ELECTRONIC MARKING OF MATHEMATICS ASSIGNMENTS USING MICROSOFT WORD 2007

Tim Lowe, Ben Mestel and Gaynor Arrowsmith

Electronic Marking of Mathematics Assignments Using Microsoft Word 2007

Tim Lowe, Ben Mestel and Gaynor Arrowsmith,
Mathematics Online Project,
Department of Mathematics and Statistics,
The Open University, Walton Hall, Milton Keynes. MK7 6AA
T.W.Lowe@open.ac.uk

Abstract

This paper describes on-going work within the Department of Mathematics and Statistics at The Open University to enable distance learning students to electronically submit assignments rich in mathematical notation and diagrams, and for those assignments to be marked and returned electronically by their tutor.

A trial is currently underway of a prototype system that enables students to submit assignments in a range of electronic formats, which are then converted to Microsoft Word 2007 format to enable tutors to take advantage of various features of this software for marking and providing mathematical comments.

The systems developed for this trial are described and preliminary findings presented.

Introduction

The Open University (OU) is the largest provider of distance learning education in Europe, with approximately 180,000 active students including 15,000 registered for courses in mathematics. Each student is supported by an assigned part-time tutor (Associate Lecturer), for each course of study undertaken. In many cases, a tutor may live some distance from individual students in their tutor group, and may sometimes reside in a different country.

A key component of the supported open learning model of teaching used by the OU is the Tutor Marked Assignment (TMA). These are assessed pieces of course-work undertaken by the student at regular points in their course of study, and marked by their assigned tutor. Typically, a 30-point course would contain 4 TMAs and a 60-point course 7 TMAs. The results of these often form a substantial part of the assessment of the course as a whole. The marking of these assignments typically contains extensive individual feedback together with explanations of methods and misconceptions where required. This feedback forms a core element of the correspondence tuition given to students by their tutor.

The traditional form of the TMA submission process requires the student to send their work to their tutor by post; the tutor then marks the script by hand and forwards it by post to the University. The University records the marks and returns the annotated script to the student, again by post. This can lead to a significant delay in the student receiving feedback on their work, which reduces the usefulness of that feedback (Gibbs and Simpson, 2004).

In recent years, many courses within the University have moved to a system of electronic Tutor Marked Assignments (eTMAs). Here, students word-process their work and submit it to the University online, by uploading a file or set of files to a dedicated web-site. The tutor then downloads the assignment to their computer, marks it using the appropriate features of a word processor and uploads the marked assignment back to the University web-site, from where the student can access the marked script. The advantages of this approach include the fact that students receive feedback on their work in a more timely manner (without any postal delays) and that they can submit their work from anywhere, at anytime (subject to the deadline for the assignment). When uploading their work, the student also gets an immediate confirmation of receipt by the University. Currently 47% of all TMAs across the University are now submitted by this route[1].

Such an electronic system has not yet been adopted within Mathematics and Statistics (and other symbolically-rich curriculum areas) due to the difficulty for students in word-processing mathematical notation and diagrams, and the similar problems inherent in tutors marking and providing feedback and teaching comments. In this paper we describe a project which aims to overcome these problems. The methods developed will be of interest to others wishing to facilitate electronic marking in symbolically rich curriculum areas. In the following sections, the requirements of an eTMA system for mathematics are outlined and the prototype system explained. Preliminary results of a trial of mathematics eTMAs running February-October 2008, involving 24 tutors, are then discussed.

Requirements of an eTMA system for mathematics

The requirements of eTMA system for mathematics were identified as follows:

The system should not affect how students produce mathematical work

A fundamental principle underlying this work is that the introduction of an electronic submission system should not alter the way in which a student produces their mathematical assignments. Whilst some students already use a variety of systems to word-process mathematical assignments, many prefer to handwrite their solutions. Indeed, there are pedagogic advantages to the latter, and consequently submission of digitally scanned handwritten pages, for example, should be permitted. In any case, often students who submit word-processed mathematical assignments first work out their solutions by hand, and then word-process the results. A consequence is the possible

[1] Internal statistics, February 2007 – January 2008.

omission of important steps that could enable a tutor to identify a student's misunderstandings. In addition, transcription errors may be introduced. Moreover, some students spend valuable time word-processing their submissions due to unfamiliarity with mathematical typesetting or through excessive attention to presentation details, possibly at the expense of the mathematics itself. However, typesetting systems should be permitted for the benefit of those students who are confident in using them.

The system should be useable by students of all levels and abilities.

Open access is a fundamental principle of the OU, with the consequence that, in general, there are no formal entry requirements for students. The mathematics courses offered range from pre-algebra studies to masters level. Any eTMA system needs to be accessible to a wide range of students, including those studying some mathematics to support other curriculum areas. It also needs to be useable by students with a variety of information technology skills ranging from computer novices to early-adopters of new operating systems. The eTMA system should not tie a student to using particular hardware or software, to which they might not have access.

Tutors should be able to use a variety of electronic marking methods appropriate to the hardware available to them.

There are several ways to annotate an electronic document, including use of commenting and review tools present in many modern word processors, and digital ink technology. Indeed, there have been trials within the OU of electronic marking using digital ink with tablet PCs (Underwood and Freake, 2007, Fisher, 2008), and similar systems have been used elsewhere (Kerr et al, 2007). Of necessity, the equipment available to tutors varies, as do their marking preferences, and therefore a range of approaches should be supported. Moreover, tutors should not require different software to accommodate student work in a variety of formats.

On the other hand, the tutors are contractually expected to have a certain level of proficiency with information technology and to have access to a computer running a recent version of the Microsoft Windows operating system, the main system currently supported by the University. The eTMA system should permit tutors to mark mathematics TMAs using whatever hardware is available to them. Whilst it may be feasible to equip all 550 mathematics tutors with a USB graphical tablet, it would be uneconomic to equip all with a tablet PC.

The system should interface with the University eTMA system, but not require any changes to it.

For the purposes of a pilot study, it has not been possible to make any changes to the University eTMA system, which supports approximately 350,000 student submissions each year. However, it was felt desirable to make as much use of the current system as possible to ensure conformity with standard procedures, and, in particular, to ensure that students' marks are correctly entered into their records.

A pilot eTMA system for mathematics

A pilot eTMA system for mathematics has been developed based on the above requirements and is shown schematically in Figure 1. It was also informed by a small scale preliminary trial undertaken during summer 2007 which involved seven tutors marking a total of 49 mathematics student submissions electronically.

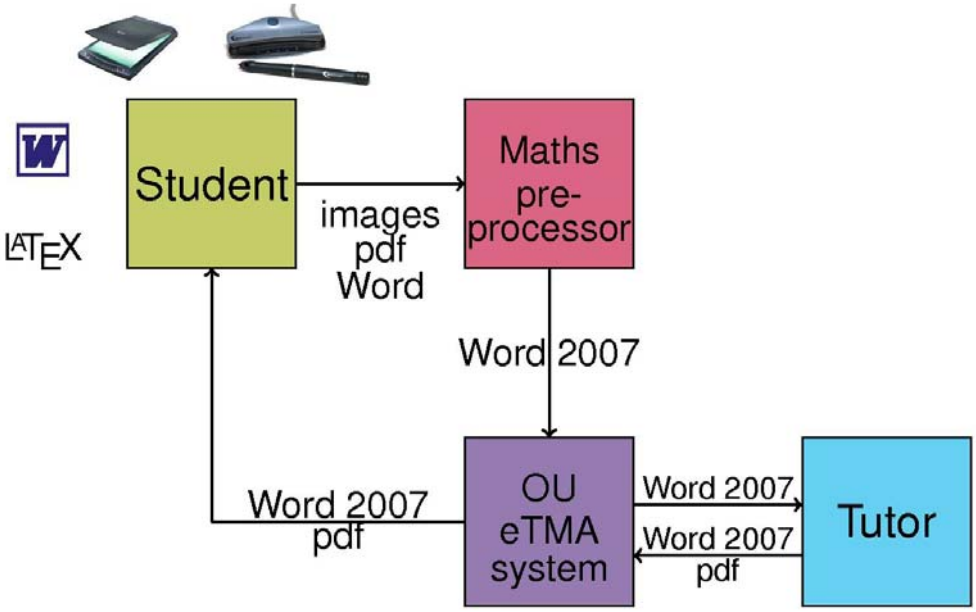

Figure 1: Outline of the pilot mathematics eTMA system.

In this system, student work is marked by tutors using Microsoft Word 2007, which was chosen because of its built-in annotation and mathematical tools. It supports both typed comments and annotations, and the use of digital ink technology2. This dual approach provides a flexible way for tutors to mark student work, whether it be a typeset document or images of scanned handwritten work. Word 2007 also includes enhanced capabilities for the input of mathematical expressions, essential for correspondence tuition in symbolically-rich subject areas. A sophisticated equation editing capability enables both a graphical, palette based method of inputting mathematics and a keyboard typed syntax (Sargent, 2006). The rendering of mathematics gives a quality near to that of the standard mathematical typesetting package TeX. Word 2007 documents are stored in the Open Office XML format, an ECMA standard (ECMA-376, 2006) which is currently being considered for adoption as an ISO/IEC standard. This open format facilitates the automatic construction of Word 2007 files.

[2] The native digital inking facilities of Word 2007 are only available when using the Microsoft Windows XP Tablet Edition or Vista operating systems. Third party plug-ins are available for users of other operating systems.

The pilot mathematics eTMA system permits students to submit work in a variety of document formats including Word 2003 (doc), Word 2007 (docx), digital images (jpg, png, gif, bmp etc) (for example, scanned pages of handwritten work or images from a digital camera) or as pdf. pdf files might be generated using, for example, LaTeX, OpenOffice, or some other word processor; or might again contain images of scanned handwriting. The student uses email to submit files to a mathematics pre-processor which automatically forms Word 2007 documents as follows.

- Image files (jpg, png, gif, bmp etc) are inserted one image per page into the Word document, and locked to prevent accidental deletion during marking.
- Each page of a pdf file is converted to an image using the open source software package ImageMagick (ImageMagick, 2008) and then formed into a Word 2007 document as described above.
- Word 2003 documents are translated to Word 2007 format using Microsoft's Office File Converter (OFC) (Microsoft Office Migration Planning Manager, 2008).
- Word 2007 documents are unchanged.
- Other files, such as worksheets from mathematical packages (Mathcad, Maple etc.) or computer code, where required, are unchanged.

In all cases bar the last two, a header is added to the document indicating the format of the original submission and reminding the tutor to return the marked file in pdf format3 since it cannot be assumed the student has Word 2007 to enable them to read the marked script4.

The processed documents are then forwarded automatically to the University eTMA system by email on behalf of the student. The University system imposes a file-size limit of 3Mb per eTMA submission. Due to the size of digital image files, it is possible that a student's submission in this trial may exceed this limit. In this case, the mathematics pre-processor decreases the size of the image by reducing the resolution of the image and/or reducing the number of colours used within it. In all cases, when the processed submission is forwarded to the University system, a copy is also returned to the student. If dissatisfied with the processed result, the student has the option to amend their submission in an appropriate way and to re-submit.

Tutors access and download the submitted script from the web-based interface to the University eTMA system in exactly the same way as those involved in courses from other programmes in the University. The return of marked scripts is similarly performed.

[3] Save as pdf functionality for Word 2007 is provided by a freely available Microsoft plug-in.
[4] A Word 2007 viewer for the Windows operating system is available, however this renders any mathematics input using Word 2007 as low quality images, removing the mathematical typesetting advantages of Word 2007.

Tutor marking of eTMAs

As previously mentioned, tutors participating in the trial are free to mark submitted eTMAs using any of the methods made available to them through Word 2007 including:

- the use of review and comment facilities;
- typed annotation inserted within the student's document;
- typed annotation placed at the end of student's document;
- typed annotation contained within text boxes and placed over the student's work;
- digital inking.

Some of these approaches are more suited to certain types of processed work than others. As a result of the processing described in the previous section, tutors receive one of two types of Word 2007 file: those essentially consisting of embedded images of students' work; and those containing editable text. For files of the latter type, any of the above approaches can be adopted. However, for those consisting of embedded images, the first two approaches are not generally appropriate. The review and comment facilities of Word 2007 do not enable specific parts of an image to be commented upon, but simply relate comments to the image as a whole. Similarly, typed comments cannot be inserted at an appropriate point in the image – they must be placed on a new inserted page. The comments are then not located close to the items of the script to which they refer. In such cases, the latter two styles of marking are more appropriate, although the need to open a text box before inserting typed comments can be time consuming.

Figure 2 shows an example of using some of the features of Word 2007 for annotating students' work.

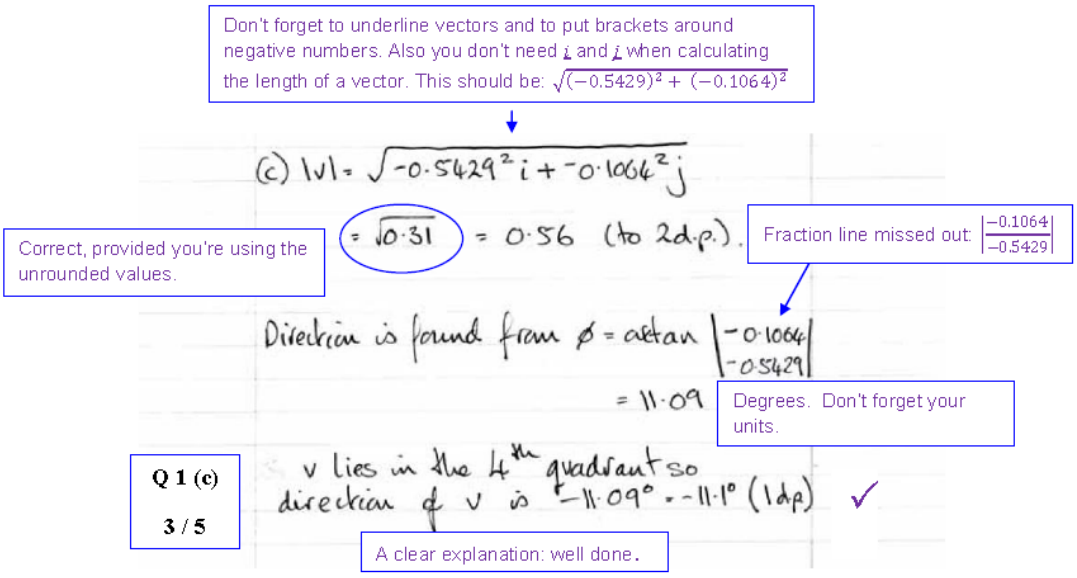

Figure 2: Annotation of students' work using Word 2007.

The results of the small preliminary trial conducted during 2007 indicated that marking work electronically is, at least initially, more time consuming than the traditional paper-based activity. This observation is supported more widely by the results of an internal OU survey across those areas of the University currently engaged in the electronic marking of student work[5].

For this reason, a range of prototype marking tools has been developed in-house for use in Word 2007. These appear as icons in an additional tab on the Word user interface, as shown in Figure 3.

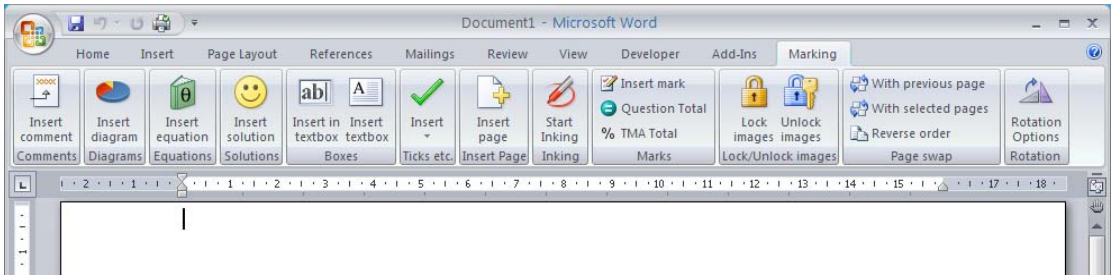

Figure 3: Prototype Word 2007 marking tools.

These tools provide the tutors with the following facilities.

- Rotation and re-ordering of embedded images, should it be required. (This may be due to errors by the student in scanning the handwritten pages, or assembling pages in the wrong order, or with the wrong orientation.)
- Insertion of ticks or other symbols at given points in the document. These are contained within text boxes to enable them to be overlaid on embedded images.
- Insertion of standard comments, equations, diagrams or short model solutions into the student's work as the basis of comments by the tutor.

This last tool was developed to enable tutors to give the same or similar comments on a range of assignments. Having a repository of common comments, equations and diagrams (which can be added to by the tutor) provides a simple way of entering these common elements, which can then be edited and customised by the tutor. Indeed, the re-use of common comments in this fashion is one of the advantages of electronic marking to the tutor. Such a system of comment repositories has also been used by Kerr et al (2007).

The mathematics eTMA trial

A current trial of the above systems involves 24 tutors across a range of mathematics courses being presented in the period February to September 2008. Tutors were selected to ensure the courses involved covered all levels

[5] Internal OU survey of Associate Lecturers, December 2007.

from Level 1 to Masters, and ranged across a variety of mathematical disciplines including pure mathematics, applied mathematics and statistics.

The trial is considering the following aspects of eTMAs for mathematics:

- whether electronic submission is of value to students, and whether it affects how they work;
- how easy or difficult tutors find marking mathematical assignments electronically, and what facilities they find useful for marking;
- whether electronic marking changes the way in which tutors mark;
- the robustness of the systems used.

At the start of the trial, the tutors were offered training in the use of Word 2007 (including its mathematical capabilities) and in the use of the marking tools. In addition, standard training packages on the University eTMA system were made available, since in most cases the tutors were novice users of the system. Support has been made available to tutors through the provision of a dedicated email address, and through an on-line discussion forum to which all participating tutors have access. This forum is also used by tutors to share experiences and best practice. To support digital inking, a graphical input tablet was provided to those tutors who requested one.

Students were recruited to the trial by each tutor offering the members of their group the option to submit assignments electronically.

Preliminary trial results

As of 1 May 2008, 157 individual students had used the trial mathematics eTMA system, making a total of 263 valid individual submissions, across 13 different courses. The average time to process a maths TMA through to the main eTMA system, including conversion to Word 2007 where required, is 1.4 minutes, and the average size of a processed submission is 733Kb.

Students had the facility to submit a dummy maths eTMA to test their (and their tutor's) use of the eTMA system, and to enable their tutor to check that their work was appropriately formatted.

Early results show that there is a wide disparity of take-up between courses, however the majority of students who submit one eTMA successfully do so again.

The type of files submitted by students to date is illustrated in Figure 4. This shows the proportion of submissions for each main file type, ignoring any additional attachments such as worksheets from mathematical packages or computer programs.

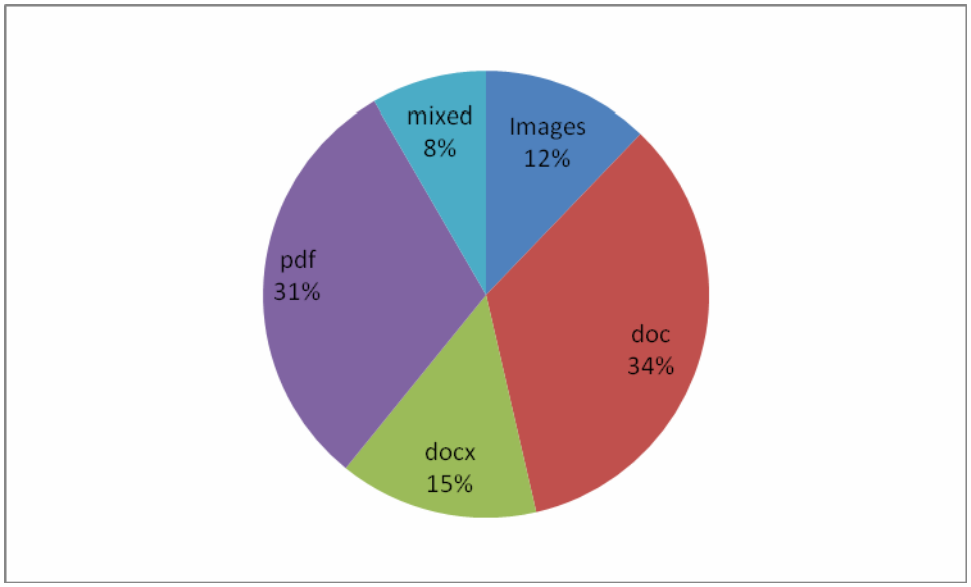

Figure 4: eTMA submission types

Figure 4 shows that, within this trial, word-processed documents are the dominant format used. This is a slightly unexpected result given the perceived difficulty for students of word-processing symbolically rich assessment work.

The plan is to contact students for feedback on their experiences at the end of the trial. However the comments made so far by tutors in their discussion forum have been analysed. Significant issues identified to date are reported below.

Marking styles used

Many of the available methods of marking eTMA have been used by the tutors, with the possible exception of the built-in commenting facility. Text contained within text-boxes is the most common method of annotation, and being used both for documents consisting of scanned images (where it is necessary) and for those containing editable text (where it is not). A number of tutors have used digital inking facilities, and some use it exclusively. Digital inking seems most popular amongst tutors using Tablet PCs, and those using add-on graphical tablets find inking less easy. Some, but not all, tutors are taking advantage of the marking tools provided. Tutors seem to find entering mathematical annotations using the Word 2007 equation facilities straightforward.

File format issues

Problems have been reported when a student produces a word-processed document using a system other than Word 2007. Sometimes symbols in the original document get replaced by meaningless glyphs when the processed document is opened by the tutor. Some of these issues seem to be related to specific fonts not being available on the tutor's computer, others due to the methods by which students saved their work originally. Occasional problems have been encountered by tutors using the "Save as pdf" functionality of Word

2007 in that some of the items contained within the document are partially omitted. Saving documents as pdf can also significantly increase the file size.

Some tutors prefer marking scanned images, as they feel their annotations are not changing the underlying work. Others prefer marking editable documents.

General

Although many tutors have found electronic marking and using the University eTMA system to be difficult in the early stages, these seem to become easier over time.

Many tutors have found marking electronically to be significantly more time consuming than the paper-based equivalent. However some, in particular those who have received relatively high volumes of electronic TMAs to mark, have noted the advantages of being able to reuse comments.

The style of feedback given to students by tutors does not seem to have changed, however some are concerned at the impersonality of typed comments.

Conclusions

A system for the electronic submission and marking of student assignments containing significant mathematical and diagrammatic content has been developed and is currently being trialled.

Whilst the trial has identified some difficulties with the approach, it also offers the possibility of significant advantages in terms of the time taken for students to receive feedback on their work. This, however, may only be realistic if the burden of electronic marking can be eased. The provision of suitable tools and materials (e.g. model solutions in a form that can be pasted into the student's document) will help to some extent.

Further refinements of the system are planned, and it is hoped in the coming years to offer such a system more widely, both in mathematics and other symbolically rich curriculum areas.

Acknowledgements

We would like to thank the Academic & Administrative Computing Services, (in particular David Boyd) and the Assignment Handling Office of The Open University for their assistance in setting up this trial, Sarah Chyriwsky for help in analysing tutor comments, and the Associate Lecturers who have taken part.

References

ECMA-376 (2006), “Office Open XML File Formats”. Available at http://www.ecma-international.org/publications/standards/Ecma-376.htm (accessed 08/05/2008)

Fisher, W (2008), “Digital Ink Technology for e-assessment “, Proceedings of the EISTA 2nd International Multi-Conference on Society, Cybernetics and Informatics, Orlando, July 2008, to appear.

Gibbs, G and Simpson, C (2004), “Conditions under which assessment supports students’ learning”, *Learning and Teaching in Higher Education*, **1**, pp 3–31.

ImageMagick (2008), http://www.imagemagick.org/ (accessed 02/05/2008)

Kerr, W, Howie, K and McLaughlin, P (2007), “Fuller, richer feedback, more easily delivered using tablet PCs”, Proceedings of the 11th International Computer Assisted Assessment Conference, Loughborough, July 2007.

Microsoft Office Migration Planning Manager (2008), http://technet.microsoft.com/en-us/library/cc179179.aspx (accessed 02/05/08)

Sargent, M (2006), “Unicode Nearly Plain-Text Encoding of Mathematics”, Unicode Technical Note, 28. Available at http://www.unicode.org/notes/tn28/tn28-2.html (accessed 02/05/2008).

Underwood, J and Freake, S (2007) “The use of Tablet PCs for marking physics assignments”. Available at http://www.open.ac.uk/cetlworkspace/cetlcontent/documents/477b8b6489921.doc (accessed 07/05/08)