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Numismatics Research through Computer and Digital Technology: Features and Future Prospects

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ABSTRACT
The research paper explores the evolution of numismatics and its intersection with modern digital technologies. Numismatics, the study of coins, is vital for reconstructing historical, economic and socio-cultural contexts, yet traditional manual methods for studying coins often face limitations such as human error and subjectivity. The integration of computational techniques, including image segmentation, pattern recognition and Geographic Information Systems, enhances the precision and efficiency of numismatic research. The paper highlights the application of advanced imaging techniques like 3D photography, digital databases and automated classification systems, which facilitate detailed analyses of coin features, legends and inscriptions. These technologies not only mitigate traditional challenges but also open new avenues for interdisciplinary studies. By advocating for standardized digital methods, the research emphasizes the transformative potential of digital tools in preserving and advancing numismatic scholarship.

General Terms
Global thresholding, Indo-Greek coin, Shannon entropy, Numismatics technology.

Keywords
Computer, Technology, Numismatics, Coin, Digital.

1. INTRODUCTION
Numismatics is a crucial source for historical writing, encompassing various aspects such as political history economic history and socio-cultural history. It serves as a testament to the settled phases of civilization, reflecting the values, beliefs and developments of societies throughout time. As a multifaceted discipline, numismatics also requires knowledge of epigraphy, art, religion and history. The field is vast, covering not only the materials from which coins are made and their sources, but also the techniques of manufacture, organization and the control of production and circulation by the state or other authorities. Advancements in technology have led to groundbreaking innovations in the humanities and social sciences. Since the 1980s, the use of digital technologies in these fields has been rapidly growing, significantly influencing history and numismatics. The interaction between numismatics and digital technology has greatly enhanced the presentation and analysis techniques of numismatic studies, opening new avenues for research and interpretation.

It is first necessary to have an understanding of the meaning of the term coin itself. According to Webster's Second Edition, "*A piece of metal (or, rarely, of some other material) certified by a mark or marks upon it to be of a definite exchange value and issued by the governmental authority to be used as money; also, such pieces collectively*." [1] This definition highlights the fundamental characteristics of coins, including their material composition, value certification and role as a medium of exchange. Understanding this definition lays the groundwork for exploring the broader implications of numismatics in historical and cultural contexts.

The most obvious physical attribute of a coin is the material from which it was produced almost invariably, up until modern times, metal. The metals selected had to be abundant enough to provide the raw material for an exchange medium, but scarce enough to have value in their own right and the selection has varied from culture to culture. In China, the initial metal of choice was copper; in India, silver; and in the west, silver or an alloy of gold and silver known as electrum. The Webster definition does not mention weight as an aspect of a coin, but in antiquity the only way of stabilizing a 'definite exchange value' was to strike a coin to a specified weight and to regulate its alloy: the tariff or exchange value of a coin bore a very close—sometimes even direct—relationship to its intrinsic value and thus it is possible to determine the relationship among denominations by comparing their weights. In some coinages the comparison of weights among series may determine the standard to which that series was struck; this, in turn, may be significant for chronology or attribution.

Type, for example, is one of the terms most misused by beginning students of coinage. It can easily be read as if one was asked, 'What type of coin is it?' and answered with a classification ('Roman' or 'Islamic' or 'U.S.') or with a denomination ('stater', 'denarius', 'peso'), or simply 'gold', 'silver' or 'copper'. Any of these would be natural responses to the sense normally conveyed by the use of the word 'type' in everyday English, but all would be wrong. For purposes, 'type' refers to the central device or motif (Doty uses the term 'dominant design') of either face of the coin. On one face of the United States cent, for example, the type is the bust of Lincoln facing r.; on the other, the Lincoln Memorial.

The most important feature of the coin is the legend where the expertise is required of the scholars. The legend may indicate the issuing authority, describe the type, combined with the type to specify the occasion commemorated, or convey virtually anything desired by the mint official (whose own name might be part of the legend). Legends may encircle the type or flank it and may continue in the exergue.

Here comes the problem of decipherment along with that the finding of a coin is also an important factor which the authors need to take into account for proper contextualization of the source. Exploration and Excavation are the two ways of finding coins. As coins have been struck in precious metals and copper alloys and since that time they have been lost, buried in hoards, placed in graves, or otherwise left behind for archaeologists to find. When coins are found as part of a scientific excavation, they can make an immense contribution to understand the ancient society. One obvious way they help archaeologists reconstruct life on ancient sites comes from the fact that they are relatively easy to date.

The First step in most of the cases which numismatists take to study this coin is to apply scientific method for its cleaning. There are a number of scientific methods, particularly for the different metals. It can be cleaned in the lab first then proper study can be done. A proper study can only depend on the expertise of the Numismatist. Usually, with the help of magnifying glasses, numismatists are doing this decipherment. After this study, there is a process of making of Catalogue and Corpus. The traditional methods particularly for the external study of deciphering any coin are very manual and limited in nature and require lots of professionalism as in the manual method there is always a chance of having human error. Therefore, the final decipherment results produced by traditional manual methods are often not unanimously acceptable among the Historians.

Catalogue and corpus are the published material and this also helps in decipherment. A coin catalog (or coin catalogue) is a listing of coin types. Information may include pictures of the obverse and reverse (front and back), date and place of minting, translation of inscriptions, description of images, metal type, mintage, edge description, the orientation of the coin, weight, diameter, thickness, design credentials, shape and prices for various grades. Defects may be described. The quality, detail and completeness of the information available about a particular coin vary according to popularity, commonality and available scholarly research.

Because of the huge number of coins in world history, there are no comprehensive catalogs. Professional collectors typically keep many books for identification and assessment. Coin catalogs are essential when dealing with ancient or foreign coins, where the inscriptions may be obscure and unrecognizably stylized, even for a native speaker. Coin catalogs today are supplemented by Internet sites, some of which have the advantage of being attached to user forums, so that issues such as counterfeiting may be discussed. With the rise of online auctions, it is now possible for collectors to research their coins at commercial sites as well as myriad collector-created sites containing research into diverse collecting specialties. Corpus is an enlarged and detailed study of a particular period or dynasty. Corpus includes a coin type and all the variety available to that type. Corpus is very tough to prepare because of that as for as ancient India is concern the aurhors have only one corpus available i.e. *The Indo-Greeks* by A.K. Narain [2], *Corpus of Indo Greek-Coins* prepared by A. N. Lahiri. [3] The Numismatic Society of India, the leading institution for the study of coins has taken the decision in the decade of 1970 to prepare corpus of all the periods of Ancient India. But it is still in pipeline. Thus the authors have no catalogue excluding the period of Indo Greek where the present authors can get the listing of all the types and variety of a particular period. Although the published literature is available and on the basis of it the authors of this aricle can try to decipher the coins. But, it has some limitations also and the process is very manual in nature. As the present authors know in the manual method, always there exists a chance of having human error. Therefore, manual methods for deciphering the coins often produce an erroneous/controversial result. This the second challenge to this discipline that there are a number of the catalogue available for the different periods. Scholars have to go manually to find about a particular coin type and coin variety. Availability of catalogue and to find the coin in that is next challenge to the discipline. Also, the authors of this paper have to keep in mind that every time there is a possibility of getting any new type or a new variety of coins, this delimits the scope of whatever traditional cataloguing has been done till yet. While studying the coins through manual/traditional processes, researcher/scholar(s) may not always draw attention to each and every aspect of coins. The authors know that how many technicalities are involved therein deciphering a coin. For example, researchers have to look at every legend, shape, symbol, design very clearly. Even if follow the manual/traditional methods there often exists a scope of controversy among the scholars about the results. For example– In case of the King and Queen coin-type of Chandragupta I the decipherment result is still not unanimous.

Forgery is also a problem in the study of coins. Fake, forgery, counterfeit: all these words describe coins and banknotes made in imitation of genuine money and passed off as the real thing. As long as there has been money, people have tried to imitate it illegally and for their own profit. It can be of two natures a) Forgery of the ancient period or the period of issuing of that type b) Modern forgery is just to produce the copy at any time. Forex. Forgeries of the earliest Greek coins were made by covering a base metal core with a layer of a precious metal called electrum so that they looked like genuine coins. The process of covering a less valuable metal (such as lead, iron or copper) with gold or silver is known as plating. Throughout history, plating has been one of the most widely used methods of creating a forgery.

Another way of forging coins was by casting. Counterfeiters would use a genuine coin to make a mold, which they would then fill with molten metal. When the metal had cooled and hardened, it would form a cast imitation of the real coin.

Sometimes, forgers would obtain the metal needed to make forgeries by clipping it from the edge of genuine coins. The melted silver or gold clippings may be used for plating. Otherwise, the precious metal might be debased ('watered down' with base metals to make a larger quantity) and used to make forgeries which were either cast or struck using forged dies. In medieval England, that process was known as 'multiplying the coin' since it could use one genuine coin to create lots of fakes.

These forgeries are producing rather adding polluted material to the discipline. And to find a original coin among the fake coin is totally depend on the expertise of the numismatist. Another way to find genuine coin is to the scientific study. The authors can find a number of website providing us the information about the details of coins of particular period or dynasty. These sites or digitalizing the discipline as well as helping the scholars in study of coins.

The next important issue in the study of coins is the position of the Government Museums and their collections. Majority of Indian museums have had a close association with the Archaeological Survey of India. As a result, they have strong archaeology sections and a coin collection is only one wing of Archaeology section. The museums specialize in collecting antiquities and treat coins as art objects or antiquities and not as money. Therefore, generally, they have coins of ancient and medieval periods. In any museum, big or small, a coin collection forms a major part of its total collection. But the space allotted for display of coins in a museum comprises only 2-3 showcases. Visually, the coins do not attract the attention of common visitors, being small in size they escape notice. Another reason for displaying only a few coins in a museum is the belief that numismatics is a specialized study and as such meant only for a few. Yet another reason for not displaying many coins is the problem of their security.

The authors have taken here the example of State Museum of Uttar Pradesh, the SML coin collection is formed by coins which were received through treasure trove finds under the Treasure Trove Act of 1878. Between 1882 and 1980 as many as 1,145 coin hoards were reported from Uttar Pradesh that is roughly 11 hoards per year or one hoard per month. Acquisition of a hoard is a matter of administrative routine but its examination, study, report and disposal often take a long time. Museum has published a comprehensive list in the year 1980 as *Coin Hoards of Uttar Pradesh* by A. K. Srivastava. [4] However, no detailed documentation or photographs of the distributed or returned coins are kept in the SML thus a very important aspect of monetary history is lost to posterity. This museum has over 100,000 antiquities. Of these 40,824 are coins, 258 are medals and 518 are seals. Thus, the auhtors can see, coins alone form the largest single type of antiquities. This is the case in the many museums of India where detailed study of coins is still needed. As a Numismatist, the authors can tell you that whatever the history have constructed of ancient period particularly about India is on the basis of 10% of the total available coin. This means 90% of the coins are still not deciphered. You can imagine the situation and its effect on the history-writing. If a researcher wants to see the coin in the museum there is a number of procedure which is not possible to follow. Thus one can see the coins in the galleries only. This fact authors would also like to highlight that these discipline unlike the decade of 60's and 70's are dying discipline. Government is also not giving the grant to promote this branch of Indology and global causes are also responsible where everybody is in search of professional courses. Thus young and brilliant minds are also not coming to this discipline. In this circumstances, the hope is the digitalization of data where the study of the coin can be done faster. Many of the museums are having small photography section where they can be digitized the image of the coin.

This is a fact that numismatic study has travelled a long journey in the reconstruction of the ancient history and culture. It proves its own importance in History where the other sources (e.g. Inscriptions, literature) of study are even silent. Though coins are very small in terms of shape and size but they carry lots of information about society, economy, culture, religion etc. of any period. Basically historians have believed that there are two types of study of any coin. First is internal and it contains information like techniques used in making of any coin, about metal and mixture of different material, value etc. Second is external, which deals with the study and analysis of different legends, symbols and mint marks, etc. Researchers consider both the internal and external types while reconstructing the history. In case of external study of the coins, the decipherment of the legends, symbols, mint-marks of the coins is very important for proper understanding of the political and socio-economic situation, the religion and cultural heritage of the past society.

The different legends, mint marks, symbols may be considered as different 'patterns' from the viewpoint of Computer Science and Engineering discipline. Basically, in the decipherment stage, researchers try to recognize different patterns in the coins.

2. DEVELOPMENT OF THE SUBJECT

Coin segmentation is the extraction of the coin region from the photo. Based on ideal assumptions of coin photos, two methods are usually used to segment round coins: the global thresholding applied by applied by N¨olle, et al. [5] and Van Der Maaten, et al. [6] and the Hough transform for circle detection applied by Reisert, et al. [7]. To segment non-round ancient coins, Zambanini and Kampel [8] proposed a relatively sophisticated approach: they apply seven discrete thresholds on the intensity image obtained by local entropy and local range of gray values and then select the best-segmented region based on a confidence score computed by the shape factor of circularity. However, all stated methods are developed only for the round or almost round coins.

The next development in the field is a patient entitled COIN RECOGNITION SYSTEM AND METHOD Applicant: Tim E. Rathjen, Bellingham, WA (US)

Inventors: Tim E. Rathjen, Bellingham, WA (US); William H. Lindhardt, Bellingham, WA (US); Charles Alden Foell, III Bellingham, WA (US); Benjamin Lindhardt, Lynnwood, WA (US)

A coin handling system performs a one or two-part coin handling and recognition process. In the first part of the two-part process, the system images bulk coins, determines the coin types or other attributes and returns at least some of the coins to the bulk coin receptacle; in the second part, the system re-images the coins and uses the coin types or attributes determined in the first part to efficiently and economically perform machine recognition of attributes of the coins. The output is used to handle the coins and to determine a price to pay for the coins. The images are bright field images Suitable for use by people. Following features are given in this project:

- Recognizer-Controller Data-store
- Recognition Criteria
- Coin Type
- Benchmark
- Search area
- Coin ID
- Coin Image
- Coin Attribute
- Coin Value
- Bin Map
- Price-Attribute Map
- Human Conassessment

3. IMPORTANT DEVELOPMENT

Numismatic Object identification using fusion of shape and local descriptors: R Huber Mork, M. Zaharieva and H. Czedik-Eisenberg

From numismatic Point of View restricting the range of possible classes an unknown ancient coin can be assigned to, is already of advantage. As the results show, an automated identification of coins is a feasible task for the computer vision. An essential impact on the accuracy rate bear the image quality of the training set and the image acquisition process. The combination of shape and local descriptors takes advantage of the very specific nature of ancient coins. Both the manufacturing process (hammer struck from manually engraved dies) as well as the alteration process (wear, scratches etc) contribute to the uniqueness of an ancient coin. Since a shape descriptor focuses on the unique feature and narrows the identification process, local descriptions capture die information and assure the final decision by selecting the correct coin type. Using solely local feature matching will not solve the identification problem since local patterns appear repeatedly not only on the same coin but also across different coins. In the scenarios of coin and coin die identification the spatial relationship of local features is an essential characteristic. Further research is required to optimize spatial constrained local features to capture die-specific information i.e. Mint signs.

They have presented a system for the identification of ancient coins based on the combination of shape and local descriptors. Due to their nature the shape of an ancient coin is well distinguishable feature for an automatic identification.

Similar to that but indifferent line An Automatic Method to Determine the Diameter of Historical Coins in Images by Sebastian Zambanini, Michael Herrmann and Martin kampel presents an image-based method for determining the maximum diameter of historical coins. It consists of two steps (1) the determination of the image's spatial resolution through a Fourier analysis i8of specific pattern produced by a ruler placed next to the coin and (2) the segmentation of the coin and computation of maximum distance between border points. Experimental results show the high accuracy and robustness of the method with an error of 1.19%. Therefore numismatists benefit from the method by a faster and more accurate processing of historical coins. This idea is related to the study of internal information of a coin, particularly about the weight. The benefits of the method for numismatists are that it has improved both the accuracy and speed of coin processing. Apart from one time manual adjustment of the unit length between two ruler marks for a given ruler type, the method is fully automatic. The method was designed to be invariant with respect to the position and orientation of the ruler and the coin segmentation is able to deal with various appearances of coin images. Thus the whole method places only minimal requirements to the image acquisition process. In continuation to that museums are also making the database with regard to their collection.

Computer Graphics is another field. Motivated from this and borrowing the idea of Pattern Recognition from Computer Science & Engineering discipline, in an UGC major project Amit Kumar Upadhyay along with of Northeastern Hill University of Department of Computer Application Dr. Anindya Halder also tried to develop the scientific computational techniques of Pattern Recognition for automatic and accurate decipherment and classification of the coins. The proposed work is a pioneering one in India and possibly in the world (as to the best of the knowledge) to apply the scientific theory of Pattern Recognition (from the Computer Science & Engineering discipline) for the decipherment of the coins in the numismatic filed of History & Archaeology. The expected results of the proposed project as it is in the process may act as an alternative primary source of information to the Historians for further study the numismatic data in future. To overcome above-mentioned challenges, in the proposed project the computational models of pattern recognition will be developed and will be applied to automatic and accurate decipherment and classification of the coins.

4. METHODOLOGY

Automatic detection of the relevant scripts/inscriptions in the Numismatic may be done using the various computational models of pattern recognition methods. For example, to identify the relevant scripts within the coins from its background can be done by applying the clustering based methods. Likewise, if some regions in the form of the scripts, figures, marks, background etc. are known apriori, supervised approach of pattern recognition, called, classification may be adopted for automatic recognition of the rest of the portion within the coins. Similarly, pattern recognition models may be further generalized or extended for recognizing the legends in the different periods of the numismatic data. Before applying the pattern recognition methods for automatic recognition of the inscriptions, the digital images will be captured from the original numismatic data and various image enhancement techniques may be required (if the quality of the acquired images of the coins are not up to the mark) to improve the quality of the images of the coin.

Computer vision techniques are employed to tackle these traditional challenges. For high-level computational tasks such as pattern recognition and coin recognition, image segmentation plays a vital role in the initial processing phase. In this context, segmentation involves assigning a value to every pixel in an image, grouping pixels that share certain characteristics—such as color, intensity, or texture—into distinct regions. Adjacent regions that are not grouped must differ significantly with respect to these characteristics. The primary purpose of segmentation is to enable further analysis of these subparts or sub-images, allowing for the extraction of high-level information. Additionally, image de-noising may be applied to enhance image quality, thereby improving the overall effectiveness of the segmentation process and facilitating more accurate analyses in numismatic studies.

5. OBJECTIVES OF THE RESEARCH

The present research contains the objectives as mentioned below:

a. Recognition of Legends in Numismatic Data: To accurately identify and extract legends from the background of coins, providing insights into their historical and contextual significance.

b. Recognition of Shapes and Figures: To classify and analyze the shapes and figures present on coins, aiding in the understanding of their cultural and artistic value.

c. Automatic Recognition of Scripts: To implement automatic recognition of scripts in inscriptions, enhancing the study of language and communication used across different periods, enriching the study of numismatics.

d. Prediction of Coin Types based on various features: To develop models for predicting the type of coin based on various features, streamlining the categorization and assessment process.

Computer vision has emerged to address these traditional challenges in numismatics. For high-level computational tasks such as pattern recognition and coin recognition, image segmentation plays a critical role in the initial processing phase. In segmentation, each pixel of an image is assigned a value that groups pixels sharing specific characteristics—such as color, intensity, or texture—into distinct regions. Adjacent regions that are not grouped must be significantly different concerning these characteristics. The purpose of segmenting an image is to analyze these subparts or sub-images further, enabling the extraction of high-level information. Additionally, image de-noising may be applied to enhance the image quality, thereby improving the segmentation process and facilitating more accurate analyses in numismatic studies.

6. GLOBAL THRESHOLDING

Global (single) thresholding [9] method is used when there the intensity distribution between the objects of foreground and background are very distinct. When the difference between foreground and background objects is very distinct, a single value of threshold can simply be used to differentiate both objects apart. Thus, in this type of thresholding, the value ofthreshold T depends solely on the property of the pixel and the grey level value of the image [10].

6.1 Automatic Threshold Selection Algorithm

1. An initial threshold (T) is chosen; this can be done randomly or according to any other method desired.

2. The image is segmented into object and background pixels as described above, creating two sets:

   i. G1={f(m,n):f(m,n)>T} (object pixels)

   i. G2={f(m,n):f(m,n)<=T} (background pixels)

3. The average of each set is computed

   i. M1=average value of G1

   i. M2=average value of G2.

4. A new threshold is created that is the average of M1 and M2.

$$T' = (M1+M2)/2$$

5. Go back to step two, now using the new threshold computed in step four, keep repeating until the new threshold matches the one before it (i.e., until convergence has been reached).

6.2 Hough Transformation

The Hough transform is a feature extraction technique used in image analysis, computer vision and digital image processing. The purpose of the technique is to find imperfect instances of objects within a certain class of shapes by a voting procedure. This voting procedure is carried out in a parameter space, from which object candidates are obtained as local maxima in a so-called accumulator space that is explicitly constructed by the algorithm for computing the Hough transform.

This Hough transform is highly optimized. It uses the midpoint circle algorithm to draw the circles in voting space quickly and without gaps. It also includes an option for searching only part of the image to increase speed if a rough estimate of the circle locations is known.

6.3 Midpoint Circle Algorithm

It is very similar to Bresenhams approach. It is based on the following functions for testing the spatial relationship between an arbitrary point(x,y) and a circle of radius centered at the origin.

$$F(x,y) = X^2 + Y^2 + r^2$$

F(x,y) will be 0 if (x,y) on the circle.

Will be >0 if (x,y) outside.

Will be < 0 if(x,y) inside.

Now consider the coordinates of the point halfway between pixel T & S (X_i +1, Y_i – 1/2).This is called midpoint and the authors of this article use it to define a decision parameter:

$P_i = f(X_i+1, Y_i -1) = (X_i +1)^2 + (Y_i-1/2)^2 - r^2$

If Pi –ve, the midpoint is inside the circle, then choose pixel T. If Pi is +ve, the midpoint is outside the circle and choose pixel S.

Similarly, the decision parameter for the next step is:

$$P_{i+1} = (x_{i+1} + 1)^2 + (Y_{i+1} – ½)^2 – r^2$$

Since $X_{i+1} = X_{i+1}$ $P_{i+1} - P_i = [(X_{i+1})+ 1]^2 – (X_{i+1})^2 + (Y_{i+1} – ½)^2 – (Y_i – ½)^2$

Hence $P_{i+1} = P_i + 2(X_i + 1) + 1 + (Y_{i+1}^2 – Y_i^2) – (Y_{i+1} – Y_i)$

If pixel T is chosen (meaning Pi < 0), they have $Y_{i+1} = Y_i$

If pixel S is chosen (meaning Pi > 0), they have $Y_{i+1} = Y_{i-1}$. Thus, P_{i+1}= Pi + 2(X_{i+1}) +1 if Pi<0 Pi + 2(X_{i+1}) +1 – 2(Y_{i-1}) if Pi>0. In terms of (Xi, Yi), they have P_{i+1}= Pi + 2X_i + 3 if P_i<0 P_i + 2(Xi - Yi) + 5 if P_i>0

Finally, compute the initial value for the decision parameter using the original definition of pi and (0,r): $Pi = (0 + 1)^2 + (r – ½)^2 – r^2 = 5/4 – r$ One can see that this is not really integercomputation. However, when r is an integer the authors can simply set P_1= 1 – r. The error of being ¼ less than the precise value does not prevent P_1 from getting the appropriate sign.

It does not affect the rest of the scan conversion process, because the decision variable is only updated with integer increment in subsequent steps.

6.4 Numismatic Coin Segmentation based on MET

In information theory, entropy is used to quantify the amount of information the entropy reflects the information content of symbols independent of any particular probability model. Image analysis takes the concept of entropy in the sense of information theory (Shannon entropy), where entropy is used to quantify the minimum descriptive complexity of a random variable. Because the entropy can provide a good level of information to describe a given image, the authors can compute the entropy of the distribution of gray levels and obtain an appropriate partition for target image.

Maximum Entropy Thresholding (MET) is the maximization of information between object and background.

Let C_1 and C_2 two classes for the object and the background respectively; the maximum entropy measure can be calculated:

$hC_1(t)=sum(pi/pC_1)*log(pi/pC_1)$ for $i<=t$
$hC_2(t)=sum(pi/pC_2)*log(pi/pC_2)$ for $i>t$
$PC_1=sum P_i$ $i<=t$ and $PC_2=sum P_i$ $i>t$

$PC_1+PC_2=1$ because the histogram is normalized

Pi estimate the probability of the gray-level value "i" $Pi=n_i/N$, where n_i is the occurrence of the gray level "i" in the image. n_i is the histogram h(i).

6.5 Evaluation of Alternative Perspectives

Numismatics should be regarded as a serious scientific discipline by developing a commonly agreed-upon data format and coding system. This system should specify both minimum and optimum data requirements to enable easy reference, correlation and analysis through computer technology. Data files must be made readily accessible to all interested parties and designed to permit integration and division, facilitating the compilation of master files, guard files, concordances and sectional files tailored to various data requirements. Working with a computer would require, generally speaking, the following stages to be undergone [11]:

(i) Preparation of Data: Available data is transformed into a coded format. It is then manually recorded on a data sheet in accordance with a predetermined format.
(ii) Key Punching: The coded data is entered into punch cards using a key punching machine to facilitate input into the computer.
(iii) Data Input: The data is fed into the computer for storage in its memory, organized by files on magnetic tapes or discs.
(iv) Program Development: A program is created to instruct the computer on processing the data and generating the required output.
(v) Data Processing: The output data is analyzed and evaluated to derive results and findings.
(vi) Preparation for Publication: The data is formatted and prepared for publication.

The code for input data is typically either alphabetic or numeric. When converting numismatic data, particularly the legends inscribed on coins, into code language, some diacritical marks are not recognized by computer languages. Therefore, it is necessary to develop an alphanumeric language, in which both alphabetic and numeric characters are integrated, corresponding to the phonetic values of vowels and consonants in the source material.

Since programming a computer requires specialized knowledge and training, scholars utilizing computers for their research often collaborate with computer technologists who are familiar with programming. This collaboration provides essential technical guidance.

To raise awareness of the potential benefits and necessity of computer techniques in numismatics, a plan should be initiated to create a master file for the compilation of an encyclopedia of Indian numismatics, as well as a sectional file for a glossary of Indian numismatics.

7. COMPUTERIZED NUMISMATIC DATA PROCESSING

As emphasized, the development of a data format and coding system should be achieved through consensus among numismatists, taking into account all basic and relevant requirements to an optimum level. To begin, a pro-forma for the data format may be proposed by numismatists. The format could include the following logs to accommodate various data requirements and provide a comprehensive scope [12]:

a. Reference Log: Serial Number, Publication Reference, Topographical Details, Material, Date, Shape, Chronological Details (Dynasty/King) and Tribe.

b. Subject Log: Term Log (for glossary), Code Number for each term.

c. Context Log: Details regarding the context of the coins.

d. Text Log: Inscriptions or legends.

e. Field Symbol Log: Code Numbers for symbols, including the order of placement.

f. Detail Log: Measurements of size, weight, thickness, etc.

g. Photo Log: Image identification through electronic photo scanning or other methods, formatted to a uniform 1:1 scale, with enhancements to a convenient size.

This structured approach aims to facilitate efficient data processing and enhance the overall effectiveness of numismatic research. The development of a code language for Indian numismatics must consider the alphabets of various old, classical, medieval and modern Indian languages, allowing for their transliteration into a common, workable alpha-numeric computer code. This alpha-numeric code will utilize the letters of the Roman alphabet alongside Arabic numerals, enabling the representation of phonetic components, including vowels, consonants, surds, sonants, nasals, gutturals and sibilants. By employing combinations of Roman letters and Arabic numerals, this system will provide a comprehensive framework for accurately encoding linguistic features.

For example, voiced ‘ṭa’, ‘ḍa’ in Sanskrit and other languages indicated in transliteration by ‘ta’ or ‘da’ by adding a dot below may be indicated by T4; the two Icoped ‘n’ in Tamil by N4 etc. The alpha-numeric code for the computer language is necessitated because the key-board of input data punching machine for data cards, tape and dice as well as the output line-printer of the computer software have only the Roman alphabet in capitals and the Arabic numerals. With the recent development of electronic language-character printer the output data, however, may be printed in the characters of any script, old, classical, mediaeval or modern.

8. APPLICATION OF COMPUTER IN INDO-GREEK COINS

A classification of the kings of Indo-Greek based on resemblance of their monograms would probably yield interesting, it can be done with the help of the computer. The process can be divided into three stages: 1. The creation of the data-base (recording of the coins); 2. The automatic classification; 3. The interpretation of this classification (to comparing this classification with the one which has been propounded by Narain [13]).

1. The creation of the data-base: When describing the coins, a certain number of variables are looked at; each of these variables can be given a greater or lesser amount of values. Here is the list of the variables according to Guillaume [14]:

- A running number
- The name of the king
- His rank (to distinguish between kings of the same name)
- The metal of the coin (AV=gold, AR= silver etc.)
- Its standard of weight (A-Attic; I= Indian)
- Its unity of weight (/6=obolus; /2=hemidrachm; 1-drachm if in silver and stater if in gold etc)
- The language of the legend (Aanepi- graph; M = monolingual; B = bilingual)
- The obverse device
- The reverse device (80 different devices)
- The obverse monogram
- The first reverse monogram
- The second reverse monogram (the numbers of the monograms are those found in Lahiri's catalogue; some additional numbers for monograms that have not been noted by Lahiri; value 0 if no monogram)
- The reference in Lahiri's catalogue

2. The automatic classification: The computer only needs a number for each king (calculated from variables 'name' and 'rank') and the values of the three variables 'monograms' (one sees that some variables of the data-base are not taken into account; this is because the base has been created not only for the present calculation but for many other applications). Here is the order in which the computer carries out the calculation:

(a) Listing, in tabular form, the monograms and the frequency with which they occur on the coin series of each king.

(b) Calculation for each pair of kings, of how many monograms they have in common.

(c) Calculation, using a suitable formula, of the distances D between the kings. The chosen formula enables us to compare each pair of kings Kl and K2 with respect to the whole set of monograms. It takes into account the following particulars how many mono- grams do kings K1 and K2 have in common (a); how many monograms are found neither on Kl's nor on K2's coins (d); how many monograms are found on K1's coins but not on K2's and reciprocally (b and c). The formula is Distance D-1-Pearson's coefficient, where

ø = (ad-bc)/(a+a) (c+d)- (a+c) b+d).

(d) Arrangement of the kings in a hierarchy according to the distances previously calculated. Firstly, the computer searches for the cluster of kings with the smallest distance between them (in this case, kings 4 and 25); this cluster is given a running number (in this case 40, following the number of the last king); then the computer repeats this operation as many times as necessary.

(e) Presentation of results in the form of a graph. The numbers of the 39 kings are to be found at the base of the graph. Each node of the graph corresponds to a cluster of kings (see previous operation). The height of a node is calculated in proportion to the distance between the kings. Thus, the lower the node is, the closer the kings are. One can see, for instance, that kings Demetrius I and Agathocles (node 41) are closer to each other than king Dionysius is to Apollodotus II (node 57).

3. The interpretation of the classification: The graph shows that the most united kings are Lysias and Antialcidas (7 monograms in common out of a total of 11 for each). As a matter of fact, we remember that these are the only Indo-Greek kings who issued joint coins. The graph also shows that the most isolated king is Telephus. It is worth remembering that, according to Tarn [15], he was a usurper and probably was not even Greek. Both these remarks are encouraging.

Let us compare the graph with the classification of the Indo-Greek kings as propounded by Narain [16]; to make the comparison easier. The authors have written the names of the kings on the graph and, in brackets, the dates for each as given by Narain. Referring now to Narain's chart, if we just consider the chronology and not the dynastic alliances, his chart and the graph match up reasonably well.

- Level 64: Zoilus II, Strato II, Hippostr- atus, Dionysius, Apollodotus II; between 95 and 70 BC (25 years)
- Level 51: Demtrius I, Agathocles, Euthydemus II; between 200 and 165 BC (35 years)
- Level 54: Menander I, Antimachus II, Lysias, Antialcidas; between 155 and 100 BC (55 years)
- Level 59: Theophilus, Philoxenus, Nicias, Diomedes, Herinaius; between 125 and 55 BC (70 years)

If we now consider the dynastic alliances as propounded by Narain, his chart and the authors graph match up to a lesser degree. Most of the early Euthydemid kings are clustered at level 58, which is good enough but, as far as dynasty of Eucratides is concerned, it is necessary for us to go right up to level 65 (this being the second last node) to find its earlier kings grouped together.

9. OTHER DIGITAL TECHNOLOGY

Digital technologies have revolutionized the field of numismatics by providing access to vast online datasets. Unlike traditional static images and written documents that historians have relied upon for years, contemporary digital resources enable scholars and audiences to interact with objects through sophisticated software. This interaction allows users to zoom in, manipulate images and customize their data experience, enhancing the study and analysis of numismatic materials.

Databases represent a significant innovation in this digital landscape, facilitating comprehensive research and comparative analysis. A growing number of museums and institutions are digitizing their collections and making them available online. Among the leaders in this initiative is the American Numismatic Society, which offers access to nearly 600,000 records of objects from its collection. Similarly, the Fitzwilliam Museum in Cambridge provides online access to its unique South Asian coin collection, further enriching the resources available to researchers and enthusiasts in the field of numismatics. The digital revolution has significantly transformed photography, particularly in the study of numismatics, where photography is crucial for understanding coins. There are two primary types of cameras commonly used for coin photography: point-and-shoot cameras and Digital Single Lens Reflex (DSLR) cameras. Point-and-shoot cameras are compact and user-friendly, making them accessible for casual photography. While they offer some limitations, particularly in zoom capabilities through the viewfinder, they typically include a macro setting, which allows for the close-range focus essential for capturing intricate details of coins. In contrast, DSLRs have become the preferred choice for professional numismatic photographers. These cameras are equipped with advanced features, including interchangeable lenses and a direct optical viewfinder, which enables precise composition and manual focus adjustments.

Digital technology has also redefined imaging concepts, lighting techniques and correction tools, enhancing the quality and detail of coin images. One notable advancement is 3D imaging, which addresses the limitations of traditional 2D photography. While 2D techniques often fail to convey the full dimensionality of coins, 3D imaging captures surface characteristics and allows for more accurate documentation and analysis. This approach facilitates realistic representations that can be utilized for educational and publication purposes, while also enabling precise measurements, particularly of volume, which is critical for numismatic studies. Web applications like the "Digital Iconographic Atlas of Numismatics in Antiquity" (DIANA) further enhance the field by providing detailed analyses of ancient coins, focusing on their iconography, chronology and geographic origins. This digital atlas offers a collaborative platform for scholars and museums, addressing the archaeological community's need for a comprehensive overview of figurative subjects and themes in ancient numismatics.

Moreover, the application of Geographic Information Systems (GIS) in numismatics is gaining traction. [17] GIS relies on geo-referenced data to analyze the spatial and temporal aspects of coin finds and hoards. By focusing on the functions and occurrences of coins within their geographical context, GIS holds significant potential for enriching numismatic research, much like its impact on archaeology. While the initial results of integrating GIS into numismatic studies are promising, further research and experimentation are necessary to refine methodologies and enhance the accuracy of interpretations.

In summary, these technological advancements are progressively improving the quality of coin imaging and analysis, paving the way for more nuanced understandings of numismatic history.

10. CONCLUDING REMARKS

In this present paper, the authors discussed some of the traditional method of image segmentation with respect to numismatic coin data. The segmentation technique of the image could be used as per the required application or the usage as image is segmented on the basis of different features. The segmentation techniques are broadly categorized on the basis of detection of discontinuity and similarity of the image. Opting a single technique or method would not provide better optimized results. The result obtained using presented maximum entropy-based thresholding approach is quite promising. It can separate object from background image better than other approaches like Global Thresholding, Adaptive Thresholding.

The numismatic research fields where computer vision methods have the potential to improve the effectiveness and impact of research work. In total, five different parts of numismatic research areas are identified: the classification of coins into given types, the identification of concrete coin specimens, the identification of coins struck by the same die, the reassembling of broken coin fragments and the segmentation and surveying of coins. For each application, a problem description is given and the use of computer vision methods required. Since computer vision methods are applied on photographs of coins, their acquisition (both in 2D and 3D) is also need to cover.

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