Focus Projects for Student Involvement in Researching the Scientific Properties of the Shroud of Turin

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Abstract

Interesting succeeding generations of students in specialized topics such as the Shroud of Turin requires active initiatives. An important pedagogical objective is served by introducing students to research at the undergraduate level. Not only does such research teach students about basic research methods, but it often stimulates lifelong interest in the topics thus researched. The purpose of the present work is to develop a set of research projects and materials suitable for undergraduate research. The projects presented here all involve computer science, specifically the application of image processing methods to digital images of the Shroud of Turin. Many image processing tools are available in languages such as Java, MatLab, Python, Processing, and specialized environments such as Photoshop, MatLab's Image Processing Toolbox, ImageJ (a Java based toolkit), and CVIPtools (a C-based image processing toolkit).

The Focus Project concept is one which the author is exploring as a way of involving students in something bigger than the typical student project. Focus Projects are long term research projects with individual components that are within the range of undergraduate researchers. Each component of a Focus Project is a project which students could complete in a single semester that would contribute as a building block in a larger research program.

A Focus Project Component fits into the overall structure of a larger research program. It consists of a body of knowledge and techniques that have been demonstrated by previous researchers, and a set of objectives that remain to be accomplished. The basic structure of a component will be described in terms of the research materials available to the students and the tools which they can apply to the work. The results of work on a Focus Project component would be not only a paper, but results, techniques, and computer codes which contribute to further work later by other students.

The present paper will describe Focus Projects, describe the current status of the Shroud of Turin Image Processing Focus Project as well as student contributions which were done as Honor's Projects and Senior Seminar projects. Future Focus Project components under development will be described briefly and some of the available toolsets will be demonstrated on images of the shroud.

1. Introduction

Narrowly held fields of research such as sindonology (the study of the Shroud of Turin) are always only a generation away from extinction unless new researchers enter the field as older ones retire or expire. The field of sindonology is particularly vulnerable not only because it has a relatively small population of researchers but also because its object of study is not generally available only being exposed to public viewing at long intervals and being available for intimate scientific study even more rarely.

The present work is to develop a set of resources and a research agenda to encourage the involvement of new researchers at the undergraduate and graduate level. Conceptually this effort seeks to fill a gap between the casual science paper done in high school or college and serious research endeavors whether undertaken at the undergraduate, graduate, or post-graduate levels.

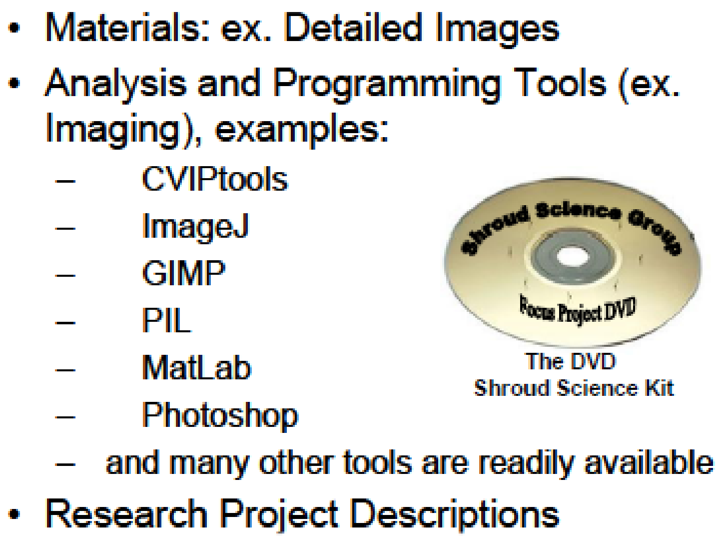

Figure 1 Elements Of a Focus Project Kit

2. Focus Projects

Most of the kinds of papers done in high school or college are limited in scope because of the time and resources available to support them. Projects at the college level only rarely take more than a few weeks or a semester simply because they are associated with a course which begins and ends in nominally a fifteen week period.

The author has been working to develop a means of doing more extended research by creating what are called Focus Projects. [1] A Focus Project is a long range project that can be decomposed into sub-projects that can be accomplished in the time frame of a semester course. The sub-projects can be interlinked to accomplish longer range objectives. One can draw the analogy of a wall composed of bricks. Each brick contributes to the growing wall and each sub-project of a Focus Project contributes to a growth in understanding. The goal of the Shroud of Turin Focus Project is understanding the Shroud of Turin to the greatest extent possible by analyzing photographic images of the shroud.

3. Tools

The fact that the Shroud of Turin in only exhibited at long intervals and the fact that it is a unique and perishable object make it impossible for most researchers to reasonably expect access to the shroud itself. However, many high resolution images have been made of the shroud which can be fruitfully studied to extend our understanding.

One of the goals of the present work is to create a research kit which can be made available to promote research. Such a kit, depicted conceptually in Figure 1, is envisioned to contain 1) images, 2) tools, especially software tools for image analysis, and 3) research projects descriptions suitable for preliminary guidance. In the context of Focus Projects the goals would be not only to conduct research but to extend the planning for future research so that Focus Project have a sustainable life and an accumulated value.

The Shroud of Turin Focus Project kit would be available in two levels: 1) an entry or preliminary level, and 2) an advanced level. The author would like to enlist the shroud community in supporting these goals by sharing images and ideas.

3.1 *Image Processing Resources*

There are many image processing resources available ranging from commercial proprietary tools such as Photoshop [2] and Matlab [3], to tools made freely available such as CVIPtools [4], ImageJ [5], GIMP [6], and the Python Imaging Library (PIL) [7].

3.2 *Research Project Descriptions*

Research projects are commonly described in white papers and project plans. The author's experience in planning research projects over many years involved generating plans to the generic outline: 1) Objectives, 2) Technical Approach, and 3) Time and Materials Planning. It isn't appropriate to fully write research proposals since then they would be the present author's proposals and not the proposals of the researchers.

However, research topics and objectives and brief descriptions that entail motivations and suggestions seem to be just what is required to fire the imagination and set directions.

The treatments given below will be limited to titles, a brief synopsis, and a summary of goals. Researchers will be expected to flesh out this sketch with more detail describing technical approaches and plans for the proposed efforts. Most, if not all, projects will required division into sub-projects and involve student researchers passing preliminary results on to others, each contributing "bricks" from which the "wall" of deeper understanding of the shroud will grow.

3.3 *Titles of Eleven Research Projects*

Below are the titles of the eleven research projects described in this paper. Each project will be sketched briefly in the descriptions that follow.

1. Universal Coordinate System
2. Color Normalization
3. Color Segmentation
4. Banding Studies
5. Study of Blood Markings
6. Development of Shroud Feature Classification Spaces
7. Taxonomy / Data Space of Shroud Images and Co-functional Viewer
8. Weave Rider
9. Blood Flow Analysis
10. Three Dimensional Information Analysis with Noise Suppression
11. Replication

4. Eleven Research Projects

1. Universal Coordinate System

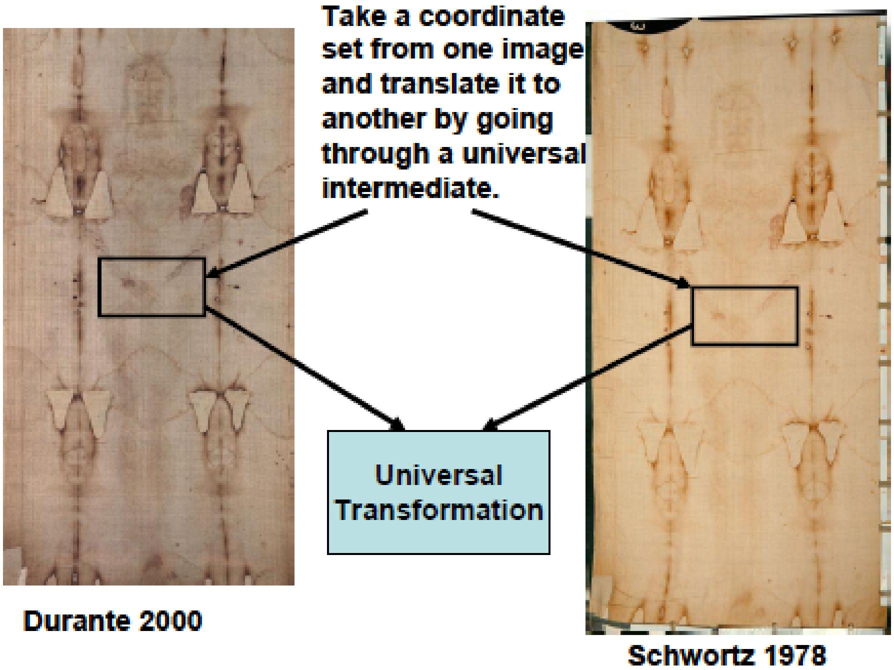

Figure 2 Project 1: The Universal Coordinate System

Description: There are many images of the shroud and even more derivative images. It would be extremely helpful to have a universal coordinate system that would let a reference to an image transfer precisely to another image which include all or part of the image referenced. This would all at least approximate samples to be extracted from multiple images under computer control. This idea was inspired by Mario Latendresse's measurement system which can be viewed at his web site or at the authors. [8]

The idea is to come up with a mathematical description that is transportable so that a reference applied to one image can be transported to another as accurately as possible. This would help facilitate precise comparisons among the various images.

Goals:

1.1 Sample coordinates which define a sample on one image should be automatically transformed into the coordinates of other sample images that would produce as precisely as possible the equivalent sample from other images correcting for scale factors, resolution and other differences.

1.2 Develop a universal coordinate system so that a sample when translated to the universal coordinate system becomes a way of universally defining the sample.

1.3 Develop a sample image viewer that shows the images and the samples and some sort of multiple sample feature so that a mosaic of the same sample from multiple images can be viewed simultaneously.

1.4 Extend the viewer so that analyses can be done simultaneously on the multiple samples to compare results side by side in analytical tables.

2. Color Normalization

Description: This is a rather fundamental problem of color representation. When a picture is taken the colors you get are due to a complex combination of factors including the illumination intensity and wavelength spectum, the kind of film or sensors, the camera settings, the way the film or image data was developed and printed and scanned. If you are going to compare different images it would be helpful to be able to as closely as possible transform the images one to another. This would allow the color spaces to be more closely compared.

Goals:
2.1 Development of the descriptive mathematics to accomplish the transformation.
2.2 Demonstration of a target transformation that serves as a reference image space. This could be standardized on one of the actual images or be a separate theoretical entity.
2.3 Develop a standard way of expressing how a specific image varies from the reference image space, and by implication can be used to transform an image among sample spaces.
2.4 Demonstration and characterization of the effectiveness, strengths and limitations of the transformations achieved and demonstrated.

3. Color Segmentation

Description: Color segmentation is the process of dividing up an image into precisely characterized regions that reflect categories of interest, ex. cloth, blood, image, scorch, water stain, etc. Algorithms that work on one image should, ideally, work on others. However that may only be true if the previous two projects successfully make transitions and transformations between images possible and precise

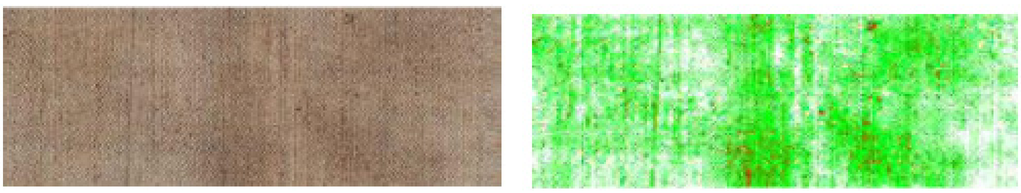

Figure 3 Example segmentation marked by false color: white= cloth, green = image, and red = blood.

Goals:
3.1 Explore and evaluate image segmentation methods based on combinations of color, texture, gradient metrics and such other techniques are found to be useful.
3.2 Illustrate the effectiveness of the methods discovered by applying them to images, especially multiple images with the same or very similar result.

3.3 Provide clear rationale for the effectiveness of the methods employed and the algorithms developed.

4. Banding Studies

Figure 4 Shroud in Reflected and Transmitted light (Schwortz 1978)

Description: The bands on the shroud have long fascinated the author, largely because they seem to imply that the image mechanism is cloth composition dependent. This is most noticeable in the interface between the image and the bands along the sides of the face. The transmitted light images taken in 1978 clearly indicate a lot of transmitted band structure as well. Characterizing the banding would seem to offer some insight into the structure of the shroud and perhaps into the image mechanism.

Goals:

4.1 Develop algorithms for band enhancement and detection.

4.2 Develop a classification system for bands which characterize them by type, probably mechanism (cause) and algorithms appropriate for their detection and objective characterization.

4.3 Explore the impact of banding on the shroud images with a view to isolation distortions in image interpretation caused by or suggested by banding, ex. images claimed to be teeth, pony tail, detail in hands, and such others as may be suggested by the study.

5. Study of Blood Markings

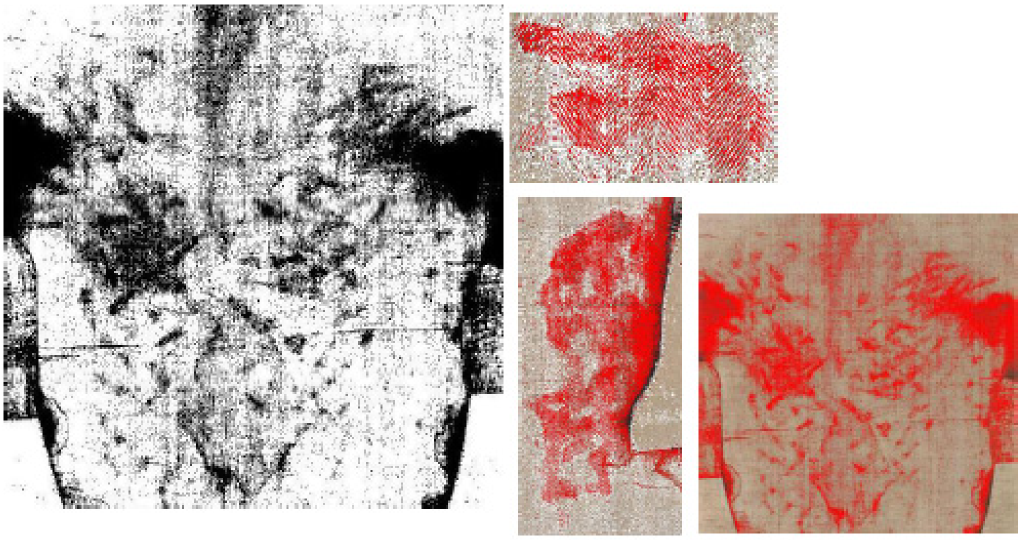

Figure 5 Study blood markings to clarify the nature of the wounds and the manner and time of their infliction

Description: There are many studies that could be made of the blood markings including the morphology, density, flow, aspects of their infliction and analysis of the structure of the flagrum, the nails, the thorns, and the lance. This project is limited to static studies, since a later project is interested in dynamic (blood flow) studies. Among the interesting questions is whether differences in the blood imaging can be associated with pre- and post-mortem flows as well as detection of serum from clotting. [9]

Goals:

5.1 Develop comprehensive algorithms to classify blood and attempt to draw narrow distinctions about the blood based on density, color, images in different spectrums of light, etc. In particular seek to discriminate between blood and scorch markings.

5.2 Analyze patterns of blood markings to reverse engineer the scourge and pattern of lashes inflicted using algorithms to identify scourge markings and patterns among the markings.

5.3 Compare blood image characteristics among wounds and their speculative morphology in light of the gospel accounts of the crucifixion to see if changes in color may correspond to time of speculated blood flow.

5.4 Cluster blood images by characteristics they have in common such as color, density, local gradients, commonality of weave stripe and interstitial characteristics. [10]

6. Development of Shroud Feature Classification Spaces

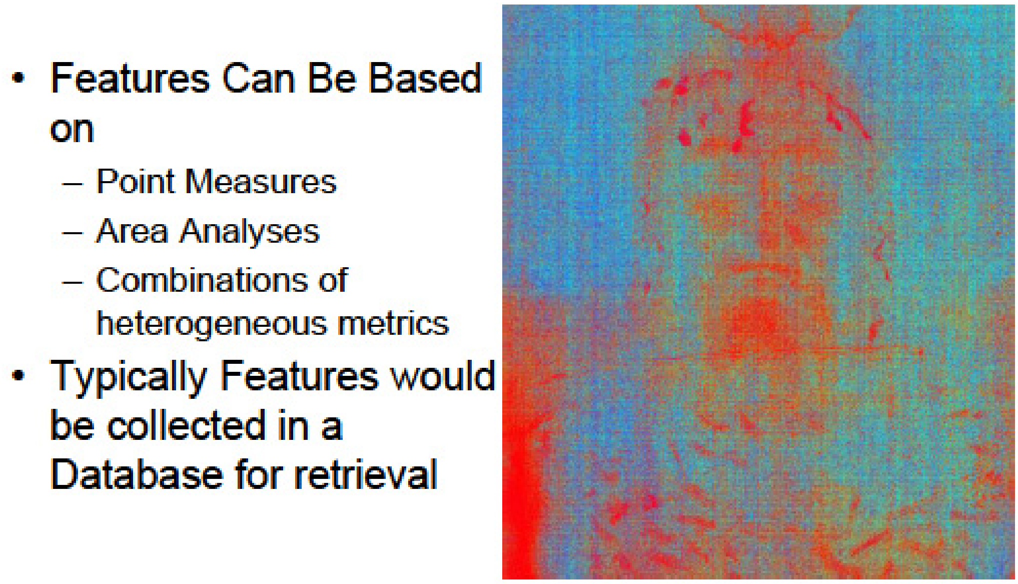

Figure 6 A Comprehensive Feature Database which related features and algorithms which detect features separately and in combination.

Description: This is related to the segmentation question but generalizes the problem beyond color alone to a wider variety of combination metrics. A key aspect of all the projects should be that the knowledge gained is accumulated in a fashion that makes it reusable among the projects. This project is wider in scope than color segmentation to included detailed descriptions of algorithms which characterize regions with a large vector of analyses results.

Goals:

6.1 Multiply feature spaces by generating combinations of algorithms and measures and applying them to individual and multiple shroud images.

6.2 Create a database of features and their defining characteristics, ideally validating them by successfully applying them to multiple images and obtaining comparable results.

7. Taxonomy / Data Space of Shroud Images and Co-functional Viewer

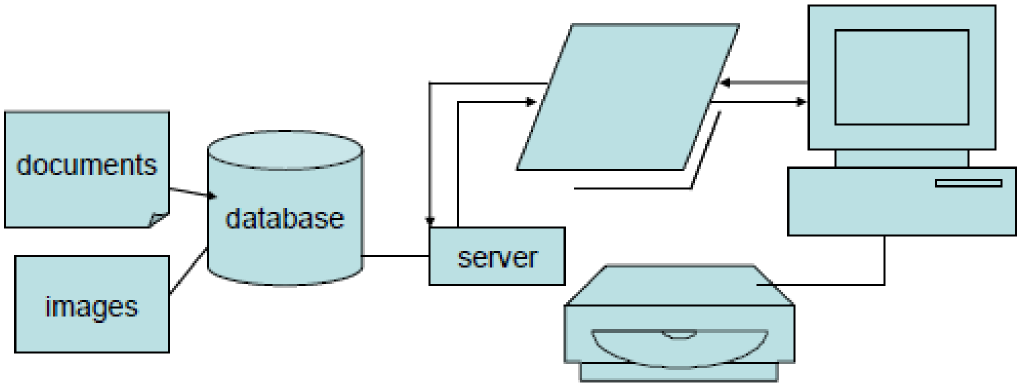

Figure 7 Shroud Research Database and Viewer

Description: Any project needs a way of preserving and disseminating its results. Scientists typically record the results of their experiments and save the data for future use. A database that uses and displays the results of the elements of the Focus Project (s) is itself a component of the work. Such a site, implemented on the internet, could share technical papers, analysis algorithms and results. Until it exists it is a development project. A number of existing products such as MySQL, various web-frameworks, and code configuration control tools could form the basis of a powerful yet inexpensive research website.

Goals:

7.1 Design a flexible database for the Shroud of Turin project which will be used to store documents, images, algorithms, commentary, transformations to universal coordinate spaces, transformations among color spaces and such other data as appropriate to support on-going research and provide access to prior research results.

7.2 Design a viewer which will allow access to the database and capable of displaying the elements contained within. Viewer may be and should be web-browser based so that delivery can be through the internet thereby served the largest possible base of researchers.

7.3 Implement 7.1 and 7.2 in stages testing with incremental demonstration.

7.4 Add dynamic features to the viewer using AJAX or other technology to allow viewers to zoom images and portions of images and link to related algorithms and papers making the viewing experience highly interactive.

8. Weave Rider

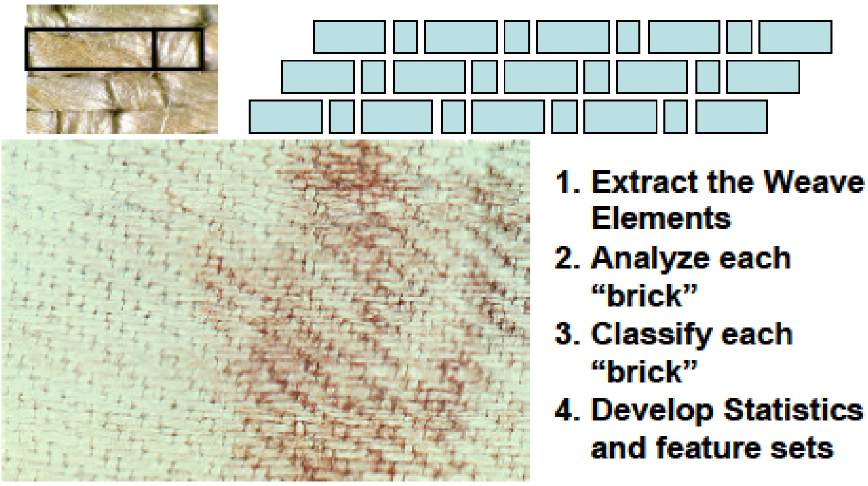

Figure 8 High resolution analysis of the shroud by characterizing each and ever element of the 3:1 herringbone twill weave, each element a "brick"

Description: Weave Rider is a name that the author has given to a project that could exist if really high resolution photographs of the shroud became available. When "weave rider" was first conceived the only such photos were those of Mark Evans from the 1978 STURP work. Only a limited number of photomicrographs were taken, but they illustrate the resolution achieveable. The idea is to build up an understanding of the shroud literally brick by brick, where a brick is an element of the weave. HAL9000 [11] in January 2008 took a set of over 1600 high resolution exposure coming to nearly 13 gigabytes of composited image of the shroud. This makes a Weave Rider application of the whole shroud a feasible project, at least for HAL 9000. Until such time as such images are released for scientific study student's might have to limit themselves to feasibility studies using Mark Evans' micrographs.

Goals:

8.1 Following the four point outline described in Figure 8 above build software to delineate and extract as "bricks" each of the weave elements.

8.2 Develop algorithms and measures to characterize each "brick" breaking it up into elements based on feature analysis of the measures.

8.3 Classify each brick by the feature/categories present.

8.4 Develop statistics and feature sets which allow completion of 8.3 above and explore development of adjacency features to cluster "bricks" into categories.

9. Blood Flow Analysis

- Develop analytical models for both blood characteristics and evolution of blood flow
- Source of blood
- Time sequencing of blood flow

Figure 9 Blood flow analysis — formulation of a flow model reconstruction

Description: Attempt to establish the time sequencing of the blood flow. The feasibility of this study would have to be studied, however it could compare the blood density in the transmitted images with the color and texture statistics in the reflected light imagery to develop a data set that could inform a theory of the origin, time evolution, and disposition of the blood on the Turin shroud to better understand the time sequencing and character of the wound markings on the shroud.

This project requires extrapolation from a blood flow theory likely informed at least partly by the scriptural accounts of the passion and crucifixion. The results of this project and the Project 5 Study of Blood Markings have the potential to illustrate consistenc y between the markings on the shroud and historicity of the gospel accounts in greater depth than heretofore recorded.

Goals:

9.1 Develop a blood density data set by examining the color and density of the blood images and serum rings if detectable and characterizable.

9.2 Develop a source/flow model which synthesizes the data into a temporal morphology model of the blood flow.

9.3 Develop animations to illustrate the results of 9.1 and 9.2.

10. Three Dimensional Information Analysis with Noise Suppression

Determine whether the three dimensional information in the shroud image (see VP-8 and John German's [12] transfer function image) can be significantly improved by signal processing

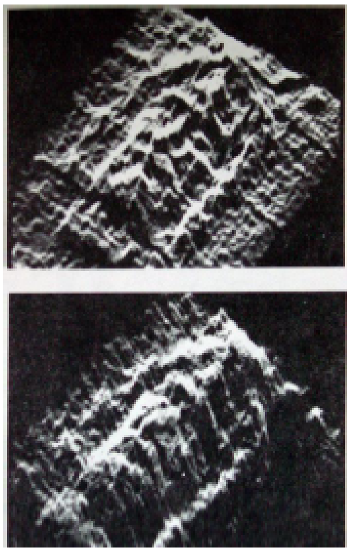

Figure 10 Two views of the shroud face, one (upper) with the VP-8 and the lower with a transform generated which German developed to match the measured fall- off characteristics with distance on the shroud.

Description: The VP-8 Image Analyzer shows the three dimensional image characteristics of the shroud which arise from a intensity versus distance fall off. However the VP-8 doesn't actually match the image falloff characteristics as modeled by cloth wrapped bodies. The objective of this project would be two fold: 1) more accurately model the actual image fall off with distance so as to create a more accurate rendering of the shroud 3D information, and 2) develop noise suppression and interpolation/smoothing algorithms to eliminate as much as possible artifacts caused by discontinuities, weaves, and dirt.

Goals:

10.1 Recover as noise free a three dimensional image as possible from the shroud image by applying a model of the intensity fall off with cloth to body distance and noise suppression and interpolation/smoothing algorithms to reduce noise and artifacts.

10.2 Use as wide a data set as possible by incorporating data from many shroud images

Note: A very impressive demonstration of this kind of project was illustrated at the Columbus Conference by the work of Dr. Petrus Soons who created impressive 3D images of the shroud by processing the Enrie photographs of 1931. [13]

11. Replication

Description: The eleventh project is a general place-keeper for a topic that is too little mentioned in shroud circles but is fundamental to good science and that is replication. Replication is often difficult in shroud studies since the object of study is not available and studies must be as noninvasive as possible.

A single experiment which reveals results can and should be replicated to verify the results. Often subsequent investigators in addition to confirming earlier results may take the work somewhat further or discover things that earlier researchers missed. Among the prior art that could fruitfully be replicated would be studies of fold marks, water stains [14], drippings, the Prey holes and others.

Goals:

11.1 The general goal is to duplicate and confirm the work of prior investigators and where possible extend the work using new insights, better technology or other means.

5. The Shroud of Turin Focus Project Kit

The Shroud of Turin Focus Project Kit of Figure 1 does not yet exist. The author envisions this work resulting in a DVD which can be distributed at cost. It is expected to have two versions, intermediate and advanced. The intermediate version would be a means of initial entry into the shroud research world and contain software, sample data, project ideas and templates. Students that did promising work with the intermediate version could apply for the more advanced version which would contain more advanced materials but also would require research agreements to ensure responsible management of the data. This two stage process would ensure that access to materials was responsibly controlled.

6. Status of Focus Projects

The author expects to make use of this paper in an ongoing effort to create research opportunities in sindonology for undergraduate students in Computer Science, in a single semester context as well as a possible choice for Senior Projects and Honors Projects. A student who graduated in the class of 2006 did an Honor Project studying the banding on the shroud by creating horizontal and vertical averaging filters. [15] Another student worked on a project to study the segmentation problem but with very limited success. This pointed up the need for a set of focused resources both to help provide ideas, guidance, and a starter set of resources.

7. The Final Objective

The Final Objective of all serious science is to know the truth as deeply and as fully as possible. The Focus Project on the Shroud of Turin will have achieved its objectives if it plays a role in generating interest among young researchers in unraveling the mystery of the Shroud of Turin.

8. End Notes and References

1. The author's web site has a link to explain Focus Projects at http://www.bridgewater.edu/~rschneid/FocusProjects/focus_projects.htm
2. Photoshop & Photoshop Elements http://www.adobe.com/products/photoshop/family/
3. Matlab Image Processing Toolbox http://www.mathworks.com/products/image/
4. CVIPtools http://www.ee.siue.edu/CVIPtools/
5. ImageJ http://rsb.info.nih.gov/ij/
6. GIMP http://www.gimp.org/
7. Python Imaging Library (PIL) http://www.pythonware.com/products/pil/
8. Mario Latendresse's JavaScript application can be viewed at his website http://www.iro.umontreal.ca/~latendre/shroud/shroudCal.html or at Ray Schneider's website http://www.bridgewater.edu/~rschneid/FocusProjects/Shroud/ShroudMeasure/shroudCal. html
9. There are claims about pre- and post-mortem flows in the shroud literature and well as various suggestions about the markings. See for example *The Way of the Cross in the Light of the Holy Shroud* by Msgr. Giulio Ricci © 1978, and *The Turin Shroud* by G. Fanti and R. Basso, Nova Science Publishers © 2008. The latter work is also interesting as a source of other research ideas.
10. See paper *Digital Image Analysis of the Shroud of Turin: An Ongoing Investigation* by the author in this

conference.

11. http://link.brightcove.com/services/player/bcpid1435443261?bctid=1435496345 is a video of the HAL 9000 work capturing
12. *An Electronic Technique for Constructing An Accurate Three-Dimensional Shroud Image* by John D. German, Jr. (1977 United States Conference on Research on the Shroud of Turin March 23-24 Albuquerque, New Mexico
13. See the video of Dr. Soons' talk at Shroud University http://www.shrouduniversity.com/videos/soons.wmv download is large 295. MB
14. Studies of folding have shown for example that the prominent water stains and the burn marks from the 1532 fire actually took place with different shroud foldings. See Guerreschi, A. and Salcito, M. (2002) http://www.shroud.com/pdfs/aldo3.pdf *Photographic and Computer Studies Concerning the Burn and the Water Stains Visible on the Shroud and their Historical Consequences.*
15. Student banding project is featured at the bottom of http://www.bridgewater.edu/~rschneid/FocusProjects/SOT.htm