TUDelft
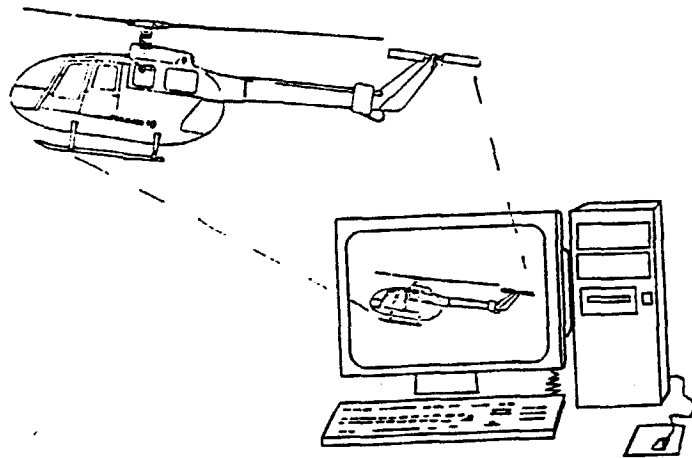
Delft University of Technology

Faculty of Aerospace Engineering

MIMO Identification Techniques and Software Development in the Frequency Domain for Helicopter and Flexible Aircraft - Progress Report 1994

by

J.K.Sridhar, J.H.Breeman[*] and J.A.Mulder

Faculty of Aerospace Engineering
Delft University of Technology, Kluyverweg 1,
2629 HS, Delft, The Netherlands
* National Aerospace Laboratory,
Anthony Fokkerweg, 1059 CM,
Amsterdam

February 1995

MIMO Identification Techniques and Software Development in the Frequency Domain for Helicopter and Flexible Aircraft - Progress Report 1994

by
J.K.Sridhar, J.H.Breeman* and J.A.Mulder
Faculty of Aerospace Engineering
Delft *University of Technology, Kluyverweg 1, 2629 HS*
Delft, The Netherlands
* National Aerospace Laboratory, Anthony Fokkerweg 2
1059 CM, Amsterdam

Summary

This report summarizes the progress made during the year 1994 under the contract/project reference number 5-83402 dated 8 February 94 between NLR and TUD. In addition, the report also gives a brief account of the work remaining and work planned for 1995. A more detailed description of the technical results in 1994 and the plans for 1995 can be found in the companion Memorandum M-702.
The significant outcome of the project during the said period was a successful development of a prototype of an interactive computer package based on Matlab 4.0 (for windows) for helicopter identification in frequency domain. The major components of this package include, estimation of high quality frequency response functions based on improved MIMO theory, interactive model structure determination, multivariate spectral analysis, handling quality metric estimates, model formulation studies, time domain simulation and user friendly menu driven sessions. The method and the software was successfully validated against the subset results derived by other member institutes of NATO AGARD WG 18. The publications brought out relevant to this project are also reported here. Finally the a tentative overview of the financial status is given.

Contents

1.0   Introduction

This report describes the progress made during the year 1994 under the contract/project reference number 5-83402 dated 8 February 94 between NLR and TUD. In addition, the report also gives an account of the work remaining and work planned for 1995. A more detailed description of the technical results in 1994 and the plans for 1995 can be found in the companion Memorandum M-702.

The MIMO project is described in Memorandum M-700 "Development of a Multiple Input/Multiple Output (MIMO) Parameter Identification Methods and Software in the Frequency Domain and the Evaluation of Optimal input Signals for the Helicopter and Flexible Aircraft - An Overview and Project plan" dated December 1994. The project consists of three parts:

1. Description of the theoretical background of the MIMO frequency domain parameter identification technique. Analysis of the advantages and disadvantages of this technique for aircraft as well as helicopters. Illustration of the technique using numerical examples drawn from the helicopter measurement data obtained by NLR during its participation in AGARD Working Group 18 "Rotorcraft System Identification".

2. Development of a software package that is suitable to apply the frequency domain technique in practice for the benefit of future NLR projects. The package will be written in Fortran and will be suitable for use on a workstation (preferable a Silicon Graphics Iris). The program will be setup in a way that will fit in the setup of the (future) NLR parameter identification software package.

3. The investigation of the advantages of the application of optimal input signals for the identification of helicopter and flexible aircraft. This will be illustrated using numerical examples based on the AGARD helicopter measurement data.

It is believed that the end results of this project will support academic and industrial activities in the Netherlands in the areas leading to model identification, validation, handling qualities evaluation, control system design etc. These can potentially play a major role in improved quality, reduced risk and cost during the development phase.

In the Project Report, Memorandum M-700, we presented the different identification approaches followed in NATO organisations, their relative merits and demerits. In Memorandum M-702 we present the reasons for the choice of frequency domain identification approach and outline their specific advantages in dealing with rotorcraft identification. We also present the MIMO software capabilities and demonstrate with a working session on BO-105 helicopter flight test data. The report will briefly touch upon further developments of the work, extensions to the software, analysis of data etc.

2.0 Summary of progress in 1994 and planned work in 1995

2.1 Highlights of Progress in 1994

The year 1994 has been a year of fruitful progress and a steady allround development in terms of literature survey (1970-1993), new MIMO theoretical developments (section 3.0), software development on work station as well as on personal computers, validation of routines with limited flight test data of BO-105 helicopter. The significant developments and findings were reported in conferences and also published in the proceedings (section 3.0).

A software-package for frequency-domain analysis and system identification for helicopters was developed, on a personal computer, using Matlab 4.0 (for Windows). The software is capable of extracting key information of coupled rigid rotor dynamic and aeroelastic modes. As frequency domain analysis can be greatly aided by graphics, user friendly plotting routines are needed. In order to be able to understand the influence of different structures for the parametric transfer-function in the fitting procedure, the analyst should be able to define different structures quickly and the influence on the fit should be visualized in a bode plot directly. Extensive graphical user interfaces with on-line help facilities were built to facilitate the interaction between the analyst and the computer, both for the plotting and for the fitting routine. This software package has been used for development and validation of the MIMO algorithms and will form the basis for the operational program to be developed during Part 2 of the MIMO project.

At the end of 1994 the following items are either completed or in progress:
1. Literature survey of frequency domain techniques for parameter identification for helicopters and flexible aircraft [Part 1 - completed].
2. Advantages and disadvantages of the MIMO technique were studied and reported [Part 1 - completed].
3. Development of Improved MIMO algorithms. [Part 1 - completed]
4. Software development of MIMO algorithms on work station. [Part 2- preliminary]
5. Interactive Software development on personal computers using matlab 4.0 (for windows). The prototype version of the program is available for demo.
   [Part 1 - completed, Part2 - in progress]
6. Validation of the software for one BO-105 manoeuvre [Part 1 - completed].
7. An overview of the project plan was published as TUD Memorandum M-700.
   [Part 1 - completed]
8. Technical results were published as TUD Memorandum M-702. [Part 1 - completed]
9. Publications; Published in 1994 = 4, Accepted/planned in 1995 = 6

2.2 Prospects of planned work for 1995

For 1995 the following items of work are planned:
1. Continuing development and improvement of the software related to state space realization, handling qualities and structural flexibility issues.
2. Extensive validation of software tools using AGARD Working Group 18 flight data namely BO-105/ PUMA/ APACHE. Development of Parametric models of several input/output combinations.
3. Development of a software organization to allow flexible management of measurement

datasets as well as analysis results.

4. *Finalizing an operational version of the Interactive MIMO software for implementation at NLR.*

5. *Writing of a User's Manual and a Program Description.*

6. *Publications (see section 3.0)*

3.0   Publications

3.1   Publications in 1994

During the year 1994 the following publications relevant to the project were brought out.

1.0   *Sridhar J.K., Mulder J.A. and W.H.J.J. van Staveren (1994) Compact Representation of MIMO algorithms with applications to helicopter flight data. Paper presented at the American Control Conference ACC 94, at Baltimore, Maryland during june 29-july 1, 1994. Published also in the Proceedings, vol 1, pp 912-917, july 1994. The revised version to appear in AIAA J.Guidance,Control and Dynamics*

2.0   *Sridhar J.K.,Adrichem M.W.B and Mulder J.A, Software on Personal Computers for Frequency Domain Analysis and System Identification for Helicopters, Paper presented at the 20th European Rotorcraft Forum held at Amsterdam during october 4-7,1994. Also published in the proceedings, paper number 85.*

3.0   *Sridhar J.K, Breeman J.H and J.A.Mulder, Development of MIMO parameter Identification Methods and Software in the Frequency Domain and the Evaluation of Optimal input Signals for the Helicopter and Flexible Aircraft- An overview and Project Plan, Published as Memorandum Number 700, Delft TU, Faculty of Aerospace Engineering, December 1994.*

4.0   *M.W.B.Adrichem, An Introduction to Rotorcraft Identification at Delft University of technology, Preliminary Master's thesis, Faculty of Aerospace Engineering, DUT, October 1993.*

3.2   Planned Publications in 1995

1.0   *J.K.Sridhar, J.H.Breeman and J.A.Mulder,'Improved MIMO algorithms with applications to identification of BO-105 Helicopter', Full length paper for AIAA J.Guidance, Control and Dynamics, October 1995.*

2.0   *J.K.Sridhar, J.H.Breeman and J.A.Mulder,'Parametric Models for BO-105 helicopter', Paper to be submitted for 21st European Rotorcraft Forum at St.Petersburg, 1995.*

3.0   *Sridhar J.K, J.A.Mulder, and J.H.Breeman, Multiple uses of Coherence functions in System Identification, Paper accepted for presentation and publication at 14th Benelux Meeting on Systems and Control at Houthhalen, Belgium during March 29-31, 1995.*

4.0   *C.A.A.M. van der Linden, Sridhar J.K and Mulder J.A. " Multi-Input Design for Aerodynamic Parameter Estimation", Paper accepted for presentation and publication at American Control Conference (ACC 95) at Seattle, Washington during June 21-23, 1995.*

5.0   *J.K.Sridhar,J.H.Breeman and J.A.Mulder, 'MIMO Identification Techniques and software development in frequency domain for helicopter and flexible aircraft -*

Technical results', Faculty of Aerospace Engineering, Memorandum No 702, February 95.

6.0   M.W.B.Adrichem, On Some Aspects of Design and Development of Interactive Helicopter Identification Software and Analysis, Master's Final thesis, Faculty of Aerospace Engineering, DUT, February 1995.

4.0   Project Team Composition and Man Power Investment

The present composition of the team will work keeping in view the present and future interests of DUT and NLR in the field of aircraft and helicopter identification. The approximate manpower investment is shown in brackets. A tentative overview of the financial status of the project is given in table 1. This table shows only the financial contribution of NLR.

Prof.dr.ir.J.A.Mulder, Project Chairman and Advisor (10%)
Dr.J.K.Sridhar, Project Leader (DUT) (80%)
Ir.J.H.Breeman, Project Leader (NLR) (10%)
Mr.Marcel Adrichem, Graduate Student (100%)
Graduate students (unspecified)

5.0   Conclusions

In this report a brief survey of the progress made in the year 94 is presented. This is related to the project between NLR and TUD under the contract number 5-83402 dated 8 February 94. The report also gives a brief summary of the prospects for work for the year 1995.

A prototype of an user friendly software package was developed on a personal computer using Matlab 4.0 (for Windows), which makes it possible to exploit the advantages of frequency domain methods for helicopter system identification. This package includes interactive features with extensive graphical facilities, which enables the analyst to select adequate model structures and to improve his insight into the behavior of complex systems such as helicopters. The package is undergoing continuous refinement with respect to quality of the estimates, user friendliness, to capture aeroelastic modes, to derive handling quality metrics and many more features. The package was tested successfully for one BO-105 helicopter experimental data and needs further to be validated against all available WG18 data.

This work concludes Part 1 of the MIMO project. Already a good start has been made on several items in Part 2. It is firmly believed that the end software product and the knowledge gained in analysis will either support or strengthen the expertise and software tools in helicopter and aeroelasticity departments of NLR and DUT. Their technical involvement and input can substantially help in motivating further planned work.

Projektnaam	: MIMO
Opdrachtgever	: NLR
Vakgroep	: A3
Projektleider	: prof. Mulder
Looptijd	: 3 jaar

Kosten	Integraal	andeel NLR
Personeel proj.afhankelijk		
TO 1220 uur	ƒ 132.980	
Personeel proj.onafhankelijk		
Proj.leider 152 uur	ƒ 25.901	
Secretaresse 40 uur	ƒ 2.908	
Materiële uitgaven		
Reiskosten	ƒ 4.105	
PC	ƒ 1.500	
Gebruik werkstation	ƒ 3.000	
Rekenkosten	ƒ 6.000	
Ov. verbr.goederen	ƒ 1.321	
Infrastructure	ƒ 8.405	
Totaal	ƒ 186.120	ƒ 80.000

Aandeel TU/NLR	%
TU Delft	57%
NLR	43%
Totaal	100%

Table 1. Tentative overview of the financial status of the MIMO project 1994.