Maple and the World-Wide Web at RMIT

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Abstract

The use of Maple and the World-Wide Web at RMIT is described. The Computer Algebra System Maple is first reviewed and Maple worksheets and the various formats in which they can be saved are discussed. A historical outline of the use of Maple in teaching both mathematics-degree and service-mathematics subjects at RMIT then follows. Finally, the description of two recently funded projects, Mathweb and M^3W^3 (Mathematical Modelling with Maple and the World-Wide Web) are described. The project Mathweb enabled Maple to be introduced into some of the large enrolment service subjects taken mainly by Engineering students at RMIT. The project M^3W^3 enabled two new mathematical-modelling subjects to be developed and introduced into the Mathematics Degree Programme at RMIT; these subjects use Maple, group projects, student mentors and electronic submission of assignments.

1 Maple

Maple is a Computer Algebra System (CAS) that can generate

- exact symbolic solutions;

- numerical approximations;

- graphs and animations in both 2 and 3 dimensions.

It is evident that CAS's will play the same role in modern teaching and learning that calculators did when they became generally available.

1.1 Origins of Maple

In 1959 MACSYMA was developed at MIT. The driving philosophy was the belief that rule-based and highly structured mathematical processes should be programmable. The success of MACSYMA showed that this was indeed possible, despite how difficult it seems to be to teach these procedures to some individual people.

In 1980 staff at the University of Waterloo in Canada began discussions of CAS's and their use in supporting both the teaching and research of Mathematics and Engineering. To achieve these ends, a Symbolic Computation Group was formed to create a new CAS. The requirements of this new CAS were threefold:

1. Allow many users simultaneous access whilst at the same time requiring minimal processing power and computer memory.

2. A clear, logical and understandable syntax.

3. The ability to be easily extended.

The outcome was **Maple** which has been extended and enhanced many times over the last decade with the most recent being Version V Release 4 (MVR4). From the point of view of developing material for delivery using World-Wide Web technology, the most significant improvement has been in the enhanced interface that allows structured text-based documentation, including mathematical formulae, to support the commands appearing in the Maple worksheet. This provides the opportunity for staff to present clear descriptions of what each delivered worksheet is meant to achieve and for students to clearly document and explain their own work. The opportunity to directly produce LaTeX 2_ε input files with all figures automatically converted to standard postscript for their subsequent inclusion means that students can ultimately generate professional high-quality mathematical typeset reports.

2   Maple Worksheets

The algebraic engine that drives Maple is accessed by the user through a so-called worksheet. Each worksheet is capable of being divided into three regions; each region may appear several times and in various levels of sophistication throughout the worksheet.

1. A text region. This area permits documentation of the material pertinent to the given application. Content is entered here using standard word-processing methods.

2. A Maple input region. Commands in this region require strict attention to syntax; it is these commands that allow the user to interact directly with the Maple engine. Our experience is that new users of Maple, both staff and students, find the command structure particularly intuitive.

3. A Maple output region. Material in this region represents the Maple engine's response to the user's commands in the input region. In versions of Maple V that are later than Release 2, the output appears in correct typeset mathematical format.

   For convenience in structuring worksheets for presentation purposes as well as reducing clutter in worksheets, it is possible to suppress output with the silent terminator ':' rather than the usual ';'. If the latter terminator is used, the complete detailed response from the Maple kernel is displayed. At times, for example when loading an appropriate package to permit more specialised calculations, the resulting information *may* be contextually irrelevant to the worksheet's main development.

An example Maple V worksheet for Release 4 can be found at the URL

```
http://www.ma.rmit.edu.au/kepler/ATCM97/example.mws
```

If you have a local copy of Maple and if your browser has been pre-configured to launch the programme based on the Mime type of the example file being delivered by the web server, accessing these files will result in launching an interactive Maple session[1]. The content of this example worksheet displays both input and text regions. Using Maple to expand any of the input commands automatically generates a Maple output region. The content provides a simple demonstration of some of Maple's capabilities.

Some of the plots resulting from the command in this example worksheet can take some time to render. For the impatient, the following links display the main plots

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[1]At RMIT, the CALTS laboratory in the Mathematics Department has been so configured.

for the intricate surfaces that are generated near the end of the worksheet; see the URL's

```
http://www.ma.rmit.edu.au/kepler/ATCM97/tube1.pict
http://www.ma.rmit.edu.au/kepler/ATCM97/tube2.pict
http://www.ma.rmit.edu.au/kepler/ATCM97/tube3.pict
```

2.1 Saved Format

Maple worksheets can be saved in various forms. These include

- Maple 'Worksheet' compressed format (but nevertheless in ASCII format) that is platform independent. Such a worksheet generated on a PC, for example, can be imported directly on to a Mac, Unix, ... format with no change. These Maple worksheets travel well in the sense that they can be delivered using web technology and successfully attached to email messages for transmission across the internet for example.

- LaTeX or LaTeX 2_ε format. This allows the simple preparation of typeset hardcopy of the entire Maple worksheet including Maple output that appears in both textual and plot formats.

3 A Brief History of Maple Use at RMIT

In 1992, Maple was integrated into the first year Mathematics degree programme through the subject MA192. This is a laboratory-style class that supports the main core subjects of this year of the degree programme. A small Macintosh laboratory consisting of 17 low-end Macintosh computers was used to present the Maple material in three different sessions to all the students. A team consisting of Howard Connell, Gary Fitz-Gerald, Liam Healy and Yousong Luo prepared material that included hard-copy versions published in the RMIT Lecture Notes in Mathematics series. One laboratory session was made available for each week for the 50 students enrolled in that year. The material has been upgraded each subsequent year to keep pace with new and improved versions of the software.

In 1993, Maple was introduced to selected small to medium enrolment service Mathematics subjects offered mainly to Engineering students at RMIT. Initially, the required Maple code was keyed in by students. The main disadvantage of this was the time involved in students' generating the requisite correct Maple syntax; this was not the main aim of these subjects.

Since 1994 the Mathematics Department has been located in Level 9 of the new Building 8 at RMIT. At the design stage of this new accommodation, several new computing laboratories were planned. The largest for undergraduate purposes, the CALTS laboratory with 50 PC's running as part of a Novell installation, has enabled a wider use of Maple in the teaching and learning of both Mathematics degree and service subjects.

In service subjects, Maple worksheets were initially supplied on floppy disk to avoid the time involved in the students keying in the correct Maple syntax. Nevertheless there were significant delays before *all* students were able to commence the laboratory session. The recent purchase by the Mathematics Department of a WWW server and the subsequent delivery of Maple laboratory sheets using Web technology has overcome these difficulties. (Each PC in the CALTS laboratory runs the latest version of the Netscape browser which is configured to launch the appropriate release of Maple so that students find themselves immediately in an interactive Maple session.)

In support of these activities, there has been a related development of hard-copy Maple material in the RMIT Lecture Notes in Mathematics series. (See references [1, 2, 3, 4, 5].) The motivation for the continued development of this supporting hard-copy material is that many students request the availability of such material. This is in spite of the fact that a large proportion of the material is available directly on the Web. It will be interesting to see if this requirement decreases as students become more attuned to the use of learning materials delivered using web technology.

Since 1994 Maple has been introduced to support several of the larger enrolment service subjects. These include MA003 — Differential Equations A, MA004 — Differential Equations B, MA019 — Finite Element Methods, MA031 — Fourier Techniques and MA032 — Boundary Value Problems. (For example, the subject MA003 has an enrolment of approximately 475 students in the first semester of each year and 200 in the second semester.)

Also since 1995 student submission of projects using email has been implemented in some of the smaller subjects. This is a simple exercise using the mailer attached to the Netscape browser running in the CALTS laboratory and the compressed form of the Maple worksheets. Not all students are comfortable with this form of submission and its use in larger subjects will need to be carefully considered before it is attempted. Many simple, but nevertheless significant, difficulties such as how to handle an "avalanche" of email messages to a submission address, need to be first considered before such a scheme is implemented.

4 Recent Projects

4.1 Mathweb

A project entitled 'Mathweb' was one of nine projects funded as a Strategic Proposal for Technology in Teaching and Learning at RMIT in 1995. A related project entitled "Enlivening the Mathematics Curriculum at RMIT with Maple" funded by the Faculty of Applied Science as part of its Quality Assurance monies supplemented the project Mathweb for part of 1995. An initial description of 'Enlivening the Mathematics Curriculum at RMIT with Maple' was given at the five-day August 1994 Workshop and Symposium 'MapleV: Mathematics and its Application' held at Rensselear Polytechnic Institute, Troy, New York (see reference [6]). An initial description of 'Mathweb' was given at the two-day December 1994 meeting 'Use of Mathematical Software in Tertiary Mathematics Teaching' held at LaTrobe University, Melbourne [7]. Details of the final outcome of 'Mathweb' were presented at the three-day July '1996 IEEE International Conference on Multi-Media Engineering Education' held at The University of Melbourne [8].

4.1.1 Project Details

Maple and the WWW have been integrated to enable the direct delivery of active worksheets to students in support of the teaching and learning of service subjects offered at RMIT. These include several of the large-enrolment subjects covering such topics as finite element methods, Fourier techniques, Laplace transforms and partial differential equations.

Use of the Mathematics Department's World-Wide Web server has provided access to Maple material in several forms:

- as *simulated* Maple sessions in HTML format;

- in read-only *Adobe acrobat* format;

- as interactive Maple sessions.

The delivery of interactive worksheets has provided students in these subjects with the opportunity to explore features of the package interactively using both graphics images and textual material. Supporting material is available in hard-copy form through the RMIT Lecture Notes in Mathematics series.

The use of electronic mail to submit Maple assignments has also been successfully used in several of these subjects.

4.1.2   Choice of Maple

Current students have little incentive to explore mathematical concepts due predominantly to their inadequate grasp of fundamentals in basic algebra, trigonometry and geometry. They are unable to perform the most straightforward manipulations, let alone the intricate calculations required of "real" applications. The introduction of Maple to the curriculum of service mathematics enables students to concentrate on the *principles* introduced in each topic. A fundamental understanding of the underlying processes is supported by a package that relieves the student of performing the manipulations required to obtain a formally correct answer to real-world problems.

One unusual but desirable feature of the introduction of Maple is the students' ability to transfer this learning to other subjects. Compartmentalising of learning is *not* a feature of learning with Maple.[2]

4.1.3   Benefits

The major benefits are as follows:

- Staff are able to introduce real-world examples currently beyond the average student's technical ability.

- Students are exposed to modern technology that allows them to concentrate on the modelling exercise at hand.

- Students are able to assimilate new material and perform real-world calculations that more closely match their own department's expectations.

- Staff are able to devote more class time to the teaching of difficult new concepts.

- Understanding of new concepts developed in the course improves because learning is not hampered by the lack of manipulative ability typical of the modern student.

These benefits were particularly apparent in the subject MA019 — Finite Element Methods where much of the pre-analysis, required as a fundamental grounding in an appreciation of the finite element method, can be left to Maple. This pre-analysis, although conceptually straightforward, is nevertheless computationally involved. More realistic approximating shapes could be realised using Maple than would otherwise have been possible.

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[2]This observation is based on recent surveys of students at RMIT.

4.1.4 Flexible Learning

Students who purchase their own copies of Maple are able to carry out the laboratory sessions at their own pace. In fact many of the students, upon downloading the Maple sessions, prefer to save them and work on them at a later more convenient time rather than work on them immediately[2]. Submission of the associated projects was predominantly by electronic mail using the Netscape mailer.

4.1.5 Evaluation

Besides the project team members, several RMIT staff were involved in monitoring various aspects of the work.

(a) Dr. H. Connell of the Department of Mathematics made a significant contribution as subject leader and lecturer for MA019. This included preparation of a 'Maple Laboratory Handbook', see reference [4], for use by students in this subject. In addition, these students acted as a pilot group by accessing Maple sessions on the World-Wide Web and by submitting Maple worksheets for assessment by electronic mail.

(b) Consultation with Mr. J. Milton of EQARD resulted in the participation of two members of the project team (Dr. G. F. Fitz-Gerald and Associate Professor W. P. Healy) in the workshop entitled 'Evaluating Educational Technology Innovations' and conducted at RMIT on 30 March 1995 by Shirley Alexander, Director of the Institute for Interactive Multimedia, University of Technology, Sydney. The paper [9] was discussed in detail at this workshop.

Evaluation of the project was carried out through a student questionnaire that was adapted from one used by Fulton [10] and extended to include questions on the use of the World-Wide Web. The questionnaire was administered, on a voluntary basis, to students enrolled in the subject MA019 in second semester 1995. As was mentioned previously, these students had used Maple, the World-Wide Web and electronic submission of assignments as part of MA019.

The following inferences may be drawn from this survey.

A. 79% of students either agree or strongly agree with the statement that more Maple should be used in teaching mathematics subjects.

B. 74% of students either agree or strongly agree with the statement that the World-Wide Web should be used more in the delivery of mathematics subjects.

C. 67% of students either agree or strongly agree with the statement that electronic mail is a convenient way to submit Maple worksheets for assessment. (This figure is remarkably high, given the early hardware/software problems encountered with the Netscape mailer.)

4.2 M^{3}W^3

A project entitled M^{3}W^3 — Mathematical Modelling with Maple and the World-Wide Web — was one of twelve projects funded as part of the LearnT Fund at RMIT in 1996. This project incorporated Maple into the second year of the Mathematics degree programme through the applied mathematics subjects MA503 — Mathematical Modelling I and MA504 — Mathematical Modelling II.

4.2.1 Student Background

These students have already been introduced to Maple in their first year where it supports the core pure and applied subjects. In this introduction, both command-line and programming features are used. This Maple material is available in hard-copy form and is supported with formally structured laboratory sessions that maintain a traditional pen-and-pencil component in parallel with the Maple sessions.

The LearnT-funded project extended the popular and successful use of Maple in the first year into the second year of the Mathematics Degree programme. An example of Maple material presented in support of the MA503 class discussions is available on the web at the URL

```
http://www.ma.rmit.edu.au/kepler/maple_worksheets/
          mechanics/ma503/flagpole/exact.mws
```

In this worksheet Maple is used to generate cross-sectional plots and to build a number of animations that describe the response of a long slender structure to a specified periodic vibration. Two such animations have been pre-recorded and are available by following the links appearing at the URL

```
http://www.ma.rmit.edu.au/kepler/maple_worksheets/
              mechanics/ma503/ma503.html
```

The first part of one of these animations consists of the following nine scenes.
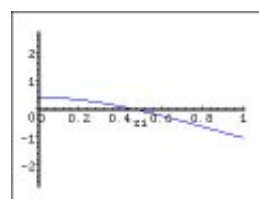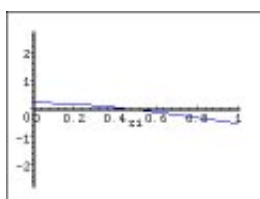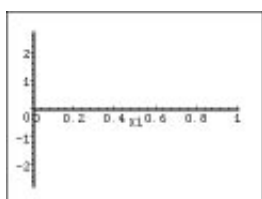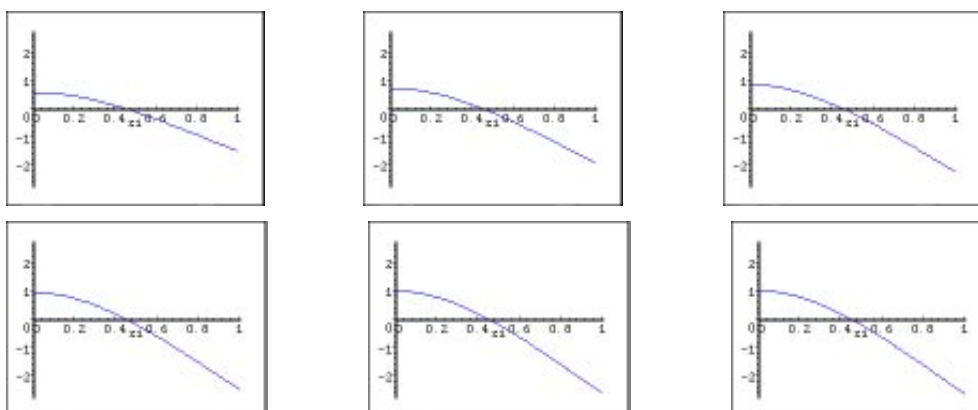
4.2.2 Project Details

This project had several distinct aspects:

1. The development of two new mathematical-modelling subjects in the second year of the mathematics degree programme. Assessment is partly based on the use of group activities. Some of the main requirements of the course include the following:

    (a) Each group submits a written report on the allocated project.

    (b) Each group apportions marks to the members making up the team.

    (c) Each member of each group participates in an oral presentation of the team's solution to each project.

    (d) Each student takes an individual responsibility for their learning.

    Surprising pedagogical outcomes identified by this project included the following:

    - Students found the non-rule-based nature of the material quite challenging.

    - Mathematics students find the discipline of being involved in group activities difficult.

    - The non-dimensionalising of given mathematical statements of real-world problems is a significant hurdle for some students. The identification of relevant intrinsic scales often proves difficult for students when they are first introduced to the notion of inspectional analysis.

2. The use of Maple to support the analytical demands of the new modelling subjects.

3. The use of small teams (usually < 4 in each group) to solve modelling problems typical of those arising in practice. For the first group activity of the year students decided on the group membership. Staff decided the membership of subsequent group activities.

   Important perceived benefits of such group activities included the following. They provided students with

   - experience in working in teams;
   - experience in leading a team;
   - experience in writing reports.

4. The use of mentors to support the groups' attempts at solving the projects. These mentors were chosen from students currently enrolled in their honours programme, postgraduate students or tutors.

5. The use of email as a means of submitting the Maple worksheets (in compressed platform-independent form) or LaTeX 2_ε documents (mostly in the form of a postscript file) that represent each group's solution to their project. An example of one group's 1996 submission can be found at the URL

   ```
   http://www.ma.rmit.edu.au/kepler/TandLforum/gp5.ps
   ```

   This postscript file was obtained by using the `export to latex` option of Maple. The plots appearing in this submission were also generated using Maple and imported into the LaTeX 2_ε document using TeX environments provided with the Maple installation.

4.2.3   Acknowledgments for M^{3}W^3 Project

Project Reference Group:	Ian Peckham & Claude Zorzan.
FLEU (of EPI) adviser:	Alistair Inglis.

References

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