Proceedings of MASPLAS'02
The Mid-Atlantic Student Workshop on Programming Languages and Systems
Pace University, April 19, 2002

Development of an Automated Coin Grader: A Progress Report

Rick Bassett, Ping Gallivan, Xiang Gao, Eric Heinen, Akarsh Sakalaspur
Western Connecticut State University and Pace University

ABSTRACT

This paper introduces a computer-operated, rare coin grading system. In the numismatic community today the official grading of coins is accomplished by human inspection. This, by its very nature, lends itself to inconsistent results that can misrepresent the actual value of a coin by thousands of dollars, and the human element can further misrepresent for personal gain. Therefore, an automated computer grading system should be a welcome unbiased alternative. To demonstrate its potential utility in this application we are developing a system that grades, appraises, and authenticates rare coins by comparing them to pre-appraised coin values stored in a database. As a first step our Web interface is structured as an educational quiz environment. Digitally scanned coin color images are represented by three histograms (hue, saturation and brightness) and one method (edge detection). Using histogram class methods, the histograms are constructed, manipulated and visualized. The outcome is a highly accurate and consistent dataset that converts the measurements of the coin features extracted into the form of a grade. Although these four coin features alone may not suffice to optimally determine a final grade, they are an important first step towards a potentially accurate and valuable system.

INTRODUCTION

This study undertakes the development of a system that is used to grade, appraise and authenticate valuable rare coins [1, 7] using advanced scanning, pattern recognition and data mining technology.

Rare coins are presently graded by human hand-and-eye inspection that often produces varied, inconsistent and sometimes dubious results. For instance one grader may assign a grade of Very Good to a particular rare coin and another grader may assign a grade of Fine to the same coin. For many rare coins a difference of a single grade can often mean thousands of dollars in difference in the estimated value [2] of the asset. Sometimes these discrepancies in grades are simply errors by the graders due to poor training, poor lighting, fatigue or misinformation. But many times the discrepancies can be attributed to dealers under-grading items so that they can purchase them for an amount that is cheaper than what they are worth or over-grading them so that they can sell the items for more than they are worth. Over and under grading are all too common occurrences in this industry due to the error rate in the human element and the financial incentives for merchants. With our automated system grading will always be consistent since no human error factors or financial incentive can be introduced into the grading process.

The proper grading of rare coins is essential in order to determine value and authenticity [3, 4], but the present manual process of grading is very subjective and often fraught with errors. The rare coin industry attempted to address the problem of grading subjectivity in the 1980's with the introduction of 3rd party grading services [5] and encapsulated coins. While these were steps in the right direction, many merchants and collectors found ways of circumventing the attempted integrity of the process, and the subjective and error prone manual grading process still remains in place.

The task of automated coin grading is significant and developing the model and the methodology has been a substantial undertaking for the team. We limited our grader to the single series of Lincoln Cents from 1909 to 2002 [6, 3] in order to gain a proper perspective on the domain, develop the software, and perform adequate testing. Over time the domain context of our grading system can be expanded from the single denomination of Lincoln Cents to include other denominations [1] of regular issue United States coins from 1792 to present date.

SYSTEM OVERVIEW AND ARCHITECTURAL DESIGN

The architecture of this automated system is presented in Figure 1. It consists of a scanner, a database, an image processor, grading system, and image browser. The scanner scans the coin and stores the image in the GIF format. The image processor is then used to extract the features of the coin image, and the resulting feature measurements are stored in the database. The grading system compares the feature measurements of the coin image to those of standard graded sample coin images to determine the grade of the coin, which is then displayed within the browser.

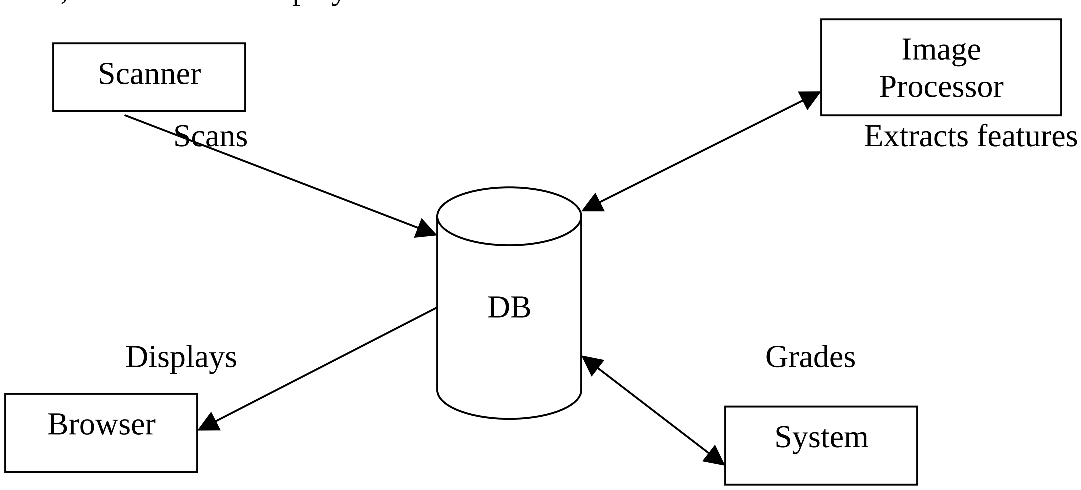


Figure 1. System overview.

The end user, usually a coin grader, is also a participant in the grading process. The user will review the coin grade provided by the automated system and may rectify the grade based on his/her coin grading experience. Those rectified grades will also be stored and indexed into the database and used as new samples to classify future coin images. Hence, the system can improve its grading accuracy and possibly achieve a high grading standard through this bootstrapping process.

Image processing is the key technology of the system. The system measures the distance between histograms (hue, saturation, brightness) to index and classify the coin image. In this paper, we describe this method in detail. Moreover, although the system focuses on the histogram distance measurement, we also introduce other image processing methods such as edge detection to improve the grading accuracy.

Histogram Measurement and Java Class

Normally, histograms are viewed as vectors and the vector class is used to construct, manipulate, and display the histogram. In terms of histogram measurement, this vector viewpoint of histograms is only valid when the measurement type of histogram level is nominal; it is necessary to add the methods for ordinal and modulo measurement type cases [1, 9]. For this reason, we have designed a histogram class in Java, emphasizing how it differs from vectors.

Public final class Histogram
 Extends Object
 Implements Fertilizable

Class Histogram is used to display in bar graph format measurement data distributed by categories. Histograms are simply arrays of bins, where each bin is associated with a range of data values and also contains a frequency count that is the number of occurrences of that particular data value in an input dataset. We define the input dataset of class Histogram is the set of pixels in an image.

Class Histogram has a construct which takes an input parameter of java image, uses a java pixel grabber to gather pixel samples, and creates three internal arrays which may represent red, green, blue and hue, saturation, brightness statistics information of the input image depending on the setting format.

Class Histogram has also implemented three histogram distance measurement algorithms: nominal, ordinal and modulo. Instead of creating distinct data types representing different types of histogram, all three-measurement algorithms are provided in one class, which makes it more comprehensive and easy to use.

The primary tasks needed to perform a histogram operation are as follows:

1. Create an Image object by either loading from an image file or using java AWT methods.

2. Create a Histogram object with the input image and its width and height values.

3. Read the histogram data stored in the object. The data consists of:

- Number of bands in the histogram
- Number of bins for each band of the image
- Lowest value checked for each band
- Highest value checked for each band

4. Perform distance measurement algorithm to compute dissimilarity between images.

<u>Experimental Results</u>


C1911


C1913


C1946


C1949S


C1956


C1952

Figure 2. Color images of sample coins.

Consider the 160x160 scanned coin color images, Cxxxx where xxxx is the coin date, shown in Figure 2. Coin images are represented by a rectangular array of picture element, called pixels. Each pixel has its red, green and blue elements, which are linear numerical values ranging from 0 to 256 and then can be converted to hue, saturation and brightness values. Sample histograms representing the frequency of each hue, saturation, and brightness levels in a coin color image are shown in Figure 3.

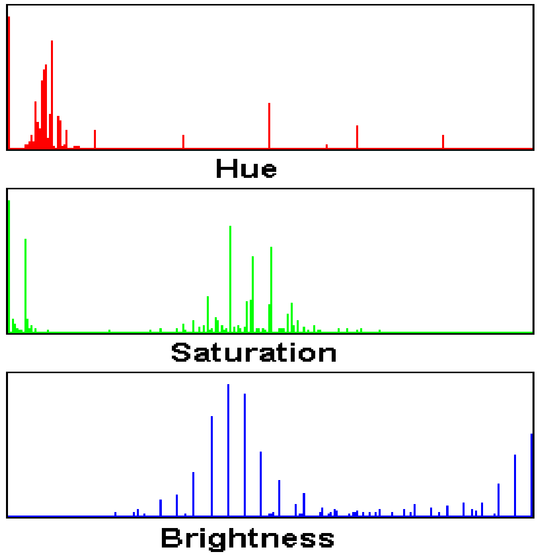


Figure 3. Sample histograms of the C1946 coin image.

Apply the modulo histogram distance measurement algorithm to the hue histograms of images, the algorithm takes $O(b^2)$ in time, where b is the number of bins in the hue histogram. Table 1 shows the distance matrix of sample coin image hue histograms and we can observe the similarities between the grading coins. The smaller the intersection number is, the smaller the distance between the coins and thus the greater the similarity. Of course, the matrix is symmetric because comparing coin A to coin B is the same as comparing coin B to coin A, and the diagonal entries of are zero because they represent the comparison of a coin to itself. The coin most similar to C1911 is C1913 with a matching distance of 150.

-	C1911	C1913	C1946	C1949S	C1952	C1956
C1911	0	150	530	416	320	275
C1913	150	0	442	377	265	205
C1946	530	442	0	206	298	395
C1949S	416	377	206	0	349	503
C1952	320	265	298	349	0	79
C1956	275	205	395	503	79	0

Table 1. Distance Matrix of Coins Image Hue (modulo) Histograms

When two-dimensional information is represented in the one-dimensional histogram, certain information is lost. Therefore, while it is true that the two histograms from the similar character images tend to be similar, the reverse statement is not always true that two images with the similar histograms tend to be similar [8]. For example, the distance measurement value between C1946 and C1949S is 206 in the above table, meaning that their hue histograms are more similar than those of C1946 and C1913 with a distance measurement value of 442. However, looking at the real images in Figure 2, we can observe that C1913 appears to be much more similar to C1946 than C1949S does. Meanwhile, we can not judge a coin based only on their hue distance measurement, more measurement need to be considered, such as saturation, brightness, measurements associated with methods such as edge detection, etc.

USER INTERFACE

An important feature of this system is the user interface. This first generation interface is set up as a 'Quiz" that a person can take that will test the coin grading knowledge of the participant (Figure 4). This format was chosen as a first step in order to collect feedback from varying levels of coin collectors in a controllable, repeatable, and fun environment. The quiz challenges the participant as well as educates them on the accuracy of a computer generated grading system. The quiz consists of a brief explanation of the Web site and then requests user input in the form of Experience Level (Beginner, Intermediate, Expert) Coin Type (Lincoln Penny), and Coin Year (year minted). Once these parameters have been selected, an image of the coin is generated as well as several reference point "hint" images to assist the grader, which are determined by the level of experience chosen (Beginner=Three, Intermediate=Two, Expert=None). Below the main image is a field of grade options in which the participant can select according to what they think the grade of the coin is. In order to offer help they will have the choice of viewing the description of each grade level by selecting the appropriate grade and clicking the 'Description' button. Once the desired grade level has been selected they will submit the answer by clicking on the 'Submit" button.

Upon submission a new page is generated which will display the image and corresponding grade chosen as well as the hue, saturation, brightness, and edge detection histograms associated with that image. The histograms will also be configured to display the accuracy value of the grade chosen and actual grade. This data will be a visual representation as to the accuracy of our system in extracting salient, usable data, which is then used to determine a grade value.

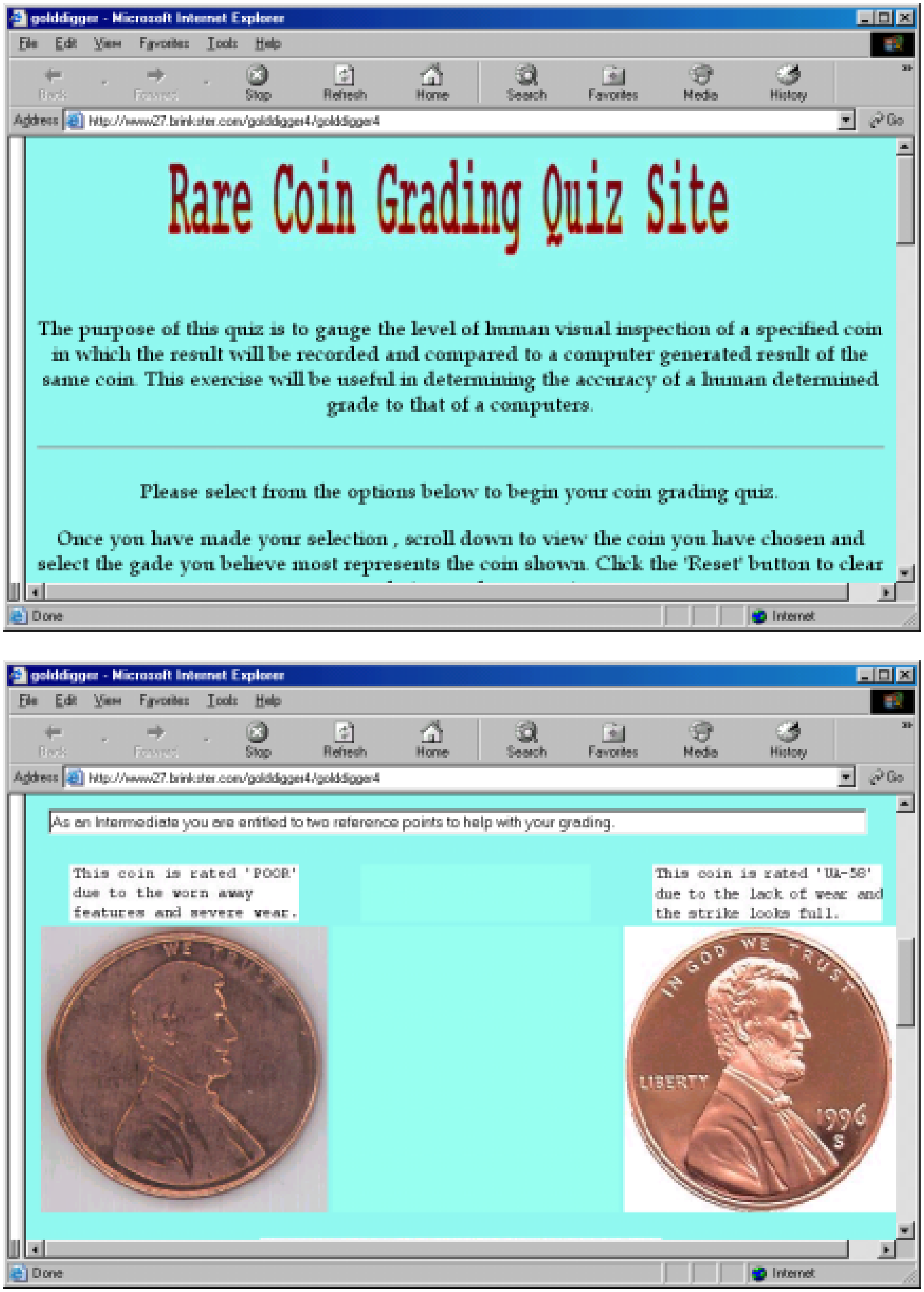
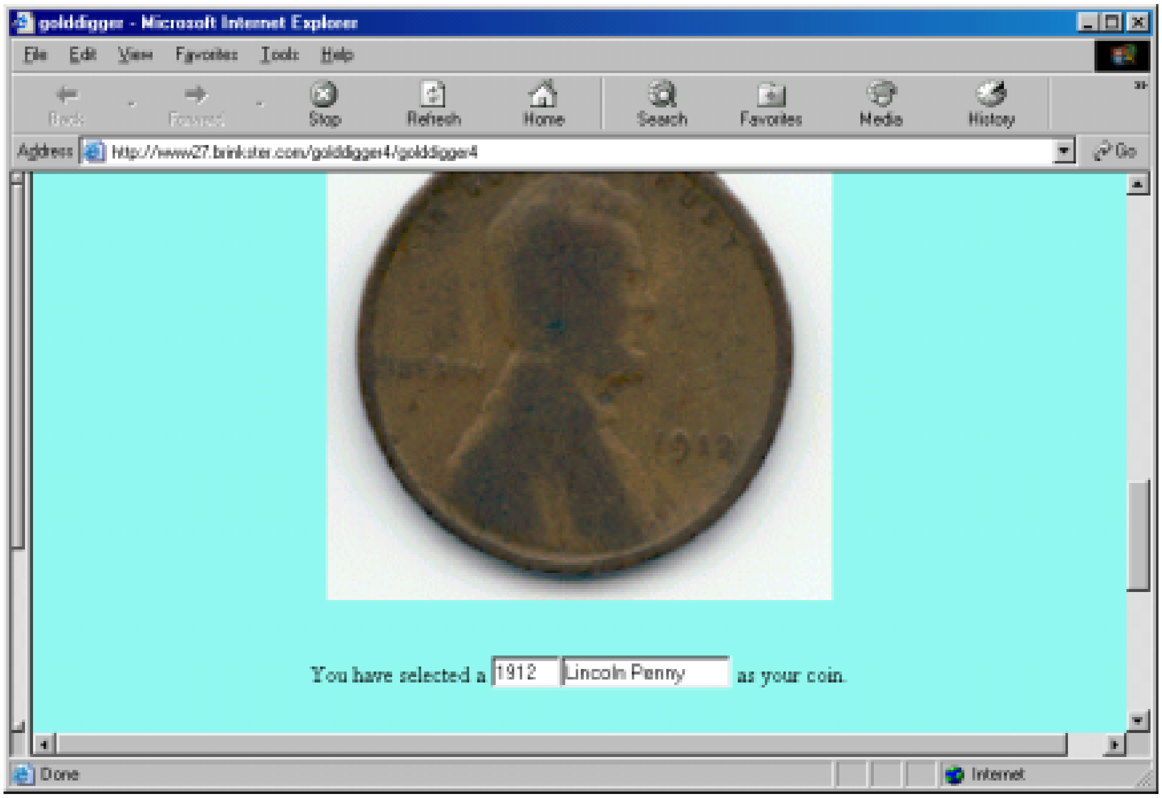


Figure 4. Screen shots of the Web based, coin grading quiz.



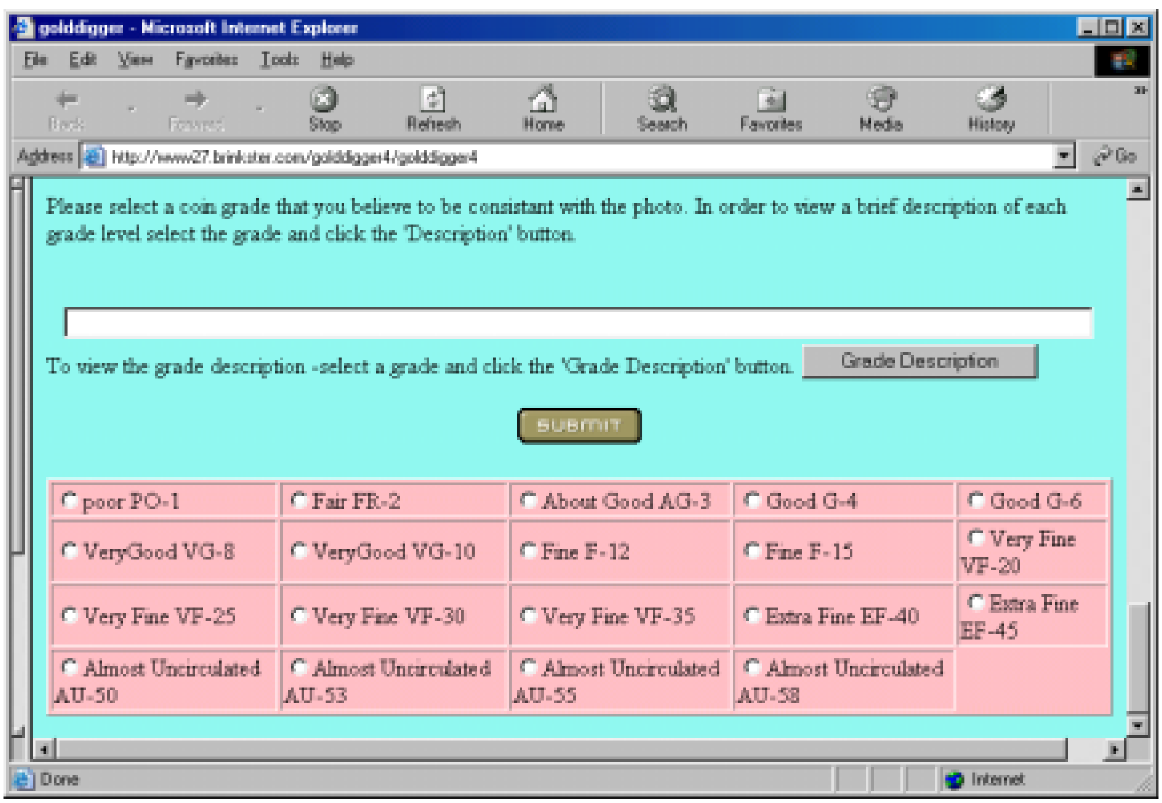


Figure 4. Screen shots of the Web based, coin grading quiz (continued).

RESULTS AND CONCLUSION

This study has undertaken the development of an automated system that is used to grade, appraise and authenticate rare coins using advanced scanning, pattern recognition and data mining technology. We currently have a database of scanned images of Lincoln head pennies and a Web based "Quiz" that allows novices and experts to assign grades to coins. This is work in progress and we will present our latest results at the workshop.

FUTURE SCOPE

We envision a user-friendly Web interface that allows the user to scan the coin to be graded and save the image in the database. A Java applet will pull the image from the database and extract predetermined features that will represent the collective attributes of the coin. A Java program will get the RGB values of each pixel in the image and use these RGB values to represent features such as hue, saturation and brightness in a form of a histogram. Using template-matching techniques and mathematical imaging the histogram of this image will be compared to the histogram of the image from the test set. Histogram distance measures will be used to index both color and gray scale images. We will use the new universal distance measure between two histograms [8, 9]. This will be capable of handling different measurement types such as nominal, ordinal (linear), modulo (angular). We will program in Java using AWT methods and classes. We hope to present Image processing and comparison methods that are much faster than existing methods.

The obstacles that exist for future research lie in the following areas. First, the photo acquisition techniques will need to be expanded and more powerful and exacting technology introduced. For the images shown here we used a high-resolution flatbed scanner and saved our coin images in GIF format. We also took some photos with a digital camera but found the scanned images to be of better quality. The coins images were taken on the face side only due to time and semester constraints with the idea of demonstrating feasibility.

An improvement might be for the researcher to photograph the images using various lighting conditions and a high-resolution camera [10]. All or various portions of the captured images would be computer enhanced to bring out salient features of the coin. We used the HVC scale and edge detection software in order to extract detailed color and edge data. These steps represent the first crucial ones on which to build upon. The following paragraph will highlight the direction this research needs to stay on.

We introduced the problem of minimum difference to grasp the concept of the distance between two histograms. Besides this measures there are various distance measures can be used in this place. Designing the algorithms to compute the distance between multivariate histograms is non-trivial because there are n factorial possible assignments [8]. We leave them as open problems to readers and the future work.

The key regions of the coin would have to be identified according to accepted industry practices and examined in great detail to identify, classify, measure, and score all features deemed significant to the overall value of the coin [10]. When these measurements have been extracted and stored, they would be compared to a preexisting database with corresponding values to determine an industry recognized "Grade" for the coin. These data related obstacles would be the next transition in the research. Though these obstacles are not seen as insurmountable, significant input from the expert grading community in general would be needed in order to establish the values related to each data item as accurate and accepted.

A second obstacle relates to the industry itself. The rituals and systems used by the graders themselves would be in jeopardy and therefore so would their livelihood. The industry would have to be approached cautiously in order to avoid potential panic due to the 'human' grader becoming obsolete. The automated system should be offered as a compliment to the human grading system, a tool not a replacement, in which to take some of the guesswork out of his craft.

The driving force to accept this technology will not come from the professional side of the industry but from the public [10]. If we were to show them an accurate and cost effective way in which to catalog their coins, eliminating human error (stress, fatigue, inexperience, low quality graders, etc.) then the industry would have to accept it as inevitable. This work offers additional leverage when dealing with the numismatic industry and society, in relation to gaining their acceptance when accuracy concerns arise.

REFERENCES:

1. Alan Herbert, "Coin Clinic," Krause Publications, 1995 pp 77-79
2. Scott A. Travers, "How To Make Money in Coins Right Now", House of Collectibles, 1996 pp 79-89
3. Q. David Bowers and Scott A. Travers, "Official Guide to Coin Grading and Counterfeit Detection", PCGS, 1997 pp 90-95
4. "Official A.N.A. Grading Standards for US Coins", American Numismatic Association, 1996 pp 85-88
5. David L. Gantz, "Planning Your Rare Coin Retirement," Bonus Books, Inc., 1998 pp 9-25
6. James Ruddy, "Photograde," Whitman Publishing, 1995 pp 73-74
7. Scott A. Travers, "The Coin Collector's Survival Manual," Bonus Books, Inc., 1996 pp 14-84
8. Sung-Hyuk Cha and Sargur N. Srihari, "On Measuring The Distance Between Histograms," J. Pattern Recognition, Vol 35-6, 2002, pp 1355-1370.
9. Sung-Hyuk Cha, "Histogram Based Image Indexing and Retrieval", Technical Report Number 173, CSIS, Pace University, 2002.
10. Jim Halperin, "How to Grade U.S Coins," Ivy Press Books, 1990