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Standards and quantification of coin iconography: possibilities and challenges

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Abstract

The use of digital technologies and big data in the humanities and social sciences provided many opportunities for cultural heritage management and research, enabling data sharing and interdisciplinary collaborations. These developments increased the need for standardized data formats. General and domain-specific standards for describing and classifying cultural data, based on linked data principles, are developed to support increasingly numerous digital collections. However, the existing standards do not fully address the particular challenges concerning the standardized descriptions of images. Here we focus on ancient coins, an official image-bearing medium. We present current approaches to coin iconography, including the application of statistical measures to infer patterns in the use of images for communication. We discuss the importance of consistent, standardized data for quantitative research, and propose a generalized approach, focused on basic concepts and limiting the level of detail for the sake of simplicity, interoperability, and compatibility with statistical methods, as a necessary first step towards creating reliable iconographic standards.

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1 Introduction

In recent years, the scope and volume of research on human history have been expanded by the advancements in information technology, which allowed the creation of large online databases of cultural data, from digital libraries to interactive virtual museum collections, preserving cultural heritage and making it broadly available. A rapidly growing field of digital humanities has been developing computational approaches for data management and analysis. This digital revolution has created new possibilities for research, but it has also opened new questions and challenged traditional methods and practices. The existing systems of knowledge organization in humanities, such as terminologies and typologies, are not always consistent, nor commonly accepted, which complicates the process of digitization and the potential for cross-disciplinary collaboration. Moving resources and research to the digital domain requires rethinking classification systems, and transforming cultural data to be suitable for computational approaches.

In this article, we discuss the importance of data standardization for the advancement of research in the humanities. We first give a brief overview of the current trends in managing digital collections of cultural heritage, especially that of classical antiquity, and discuss the issues concerning the development of standards for describing iconography, focusing on ancient coins. Here we will present different approaches to coin images, including recent examples of using quantitative methods to study their meaning, and attempts at creating standards to describe and classify them. On the example of our recent study investigating the informational value of images on Ancient Greek coins, we discuss the challenges of choosing the appropriate level of detail to keep standards useful, but simple, and illustrate the importance of reliable, standardized data as a prerequisite for a successful implementation of statistical measures.

The Linked Open Data principles of the Semantic Web (Berners-Lee, 2006) provided a framework for data standardization and organization using ontologies, formally defined sets of key terms and concepts marked by unique identifiers, connected with semantic links. Adopting this systematic way of describing, managing, and storing data enabled cross-disciplinary

collaborations and data sharing between the researchers in different disciplines of the humanities (Binding and Tudhope, 2016; Huvila, 2019). The CIDOC Conceptual Reference Model, developed by the International Council of Museums, first offered a general framework to represent cultural heritage (CIDOC, n.d.). This standard was further developed by international collaborative projects such as CLAROS (Kurtz *et al.*, 2009), *Europeana* (Doerr *et al.*, 2010; Europeana, n.d.), and ARIADNE (ARIADNE, n.d.), which support digitization and integration of collections of diverse data types: books, manuscripts, music, art, and archaeological artefacts.

General standards and mediating platforms provide essential technical and logistic support for creating domain-specific standards. Early on, scholars of the Ancient World have recognized the potential of standardized data formats for organizing digital cultural data, and adapted them to fit the needs of their own research (Elliott *et al.*, 2014). These efforts have mostly focused on developing guidelines and tools for editing corpora of literary sources (Perseus Digital Library, n.d.; Smith *et al.*, 2000), epigraphic documents (Elliott *et al.*, 2006; Liuzzo, 2014), and prosopographies (Bodard *et al.*, 2017) of Greco-Roman antiquity. Recently, specialists studying material culture joined this initiative, creating standardized concepts and ontologies for organizing digital collections of coins (Nomisma.org, n.d.; Gruber *et al.*, 2013), weights and measurements (Pondera, n.d.; Doyen, 2018), and pottery (Kerameikos.org, n.d.; Gruber and Smith, 2015). The *Pelagios* project (Pelagios Network, n.d.; Barker *et al.*, 2016) provided a common platform integrating different resources through standardized identifiers for annotating ancient places. However, despite rich online collections of artefacts bearing figurative representations (e.g., Arachne, n.d.; Classical Art Research Centre, n.d.; Bibliothèque nationale de France, n.d.; British Museum, n.d.), there is currently no standardized approach for encoding ancient images. A popular tool for analysing mythological depictions in ancient art, the *Lexicon Iconographicum Mythologiae Classicae*, is available online as a database of records on ancient artefacts and the associated bibliography (LIMC France, n.d.), but its potential as a semantic knowledge organization system has not been fully explored.

2020). The early coins usually featured images only on one side, while the other was either blank or included a punch mark bearing a geometric design. However, the designs composed of figurative motifs were soon present on both sides of the coin (obverse and reverse types), depicting deities, mythological figures and creatures, animals, plants, and objects, sometimes even visual puns alluding to the city's name (Head, 1911, p. lv ff; Kraay, 1976, p. 2 ff.). By the beginning of the 5th century BCE, most of the coin-producing city-states started minted certain images consistently, thus allowing users to recognize the authority that guaranteed their authenticity and value. Despite some images being shared by multiple authorities, the existence of stable, 'diagnostic' design types, mainly associated with a single authority, has allowed numismatists to use these images to classify and date the coins (Weir, 2010).

Over the last couple of decades, numismatic research has been profiting from the creation of large online databases. The *Nomisma* project, a collaborative international initiative hosted by the American Numismatic Society, developed a structured scheme for the digital representation of numismatic data, together with a general ontology built upon the existing classification systems, providing concepts to describe relevant numismatic categories (Gruber, 2010; Gruber, 2019). *Nomisma* is envisioned as a mediating platform, connecting databases covering different periods and different kinds of numismatic data (single finds or coin hoards from archaeological contexts, museum collections, auction catalogues), and making them openly available (Gruber *et al.*, 2013). Using linked data standards helps to create machine and human-readable data, allows integration of numismatic data with other material, and offers options for quantitative research using semantic queries (Heath, 2018). The *Nomisma* ontology strives to offer a sufficient number of key concepts to adequately describe numismatic data, identify and harmonize the inconsistencies between different data sources, while balancing the level of detail to fit the varied needs of its users (Tolle *et al.*, 2018).

At the moment, data standardization led by the *Nomisma* project is focused mainly on the technical aspects of coins, their condition, physical properties (size, weight, metal), denomination, authority, provenance, and date (Nomisma.org, n.d.). As of yet,

standardized options for annotation of obverse and reverse design types are limited to marking the identity of the portrait head (object property 'nmo:hasPortrait', cf. Nomisma.org, n.d.). However, this marker is not consistently applied to all entries in the dataset. The images are usually described in free-text format, using traditional specialist terminology referring to the place of a motif on a coin (e.g., 'to r./l. of. . .', 'in field', 'in exergue'), in a way that resembles the shorthand of heraldic blazons, although it is far less standardized. Despite the typology of ancient coins being relatively well-established through several generations of reference works, there is still a considerable lack of consensus on how to describe coin images and define individual motifs. In addition, most digital databases largely rely on human coders for data entry—often a heterogeneous group of collection curators, specialists, and interns, with a variable level of quality control and error management (Gruber *et al.*, 2013; Tolle and Wigg-Wolf, 2015). These issues are not limited to numismatics, but shared with other disciplines working with material culture. For their database of ancient and Byzantine weights, the *Pondera Online* team has replaced the error-prone and variable free-text descriptions of iconography with drop-down lists of predefined motifs nested in categories (e.g., animal, deity, human), while also allowing for detailed annotation by introducing additional fields describing the technique, position of the motif, etc. (Pondera, n.d.).

For the most part, any confusion can be mitigated by accompanying the description with a photograph of the object itself and linking it to standard reference works and printed catalogues. However, due to the variable availability and format of data sources, the transformation of reference works into referential databases is for the most part still ongoing (García *et al.*, 2019). Despite the huge progress in making numismatic data available and partially standardized, which has increased the possibilities to conduct large-scale quantitative studies concerning coin production and circulation, any attempt to conduct similar research on images would likely be constrained by the raw format of descriptions and require a substantial amount of preparatory work.

A notable step towards the standardization of coin images has been made as a part of the ongoing *Lexicon Iconographicum Numismaticae (LIN)* project

coordinated by Maria Caccamo Caltabiano. Their goal is to develop ‘an objective and scientific method for interpreting coin types’ based on a structural analysis of motifs, hoping to understand the visual ‘language’ of coins, considered to be analogous to spoken or written language (Caccamo Caltabiano, 2018, pp. 77–8). An important contribution of this project is an online database of ancient coin iconography (*DIANA*), based on the previously published indices (Caccamo Caltabiano, 2007). At present, the database includes 938 Greek and Roman coins, their motifs organized in a hierarchy of four macro-categories (person, animal/monster, flora, and object) with numerous subcategories (posture, sex, age, clothing, attributes). The metadata give information on the provenance, value and date of each coin, allowing the users to explore the distribution of motifs and their combinations through time and space (Caccamo Caltabiano *et al.*, 2013; Celesti *et al.*, 2017). Still under development, this database is mainly used by the researchers associated with the LIN project for case studies focused on specific motifs and their assumed semantic links, trying to interpret the observed diachronic patterns of use of these images by different ancient mints (Puglisi, 2014; Sapienza, 2017). While undoubtedly useful for information organization, the explanatory power of their semantic approach has been criticized (de Callatay, 2018).

The potential of comprehensive coding of iconographic elements pioneered by the *DIANA* database was further developed through the cooperation between the computer scientists from the Big Data Lab at the Goethe University in Frankfurt and numismatists working on the ongoing *Corpus Nummorum Thracorum (CNT)* project based in Berlin (*Corpus Nummorum Online*, 2014–20). In a recent article, Patricia Klinger and colleagues address the disadvantages of using unstandardized free-text descriptions to represent coin iconography in digital databases, which reduces the querying options to simple keyword searches (Klinger *et al.*, 2018). Using the *CNT* Greek Coins data, they devised a natural language processing-based, semi-automatic process to convert obverse and reverse descriptions to a machine-readable format compatible with the linked data principles. Applying machine-learning algorithms makes this approach less reliant on manual interventions, while still allowing expert supervision. It has a lot of potential to be used

on different numismatic collections and applied to other types of image-bearing objects such as pottery and seals, as an important step towards creating standardized typologies.

Another line of ongoing research is employing automatic image recognition technology, aiming to develop techniques for computer-aided image-based classification of ancient coins. The goal is to help increase the accuracy and speed of primary data processing, expand the research potential of numismatic material, and aid cultural heritage management efforts in combating illegal coin trade (Zaharieva *et al.*, 2007; Jarrett *et al.*, 2012; Cooper and Arandjelović, 2020). Despite the still limited practical success of this method, in their computational approach to coin images, these studies are among the few that consider the information contained in the images in quantitative, mathematical terms, emphasizing the overall structure of images and their regularities, rather than idiosyncrasies.

Numismatists have early recognized the usefulness of statistics for studying the ever-increasing collections of coins and inferring patterns in their sizes, weights, denominations, and iconography, attempting to reconstruct ancient monetary systems and economies (Doyen, 2011; de Callatay, 2011). Images are instrumental for detecting individual types in a coin series (characterized by a unique combination of obverse and reverse dies), and estimating the total number of coins produced by an issuing authority in a given period. Quantitative methods have recently been used to study images themselves, in an attempt to understand the intentions behind the choice of certain motifs and their meaning (Faucher, 2018; Iossif, 2018). Instead of discussing the characteristics of a small number of well-known examples, quantitative approaches provide an opportunity to study the images in the context of all known examples, thus avoiding giving undue importance to potentially exceptional objects (Iossif, 2011; de Callatay, 2018). However, these studies are still limited by the affordances of the database queries, and the lack of reliable coin typologies.

In our recent study, we took a different approach to images on coins produced in the ancient Mediterranean states until the end of the Hellenistic period. We quantified the amount of information concerning the issuing authorities and the economic

taken into account. We considered individual figures (persons, creatures, animals, plants, and objects), focusing on their general features and disregarding details such as posture, age, hairstyle, and clothing (including jewellery and armour). Similarly, we did not include motif repetitions and partial representations (head, forepart, or hind part of an animal). Attributes (objects associated with a particular person), insignia (diadems, headbands, crowns, hats, staffs), and specific motif variants (incuse squares, helmets, and shield types) were coded separately. We standardized alternative spellings or terms for the same motif. In order to avoid introducing unnecessary changes to the data, we followed the original descriptions as close as possible. However, we identified two types of issues stemming from the fact that online collections are often compiled from multiple sources, by several different coders.

- (1) Identification of persons. For the most part, the persons depicted on coins are easily identifiable by their appearance and attributes as particular gods, goddesses, heroes, nymphs, or other mythological characters. However, due to the heterogeneity of sources, there are discrepancies regarding the identification of portrait heads, especially in the case of motifs known exclusively from poorly preserved or rare examples. The designs of two similar coin types (sharing date, authority, and denomination) could thus be interpreted differently, often as a result of the varying state of preservation or slight variations to be expected in coins struck by hand from individually cut dies. For example, the female portrait head on Syracusan silver tetradrachms is variously described as ‘Arethusa’, ‘nymph’ or ‘(female) head’ (compare the following coins from the MANTIS database, ANS 1997.9.20 and ANS 1984.46.12 dated 480–475 BCE; ANS 1997.9.39 and ANS 1997.9.42, dated 415–405 BCE)¹.
- (2) Addition, omission, and misidentification of motifs. In some cases, the descriptions either introduce motifs that are not present on the coin, omit motifs that are present, or confuse one motif for another. These issues can be a

matter of subjective interpretation as much as a coding mistake.

The raw text format of these descriptions makes it hard to spot such inconsistencies, which may hinder standardization efforts. Including more detail increases the number of unique motifs, and by extension, unique design types. This, in consequence, influences the outcome of measures dependent on the frequency distribution of data types, such as the conditional entropy measure that we used in our study, by adding noise and obscuring or inflating the results of statistical analyses, especially when these analyses are performed on relatively small datasets. In the process of systematization and quantification of cultural data, it is necessary to apply a certain level of generalization and abstraction, which reduces the level of detail in the data—but the same is true of any classification system. Coding the data consistently throughout the dataset, according to a pre-established standard, helps to avoid ambiguity and eliminates potential biases.

4 The level of detail and statistical measures: the implications of coding decisions

In order to illustrate the impact of coding decisions on the outcomes of statistical analyses, we used the dataset compiled for our previous study, and recoded obverse and reverse design descriptions adopting two extreme approaches to transform them into strings of individual motifs: a very fine-grained (‘specific’) and a very coarse-grained (‘general’) encoding. The basic set of considerations for identifying individual motifs remained unchanged: we disregarded variants of the same motif, including motif repetitions on a single coin and spelling variants. [Table 1](#) summarizes the differences between the ‘general’ and ‘specific’ coding approaches.

We proceeded to explore the possible implications of these two coding variants on the conditional entropy measures, and on the diachronic trends of information about the authorities and denominations present in coin designs that we had identified in our original study ([Pavlek et al., 2019](#)). Each coding

Table 1. Summary of coding guidelines for general and specific motif encoding

General encoding	Specific encoding	Example
rare motifs are replaced with more frequent equivalents (when available)	no generalization	boy → man apple → pomegranate
similar motifs are collapsed into a general category	no generalization	cockleshell, murex shell, scallop shell → shell
additional motifs (attributes, insignia) are not included	additional motifs are included → except for attributes appearing exclusively with a person * (attributes of a specific person appearing independent of this person are included)	diadem, sceptre, kausia (hat) * (pileus = cap of the Dioscuri, city walls crown = turreted crown of Tyche → included only when not appearing with Dioscuri/Tyche)
specific motif variants are not included	specific motif variants are included	incuse square types (different partitions), helmet types (Attic/Corinthian/Macedonian), shield types (Boeotian/Macedonian)
generic terms are used for persons instead of names → except for gods and goddesses (identifiable by attributes)	persons are named (when names are available)	king → Ptolemy I/queen → Arsinoe II hero → Herakles/heroine → Atalanta nymph → nymphArethusa river god → rivergodAcheloo

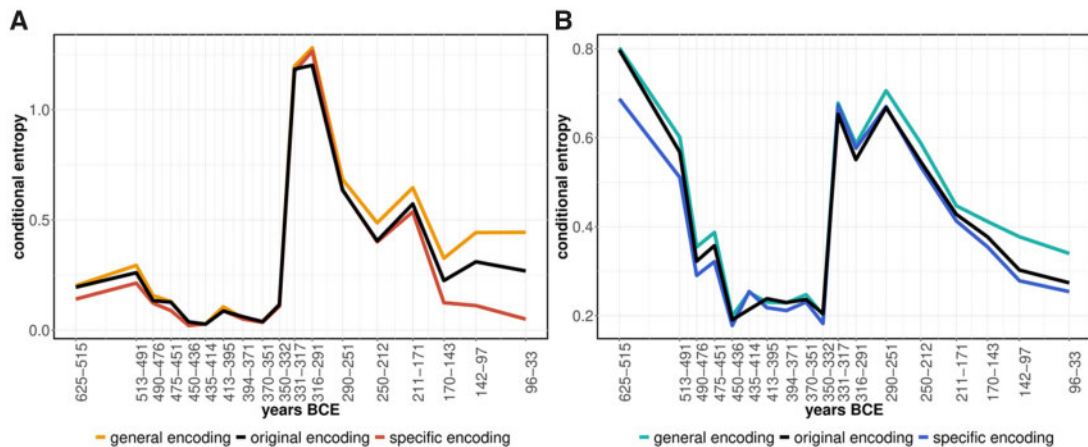


Fig. 1 Diachronic change of conditional entropy of authorities given designs (A) and denominations given designs (B) through eighteen time intervals, compared between the three encoding variants: original (black line), generalized, and specific (coloured lines). With time, coin designs become more informative about denominations (the conditional entropy of denominations given designs decreases), but not about authorities. In both cases, the peak in conditional entropy is influenced by the standardized coinage issued by Alexander the Great and his successors

variant generated a different number of unique design types, resulting in two versions of the dataset characterized by a different number of unique coin types, sharing the same date, authority, denomination, and

design. We measured the conditional entropy of authorities and denominations given designs, respectively, over all coin types issued within each of the eighteen time intervals. Even though the general

trends look similar, the conditional entropy values display subtle differences between the original encoding and the two extreme variants (see Figure 1).

With these differences in mind, we can draw some insights on the influence of two coding alternatives on the frequency distributions of unique motifs, designs, and coin types, and their subsequent effect on the outcome of information theoretic measures. This influence is especially noticeable when considering the difference between the general and specific coding of

portraits of historical and mythological persons. In line with the guidelines presented in Table 1, persons are coded using generic terms ('king', 'queen', 'nymph' etc.) in the general coding variant. In the specific coding, the persons that the experts identified based on the coin legends (inscriptions) or inferred from the context (the time and place of the coin's issue) were labelled by name. When the source databases omitted the person's name, as in the example of the Syracusan nymph Arethusa cited above, we

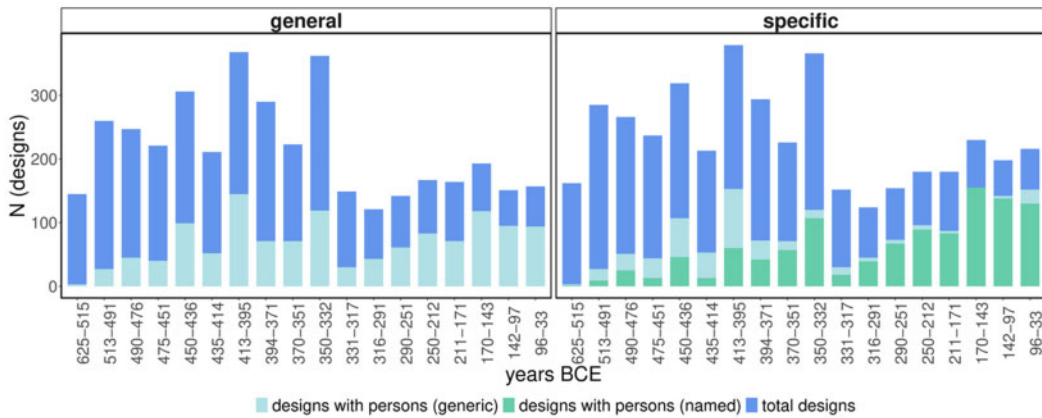


Fig. 2 Frequency distribution of unique design types (blue) in the 'general' and 'specific' datasets. The designs featuring generic persons ('king', 'nymph' etc.) are marked in light blue. The designs featuring named persons (e.g., 'Ptolemy I', 'nymphArethusa') are marked in green

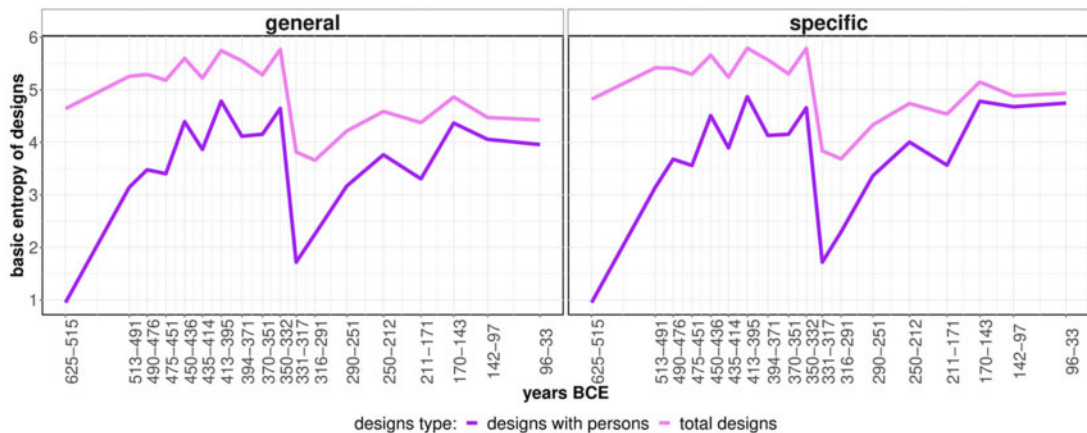


Fig. 3 Diachronic change of basic entropy of designs, measured for 'general' and 'specific' versions of the dataset through eighteen time intervals, separately for designs featuring persons (purple line), and all other designs in a period (pink line)

assigned the names based on the analogous coin types, verifying the suspicious cases in the referent literature (Head, 1911; Kraay, 1976). We strived to be systematic and consistent throughout the coding process, focusing primarily on resolving inconsistencies, and refrained from taking sides in complex numismatic debates on portrait attribution, which were beyond the topic of our study and our level of expertise.

Figure 2 presents the number of unique design types over eighteen time intervals, highlighting the proportion of designs featuring persons. In the ‘specific’ dataset, most persons depicted on coins are identifiable by name, especially in the later periods. Treating them as individual motif types, separate from the generic, unnamed persons, adds to the diversity of motifs composing the designs. This contributes to the increase of the basic entropy of designs (see Figure 3), making them less predictable. Additional design types in the specific coding affect the mapping between designs and authorities or denominations (frequencies of unique denominations and authorities being constant for each of the coding alternatives), inflating the estimates on the amount of information in coin designs. This is why the ‘specific’ designs are overall more informative (indicated by lower conditional entropy values in the final periods) than the ‘general’ ones, especially about the issuing authorities (see Figure 1).

In the Hellenistic period, following the death of Alexander the Great, portraits of rulers appeared on coinage, replacing images of gods and heroes (Carradice, 1978). The portraits of mythological persons, despite their generic character, are identifiable by their attributes, e.g., a lion-skin for Herakles or a helmet for Athena. Hellenistic royal portraits, unlike the generic depictions of the Persian Great King, do display a considerable level of individuality (Carradice and Price, 1988; p. 123 ff.). However, some portraits also tend to be stylistically similar and emphasize the resemblance between the members of the same dynasty, meant to signal continuity and legitimacy of the rulers as heirs of Alexander (Thonemann, 2016, 145 ff.). The attribution of a portrait to a particular historical ruler is thus largely reliant on context: ruler portraits usually appear on their respective coins, often accompanied by inscriptions denoting them as the issuing authority. The existence of inscriptions on coins would assume a certain degree of literacy in their users, and add to the

information encoded in the coin. However, before the middle of the 5th century BCE, the inscriptions were rare and mostly limited to place names (‘ethnics’), followed by the names of rulers and magistrates in the later periods (Kraay, 1976, pp. 2–7; Carradice and Price, 1988, pp. 57–60). In contrast, gods and mythological beings were rarely explicitly named. Nevertheless, as most coins were produced and used locally, it is likely that the contemporary users could recognize the persons depicted on coins, even if recognizable attributes or labels were missing (Weir, 2010).

The ambiguity of designs featuring persons, however, often presents a problem for modern numismatists striving to describe and classify them.² It is, therefore, important to consider the way we code the coin designs, choosing the appropriate level of granularity depending on the hypothesis we are planning to test. In the case of our recent study, since our hypothesis was concerned with the information encoded in the coin’s graphic designs, a generalized coding approach seems to be more appropriate to capture the information directly present in the images, and to avoid introducing artificial complexity derived from the inscriptions and general historical context.

5 Conclusion

The last decade has witnessed a growing number of digital resources, advancements in computer-assisted approaches, and the development of standards for annotating cultural data. This opened new possibilities for management and presentation of cultural heritage. Standardized databases present a way to organize the data, making it more reliable and available for research, suitable for testing different questions using a variety of approaches. However, many challenges remain, especially concerning the digitization of collections of material culture, where finding a generally applicable standard to describe graphic representations seems to be particularly difficult.

In this article, we focused on coins, objects marked with graphic designs, produced in large quantities and disseminated mostly by political authorities, serving primarily as media of exchange. Their official character, together with a substantial number of examples preserved since antiquity, makes them particularly suitable for standardization. In the field of ancient

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Notes

- 1 Accessible online at: <http://numismatics.org/collection/> followed by the catalogue number (e.g., <http://numismatics.org/collection/1997.9.20>).
- 2 For recent examples of studies discussing iconographic representations on the coins issued by Roman emperors through the analysis of relative frequencies of particular coin types, cf. [Noreña, 2001, 2011](#); [Rowan, 2012](#); [Manders, 2012](#).