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A CAD Software Package for Multivariable Control Systems with State-variable Description*

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Abstract

A computer aided design software package for Multivariable Control Systems with State-variable description (MCSS for short) has been developed. MCSS can be used to solve most of the analysis and synthesis problems in control engineering. During MCSS development, a set of systematic methods and rules in software structure are proposed. A new way to install a large scale software on a microcomputer system with limited memory has been proposed. Many effective up-to-date numerical methods are applied and some of which are presented by the authors. Now, MCSS has been used in the area of control engineering and proved to be very effective.

With the development of modern control theory, the state-variable description approach is widely used in the analysis and design of multivariable control systems. Because of the complexity of the computation, it is difficult for engineers to apply the modern control theory in practice. MCSS has built a bridge between the theory and the practice. It can be used to solve most of the analysis and synthesis problems in control engineering.

1. Functions of MCSS

MCSS is composed of five parts:
System Model Transformation and Reduction

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This part consists of three functions.

1) Minimal realization: the frequency domain model is realized to the time domain model with minimal orders;
2) Transforming the system model from time domain into frequency domain;
3) Model reduction: the model is reduced to the one with less orders [1].

System Analysis

The seven functions of this part are as follows:

1) Transforming system into controllable standard canonical form;
2) Transforming system into observable standard canonical form; (In 1) and 2), one can select Luenberger's first or second or Wonham's standard canonical form)
3) Controllable canonical decomposition;
4) Observable canonical decomposition;
5) Determining the stabilizability of a system;
6) Determining the detectability of a system;
7) Determining the stability of a system.

System Synthesis

It is the central part of MCSS. This part consists of six functions.

1) Designing the feedback regulator using pole assignment method;
2) Designing the state observer;
3) Solving matrix Riccati equations (differential and algebraic Riccati equations);
4) Designing the linear optimal controller with quadratic performance criterion (L. Q. problem);
5) Designing Kalman filter;
6) Designing the linear optimal controller with quadratic performance criterion and Guassian noise (L. Q. G. problem).

All the functions just mentioned can be used for both the continuous-time and discrete-time systems. Because of the importance of solving the Algebraic Riccati Equation (ARE for short), MCSS provides with the following four methods for ARE:

1) "Trial and error" method[2];
2) Sign function method;

3) Distributed computation method [3];

4) Spectrum decomposition method.

When a system is uncontrollable but stabilizable, MCSS provides automatically with an effective method to obtain all the results.

System Simulation

All the functions mentioned in the first three parts above can be simulated in this part. The simulation results are obtained in the forms of both data and graph.

System Data Maintenance

As a complete and convenient application software system, MCSS presents an easy way for users to maintain the data used for solving their problems.

2. Structure of MCSS

The Environment of MCSS

MCSS has been installed on different kinds of computer systems. Though MCSS will take the storage capacity over 600k bytes, it can run on a computer system in which the memory capacity is only equal to 64k bytes.

MCSS possesses a management system. In the process of programming, we paid great attentions to the reliability, testability, maintainability, efficiency, understandability and adaptability of the program. MCSS has been designed to be an application software system based on the computer's operating system.

The commands of MCSS are easy to understand and master. MCSS is transparent to users.

Programming of MCSS

In programming, a set of systematic methods and rules in software structure are proposed for the development of application software system[4]. The main methods and rules are as follows: taking the advantages of the structured programming method; considering the specialities of application software system; using the structured programming flow, function decomposition and top-down design methods.

The Treatment of Data Structure

MCSS is programmed in FORTRAN language. In order to use the unified management method for memory and external storage, a

data management system is given. The main tasks of this system are as follows:

1) Building a document for all existing data;
2) Setting a memory area for all data;
3) The changing of information in static area is not permitted unless the privileged program;
4) The dynamic area in the system are partitioned.

Software Verification and Validation

The reliability of software is an important measure of the software. It primarily depends on the verification and validation of the software. A "trial and error" method is presented in MCSS's verification. A lot of other verification methods, such as verification using a program itself, verification using other programs, and using different algorithms to solve the same problem then comparing the results, are also given.

Structure of Large Scale Software Package

MCSS is suitable for different computer systems with both large and small memory. In order to install the software system on different computers, different structures have been designed to suit each program level.

Install a Large Scale Software Package on a Computer with Small Memory

A lot of technical problems have been solved to install MCSS, which takes over 600K memory, to the microcomputers [5].

3. Algorithms of MCSS

In order to make the computation more reliable, stable and take less memory, some up-to-data numerical algorithms, such as singular value decomposition algorithm, QR algorithm, Householder transformation, Cholesky decomposition, etc., have been used. The algorithms for solving ARE have been summed up [3]. Some effective algorithms, including sign function method and spectrum decomposition method, have been selected.

Furthermore, we developed some new effective algorithms as follows:

1) "Trial and error" approach to the solution of ARE[2];
2) Distributed algorithm for solving ARE in weakly coupled

large scale systems[3];

3) A singular value decomposition approach to the model reduction [1];

4) A general algorithm is developed to solve ARE, in which the control system is uncontrollable but stabilizable.

A set of algorithms with redundancy have been proposed and a technique for automatically changing algorithms has been given. They make MCSS more reliable.

4. Conclusion

MCSS is an application software system. It has been used in many institutes and universities in China and proved to be very effective. With the development of modern control theory, computer science and technology, MCSS is going to be expanded and will take the advantages of the expert system and intelligent database.

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状态变量法描述的多变量控制系统的计算机辅助设计软件包

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摘 要

本文介绍了用状态变量法描述的多变量控制系统的计算机辅助设计软件包（简称MCSS）。MCSS可用于解决控制工程中经常遇到的分析和设计问题。在MCSS的开发中，提出了设计软件结构的一系列方法和规则，以及在小内存的微型机上装配大型软件的方法。MCSS中采用了许多新的、有效的数值解法，其中的一些是由本文的作者们所给出的。目前，MCSS已有效地应用于控制工程之中。

《反馈系统动力学》简介

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《反馈系统动力学》（Dynamics of Feedback Systems） A. I. Mees著，共215页，John Wiley Sons出版公司出版（1981）。

本书手稿曾获得1979年度Adams奖，尔后又增添了至1981年初这一领域的最新成果而成为目前这本出版物。作者A. I. Mees博士是英国剑桥大学数学和数理统计系教授，所撰写的论文涉及控制理论、动态系统、数学生物学及相关的课题，他还是模式识别方面的顾问教授。正因为作者兼具理论和应用方面的造诣，使得他所著的《反馈系统动力学》具有鲜明的特征：既使得数学工作者了解反馈系统理论的工程背景（因为书中举了不少诸如生物学、生态学等学科通俗的例子），进而能将许多原本束之高阁的数学分支应用于反馈控制系统，又使得从事自动控制实际工作的学者能领会出深藏于抽象数学理论背景后的物理图象（因为书中就大多数定理给予了图解释），因而能使他们的工作更具一般性且能在实际工作中应用这些数学成果；另一方面，即便对于他们彼此所熟悉的领域，书中内容也颇值一阅（只是可少花些时间），原因是描述语言的新颖以及着眼点和出发点的不尽相同。总之此书对上述两类基础不一的读者都有收益，而且又都能由此找到各自进一步研究的课题。

上述特征决定了本书拥有广泛的读者，同时也不失为一本理想的控制论方面的教材。作者同时展开了微分方程和输入—输出方法的研究，并着重介绍该领域的最新进展。比如，书中讨论的分叉、浑沌、突变乃是80年代众多学科投之于极大兴趣的研究方向，而反馈概念则是控制论的精髓。研究表明，书中的许多处理方法已在被人们誉为“新三论”——突变理论、协同理论（亦称协同学）和耗散结构理论的探索中发挥效用。