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Research in Progress: Application of Digital Image Processing to Analysis of AD 7th-12th Century Eastern Mediterranean Silk Textiles

Overview
While comparing images of historic silks with technical data, I have often wondered how recent technological improvements might contribute to textile analysis. What other factors can be defined and objectively measured, in addition to well-established criteria such as material type, thread count, twist direction and weave structure?

Through my doctoral research, I have been exploring how computer-based digital image processing methods can provide a supplementary source of data for technical textile analysis. Image processing, also known as computer vision, is used in modern textile manufacturing for error detection and quality control. Research describing applications of image processing methods to textile production include studies by Zhang and Bresee (1995), Cybulska (1999), Behera (2004), Behera and Mishra (2006) and Drobina and Machnio (2006).

Computer-based image processing can support textile research in two complementary ways: improved pictorial information for human interpretation and automated, machine-based data processing (Gonzalez and Woods, 2008). Several researchers have applied image analysis methods to archaeological textiles including El-Homossani (1988), Cork, Cooke and Wild (1996), Bischoff and Murray (2005) and Scharff (2007). In recent years, significant imaging technology improvements in fields such as medicine and material science have enlarged the set of techniques available for application to historic textiles.

The main advantages of using image processing as a tool for documenting historic textiles are speed and non-invasive data collection. Manual documentation of fine or complex textiles can be slow and tedious. Similarly, detecting the incidence and type of faults through visual inspection over a large area can be difficult. To aid in this process, algorithms can be written to extract diffuse physical and production details from surviving textiles. In addition, measurements of important characteristics such as yarn diameter and weave density are highly variable and rely upon statistical sampling to obtain meaningful measurements. When correctly defined and validated, automated image processing can produce results that are specific, objective and reproducible.

Designing a research programme that does not involve direct intervention with textiles in institutional collections is a practical way to work within the contemporary research environment. Staffing limitations and conservation policies, while essential to protect fragile textiles, make collections access challenging, especially for the extended period of time necessary to thoroughly analyse technical attributes. Most institutions have visitation policies that limit handling and the use of probes. Alternatively, image capture can occur *in situ* according to a defined research protocol. Such an approach is appropriate for a research programme intended to compare textiles held by a number of different institutions.

From a research point of view, digital image processing should be regarded as an additional source of data, complementary to the information gained from first-hand textile artefact studies. Detailed, piece-specific analyses prepared by experts with extensive access to historic textiles remain an essential resource to textile studies. For instance, the limitation of not being able to photograph the reverse side of a textile because of mounting conditions or fragility must be considered in designing a research plan.

Technical Analysis of Professional Silk Workshop Products

By applying image processing methods to analysis of surviving silks attributed to the Eastern Mediterranean region between 7th-12th centuries AD, my research goal is to obtain a more specific and detailed understanding of professional silk workshop production practices. During this time interval, sophisticated figured silk textiles were woven on drawlooms at various production centres. Drawlooms represented a work-saving application of technology to the problem of pattern replication. By separating the warp threads by function into binding and figure groups, patterns could be repeated by following prescribed sequences. Fortunately, a reasonably large population of drawloom woven silks attributed to Byzantine and Eastern Mediterranean workshops survive in various collections. Many fragments have been extensively studied from an art historical perspective with attention devoted to the interpretation of motifs and patterns depicted on the textiles. Scholars contributing research from this perspective include Grabar (1956), Beckwith (1974), Starensier (1982) and Muthesius (1995, 1997 and 2004).

No archaeological evidence survives to provide evidence about how, when and where these textiles were produced. Most silk textiles in institutional collections come from elite burials or were obtained through excavations with limited contextual evidence. In contrast to art historical-based research, my research focuses on textiles from a production point

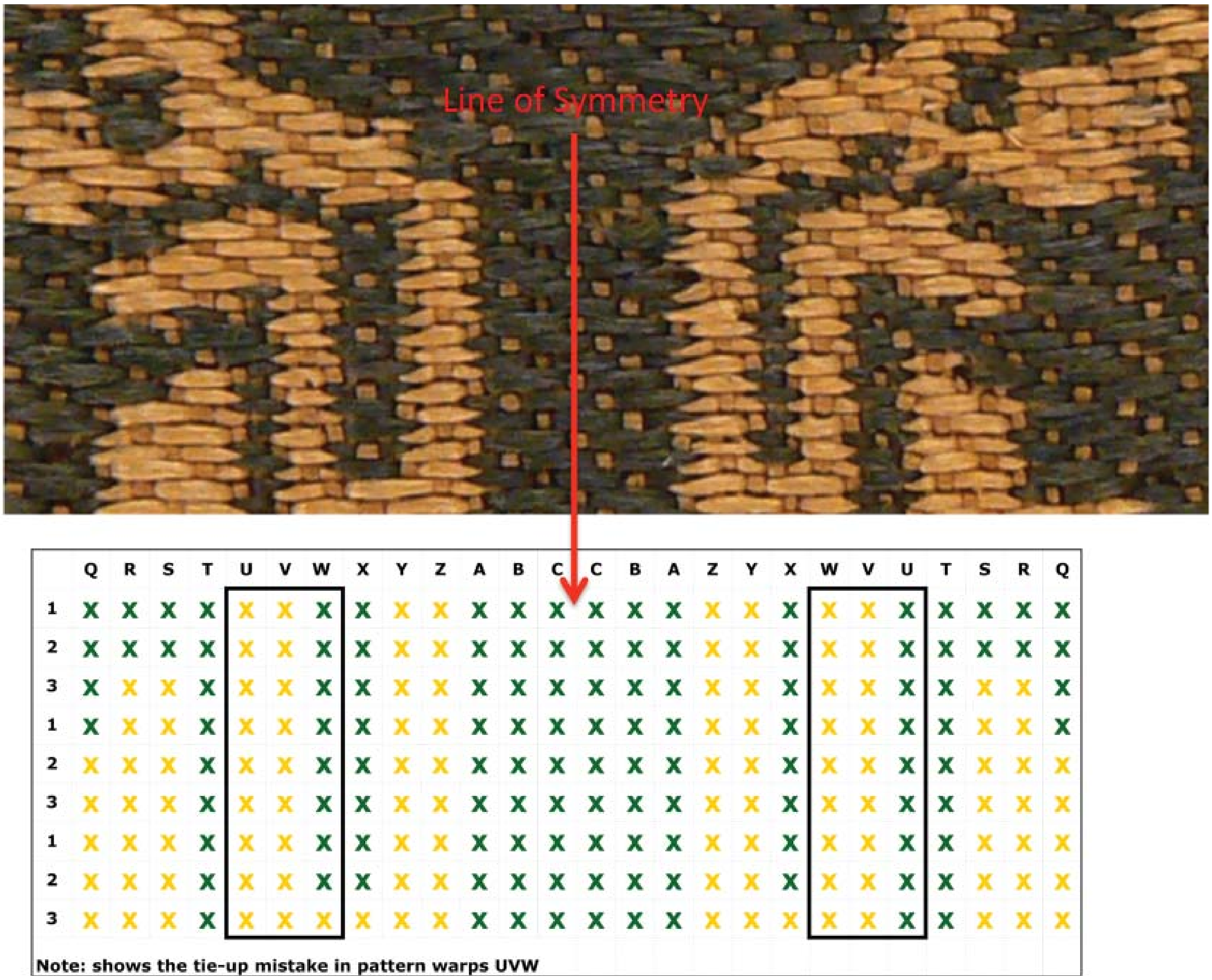

Fig. 1. Error diagram - incorrect pattern warp tie-up.

of view, resulting from a series of decisions involving materials, design and technology. My specific objectives are: to distinguish the characteristics of textiles woven in professional workshops, document the organisation and decisions involved in the production process, and use this information to discern patterns of practice for workshop attribution.

During the past five decades, institutions such as CIETA (Centre International d'Étude des Textiles Anciens) and the Abegg-Stiftung have published extensive technical analyses documenting weft-faced compound weave figured silks attributed to the Eastern Mediterranean and Central Asian regions. Many textiles have also been published in a number of museum catalogues, for example, the Musée national du Moyen Âge and the Musée historique des tissues. These mainly piece-specific analyses prepared according to the CIETA method of textile analysis provide an essential basis for technical textile research.

Complementary to the CIETA approach (CIETA, 1979, 1987), computer image processing combined with the cross-sectional analytical capabilities of a relational database provide a means to capture and analyse low level details using established statistical methods. In effect, the proposed methodology is a sort of "industrial inspection" for historic textile analysis. The idea is to apply relevant tools from textile material science to characterise various textile attributes. To date, I have defined twenty technical "tests" grouped into the following categories:

- **Material characterisation** evaluates the qualities of the fibre and yarn as the products of industrial processes in their own right. I am looking at three different attributes: yarn diameter, helix angle and if possible, fibre diameter. The basic idea is that professional workshops used professionally prepared inputs with less variation than would be found in home or cottage settings.
- **Textile characteristics** refer to the function and qualities of historic silks as cloth. This set of characteristics applies relevant concepts from material science such as fabric weight, density, performance and appropriate use assessment.
- **Design analysis** looks at the particular methods used to accomplish a given pattern. This concept is complementary to an art historical, motif-based approach by focusing on how a design was rendered from a technical weaving perspective.
- **Quality** as applied to weft-faced compound weave textiles is measurable in terms of mistakes. There are various types of faults in weaving including design, material, loom preparation (Fig. 1) and execution errors (Fig. 2). These have been noted in the literature, but not systematically measured and subjected to statistical analysis.
- **Management characteristics** refer to production planning evidence found in textile remains. Examples include pattern design for production
- efficiency and alternate weft sequencing to save work. As above, these attributes have been noted in the literature, but not statistically measured among a large set of textiles.

Collectively, these data also provide evidence for loom characteristics including: binding and pattern harness capacity, loom physical dimensions, reed/warp spacing, beater characteristics, tensioning devices for binding and pattern warps, and physical relationships. In all likelihood, we will never know how the looms looked, but there is greater scope to evaluate how they functioned through technical analysis.

In order to develop my specifications, I needed to obtain a large population of textile images. I had the good fortune to be able to spend a week at Dumbarton Oaks in Washington, D.C. photographing the portion of the collection relevant to my research (Fig. 3). This collection has never been published, so seeing the textiles first-hand was a treat. At this stage, the collection was ideal for my purposes; it is extensive enough to represent a solid cross-section of relevant textiles in various survival states without being overwhelming. I was able to obtain about 80 gigabytes of digital images taken at different macro and microscopic scales (Figs. 4-5).

The experience was also extremely valuable in helping me to define a formal protocol for photographing textiles *in situ*. Unexpectedly, my most significant problem relates to reflection and glare from the textile fibres rather than glass or mounting materials. When photographing collections in the future, I will use a polarising filter to diminish the light distortions that affect my measurements.

During the summer of 2010, I worked with a Master's level computer engineering student at the University of Birmingham to develop the technical basis for my project. In a convergence of learning opportunities, my software development served as my colleague's M.S. research project. We have made significant foundation progress, but several technical challenges remain. Although image analysis is widely used in modern industrial textile production, historic textiles have some different characteristics that make automated detection more difficult, including variables such as: fragmentary conditions, deterioration, lighting and mounting differences. Since my colleague has now graduated, I am looking for another student to complete the digital image characterisation

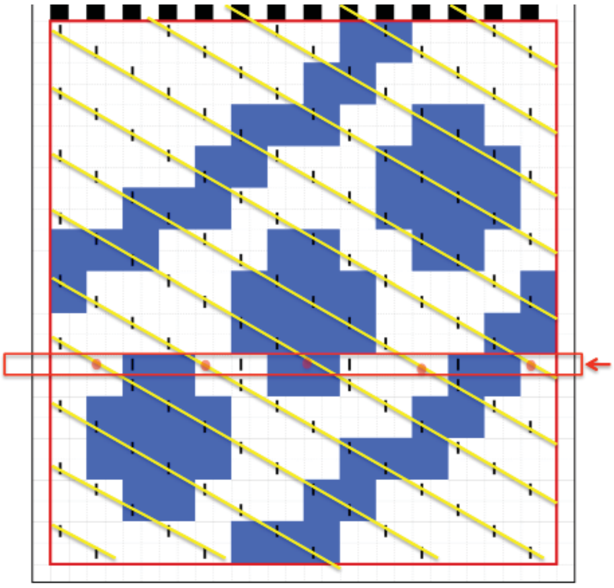

Fig. 2. Error diagram - incorrect binding shed sequence.

Fig. 3. Microscope set-up at Dumbarton Oaks storage and study room. © Julia Galliker.

Fig. 4. Macro scale image of Dumbarton Oaks BZ.1953.2.126 - Large roundel with candelabra tree. © Julia Galliker.

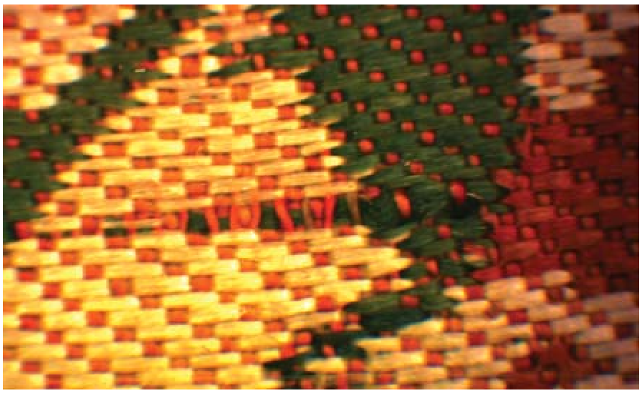

Fig. 5. Micro scale image (0.7x magnification) of Dumbarton Oaks BZ.1934.1 - Sampson and Lion. © Julia Galliker.

software application.
My next steps include software testing and preliminary analysis of results. If all goes according to plan, I hope to proceed with larger scale data collection during the summer of 2011. I am interested in hearing from others working on similar or complementary approaches.

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Queries

Nancy Spies has these questions to the ATN readers:
Anna Contadini, in her book, "Fatimid Art at the Victoria and Albert Museum" (p. 49), says that "On receiving the threads, the weaver had first to use a pumice stone to clear off their blackish crust ...". The footnote takes me to S.D. Goitein's "Mediterranean Society" (vol. IV, p. 408, note 205) which, in turn refers me to the 11th-century "Ma'alim al-Qurba" by Ibn al-Ukhuwwa of Egypt. In this, I read, in Chapter XXX, that "... the thread [must be] of good quality and freed of black crust by means of rough black stone." There is, however, no further mention of this black crust in either al-Ukhuwwa, Goitein, or Contadini. What is this black crust? What was the process that caused the black crust to form on the linen thread? Is there any primary documentation, other than al-Ukhuwwa?
Al-Shayzari, in his "Book of the Islamic Market Inspector" written in 12th-century Cairo, says that cotton carders "... must not mix new cotton with old nor red cotton with white." Was this red cotton a naturally-occuring cotton color? If not, did the Egyptians dye the cotton before spinning it? By "red", could al-Shayzari possibly mean some form of brown or orange?
We know from Maureen Fennell Mazzaoui, "Italian Cotton Industry in the later Middle Ages, 1100-1600.", that "cotton from certain regions of Anatolia was red in color, a condition caused by excessive humidity or insect damage." (p. 173, footnote 69). Did the same occur in Egypt or did Egypt perhaps import this red cotton?

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