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Comments on “Design of fractional adaptive strategy for input nonlinear Box–Jenkins systems”

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ABSTRACT

This note points out some errors in the identification model and implementation issues of adaptive strategies presented by Chaudhary and Raja for estimation of input nonlinear Box–Jenkins (INBJ) systems (Chaudhary and Raja, 2015 [1]). This note proves that identification model presented in above mentioned paper is incorrect and in stepwise manner suggests some suitable corrections. Authors claim to propose two algorithms for INBJ systems in above mentioned paper: fractional least mean square (F-LMS) algorithm and auxiliary model fractional least mean square (AM-FLMS) algorithm. AM-FLMS algorithm is not presented in this paper, but results of this algorithm are provided. The adaptive algorithms presented by authors are not implementable due to the presence of unknown noise terms in information vector. Authors have ignored these critical issues. Finally, corrections on the basis of established techniques are also mentioned that solve the problems in the above mentioned paper.

1. Introduction

The identification of input nonlinear Box–Jenkins (INBJ) systems using fractional least mean square (F-LMS) algorithm and auxiliary fractional least mean square (AM-FLMS) algorithm is considered in [1]. This note points out the critical issues with the identification model used by authors and the reasons that make it impossible to implement the FLMS and AM-FLMS algorithms proposed in [1]. The intention is to bring the authors attention to the well known methods which have solved the problems that authors are dealing with in [1].

2. Issues with identification model and solutions

This section focuses on the issues with identification model presented in [1]. Before pointing out the inconsistencies in the identification model presented by authors, let us have a look at some expressions provided in [1]. These expressions are referred rigorously in the upcoming arguments and this makes it reasonable to mention these expressions here in exactly same manner as in [1]. The authors presented identification model for INBJ systems using expressions from (1)–(13). The model derivation went out smoothly only for expressions (1)–(8). The parameter vector is presented in Eq. (9) [1]:

$$\theta = \left[\mathbf{a},\ \mathbf{mb},\ \mathbf{c},\ \mathbf{a}c_1,\ \mathbf{a}c_2,\ \ldots, \mathbf{a}c_{n_c},\ \mathbf{mb}c_1,\ \mathbf{mb}c_2, \mathbf{mb}c_{n_c},\ \mathbf{a}d_1,\ \mathbf{a}d_2,\ \mathbf{a}d_{n_d},\ \mathbf{d}\right]^T \in R^{n_0}. \tag{9}$$

The definition of n_0 as provided by authors is (below Eq. (9) in [1]):

$$n_0 = n_a + l n_b + n_c + n_a n_c + l n_b n_c + n_a n_d + n_d.$$

The information vector mentioned in [1] is:

$$\boldsymbol{\phi}(t) = [\boldsymbol{\psi}(t), v(t-1),\ v(t-2),\ \ldots, v(t-n_a+n_d),\ \ldots, v(t-n_a n_d)] \in R^{n_0}, \tag{10}$$

$$\boldsymbol{\psi}(t) = \left[\boldsymbol{\psi_0}(t), -y(t-1), -y(t-2),\ \ldots, -y(t-n_a+n_c), \ldots, -y(t-n_a n_c)\right] \in R^{n_a+n_c+n_a n_c}, \tag{11}$$

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$$\boldsymbol{\psi}_{\mathbf{0}}(t) = [f(x(t-1)), f(x(t-2)), \ldots, f(x(t-n_b)), \ldots, f(x(t-n_b n_c))] \in R^{l(n_b+n_b n_c)}. \quad (12)$$

The issues with the definitions of parameter vector and information vector are listed below:

i. Authors claim in Eq. (12) that $\boldsymbol{\psi}_{\mathbf{0}}(t) \in R^{l(n_b+n_b n_c)}$. This is incorrect as there are $n_b n_c$ elements in the vector provided in (12). The dimensions written by authors do not match with number of elements in vector.

ii. It is given in (11) that $\boldsymbol{\psi}(t) \in R^{n_a+n_c+n_a n_c}$. This is incorrect as there are $n_a n_c + n_b n_c$ entries in the vector provided in (11). The dimensions written by authors do not match with number of elements in vector.

iii. From the definition in (10), $\boldsymbol{\phi}(t) \in R^{n_0}$ where $n_0 = n_a + l n_b + n_c + n_a n_c + l n_b n_c + n_a n_d + n_d$. This is incorrect as there are $n_a n_c + n_b n_c + n_a n_d$ entries in the vector provided in (10) by authors. The dimensions written by authors do not match with number of elements in vector.

iv. From Eq. (13), provided by authors:

$$y(t) = \boldsymbol{\varphi}^T(t)\boldsymbol{\theta} + v(t). \quad (13)$$

There is no vector defined using $\boldsymbol{\varphi}(t)$. This is a typo mistake and $\boldsymbol{\phi}(t)$ should replace $\boldsymbol{\varphi}(t)$ as information vector. So, correct equation would be:

$$y(t) = \boldsymbol{\phi}^T(t)\boldsymbol{\theta} + v(t). \quad (13')$$

v. From above mentioned points $\boldsymbol{\phi}(t) \in R^{n_a n_c + n_b n_c + n_a n_d}$ and authors claim that $\boldsymbol{\theta} \in R^{n_0}$. This means that $\boldsymbol{\theta}$ and $\boldsymbol{\phi}(t)$ are vectors of different dimensions. Expression (13) in [1] requires inner product of θ and $\boldsymbol{\phi}(t)$. This means inner product of $\boldsymbol{\phi}(t)$ and $\boldsymbol{\theta}$ in (13) is impossible and identification model provided by authors in [1] is erroneous.

vi. There is a typo mistake in the definitions (10)–(12). According to these definitions, $\boldsymbol{\phi}(t)$ is a row vector while $\boldsymbol{\theta}$ is a column vector. This means inner product of $\boldsymbol{\phi}(t)$ and $\boldsymbol{\theta}$ in (13) will not result in a scalar. This typo mistake can be corrected by taking transpose of definitions in (10)–(12).

vii. From (10), it can be seen that first $n_b n_c$ entries of $\boldsymbol{\phi}(t)$ are occupied by:

$$\boldsymbol{\psi}_{\mathbf{0}}(t) = [f(x(t-1)), f(x(t-2)), \ldots, f(x(t-n_b)), \ldots, f(x(t-n_b n_c))],$$

while first n_a entries of $\boldsymbol{\theta}$ are occupied by $\mathbf{a}$. This means even if inner product of $\boldsymbol{\phi}(t)$ and θ in (13) is considered as possibility then there are terms with coefficients from $\mathbf{a}$ and information from $\boldsymbol{\psi}_{\mathbf{0}}(t)$. These terms are not part of the definition of BJ system mentioned by authors in (1) and (8).

viii. Authors claim that the length of $\boldsymbol{\theta}$ is $n_0 = n_a + l n_b + n_c + n_a n_c + l n_b n_c + n_a n_d + n_d$. The length is inconsistent with expressions (7) and (8) provided by authors in [1]:

$$[A(z)C(z)]y(t) = [B(z)C(z)]f(x(t)) + [D(z)A(z)]v(t), \quad (7)$$

$$\begin{aligned} y(t) = &-\sum_{i=1}^{n_a} a_i y(t-i) - \sum_{i=1}^{n_c} c_i y(t-i) \\ &-\sum_{i=1}^{n_a}\sum_{j=1}^{n_c} a_i c_j y(t-(i+j)) \\ &+\sum_{i=1}^{n_b} b_i f(x(t-i)) + \sum_{i=1}^{n_b}\sum_{j=1}^{n_c} b_i c_j f(x(t-(i+j))) \\ &+\sum_{i=1}^{n_a} a_i v(t-i) + \sum_{i=1}^{n_d} d_i v(t-i) \\ &+\sum_{i=1}^{n_a}\sum_{j=1}^{n_d} a_i d_j v(t-(i+j)) + v(t). \end{aligned} \quad (8)$$

This point is further explained below along with proposed corrections.

ix. If we use definition $n_0 = n_a + l n_b + n_c + n_a n_c + l n_b n_c + n_a n_d + n_d$ (as provided in [1]) to evaluate length of parameter vector for examples provided in Section 3 of [1]. In example 1, $l = n_b = 2$ and $n_a = n_c = n_d = 1$. This means $n_0 = 13$ from definition provided by authors in Section 1 of [1] but, $\boldsymbol{\theta}$ provided by authors in Section 3 shows that $n_0 = 10$. This contradiction in two sections of [1] highlights the flaws in the identification model presented in Section 1 of [1].

This completes the discussion on inconsistencies in identification model presented in [1]. Next, we suggest valid and compatible information and parameter vectors in a stepwise manner.

It is obvious from (8) that the required polynomials for input INBJ system are: $A(z)C(z)$, $B(z)C(z)$ and $A(z)D(z)$. Using (3)–(6), $A(z)C(z)$, $C(z)B(z)$ and $A(z)D(z)$ can be written as:

$$\begin{aligned} A(z)C(z) &= 1 + (a_1 + c_1)z^{-1} + (a_2 + a_1 c_1 + c_2)z^{-2} + \ldots + a_{n_a} c_{n_c} z^{-(n_a+n_c)}, \\ B(z)C(z) &= b_1 z^{-1} + (b_2 + b_1 c_1)z^{-2} + \ldots + b_{n_b} c_{n_c} z^{-(n_b+n_c)}, \\ A(z)D(z) &= 1 + (a_1 + d_1)z^{-1} + (a_2 + a_1 d_1 + d_2)z^{-2} + \ldots + a_{n_a} d_{n_d} z^{-(n_a+n_d)}. \end{aligned}$$

This means $A(z)C(z)$ has $n_a + n_c$ coefficients, $C(z)B(z)$ has $n_b + n_c$ coefficients and $A(z)D(z)$ has $n_a + n_d$ coefficients. This means $\boldsymbol{\theta}$ should be:

$$\begin{aligned} \boldsymbol{\theta} = [&(a_1 + c_1), (a_2 + a_1 c_1 + c_2), \ldots, a_{n_a} c_{n_c}, m_1 b_1, m_1 \\ &\times (b_2 + b_1 c_1), \ldots, m_1 b_{n_b} c_{n_c}, m_2 b_1, m_2 \\ &\times (b_2 + b_1 c_1), \ldots, m_2 b_{n_b} c_{n_c}, \ldots, m_l b_1, m_l \\ &\times (b_2 + b_1 c_1), \ldots, m_l b_{n_b} c_{n_c}, (a_1 + d_1), \\ &\times (a_2 + a_1 d_1 + d_2), \ldots, a_{n_a} d_{n_d}]^T \in R^{n_0}, \end{aligned} \quad (9')$$

where

$n_0 = 2n_a + l(n_b + n_c) + n_c + n_d$.

If we use above mentioned definition n_0 for examples provided in Section 3 of [1], then results become consistent. In example 1, $l = n_b = 2$ and $n_a = n_c = n_d = 1$. This means $n_0 = 10$ from above mentioned definition. This result is consistent with parameter length provided by authors in Section 3 of [1]. This matching validates the new definition of parameter vector given above. This approach is extended further to give correct definition of information vector.