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A Computer Aided Learning Package for Tolerance Analysis

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Abstract

In addition to the core technical subjects covered in a typical engineering degree curriculum, it is common to see modules on more general 'engineering design' topics such as aesthetic design, reliability, electromagnetic compatibility, design for manufacture and test and tolerance design. This paper presents an overview of a tolerance analysis CAL package that has been developed to support such lecture courses.

In terms of technical content, the package contains an introduction to where variability arises in electronic circuits, the effect it has on circuit performance and the significance of tolerance design at an early stage in the product design process.

A number of tolerance design tools are described from deterministic, pass/fail boundary walking approaches to stochastic methods such as Monte-Carlo. The package contains theory, knowledge and understanding, assessment and illustrative demonstrations/games.

This project has taken CAL package design a stage further than simply creating a package presenting technical material. Consideration has been given to pedagogical aspects such as how the learner can gain the information required in the most appropriate way for them. Further, consideration has been given to inclusivity across the student population by considering some of the more common disabilities.

To accommodate the flexibility required of these objectives, a highly modular approach to the material has been adopted. There are small chunks of theory, supported by mini tests and interactive demonstrations and/or games for each tool and technique. The sequence of these blocks is altered by the package depending on the learning style of the user.

At the practical level the CAL package has been written in HTML and JAVA script. The final product has been initially trialed on an appropriate level of students with very good feedback.

1. Introduction

Technology based training has evolved with rapid advancements in computer technology over the past decade. Many of the earlier systems were primarily text based with simple tutorial or drill practice applications, typically written in Assembler, Algol or Pascal. Today, computer aided learning comes in many forms from plain HTML web pages, possibly with simple JAVA applets illustrating very specific points within a subject or discipline, to complete multimedia courses.

Surfing the net produces vast numbers of 'hits' these days. Whilst many of these are either dead, repeats or mis-named pages, the result will frequently show a very large number of potentially usable tools for educators to make use of.

A recent survey at York [1] resulted in the identification of a range of Cal packages and tools for the courses in the Department of Electronics' undergraduate degree programmes. The result is a very simple web 'portal'.

One thing that became apparent during that exercise was the diversity in methods used for depicting information, the diversity of computer packages used and the complete lack of standardisation of material presentation. In the packages there is a variable amount of interactivity offered to allow the student to actively engage in the material and raise their levels of interest, understanding and retention.

To be fair these are relatively minor matters. Perhaps the important measure is their effectiveness as a learning instrument.

2. CAL in the modern curricula

The use of educational software, or courseware, is rapidly becoming a popular activity in some parts of higher education teaching. The drive for this change in teaching methodology arises from the expansion of the Internet and the exponentially falling cost of powerful desktop computers. With increasing pressure on lecturers and teaching time at university level and on metrics geared towards student success rates, it is becoming difficult to ignore the possibility of using computer-aided learning. The benefits can be:

- increasing student interest and engagement with material
- increasing depth of learning

The first step in deciding whether or not to create some coursework to use for a particular aspect if the curriculum is to consider whether CAL is the most suitable medium for the subject matter. An evaluation should be undertaken of existing material to consider how a piece of

CAL could coexist or supplement the current method of teaching. The reason for using CAL should satisfy each of the following three basic criteria:

(i) Compliment or add value to teaching

(ii) Enable more effective learning

(iii) Save in teaching time

Assessment of the long term effectiveness and reward is difficult. CAL may increase interactivity and hence interest, retention and general student motivation. However CAL can take the student a step further from human contact during learning making the learning process more impersonal.

The development of CAL tools involves a considerable initial time investment in addition to any hardware and software costs for the development infrastructure. 'Payback', if this is an issue, only really results when the package is used repeatedly. The development of CAL packages, from a 'payback' point of view, best suits courses or modules where there is a good flow through of students and where the core technical content is stable and unchanging. An alternative is where the students are geographically dispersed and difficult to reach for face to face meetings.

3. Background to the tolerance analysis package

The package described in this report is the result of an undergraduate singleton project with the objective of investigating the wider issues of the use of CAL within an HE curriculum. The course chosen as the vehicle for the project was a stable and unchanging course called 'Engineering Design'. This course, based on a course text [2], comprises a series of lectures looking at the broader issues of design such as design for manufacture, design for test, design for the physical environment, tolerance analysis, reliability, and cost. The audience is second year undergraduate students taking a range of degree programmes in the electronics field. The course is core material and is taken by approximately 100 students each year.

The technical challenge of the project was increased by including in the project specification that there should be an investigation into individual student learning styles and disabilities and how such factors affect the use of CAL packages.

4. Brief introduction to tolerance analysis

In any electronic circuit every parameter of every manufactured component, from a simple resistor to the most complex system, has a tolerance associated with it. the design of a circuit, such as a low pass circuit, by analytic methods, results in component values specified to a number of decimal places of precision. To realise the circuit in practice such values can only be obtained by precise manufacturing selection or by 'select on test' methods. Such routes lead to an increased component and hence product cost.

Further, to make multiple products requires many components to be purchased, all of which have different values for each parameter. A well-designed circuit will be one that meets specification for every component within the tolerance limits of each parameter.

The objective of the tolerance analysis part of the Engineering Design course is to introduce the need to consider tolerance in electronic circuit design and to introduce students to a range of techniques that can be used to predict the tolerance of a circuit to component tolerances. Both deterministic and stochastic methods are included in the course as is design centring.

The specification for the technical content of the package included the definition of terms such as component space, region of acceptability and tolerance region, introduction of tolerance analysis techniques and the impact of tolerances on production yield. The non-technical specification included consideration of student learning style and disabilities.

5. Learning style

It is common practice at York for students to be assessed for their learning style preference. This assessment is used to enlighten students and inform the teaching process of any likely gross style mismatches. Results over the past years show similar learning style preferences with the more artistic music technology students being, on average, different from the traditionally science based electronics students. The difference becomes noticeable as students develop in maturity and lecturer student interaction increases.

The primary research question posed for this project was "Can the CAL package present the technical material to each student in a manner that is sympathetic to their personal learning style?"

There are a number of different learning style assessment instruments. The one selected for use was the 'Index of Learning Styles' formulated by Richard Felder and Linda Silverman at North Carolina State University [3]. The assessment analyses learning preference in four dimensions:

- Reflecting and/or acting upon information (Active/Reflective dimension)
- Seeing and hearing information (Visual/Verbal dimension)
- Reasoning logically or intuitively (Sensing/Intuitive dimension)
- Analysing and visualising information linearly or in blocks (Sequential/Global dimension)

Active learners tend to retain and understand information best by doing something, by actively engaging in and with the technical material, discussing it, applying it or explaining it to others. Reflective learners prefer to think about the material quietly first. Active learners tend to like group work more than reflective learners, who tend to prefer to work alone.

Visual learners retain information best when it is presented in pictorial, graphical or animated form or when it is demonstrated. Verbal learners prefer material in textual form, written or spoken.

Sensors prefer to solve problems using well-established methods and by generally learning facts but tend to dislike complications and surprises. Alternatively, intuitors like innovation and dislike repetition. If intuition is overemphasised, the student may miss important details or make careless mistakes. If sensing is overemphasised, they may rely too much on memorisation and familiar methods and may not concentrate enough on understanding and innovative thinking.

Sequential learners prefer material in linear steps, with each step following logically from the previous one. Global learners prefer to learn in large jumps, absorbing material almost randomly without seeing connections, then suddenly seeing the overall picture. Sequential learners tend to follow logical stepwise paths in finding solutions whereas global learners may be able to solve complex problems quickly or put things together in novel ways once they have grasped the big picture, but they may have difficulty explaining how they arrived at the solution.

Learning style is a preference. Rarely is a person at an extreme of any dimension. The individual is therefore a mix of the word pictures of the extremes. It is the richness of mix within individual students that make a particular student group interesting and sometimes challenging to educate.

In much the same way that one particular text book will not sit comfortably with every student, another side effect of learning style preference, so too may a CAL package not suit every student. Is it acceptable, for example, for me with my particular communicating style preference, to dictate rigidly that all students must learn a particular subject the way I want them to? A rigidly designed CAL package can impose this restriction. How this is achieved is addressed later in this paper.

6. Inclusivity and CAL package design

One of the objectives of the tolerance analysis package was to ensure the widest number of students possible could use it. This includes students with disabilities commonly encountered in the University in particular colour blindness and dyslexia.

Typically within UK Universities partial or completely blind students are given a grant by the government for software and hardware to help them access information. There are two options for this equipment; a special screen reader that repeats what is on the screen verbally or a Braille display that converts the information on screen into Braille for the user.

A number of guidelines for disabled access to information are available [4 - 7]. For example, the Web Accessibility Initiative produces advice on what needs to be done to a web site to make it compatible with screen reader and Braille display technology. The most significant point is to provide alternative text for images and animated GIF's that describe the images or the point being made.

Use of alternative text is common as a means of dealing with the diversity of web browsers and their variable capability of dealing with images. A typical alternative text might be a short statement about the image or that a graphical web browser is required to display the contents. For the visually impaired, such a statement adds, at best, nothing to the understanding and at worst results in frustration. The disabled person needs not only a description of the image but also an explanation of its objective and purpose.

A less common disability is deafness. The guidelines for compatibility with hearing impaired students basically lie in the avoidance of sounds and spoken sections of text. Whilst the later is relatively trivial to overcome, the use of sound in videos or animations is much more common. The hearing impaired require additional text, perhaps simply a written narrative of the video or subtitles for the animation.

The most common disability encountered at York is dyslexia. Most people think of dyslexia as word blindness and hence a problem with reading. Whilst it is

true that many dyslexic students have a difficulty with reading, it is by no means true that all do. In some cases, dyslexia manifests itself as a problem of spelling or writing or a problem with short-term memory.

Recommendations for dealing with dyslexia are also broad. Common advice given to staff at York include extra time for students to gather and assimilated information and provision of information on coloured paper. Tintavision, a London based organisation, offer background colour assessments and advice on colour schemes for dyslexia sufferers.

Closely associated with the colour aspect of dyslexia is colour blindness.

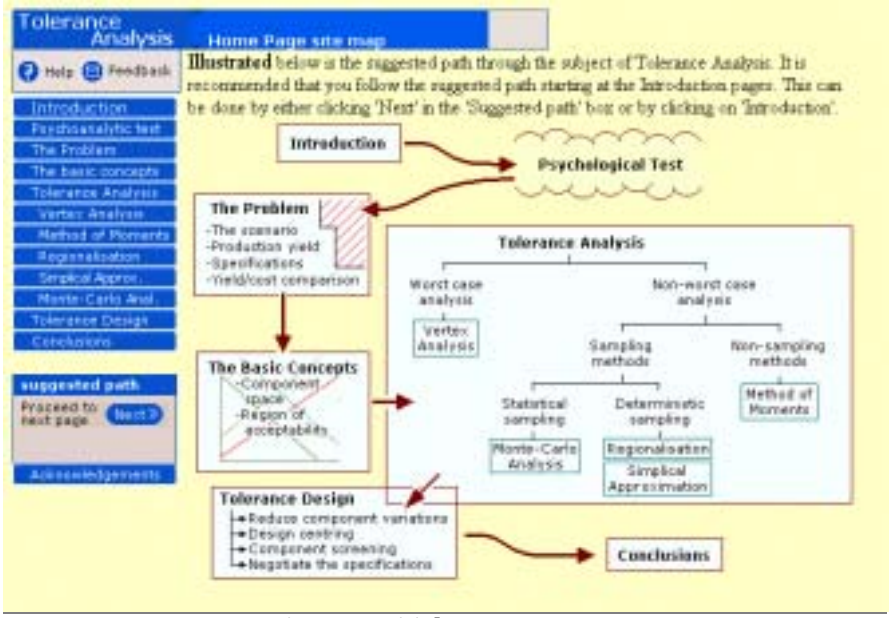

Figure 1 Initial Screen

7. The final product

To enable information to be presented to a user in a manner sympathetic to their individual learning style their preference must be known. The tolerance analysis package includes a learning style preference assessment questionnaire which the user is advised to take at the outset. The questionnaire is a multiple-choice inventory with the questions posed in web form basis. The user checks the answer of their choice and the form retains the answers as internal variables within a JAVA function. At the end of the questionnaire the learning style preference is calculated and information about the preference provided to the user for information. The results of the assessment are also saved to the users local directory using a 'cookie'. This cookie is then read each time that the user returns to the package. It would be possible for other packages to read the same cookie and hence also make use of the users learning style preference information. The 'cookie' also retains information about the colour scheme chosen by the user.

The technical content is divided into small discrete modules that have been storyboarded. The basis of the storyboard, shown in figure 1, is presented to the user as the opening screen of the package. As can be seen the main topics are listed in menu form down the left-hand side. Included are some common features such as help and home. At the bottom of the left-hand menu list is the suggested path box within which there is a 'Next' button. Provided the student has completed the psychometric test this button will advance them through the material in a learning style sympathetic manner as previously outlined.

Those students with a strong 'global' learning style preference will also see this screen more often as it shows the global picture of the material and the place of each of the sub-modules within it, more clearly.

As soon as the main package is entered, the screen takes on the form of a page with horizontally arranged tabs which provide additional and related material to each topic. Figure 2 shows an example of this for the introductory page. This page contains an introduction to tolerance analysis, a description of how the site works and the colour configuration page used as part of the disability feature.

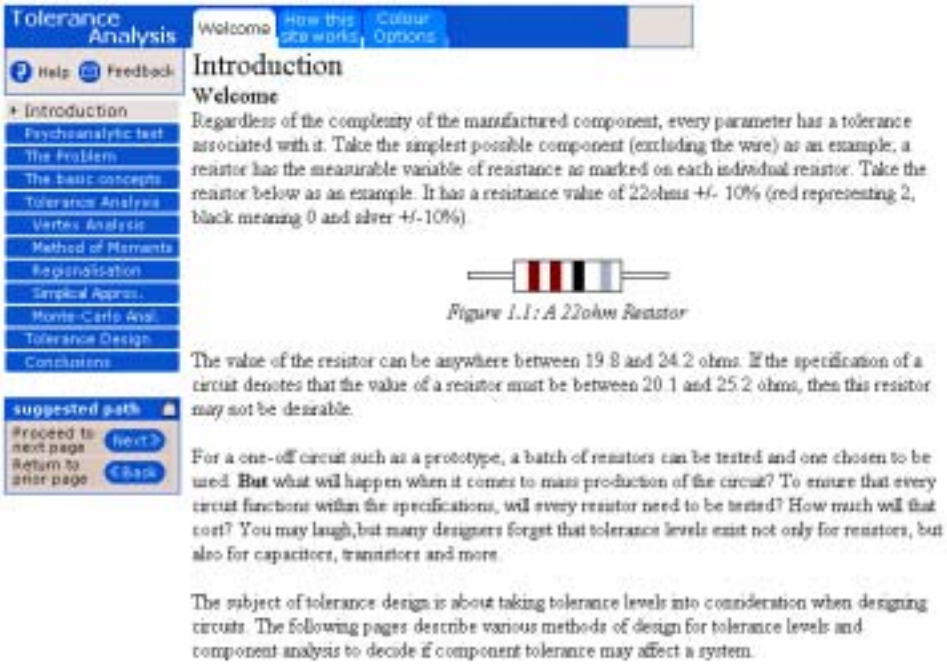

Figure 2. Introduction screenshot

The main technical sections of the package contain interactive diagrams, worked examples, simple applets to illustrate specific learning points and printable sets of lecture notes for each section. It is intended to extend the package to include self assessment tests and more dynamic and interactive 'games' or simulations of the learning points.

8. Trials

The package has been trialled on a cohort of 100 students who were asked to review the package and complete a short questionnaire. Results of this initial trial showed that students were able to interact with the material well and those that completed the psychometric assessment found the subsequent route they were led through the material easy. Whilst this is a long way from a rigorous assessment of the merits of the package and indeed the merits of the inclusion of a learning style assessment, it is encouraging. More rigorous testing will be carried out when the product is fully developed.

9. Conclusions

A computer aided learning package for tolerance analysis has been created. The objective of the exercise, whilst primarily the creation of a student learning resource, but was additionally used as a vehicle to investigate the practicality and effectiveness of using the users' learning style preference to increase the effectiveness of the package.

It was also used as a vehicle to investigate what could be included in a computer based learning package to increase student inclusivity through consideration of some disabilities. Early feedback on the current version is encouraging.

10. References

[1] "Are we approaching CAL correctly? A programme manager's perspective", Ward, AE, 11th EAEEIE Annual conference, Ulm, Germany, April 2000

[2] "Electronic Product design" Ward and Angus, Chapman and Hall, 1996, ISBN 0-412-63200-4

[3] 'Index of Learning Styles' formulated by Richard Felder and Linda Silverman at North Carolina State University, http://www2.ncsu.edu/unity/lockers/users/f/felder/public/RMF.html

[4] The Dyslexia Handbook, 2001. The British Dyslexia Association.

[5] Specific Learning Difficulties (Dyslexia), 1994 G Reid.

[6] A focus on Dyslexia, 2001. N Rea, University of York

[7] Web content accessibility guidelines, http://www.w3.org/WAI/WCAG1A-Conformance