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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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.

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

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.

Historical artefacts are often fragmented and their original context is not always known, which makes them challenging to study. The research on ancient art has thus been mostly oriented towards description and interpretation of individual examples or groups of artefacts, rather than conducting large-scale studies seeking general trends. However, the availability of digital art collections has renewed the interest in iconography, a discipline of art history focusing on the content of images (subject matter), aiming to classify them and interpret their meaning (Panofsky, 1939; cf. Müller, 2011). Some systematically organized collections of iconographic material established since the beginning of the 20th century are partially digitized and available online (e.g., The Index of Medieval Art, n.d.; Warburg Institute, n.d.). *Iconclass*, the first collection-independent classification system for iconographic data, developed by Henri van de Waal in the Netherlands (published in print 1973–85), has been recently converted to a semantic ontology format (*Iconclass*, 2009). The Getty Research Institute developed several standardized vocabulary lists to support the linked databases of cultural data, including a thesaurus of iconographic terms (The Getty Research Institute, 2018). There were also initiatives to expand the CIDOC-Conceptual Reference Model ontology to include domain-specific concepts for annotating iconographic material (Dentamaro *et al.*, 2007; Carboni and de Luca, 2019). The advancement of image manipulation and recognition technologies has inspired the debates on the future of art history in the digital age, discussing the potential of standardized semantic ontologies for supporting traditional qualitative approaches, as well as developing quantitative methods to study visual culture (David, 2015; Lozano, 2017; Gartner, 2019). Despite the challenges posed by the ambiguous character of visual culture, using standardized systems to describe and organize images would not only help manage the growing body of data, but also support the application of different methodologies testing novel research questions.

(Tehrani, 2013; Berezkin, 2015), literature (Hughes *et al.*, 2012; Yucesoy *et al.*, 2018), paintings (Sigaki *et al.*, 2018), music (Klimek *et al.*, 2019; Youngblood, 2019), and films (Sobchuk and Tinitis, 2020). Quantitative methods are useful for modelling and statistical hypothesis testing using big, consistent, and systematically organized datasets, containing information in the form of measurements or discrete observations (on different types of quantitative research, see Morin, 2015). These observations usually come from small-scale, qualitative studies, focusing on interpreting specific phenomena. The choice of the appropriate method depends on the scope, the research question, and the nature of the data used in a study. It is, therefore, important to keep in mind the requirements of a particular approach when considering the design and possible applications of digital corpora and data standards (cf. Roberts and Winters, 2013).

Coins emerged in at least two independent locations. Most of the coins used in the world today are stemming from a Greco-Lydian invention at the end of the 7th century BCE. The coins produced throughout the ancient Mediterranean world were marked with images that identified them as a valid means of exchange and store of value, issued by a certain authority. As a contrast, another independent tradition of metal coinage, which emerged in 5th century BCE China, produced coins marked only with inscriptions (Scheidel, 2008). Figurative images are present on the earliest known coins found at the Artemision at Ephesos (Karwiese, 1991; Kerschner and Konuk,

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.

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 Callataÿ, 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 Callataÿ, 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.

matter of subjective interpretation as much as a coding mistake.

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.

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/heroina → 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

This lack of standardized descriptions hinders the possibilities for studying large diachronic patterns of structure, evolution, and transmission of images using quantitative methods. The use of statistical measures and models requires the data to be in an unambiguous, standardized format. In order to be able to see the ‘big picture’ quantitatively, it is necessary to adopt some degree of abstraction and generalization, albeit at the expense of detail. On the example of our study on the informational value of images on ancient Greek coins, we illustrated the importance of standardized data for quantitative studies, and pointed out some issues worth considering when developing standards for encoding images. We showed that a generalized coding approach, focused on basic concepts rather than their specific manifestations and variations, is more suitable for quantitative analyses than a specific coding, capturing a greater level of detail, but introducing noise in statistical measures. Generalized coding could thus be regarded as a necessary first step towards creating reliable and generally applicable standards for iconographic descriptions.

specific motif types and relationships between different motifs, as well as providing rich metadata and including competing expert interpretations of particular aspects of iconography would open further possibilities for conducting in-depth studies. The ongoing efforts in digitization of reference catalogues, development of computer-assisted methods for image identification, as well as further application of linked data principles allowing the integration of existing data standards and the development of new ones will undoubtedly expand the possibilities of future research on coin images and visual culture in general.

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The data are available at: https://osf.io/gd4mv/?view_only=c1d21aa0ebf848e78a6b65f44ca33f3a.

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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](#).

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