Transfer function modelling: a student-centred learning approach

Aidan O'Dwyer,
School of Control Systems and Electrical Engineering, Dublin Institute of Technology
19 September 2007

International Symposium for Engineering Education, Dublin City University

Structure of Presentation

1. Introduction
2. Procedure
3. Model Determination
4. Some Experimental Results
5. Pedagogical Issues
6. Conclusions

1. Introduction

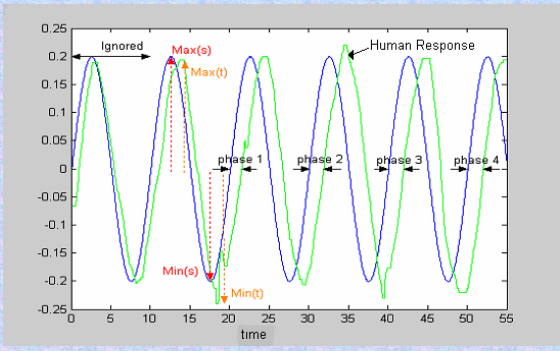
The paper reports on the development of an ***innovative undergraduate experiment*** which estimates a model of a persons' eye-brain-hand motor response.

In the experiment the person is successively asked to track, with a mouse, ten sine wave signals at different frequencies on a computer screen.

Based on the average of the data recorded, the persons eye-brain-hand motor response in the frequency domain is recorded (and may be summarized on a Bode plot).

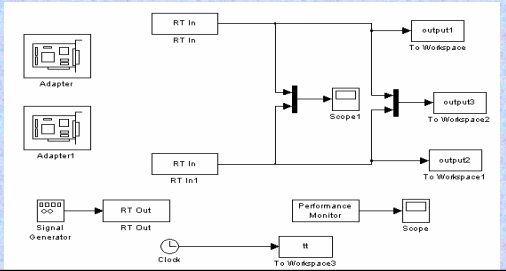
Subsequently, the parameters of a single-input, single-output (SISO) process model may be determined.

A typical example of one sine wave input signal, and a person's tracking attempt, is shown.

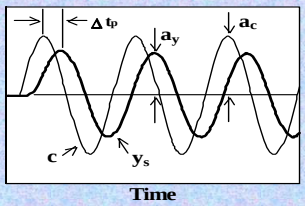


2. Procedure

A computer with a data acquisition card and suitable software is used to record the input sine wave (generated in SIMULINK) and the persons' tracking attempt. Implementation:



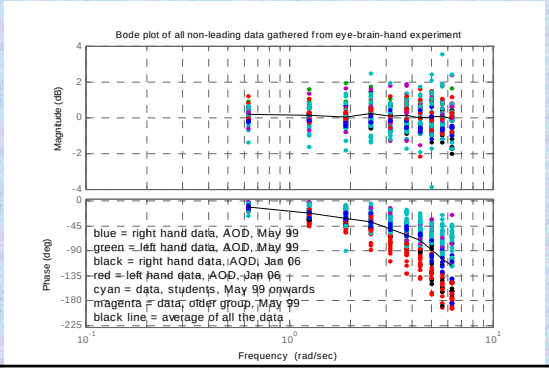
The peak-to-peak amplitude and phase shift of the output was recorded for each frequency.



Amplitude ratio, Phase,

$$AR = \frac{a_y}{a_c} \qquad \phi = -\frac{\omega \Delta t_p}{2\pi} \times 360^o$$

Based on an average of the amplitudes and phase differences recorded, a ***Bode plot*** is drawn from the data. The figure shows the Bode plot of all the data gathered.

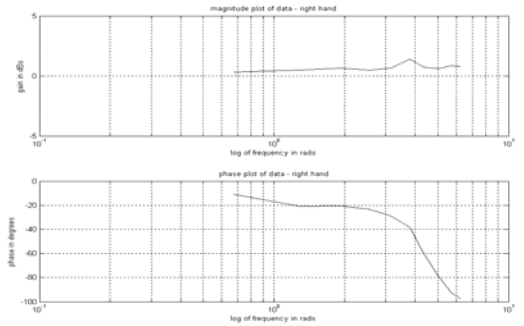


3. Model determination

- A model may be determined directly from the Bode plot, or using an analytical technique.
- It is clear from the figure that subjects tend to be able to follow the amplitude of the sine wave accurately. Therefore, on average, the ***gain,*** K_m, of the model is approximately 1.0.
- The phase varies with frequency in an approximately linear manner. A ***time delay*** (reaction time), τ_m, may be fitted to this data. The average eye-brain-hand motor response reaction time is 0.25 seconds.

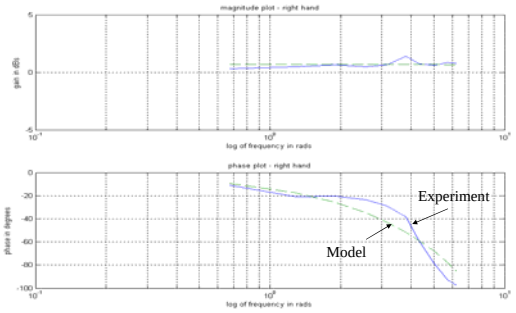
4. Some experimental results

Bode plot of authors' response (age 36): right hand

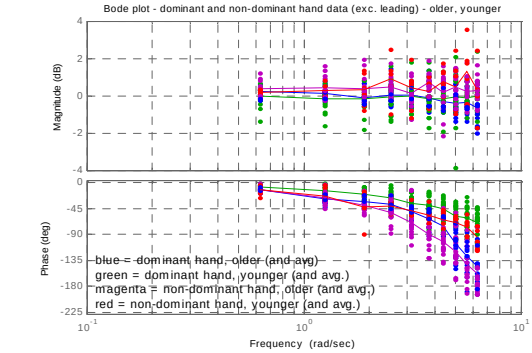


Model identified: $K_m = 1.08$, $\tau_m = 0.24 \text{secs}$

Validation of model and original data:



Youth versus Middle Age …



Summary of results obtained

Condition	*Delay determined*
Average of all data gathered	0.25 s
Average, dominant hand data, students, May 99 - Jan 06	0.14 s
Average, dominant hand data, 22 year old male, May 99	0.16 s
Average, dominant hand data, 36 year old male, May 99	0.20 s
Average, dominant hand data, 42 year old male, Jan 06	0.32 s
Average, non-dominant hand data, students, May 99 - Jan 06	0.20 s
Average, non-dominant hand data, 22 year old male, May 99	0.19 s
Average, non-dominant hand data, 42 year old male, Jan 06	0.41 s

5. Pedagogical Issues - 1

- Since its development in 1999, this experiment has been carried out by students taking a control engineering option in the programmes in electrical/electronic engineering at DIT.
- The experiment does not require strong mathematical foundations.
- The author has found that students are enthusiastic about the experiment and frequently spend over the allocated time on aspects of it.

Pedagogical Issues - 2

Formal Student Feedback 2005-6

Please answer the following questions. To answer each question, please write a number between 1 and 5, with 5 - strongly agree, 4 – agree, 3 – unsure, 2 – disagree 1 – strongly disagree

1. *The work was a beneficial learning experience (compared to other exercises)* – **Average score: 4.3**
2. *The work is user-friendly* – **Average score: 4.2**
3. *The work complements and enhances my understanding of lecture material* – **Average score: 4.5**
4. *The work is fun and sustained my interest* – **Average score: 4.5**
5. *I became more interested in the material because of this work* – **Average score: 4.0**
6. *There is enough time to perform the work* – **Average score: 3.0**
7. *I would recommend this work to others* – **Average score: 4.3**

Pedagogical Issues - 3

Student feedback is very positive; the reasons for this, in my opinion, are:

- The experiment provides direct feedback to the user on the PC screen.
- The experiment is not excessively time-consuming; a typical experiment time to gather one set of data, at 10 frequencies, is 10 minutes.
- A competitive edge among (typically, male) students is frequently observed, with a desire to have the shortest reaction time.
- A motivational aspect for some students is the application of the idea in biomedical engineering, possibly in the diagnosis of some motor response disorders.

6. Conclusions

- The paper reports on an innovative undergraduate experiment, which estimates a model of a persons' eye-brain-hand motor response.
- The experiment is practical and straightforward to carry out, taking typically 10 minutes, though it is somewhat repetitive.
- The data from the experiment may be analysed by the students to determine the transfer function model.
- Alternatively, for students without the required mathematical foundations, a programme written by the author may be used to determine the model.
- For future work, the use of a less predictable alternative to the sine wave signal would be desirable.