Advances in dynamic response reconstruction using non-linear time domain system identification.

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Abstract

This thesis forms part of an existing research programme to further improve the QanTiM time domain service load simulation system. Service load simulation is the reproduction of actual service responses in full scale laboratory tests, on dynamically loaded multiple axis computer controlled servo-hydraulic test rigs. A well-developed science in the frequency domain contrasts with the relatively new time domain service load simulation techniques. It is thus necessary to gain a better understanding of this time domain simulation technique and operation thereof. Furthermore, the existing time domain techniques use linear modelling techniques, which may be a limitation when simulating practical non-linear systems. The improvement of time domain simulation is addressed in two parts, firstly the effect of varying input parameters and operating procedures for the existing linear techniques, and secondly the development and implementation of non-linear time domain based system identification routines for use within service load simulation.

- The investigation into improved performance of the existing linear techniques was based on practical test rig experience and empirical research. Numerous simulations were conducted internationally using both single and multiple axis test rigs. This research resulted in a set of rules and guidelines for improved and simplified simulation. Some of these rules have been implemented in revisions of the existing simulation package and various guidelines for further research into improved and simplified simulation practices were established.
- Investigation into possible non-linear simulation was preceded by literature survey into appropriate modelling techniques. The Non-linear Auto Regressive with eXogenous input [NARX] - model description was adapted and implemented for general non-linear modelling and system identification, and subsequently applied in service load simulation. The NARX non-linear modelling technique proved ideal for general non-linear modelling and system identification problems, even for non-square systems with severe geometrical non-linearity. It does however demand immense computational power, and is plagued by potential numerical instability. The increased accuracy gained by modelling the non-linearity in practical simulations does presently not warrant the additional computational effort and possible instability problems.

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PART I: EMPIRICAL RESEARCH INTO IMPROVED LINEAR SIMULATION

CHAPTER 3

Nomenclature

t	Time
$u(t)$	Dynamic input signal
$y(t)$	Dynamic response signal
$\hat{y}(t)$	Predicted dynamic response signal
$e(t)$	Error signal
X	Regression matrix
Θ, a, b, p	Model parameters
m	Number of model parameters
na	Dynamic model order for output $y(t)$
nb	Dynamic model order for input $u(t)$
nk	Time delay
n_k	Model order for output channel k (ARX "full order")
nu	Number of input channels
ny	Number of output channels
L	Degree of non-linearity
PSD	Power spectral density
SISO	Single Input, Single Output
MISO	Multiple Input, Single Output
MIMO	Multiple Input, Multiple Output
ARX	Auto Regressive with eXogenous output
NARX	Non-liner Auto Regressive with eXogenous output
FEM	Finite Element Method

A standard set of terminology exists within the QanTiM test and simulation software package. Terminology regarding time history data sets and data processing will, where possible, follow the standards set within QanTiM. Standard file names and processes are presented below, together with a simplified diagram of the QanTiM simulation process.

IDDRV	Identification drive time history data
IDRES	Identification response time history data
FIELD	Measured field response time history data. During simulation, an identifying number is usually appended to the file name, e.g. FIELD21. This number is applied to all subsequent files that relate to this field file
DESRES	Desired response time history data (DESRS21)
RITRES	'Raw' iteration response file. Normally used as RIT01RES where the number 01 indicates the first iteration
ITRES	Iteration response file, subsequent to general response processing (IT01RES)
FINDRV	Final drive time history data, for use in laboratory simulation (FINDRV21)
FINRES	Final response time history data, as measured during laboratory simulation (FINRES21)
F2D	FIELD to DESRES - User definable function for processing field data
PREPRO	User definable function to pre-process IDRES prior to inclusion into UYDAT
GPREPRO	General response pre-processing function, applies bandwidth filtering, de-trending
UYDAT	Combined IDDRV and IDRES, subsequent to processing by PREPRO and GPREPRO