Terras, M. (2001). "Towards a reading of the Vindolanda Stylus Tablets: Engineers and the Papyrologist", HumanIT, Volume 5, Issue 2, 2001. (http://www.hb.se/bhs/ith/23-00/mt.htm)

Towards a Reading of the Vindolanda Stylus Tablets: Engineering Science and the Papyrologist.

Melissa Terras: melissa.terras@ucl.ac.uk

Keywords

Image Processing, papyrology, collaborative projects.

Abstract

We introduce a collaborative project between the Department of Engineering Science and the Centre for the Study of Ancient Documents at the University of Oxford regarding the analysis and reading of the Vindolanda Stylus Tablets. We sketch the imaging and image processing techniques used to digitally capture and analyse the tablets, the development of the image analysis tools to aid papyrologists in the transcription of the texts, and lessons that can be learned so far from such an inter-disciplinary project.

Introduction

The discovery of the ink and stylus tablets from Vindolanda, a Roman Fort built in the late 80s AD near Hadrian's Wall at modern day Chesterholm, has provided a unique resource regarding the Roman occupation of northern Britain and the use and development of Latin around the turn of the first century AD. However, although papyrologists have been able to transcribe and translate most of the ink tablets, the majority of the stylus tablets remain unread because of their physical characteristics. An EPSRC jointly funded project at the Department of Engineering Science, and the

Centre for the Study of Ancient Documents (CSAD), University of Oxford, was initiated three years ago to analyse these tablets and develop new image processing techniques to retrieve information from small incisions in damaged surfaces, the techniques under development being applicable to a wide variety of engineering problems. Some significant progress has been made using wavelet filtering to remove woodgrain in images of the stylus tablets, and developing and appropriating Shadow Stereo techniques to identify candidate writing strokes. However, to aid in the complex cognitive and perceptual processes involved in papyrology, an appropriate knowledge based interface is being developed to ensure that the papyrologists can utilise such algorithms, and this interface will also incorporate the lexical and visual knowledge papyrologists rely on to help them read such ancient texts. This paper gives a brief background to the project, before discussing the steps taken towards developing the computer application to aid the papyrologists in the transcription of the texts. Focussing on the interaction between the engineers, the papyrologists, and the techniques used to identify the computational tools required, the paper discusses the benefits and problems surrounding such a multi-disciplinary project, and what lessons can be learned from such a project that are relevant to the field of Humanities Computing.

The Vindolanda texts

The two types of texts discovered at Vindolanda are unparalleled resources for classical historians since textual sources for the period in British history around AD 90 to AD 120 are rare. The ink and stylus tablets from Vindolanda are a unique and extensive group of written documents from the Roman Army in Britain, and provide a personal, immediate, detailed record of the Roman Fort at Vindolanda from around AD 92 onwards (Bowman and Thomas 1994; Bowman 1997).

The ink tablets, carbon ink written on thin leaves of wood cut from the sapwood of young trees, have proved the easiest to decipher. In most cases, the faded ink can be clearly seen against the wood surface by the use of infra red photography, a technique used frequently in deciphering ancient documents (Bearman and Spiro 1996). A major digitisation project is current being undertaken by the CSAD to produce high resolution infra red scans of these texts (now held at the British Museum, London) to enable their further transcription and reading. The majority of the six hundred writing tablets that have been transcribed so far contain personal correspondence, accounts and lists, and military documents (Bowman and Thomas 1994).

The two hundred stylus tablets found at Vindolanda appear to follow the form of official documentation of the Roman Army found throughout the Empire (Turner 1968; Fink 1971; Renner 1992). It is suspected that the subject and textual form of the stylus tablets will differ from the writing tablets as similar finds indicate that stylus tablets tended to be used for documentation of a more permanent nature, such as legal papers, records of loans, marriages, contracts of work, sales of slaves, etc (Renner 1992). Manufactured from softwood with a recessed central surface, the hollow panel was filled with coloured beeswax. Text was recorded by incising this wax with a metal stylus, and tablets could be re-used by melting the wax to form a smooth surface. Unfortunately, in nearly all surviving stylus tablets[i] the wax has perished, leaving a recessed surface showing the scratches made by the stylus as it penetrated the wax[ii]. In general, the small incisions are extremely difficult to decipher. Worse, the pronounced woodgrain of the fir wood used to make the stylus tablets, staining and damage over the past two thousand years, and the palimpsestic nature of the re-used tablets further complicate the problem; a skilled reader can take several weeks to transcribe one of the more legible tablets, whilst some of the texts defy reading altogether. Prior to the current project, the only way for the papyrologists to detect incisions in the texts was to move the text around in a bright, low raking light in the hope that indentations would be highlighted and candidate writing strokes become apparent through the movement of shadows, although this proved frustrating, time consuming, and insufficient in the transcription of the texts.

Image: stylus tablet

Figure 1: Stylus tablet 836, one of the most complete stylus tablets unearthed at Vindolanda. The incisions on the surface can be seen to be complex, whilst the

woodgrain, surface discoloration, warping, and cracking of the physical object demonstrate the difficulty papyrologists have in reading such texts.

Image Processing Techniques

From an Engineering Science, rather than from a classics view point, the stylus tablets can be regarded as “noisy”, uneven surfaces with shallow, narrow, indentations which contain information that needs to be retrieved. There are many cases where subjects might fall into this category: looking for geological faults or valleys in satellite images, or looking for surface scratches on machinery in the case of industrial inspection, for example. Many techniques that have been developed to find such incisions in objects, such as three-dimensional microscopy of various sorts, or indirect methods from computer vision such as structured light or binocular stereo (Horn 1982). However, any analysis of images of the stylus tablets would prove tricky; the images are very noisy, textured, and large (because of the need for detail), and there is low contrast between what may and may not be a candidate hand writing signal. Because the writing is incised it invites three-dimensional analysis, particularly as the analysis of only a single image of the tablet taken from a single viewpoint would make it difficult to distinguish incisions of interest from fine lines such as woodgrain or stains. The woodgrain and warping of the tablet complicate the shape of the surface and make any image capture and subsequent processing more difficult. At the outset of the project, we evaluated a wide range of alternative imaging and analysis techniques. Some were rejected on the grounds of cost, others on the grounds of potential damage to what are priceless documents. As a result, we concluded that the currently optimal approach would be image analysis using one or more light sources and a single high-resolution camera, positioned (nominally) vertically above the tablet.

In 1998 the Department of Engineering Science and the Centre for the Study of Ancient Documents at the University of Oxford were jointly awarded a research grant by the Engineering and Physical Sciences Research Council (EPSRC) to develop techniques for the detection, enhancement and measurement of narrow, variable depth features inscribed on low contrast, textured surfaces (such as the Vindolanda stylus tablets). To date, a wavelet filtering technique has been developed that enables the removal of woodgrain from images of the tablets to aid in their transcription (Bowman, Brady et al. 1997). In addition, we have developed a technique called “Shadow Stereo”, in which camera position and the tablet are kept fixed; but a number of images are taken in which the tablet is illuminated by a strongly orientated light source. If the azimuthal direction of the light sources (that is, the direction to the light source if the light were projected directly down on to the table) is held fixed, but the light is alternated between two elevations, the shadows cast by incisions will move but stains on the surface of the tablet remain fixed. This strongly resembles the technique used by some papyrologists who use low raking light to help them read the incisions on the tablet (Molton 1999).

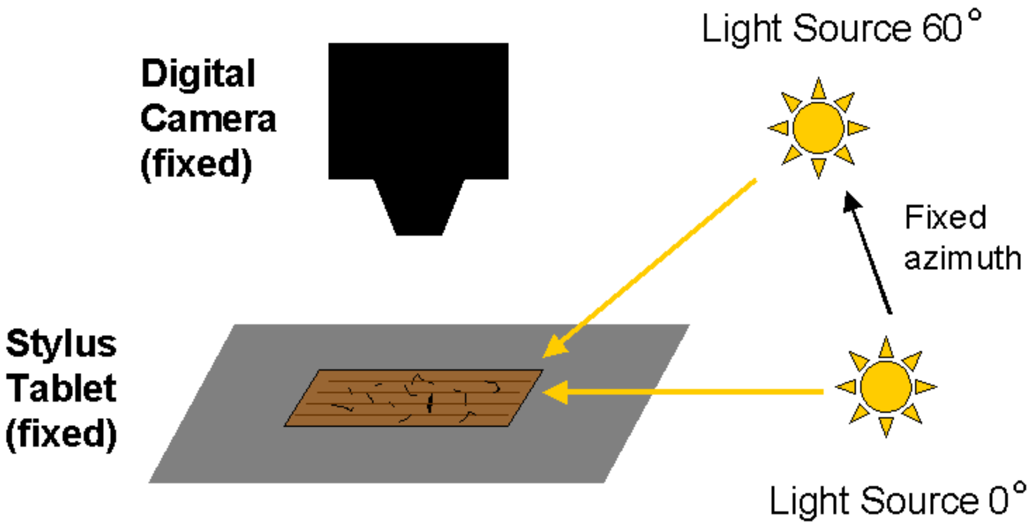

Image: Figure 2: A Diagram of the image capture system. Whilst the elevation of the light source changes around the tablet, the camera and tablet remain stationary.

Edge detection is accomplished by noting the movement of shadow to highlight transitions in the two images of the same tablet, and so candidate incised strokes can be identified by finding shadows adjacent to highlights which move in the way that incised strokes would be expected to (Schenk 1998). The difficulty comes in making these steps precise. Although this is not a standard technique in image processing, encouraging results have been achieved so far, and a mathematical model has been developed to investigate which are the best angles to position the light sources (Molton 1999). Work currently being undertaken is extending the performance and scope of the algorithms, and the papyrologists are beginning to trust the results and suggestions which are being made about possible incisions on the tablets. Future work will be done in relating the parameters of analysis to the depth profile of the incisions to try and identify different overlapping writing on the more complex texts.

The need for an interface

However, whilst this technique has had some success in analysing the surfaces of the tablets, there needed to be some way of facilitating the papyrologists in analysing the results from this technique. Granted, the resulting algorithms can easily be coded and added to PhotoShop using their Visual C++ plugin, but although this would allow others to apply the algorithms themselves and use the image processing tools that are already available (and familiar to) the papyrologists, it would do little to actually provide a tool that would actively help the papyrologists in the transcription of the texts by incorporating their knowledge into the system and building on the process they already go through to obtain a reading of such texts.

Papyrology and Computing

The use of computing in the field of Papyrology[iii] has enjoyed some notable successes. There are many established imaging projects, such as those at the CSAD[iv], and the Oxyrhynchus Papyri Project[v]; excellent database projects and systems such as the Duke Bank of Documentary Papyri[vi], and APIS[vii] (Advanced Papyrology Information System); and repositories of information in a user friendly format such as the Perseus Project[viii]. Many standards are already in place for the digitisation and markup of ancient texts, and papyrologists are making more use of the kind of image manipulation tools provided by the likes of PhotoShop (Bagnall 1997). However, currently no systems exist to support papyrologists in the process of reading ancient texts. Indeed, little work[ix] has been done to discuss how information is actually extracted from these texts (in whatever shape or form they may be), and there does not exist detailed cognitive and/or perceptual information processing models of the papyrology process. From a Cognitive Psychology stance, although there has been a lot of study of the processes involved in reading (Gibson and Levin 1976; Eysenck and Keane 1997), few conclusions have been drawn as to how a reader would approach such damaged, fragmentary, foreign language texts and construct a logical, acceptable meaning. Also, although image processing is an expansive field in the discipline of Engineering Science (see Gonzalez and Woods 1993) little work has been done on the role of knowledge and reasoning in the analysis and understanding of complex images; proposals for integrating image analysis algorithms with techniques for the representation and mobilisation of knowledge (the subject of the field of Artificial Intelligence) remain few.

Knowledge Elicitation

The problem with trying to discover the process that papyrologists go through whilst reading an ancient text is that experts are notoriously bad at describing what they are expert at (McGraw and Harbison-Briggs 1989). Experts utilise and develop many skills which become automated and so they are increasingly unable to explain their behaviour, resulting in the troublesome “knowledge engineering paradox”: the more competent domain experts become, the less able they are to describe the knowledge they use to solve problems (Waterman 1986). Added to this problem is the fact that, although knowledge elicitation and acquisition from experts is becoming increasingly necessary for the development of computer systems, there is no consensus within the field as to the best way to proceed in undertaking such a study. In this project, it was decided to utilise the outline suggested in McGraw and Harbison-Briggs (1989) as it the most comprehensive protocol developed to date. Steps taken were the building up and understanding of domain area literature (a “Knowledge Library”), records kept of meetings and conclusions drawn from these, and the adoption of some suitable knowledge acquisition tools relevant to the project, such as; walking through the process with the papyrologists, viewing them working and discussing with other experts, documenting their notes and working hypotheses as they reached a final reading of some example texts, analysis of transcripts of spoken discussions, etc. At Oxford we have the luxury of having one of the highest concentrations of papyrologists in the world, and this has aided the knowledge elicitation process a great deal.

The Papyrology Process

Through this it has been possible to build up a model of how papyrologists approach and start to understand ancient texts (although more work remains to be done with Cognitive Psychologists to interpret how this relates to current theories about the resolution of ambiguity in texts and what this can bring to our understanding of the reading process.) For example, it can be shown that papyrologists look at the whole of a text, not just at individual letters one at a time, and are continually putting any hypothesis or predictions to the test by relating them to the wider context of the document, and corpus of texts, as a whole. There is continual reference to other lexical and grammatical sources. The readings are based on prediction and the narrowing of the ambiguity surrounding the texts by recursive re-evaluation and reasoning. Comparisons at the stroke, letter, grammatical unit, and word level are continually made[x], and a final reading of the text is produced when all ambiguities are resolved to the best that they can be: in many respects the transcriptions of some texts will always remain working hypotheses. From this it can be seen that although an image processing system such as the one described above is inordinately helpful in highlighting areas of the text which may be possible letters, there are many more contextual and recursive elements in the transcription of such documents which are not reflected in the viewing of an image by existing tools (such as PhotoShop), and an essential part of this project is to construct a system which will take into account the techniques the papyrologists use to read these texts.

Developing the tools

Two types of tools are being developed to aid in the papyrology process; one to assist in the prediction of possible language structures which will help the papyrologists to reach a resolution of the ambiguity in the texts faster than they can at present because of the manual nature of the task, and another to help aid in the tagging, cross referencing, and annotation of the images to aid comparison of the visual data. These will then be combined to provide a tool where the papyrologist can identify an area of the image that may be a possible writing incision, and use the expertise contained within the system to suggest what language structure this may represent. It should be stressed here that this is not an attempt to build an "expert system" that will automatically "read" and provide the best transcription of the texts, it is a means to which papyrologists will be able to mobilise disparate knowledge structures, such as linguistic and visual clues, and use these in the prediction process to aid in the resolution of the ambiguity of the texts. Any recommendation made by the system will only be a suggestion to the papyrologist, who will control the parameters through means of a graphical user interface to avoid having to use any complex use of computers. The advantage of developing such a system is that it enables the papyrologist to maintain an explicit record of the alternative hypotheses developed, and to switch effortlessly between these initially competing hypotheses, allowing them to see the development of their reading of the texts and trace any conclusions back to their initial thought processes.

Work is nearing completion on gathering the statistical information for the construction of the language tool. Because of the nature of the tablets there are no existing comprehensive corpora of texts which directly relate to the language written in the stylus tablets. However, the majority of the wooden writing tablets have been transcribed, resulting in almost 20,000 characters of text, and although the subject matter between the texts is expected to differ, the form and structure of the language used in both will be closely related due to them being from the same physical and temporal source, and also due to the fact that it would probably have been the same people who were involved in the writing of both sets of texts (due to the levels of illiteracy in the society). The transcriptions of the writing tablets have been marked up in XML to retain the conventions by which papyrologists transcribe documents[xi], converted to COCOA encoding using a XLST stylesheet (Piez 2000), and analysed using TACT and WordSmith Tools to draw up indexes, a concordance, and lemmas of the text, whilst providing detailed statistical analysis of what combinations of letters are most and least likely, which letters and combinations are most likely to be deemed ambiguous by the papyrologists, which letters/combinations are most likely to be scribal corrections, or indications of abbreviations, etc. A set of rules will now be drawn up and constraint sets identified to allow a system, based in LISP, to help the papyrologist access the linguistic data to assist in the prediction of the language sequences.

Plans for the visual interface include building a prototype interface utilising XML to mark up and cross reference images and their transcriptions to allow easy consultation, labelling, and annotation. The final visual interface will utilise Java (for image viewing and processing), LISP for the predictional elements, and other image processing algorithms will be implemented in C++, with all modules of the system being tied together by the Java Native Interface. Rapid prototyping and integrated user evaluation will be used to ensure that the developing interface is user friendly, and the building of this system is planned to take around 12 months.

Project Aims

The aims for this part of the project are, then, to produce a stand alone application which will assist the papyrologists in interrogating the visual information created during the Shadow Stereo analysis of the texts; a set of image analysis tools to work in tandem with the image processing tools being developed by the other engineers. The overall aim is of course to aid in the transcription of the stylus tablets, but it is hoped that the tools may be also be used by papyrologists working on other texts, and through this process we are gaining a further insight into the papyrology process itself which is relevant to researchers working in Cognitive Psychology.

Lessons from the inter-disciplinary project

The project is also interesting to the humanities computing scholar because of its inter-disciplinarity. It is suspected, and hoped, that in the future such collaborations between disparate disciplines will become more commonplace. The attempt to solve complex humanities-based problems by utilising the technical skills of a scientific discipline is an intriguing and fruitful prospect; granted, other projects utilising similar collaborations exist in IT and the Humanities at present, but not many on this technical or physical scale. This project also marks a seven-league-boot step away from the "look, I made a web page!" plateau where too many humanities computing projects are still stuck regarding their application of IT in their projects. Working in such an interdisciplinary field can be rewarding, the facilities available with such collaborations excellent, the environment stimulating, and the conclusions reached illuminating. However, the partnership between such disparate disciplines can throw up some interesting, and unforeseen, challenges. This project benefits from a good relationship between the supervisors of both parties, but it is obvious that without such an association communication between the two groups would be very much hindered. Communication between the teams is still at times difficult, partly due to the different working practices of the two, and the two different languages, linguistics and mathematical, used to communicate ideas. A humanities computing individual required to bridge such a gap needs to have the suitable personal and domain based skills to communicate at a desirable level with both sides of the equation, and it can be difficult to acquire and maintain suitable expertise across both disciplines. From an administrative viewpoint, being placed between (or across) two academic disciplines can prove problematic, as the academic system (in a traditional UK environment, anyway) is not ready to cope with such an un-pigeon-hole-able working practice, and however trivial these problems may be, they can add to a feeling of disenfranchisement: as always, the humanities IT scholar is neither one thing nor another.

Conclusion

This project interlaces many different computational and literary based techniques to try and find a way of accessing the information contained within the Vindolanda Stylus texts. However, although this project is an example of a collaboration which has resulted from trying to find a solution to a certain technical problem, it is also an indication of the way diverse and disparate disciplines can collaborate in order to overcome more difficult problems in their own respective fields. In doing so, the results can often be relevant to other disciplines, or applicable to other problems, as well as their own. It is the place of the scholar in computing and the humanities to provide the skills needed to facilitate communication in such inter-disciplinary environments , and, however challenging at times, such a role can be rewarding, both for the individual, and for the discipline as a whole.

Acknowledgements

Thanks to Prof. J.M. Brady and Dr Alan Bowman who are currently supervising (and encouraging) this research. Thanks also go to all others involved in this project: Xiaobo Pan, Nick Molton, and Veit Schenk from the Department of Engineering Science, and Charles Crowther, Roger Tomlin, and John Pearce from the Centre for the Study of Ancient Documents, University of Oxford. Thanks are also due to Dr Seamus Ross from the Humanities Advanced Technology and Information Institute, University of Glasgow, for his continuing support and advice.

Bibliography

Bagnall, R. S. (1997). "Imaging of Papyri: a Strategic View." Literary and Linguistic Computing **12**(3): 153-154.

Bearman, B. H. and S. Spiro (1996). "Archaeological Applications of Advanced Imaging Techniques." Biblical Archaeologist **59:1**.

Bowman, A. and J. D. Thomas (1994). The Vindolanda Writing-Tablets (Tabulae Vindolandenses II). London, British Museum Press.

Bowman, A. K. (1997). The Vindolanda Writing Tablets. XI Congresso Internazionale di Epigrafia Greca e Latina, Roma.

Bowman, A. K., J. M. Brady, et al. (1997). "Imaging Incised Documents." Literary and Linguistic Computing **12**(3): 169 - 176.

Eysenck, M. W. and M. T. Keane (1997). Cognitive Psychology, A Student's Handbook. Hove, Psychology Press.

Fink, R. O. (1971). Roman Military Records on Papyrus, Case Western Reserve University.

Gibson, E. J. and H. L. Levin (1976). The Psychology of Reading. Cambridge Mass, MIT Press.

Gonzalez, R. C. and R. E. Woods (1993). Digital Image Processing, Addison-Wesley Publishing.

Horn, B. K. P. (1982). Robot Vision, MIT Press.

McClelland, J. L. and D. E. Rumelhart (1986). A distributed model of human learning and memory. Parallel distributed processing: Vol. 2. Psychological and biological models. D. E. Rumelhart, McClelland and T. P. R. Group. Cambridge, MA, MIT Press.

McGraw, K. L. and K. Harbison-Briggs (1989). Knowledge Acquisition: Principles and Guidelines. London, Prentice-Hall International Editions.

Molton, N. (1999). “The Choice of Light Position for Shadow Stereo with Inscribed Tablets.” Forthcoming.

Piez, W. (2000). “XSL- Characteristics, Status, and Potentials for Text Processing Applications in the Humanities.” Forthcoming (presented at the Association of Literary and Linguistic Computing Glasgow 2000 conference).

Renner, T. (1992). The finds of Wooden Tablets from Campania and Dacia as Parallels to Archives of Documentary Papyri from Roman Egypt. Copenhagen Congress paper.

Terras, M. (2001). "Towards a reading of the Vindolanda Stylus Tablets: Engineers and the Papyrologist", HumanIT, Volume 5, Issue 2, 2001. (http://www.hb.se/bhs/ith/23-00/mt.htm)

Schenk, V. U. B. (1998). Visual Identification of Fine Surface Incisions. St Cross College, Oxford, University of Oxford. .

Turner, E. G. (1968). Greek Papyri, An Introduction. Oxford, Clarendon Press.

Turner, E. G. (1973). The Papyrologist at work, Duke University, Durham, North Carolina. **The J.H.Gray Lectures, GRBS Supplement**.

Waterman, D. A. (1986). A Guide to Expert Systems. Reading, MA, Addison-Wesley.

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[i] It is suspected that around 2000 of such tablets exist outside Egypt (Renner 1992).

[ii] Only one stylus tablet, 836, has been found so far with its wax intact. Unfortunately this deteriorated during conservation, but a photographic record of the waxed tablet remains to compare the visible text with that on the re-used tablet.

[iii] Papyrology, simply defined as obtaining "a body of knowledge …from the study of papyri", is now taken to cover " as a matter of convenience…the study of all materials carrying writing… done by a pen" (Turner 1968).

[iv] http://www.csad.ox.ac.uk

[v] http://www.csad.ox.ac.uk/POxy/

[vi] http://odyssey.lib.duke.edu/papyrus/texts/DDBDP.html

[vii] http://odyssey.lib.duke.edu/papyrus/texts/APISgrant.html

[viii] http://www.perseus.tufts.edu/

[ix] Youtie (1963) and Youtie (1968) are the only discussions published as yet as to what the papyrology process actually entails, with some higher level discussion available in Turner (1973).

[x] This can be seen to corroborate the interaction activation model of visual word recognition developed by McClelland and Rumelhart (McClelland and Rumelhart 1986).

[xi] The Leiden system, (Turner 1973).