MULTIVARIABLE IDENTIFICATION OF AN ACTIVATED SLUDGE PROCESS WITH SUBSPACE BASED ALGORITHMS

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A project report submitted in partial fulfilment of the

requirements for the award of the degree of

Master of Engineering (Electrical - Mechatronics & Automatic Engineering)

Faculty of Electrical Engineering

Universiti Teknologi Malaysia

MAY 2011

To my beloved mother, father and grandmother

ACKNOWLEDGEMENT

In preparing this project report, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main project report supervisor "**Dr. Norhaliza Abd Wahab"**, for encouragement, guidance, critics and friendship. Without her continued support and interest, this project report would not have been the same as presented here.

ABSTRACT

The objectives of this project are to identify a linear time-invariant dynamical model of an activated sludge process. Such a system is characterized by stiff dynamics, nonlinearities, time-variant parameters, recycles, multivariable with many cross-couplings and wide variations in the inflow and the composition of the incoming wastewater. In this project study, an identification approach based on subspace methods is applied in order to estimate a nominal MIMO state space model around a given operating point, by probing the system in open-loop with multi-level random signals (MRBS). Three subspace algorithms are used, and their performances are compared based on adequate quality criteria, taking into account identification/validation data. As a result, the selected model is a very low-order one, and it describes the complex dynamics of the process well. Important issues concerning the generation of the data set and the estimation of the model order is discussed.

ABSTRAK

Tujuan dari projek ini adalah untuk mengenalpasti model masa-invariant linear dinamik daripada proses lumpur aktif. Sistem seperti ditandai oleh dinamik kaku, nonlinier, masa-variasi parameter, mengitar semula, multivariabel dengan banyak lintas kopling dan variasi yang luas dalam arus masuk dan komposisi air sisa yang masuk. Dalam kajian ini projek, pendekatan berdasarkan kaedah pengenalan Subspace diterapkan untuk menganggarkan keadaan MIMO space model ukuran dasar sekitar titik operasi tertentu, dengan menyiasat sistem dalam loop terbuka dengan isyarat rawak multi-level (MRBS). Tiga algoritma Subspace yang digunakan, dan prestasi mereka berbanding berdasarkan pada kriteria kualiti yang mencukupi, dengan mempertimbangkan pengenalan akaun / data validasi. Akibatnya, model yang dipilih adalah sangat rendah-order satu, dan itu menggambarkan dinamika kompleks dari proses dengan baik. Isu penting tentang generasi dari himpunan data dan estimasi model urutan dibahas.

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LIST OF ABBREVIATIONS

MIMO	-	Multiple Input Multiple Output
PRBS	-	Pseudo Random Binary Signal
PEM	-	Prediction Error Method
IVM	-	Instrumental variable method
M-PRBS	-	Multi level PRBS
MOESP	-	Multivariable Output-Error State-space model identification
N4SID	-	Numerical algorithm for Subspace State Space System Identification
LTI	-	Linear Time Invariant
PI	-	Proportional Integral
PID	-	Proportional Integral derivative
LQR	-	Linear-Quadratic Regulator
SVD	-	Singular Value Decomposition
MRSE	-	Mean Relative Squared Error
MVAF	-	Mean Variance-Accounted-For

LIST OF SYMBOLS

U_p	-	Block Hankel past input matrix
U_f	-	Block Hankel future input matrix
Y_P	-	Block Hankel past output matrix
Y_f	-	Block Hankel future output matrix
W_p	-	Block Hankel matrices consisting of past inputs and past outputs
W_f	-	Block Hankel matrices consisting of future inputs and future outputs
Γ_i	-	Observability matrix
Δ_i	-	Controllability matrix
H_i	-	Block triangular Toeplitz matrix
X_i	-	State sequence
O_i	-	Oblique projection
$\Gamma^\dagger$	-	Moore-Penrose pseudo-inverse of the Observability matrix

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The activated sludge process is defined as a system in which a large number of biological organisms are maintained and continuously circulated to be in constant contact with the organic wastewater in the presence of air. The bio process is principally constituted by two sequential tanks, an aerator and a settler. The bacteria and other microorganisms feed on the organic matter constituent of the incoming wastewater, thereby reducing the strength of the waste. The sludge is separated from the mixed liquor in the solids separator (settler). The arranged sludge portion is reprocessed as return activated sludge from the settler to the aeration reactor so that the micro-organisms content in the reactor is maintained at the reaction sustenance level. Excess sludge, which is not recycled, is extracted from the system as waste activated sludge and consequently processed for deferent uses.

1.2 Problem Statement

- There are a lot of system identification techniques, the most traditional system identification techniques are the prediction error method (PEM) and the instrumental variable method (IVM).

- Computing the PEM model can sometimes be very difficult.
- The IVM attempts to deliver parameter estimates by only solving linear equation systems.

1.3 Objectives

The objective of this project includes three subjects.

- Design the input excitation using multilevel PRBS signal.
- Apply subspace algorithm;
- MOESP (Multivariable Output-Error State-space model identification)
- N4SID (Numerical algorithm for Subspace State Space System Identification)
- Robust N4SID (Robust Numerical algorithm for Subspace State Space System Identification)
- Compare the performance of the three methods of the subspace algorithms

1.4 Scope of Study

This study focus on finding the best model for activated sludge process, for this approach, three methods of the subspace algorithms are used.

- MOESP
- N4SID
- ‘‘robust’’ N4SID

1.5 Importance of Study

The identification techniques convert a non-linear system to a linear time invariant (LTI) system, therefore the identified system can use easily for further approaches such as computer estimation instead of doing experimental act on the real system or designing controllers for the system because designing controller such as PI or PID for the linear system is easier than to a non-linear systems.

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