model in forward line of the system, shown on Fig. 1.

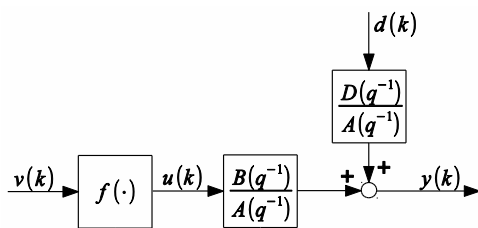


Fig. 1. The system with Hammerstein model.

A piecewise polynomial disturbance, with its own dynamics, acts on the system, and its form is shown in Fig. 2.

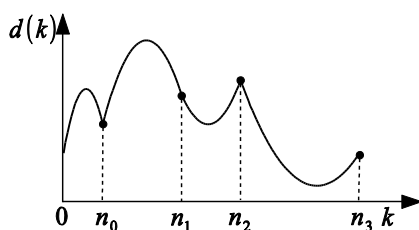


Fig. 2. An example of the piecewise polynomial disturbance.

The nature of this disturbance is more deterministic than stochastic. Piecewise polynomial disturbance is defined as follows

$$d_k = \begin{cases} f_0(k) = f_{00} + f_{01}k + \dots + f_{0m_0}k^{m_0} & 0 \leq k < n_0 \\ f_1(k) = f_{10} + f_{11}k + \dots + f_{1m_1}k^{m_1} & n_0 \leq k < n_1 \\ \vdots & \vdots \\ f_l(k) = f_{l0} + f_{l1}k + \dots + f_{lm_l}k^{m_l} & n_{l-1} \leq k < n_l \end{cases}, \quad (1)$$

and

$$\bar{m} = \max \{m_0, m_1, \dots, m_l, \dots\}. \quad (2)$$

During identification, signals which excite the system have an important role. Excitation signal must be such chosen that excite the largest possible range of amplitudes and frequencies. The selection of excitation signal quite depends on the system which is identified. In fuzzy models identification, signals, such as PRBS or Gaussian noise, do not give good results. On the other side, a multi-sinusoidal excitation signal, with the addition of a weak Gaussian noise, in most cases gives good results [2]. This excitation signal must not be much noised, because with increasing in noise level, the variance of estimated parameters is also increased [3].

Hammerstein model is identified by TS model. The identification of TS model consists of two steps. In the first step, the identification of premise part of the TS model is carried out. By GK algorithm, a classification of the input-output space is performed. For obtained regions, membership functions are determined. For simplicity it is taken that all membership functions are Gaussian functions.

In the second step, parameters of the local ARX models are determined. During identification, it is necessary to remove the influence of piecewise polynomial disturbance. The rejection of piecewise polynomial disturbance is performed with introduction of an appropriate filter by which the input and output signal is filtered [4]. Parameter estimation is carried out by Kaczmarz algorithm [5] based on filtered observations.

The methodology presented in this paper is demonstrated through simulation.





