MAKING LECTURES COME ALIVE WITH A DATA PROJECTOR

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Abstract. The relatively recent advent of widely available data projectors, coupled with the availability of CAD packages for control systems with graphical input/output facilities provides a mechanism for transforming lectures into shows where students can see control systems come alive. Experiences over a range of control systems courses at Dublin City University (DCU) have been positive, where a data projector has been used over a trial period of eighteen months.

Key Words. Computer-aided instruction, computer-aided design, data projection, system theory, adaptive systems

1. INTRODUCTION

Data projectors, in the current context, are taken to mean devices which allow the projection of a computer screen image onto an opaque white screen. The basic objective of such a device is to give a demonstrator or instructor the facility to show an audience or student class an enlarged image of the computer screen that he/she is working on and the effects of the computer commands that he/she is issuing. In a control systems scenario, this might allow a classroom of students to follow a lecturer through the design and evaluation of a control system.

Such an educational medium is not new. However, recent improvements in the technology have dramatically improved the performance/price ratio, making a data projector a cost-effective instructional tool. A range of such devices, along with performance and price specifications, is discussed in Section 2.

At Dublin City University (DCU), this educational medium finds use on most courses related to signals, systems and control system design. In particular, the data projector is used heavily in a master's level course on Adaptive Systems in Signal Processing and Control. This course benefits greatly, since many of the computations required in the evaluation of examples are iterative, the only effective demonstration medium being through computer-based analysis.

Control systems and the study of signals and systems in general is an ideal candidate for the data projector medium. A number of well-known CAD packages for signals and systems are available, and many real-world examples may be drawn on. In addition, many control engineering textbooks are now oriented towards CAD and in many cases custom software is provided to aid in the evaluation of examples.

Demonstrations of applications and examples through the use of the computer/projector combination at DCU have been found to be particularly effective. Students seem to be generally enthused with the colour, variety and dynamic movement which such a medium brings to a lecture.

2. DATA PROJECTORS

In order to be useful in a lecture scenario, a projector should have the capability to project an image of a computer screen onto a large screen, capable of being viewed by a large (> 40 people) audience. A similar facility could, in theory, be provided by a large VDU screen. However, devices of this type capable of generating an image of
approx. 2m x 2m would lack portability, an
possibly be prohibitively costly. In sourcing a
suitable device for the School of Electronic
Engineering at DCU, effort was concentrated
on a portable device, allowing its use in
meetings, presentations (both internal and
external) and classroom situations. Portability
between classrooms was also an
issue. Generally, data projectors may be
divided into three broad categories:

(a) Palette-type devices
(b) Pure data projectors
(c) Video projectors

Palette-type devices consist of a rectangular
frame containing a translucent LCD screen.
This is placed on top of an overhead projector
(OHP), and selectively attenuates the OHP
image. As far as the author is aware, these
represented the earliest portable data
projection devices. Originally, only
monochrome devices were available, but now
colour devices, up to VGA quality, are
available.

<table>
<thead>
<tr>
<th>Type</th>
<th>Palette</th>
<th>Data Proj.</th>
<th>Video Proj.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>2.4</td>
<td>2.4</td>
<td>3</td>
</tr>
<tr>
<td>Portability</td>
<td>2</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>Cost</td>
<td>+ cost</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Main Advantage</td>
<td>Portability</td>
<td>Exact</td>
<td>Extra</td>
</tr>
<tr>
<td>Main Disadvantage</td>
<td>400w OHP required</td>
<td>Limited</td>
<td>High</td>
</tr>
</tbody>
</table>

Pure data projectors, unlike video projectors
accept VGA-type output only. Video
projectors, on the other hand, accept RGB-
type inputs and sometimes have an auxiliary
data input as well. If not, a converter may be
used to modify the VGA signal to RGB
format. While providing the extra facility for
video projection, video projectors are
generally more expensive, and if a data
projection only facility is required, incurs
unnecessary expense. Video projectors,
however, generally offer better resolution,
with horizontal scanning rates up to 80kHz,
while a maximum rate of 35kHz (< SVGA) is
available on pure data projectors.

Table 1 summarises the relative merits of
each category of device. Generally, it has
been found that pure data projectors offer the
best compromise for classroom use. The
following table reviews a number of
machines (not an exclusive list) and gives an
estimate of cost at Irish prices in US$ (excluding sales tax).

<table>
<thead>
<tr>
<th>Make</th>
<th>Model</th>
<th>Type</th>
<th>Quality</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barco</td>
<td>300</td>
<td>2</td>
<td>VGA</td>
<td>9000</td>
</tr>
<tr>
<td>Barco</td>
<td>600</td>
<td>3</td>
<td>SVGA</td>
<td>13500</td>
</tr>
<tr>
<td>GE</td>
<td>310</td>
<td>3</td>
<td>SVGA</td>
<td>18000</td>
</tr>
<tr>
<td>Sanyo</td>
<td>PLC800PB</td>
<td>2</td>
<td>VGA</td>
<td>18500</td>
</tr>
<tr>
<td>Sony</td>
<td>7799</td>
<td>3</td>
<td>2</td>
<td>12000</td>
</tr>
<tr>
<td>Sharp</td>
<td>XG3800E</td>
<td>3</td>
<td>VGA</td>
<td>12000</td>
</tr>
<tr>
<td>Sharp</td>
<td>1050</td>
<td>1</td>
<td>VGA</td>
<td>8000</td>
</tr>
</tbody>
</table>

In addition to the information shown in
d Table 2, there is a wide diversity in extra
features on each device. Some have
motorised focus and interchangeable lenses,
some have remote control and some have
built in 'disk-play' devices. Also, Table 2
concentrates only on portable devices; a wide
range of ceiling mount projectors are also
available. A comparison of a subset of the
devices listed above is given in Tomalski

Experience in choosing a data projector has
shown that, in spite of specification
similarities, there can be a significant
difference in projection quality and
brightness between devices, which can only
be ascertained by means of side-by-side
testing.

3. PROJECTOR USE AT DCU

In the School of Electronic Engineering at
Dublin City University, use of the data
projector as a lecturing aid spans a number
of courses. As stated previously, these
courses are generally involved with some
aspect of signals or control systems, but it is

1 Palette devices have generally got poorer
resolution than pure data projectors, but
some can do up to VGA.
2 Currently only VGA is available, but an
SVGA device is due shortly.
3 If a converter is required, portability is
impaired.

4 Refer to Table 1.
5 This is given in terms of the resolution,
which is determined by the maximum
horizontal scan rate.
6 Includes the cost of a computer to RGB
converter, where appropriate.
7 Requires a 400w OHP.
also used extensively in courses on software engineering.

3.1 Hardware and Software

A standard projection rig has been set up which facilitates fast set-up times and ease of use. This consists of a two tier trolley/stand with the top platform having a tilt adjustment in two dimensions. The projector occupies this platform, with the lower level reserved for a 486 notebook PC, as shown in Fig.1. The PC sees the projector as an external monitor, but the colour LCD display on the notebook PC remains active. This feature is important, since it allows the lecturer to face the class and divide his/her attention between the class and the monitor easily. Unfortunately, many notebook PCs blank the LCD screen when an external monitor is detected.

Fig.1. Trolley with projector and PC

For control systems courses, the principal tool is the MATLAB/SIMULINK suite, which is run in the Windows environment. This is complemented by a number of the associated toolboxes, including the Signal Processing and the Control Systems Toolbox. In addition, a custom toolbox, containing custom-built MATLAB macros and functional blocks, is also mounted.

3.2 Control Systems Courses at DCU

In the four year BEng programme in Electronic Engineering at DCU, the following courses are available:

(a) System Dynamics I, Year 2, compulsory.
(b) System Dynamics II, Year 3, compulsory.
(c) Control Core, Year 4, compulsory.
(d) Digital Control Option, Year 4, optional.

In addition, a number of control-related modules are available on the MEng course in Electronic Systems. The author currently teaches on courses (b) and (d) above and a course on Adaptive Systems in Signal Processing and Control in the MEng. The data projector is used on each of these courses, with utilisation highest on the MEng course and the Digital Control Option. Examples of the type of use to which the computer/projector set is put are given in Section 5.

4. THE ROLE OF COMPUTER-ASSISTED INSTRUCTION IN CONTROL SYSTEMS

The general approach in the presentation of control systems techniques roughly follows the following steps:

- Presentation of the theory associated with the technique,
- Evaluation of an illustrative example,
- Review of performance and examination of practical additions.

Computer-aided presentation has been found to be particularly effective for the last two stages outlined above. It allows multiple examples to be evaluated over a wide range of operating conditions, proving beyond doubt the validity of the theory. It also provides a facility for immediate and graphic answers to 'what-if type student questions.

An increasingly popular feature of modern control systems textbooks is the production of a set of computer programs or subroutines to accompany the text. These include titles from authors such as Phillips and Nagle (1990), Thompson (1989), Thaler (1989), Golten and Verwer (1991), Franklin et al (1990), Dorf (1992) and Bishop (1993). In some cases, a set of computer program listings are provided (for example, in Thompson (1989)), others provide a disk containing a dedicated software package (e.g. in Thaler (1989), Golten and Verwer (1991) and Dorf (1992)) while other authors provide the software as an optional extra (as in Phillips and Nagle (1990) and Franklin (1990)). The text by Franklin et al (1990) has the interesting feature that the software associated with the text is a set of MATLAB M-files, which complement those contained in the MATLAB Control Systems Toolbox. Finally, the text by Bishop (1993) is based around MATLAB and gives all the MATLAB macro code in the text associated with each example. This book is a companion to Dorf (1992).
These books generally provide either general CACSD software or software which may be used to illustrate the examples in the text, in which case code is often included to provide plots, etc. Such material provides easy entry to computer usage during classroom sessions, for even if one of the above texts is not being followed, examples relevant to the course (with supporting software) may be extracted. This methodology incurs a small overhead in preparation time.

5. EXAMPLES

Within the courses specified in Section 3.2, the data projector/PC combination is used for a wide variety of demonstrations. Some particularly effective ones are outlined in the following sections:

5.1 PID Parameter Tuning

A classical feedback loop is set up with a conventional three-term controller in the forward loop. With multiple simulation runs, students may clearly see the effects on the time response of variations in each of the controller parameters. Also, the addition of effects such as control signal saturation, output noise and square-wave setpoints provide clear motivation for the practical additions of anti-integral windup, derivative filtering and derivative on output only, respectively.

5.2 Optimal Controller Calculations

Using SIMULINK, a simple state-feedback loop is set up. In the background, MATLAB provides a recursive solution to the matrix Ricatti equation, allowing the lecturer to demonstrate the variation in feedback gains, closed-loop poles and the responses of state and control signals according to the choice of state and control weighting matrices.

5.3 Adaptive PID Controller

Fig.2 shows a phase-margin explicit adaptive PID controller utilising recursive least squares for identification. Using this set-up, responses may be demonstrated for variations in:

- Forgetting factor
- Initial covariance scaling
- Initial model parameter estimates
- Order of plant model
- Identification algorithm (e.g. LMS)
- Setpoint signal
- Phase margin specification
- Actual plant parameters

Fig.2. Adaptive PID controller demonstration

6. CONCLUSIONS

The inclusion of computer-aided presentation in control systems lectures has been well received by the students. The extra overhead in terms of preparation and set-up has been more than compensated for in teaching effectiveness.

REFERENCES