Definitions of vagueness, uncertainty and their combination in the Cultural Heritage Domain

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Abstract

Vagueness and uncertainty are inherent characteristics of Cultural Heritage research. Chronological attributions, spatial references, typological classifications, material descriptions, and provenance statements are frequently expressed with limited precision or confidence. While these phenomena are ubiquitous in archaeological and related disciplines, their conceptual distinction and formal treatment in research data infrastructures remain inconsistent. This white paper proposes a structured discussion of the terms vagueness, uncertainty, fuzziness, and wobbliness, distinguishing them analytically and examining their interaction in practical data modelling scenarios. Building on use cases from numismatics, ceramology, the natural sciences, and the Linked Open Data environment, we analyse how vagueness relates to gradational imprecision, whereas uncertainty concerns the epistemic status of statements that are either true or false but cannot be asserted with full confidence. We further introduce fuzziness/wobbliness as an umbrella concept for complex real-world constellations in which vagueness and uncertainty co-occur, interact with database constraints, or emerge through ontology mappings and system limitations. The document assembles and compares community-driven working definitions developed within the NFDI4Objects "Community-Standards for modelling fuzziness & wobbliness in research data using Semantic Web technologies and formalisms" (FuzzyWobblySW) Temporary Working Group (TWG), aiming to establish a shared terminological and modelling framework. By clarifying these concepts and outlining modelling strategies – including probabilistic approaches, graded semantic mappings, and Wikibase-based implementations – the paper contributes to a more transparent, interoperable, and FAIR-compliant approach to handling doubtful, imprecise, and ambiguous information in Cultural Heritage knowledge graphs.

Introduction

The first part of this document comprises definitions of the terms 'vagueness', 'uncertainty', and their combination, as we consider this necessary for further discussion. As the participants are likely to have different definitions of these terms, they are, of course, not yet final. However, they should serve as a working basis for the discussion within the TWG. Our aim is to create our own definitions within the TWG community. For this purpose, we have created separate sections for contributions or comments after each of the three existing definitions. These should be filled out in suggestion mode. The existing definitions should not be changed.

Overall, this document still has a strong numismatic basis, as we have been working with researchers in this field for a long time. However, we hope the TWG participants can support us with their domain knowledge from other fields to broaden the basis of this document.

Definition: Vagueness

Background and Explanation

The concept of vagueness is widespread in archaeological research. Many properties of an archaeological object, such as its date and place of manufacture, can only be specified very vaguely - if at all. Due to the long time gap between the production of an object and the present day, one of the main challenges of archaeological research is to make this data as precise as possible. Let's look at the example of dating finds: The possible dating range in particular often has to be given in longer periods (e.g. 100 – 200 AD), as the date of manufacture can only be given very vaguely due to a lack of reliably datable finds, but the production cycle was probably much shorter. This is particularly problematic if the dating of other archaeological findings is based on this vague data. Generally, relative dating - whether by typological means or through cross-dating creates the danger of circular conclusions, whereby finds that are dated by, e.g. a specific type of pottery or a scientific date are used to date the same pottery from other finds. It is especially apparent when imports or features from one material culture or site with more precise dating are used to cross-date finds of different archaeological cultures, e.g., without written records or generally less detailed chronological ranges (terminus post quem) (Harris 1989).

Further, the object's preservation state can also influence the possibility of dating. If important features of the object are no longer recognisable, exact dating can be very difficult. Although the previously mentioned limitations apply, generally forms of relative dating, such as typological, stratigraphic, or cross-dating, as well as the inclusion of scientifically derived dates, e.g., through radiocarbon, provide, in many cases, the closest match to rarely available calendar dates. These time spans differ - depending on the method - and the interval and its inherent properties should generally be expressed as detailed as possible, e.g. through Allen operators (Allen, 1983) and the fuzzy version in CIDOC CRM (Bekiari 2024, pp. 43–46, cf. Holmen/Ore 2010).

However, vague information on archaeological objects is also possible for other important properties. In contrast to dating, these properties of an object can be measured objectively (as long as the object is available for a measurement), but are not always specified or obtained with the highest precision or resolution. For example, during the initial analysis of an object, its weight - regardless of the decimals originally present on the scale - was only recorded with one decimal place. Such a specification might not provide sufficient accuracy outside the current scope of this analysis. Obviously, this also raises the question of what degree of precision (number of decimal places) one would like to aim for in research questions. The information can be considered vague if more decimal places than recorded are required for a new study on this object. Additionally, a further degree of vagueness arises from the specification of measurable properties of an object with clear boundaries. For example, a weight specification such as 5.5 g indicates fixed limits: the weight is between 5.45 g and 5.54 g, even though the lower and upper boundaries could be extended to any number of decimal places within these limits. By contrast, stating the weight with words like 'approximately' (e.g. approx. 5.5 g), no upper or lower limits are discernible, and therefore the vagueness of the statement is significantly higher.

Further challenges of vagueness arise in combination with uncertainty. Every scientific measurement possesses inherent systemic components of variability or uncertainty. Intra- and inter-observer error, systematic and instrumental error (e.g. calibration and resolution), as well as potential ambiguities, e.g. in landmark identification or definition, exist to varying degrees in every environment and can usually be tested and (partially) be accounted for (Taylor 1997). Depending on the circumstances, their effect might even be negligible or irrelevant to the undertaken research.

However, if a person enters an approximate weight indication into a database with the note that the information itself is uncertain, the measurement's usability for scientific evaluation rapidly diminishes. Generally, such statements of uncertainty are more crippling to research than the inherent systemic components of variability or uncertainty of scientific measurements.

Such notions are directly tied to how researchers and institutions procure, archive, and disseminate data, specifically to how their systems handle vagueness. How should vague information be entered into a database so that a vague entry does not become an absolute entry (weight: approx. 5.5 g ? weight: 5.5 g), as the database does not support the handling of such vague data? This also applies to an entry with upper and lower bounds.

This phenomenon - the quality and detail of measurement recorded (the precision) - is separate from the general impossibility to generate total precision on any measurement. Measurement accuracy and the recording of accuracy will therefore always be a trade-off among measurement precision, research needs, and archival purposes, and may differ in every case or environment.

A different approach to handling vagueness can be applied when, e.g. a producer of Roman ceramics worked in different production centres. When the name stamp involved is known to have been recorded at another production centre (this phenomenon is also known as "wandering potter", Hartley 1977), both centres can be connected by an AND statement, and a weight of 100% can be assigned to each relation. A different example of handling vagueness in pottery studies occurs when attributing incomplete vessels to potform types. Standardised pottery like Samian may have identical footrings across different form types, whereas the rims may be entirely different. Hence, a single footring can be attributed to different potform types, connected by an **OR** statement. The amount of OR possibilities involved then defines the percentage expression related to the vagueness within the possible attribution to several potform types (Thiery et al. 2022). It is worth noting that **OR** relationships (whether they be equal or not), together with existential negations, are difficult to express in many visual languages, including maps.

Community Definition: Vagueness

Below we list examples of different definitions that can be found in literature. We start with a definition generated during our collaborative TWG meetings.

Definition §V.1: NFDI4Objects TWG Community Definition

"Vagueness refers to a lack of precision in a statement, especially when it comes to categories, terms, or boundaries that are inherently gradational or context-dependent; greater vagueness implies less precision, and vice versa. Vagueness is an indicator of how far a statement is assertive. Such an indicator would normally be qualitative, a quantitative indicator should be explicitly justified." (FuzzyWobblySW TWG)

Definition §V.2

"Vagueness is a measure of precision of a statement. A higher vagueness means that the statement is less precise and vice versa." (Weigel 2024)

Definition §V.3

"Vagheit: Aussage zu einer Information ist unpräzise formuliert und lässt Spielraum zur Interpretation zu. Beispiele: Tomate ist reif, Musik ist laut, Glühbirne ist hell, Morgen wird es einen leichten Regen geben (mit 20% Intensität)." (Unold & Bruhn 2017)

Definition §V.4

"Vagheit ist ein Maß für die Präzision einer Aussage. Eine vage Aussage trifft also nur zu einem gewissen Grad zu. Trifft beispielsweise der Wetterbericht die Aussage »Morgen wird es Niederschlag geben«, so könnte morgen ein leichtes Nieseln, ein mäßiger Regen oder ein schweres Gewitter stattfinden. Abhilfe könnte hier beispielsweise die Angabe der Niederschlagsmenge leisten. Doch nicht zu verwechseln ist eine solche vage Aussage mit einer unsicheren Aussage." (Unold et al. 2019, sec. 3)

Definition §V.5

"Vagueness is a measure of the precision of a statement. A vague statement only applies to a certain extent." (Thiery & Mees 2023)

Definition §V.6

Øyvind Eide: *"There is no precision, only varying degrees of vagueness."* (inspired by CIDOC CRM / Martin Dörr)

Definition: Uncertainty

Background and Explanation

Comparable to vagueness, uncertainty is a constant companion in archaeological research. In particular, assignments of an object to manufacturers, authorities, and sometimes even material cultures or technocomplexes can often be indicated as uncertain, as in many cases this information cannot be derived directly from the object. As a result, archaeological research results are foremost a product of their time, both in reflection of the accessible knowledge of the past, scientific possibilities, but also interpretation. Even scientific data, notwithstanding measurement errors, can change through advancement in analysis. Modern research has accepted that even statements generally assumed to be 'true' are never imply one hundred percent certainty. Archaeological research demands assigning objects to instances with varying degrees of certainty, such as a specific coin stamp or an authority. For example, coins are usually attributed to authorities such as emperors or local rulers. However, such associative information can be lost over time or remain undiscovered, making the attribution uncertain, e.g., if no inscription (coin legend) or other insignia belonging to the authority or other sources are documented. In archaeology, the loss of information and thus assignment certainty through taphonomy, the lack of discovery, historical ambiguity or other sources can often not be disentangled. Possible uncertainty in such an assignment should therefore be noted in the data record, in order to indicate the unknown or ignorance we have that can even be used to allow reasoners to calculate alternative values (Tolle et al., 2026). One way to do this would be to mark the assignment as uncertain, for example, by ticking a checkbox. Furthermore, other assignments of authority can be added as alternatives. This would result in a vague statement in case any other alternative can be neglected.

A more complex solution is to add percentages that directly indicate the degree of certainty of this assignment. There are several possible ways of assigning these probabilities. A straightforward approach is for the specialist to assign a percentage directly, based on their own judgment of certainty. However, this practice has notable limitations: the assigned probability may be influenced by contextual factors such as the assessor's affective state or situational pressures, and simultaneously, it imposes a cognitive burden on the assessor. Moreover, without clear grounding, the interpretation of a specific probability value (e.g. 53 %) can be ambiguous and difficult to justify (cf. Leonelli 2016; Taleb 2007). Scientific reasoning has embraced structured probabilistic frameworks to mitigate this (e.g. Kintigh et al., 2014; Bayliss 2015), and many recent projects in archaeology are starting to implement probability methods applicable with Bayesian statistics, taking multiple uncertainty factors, e.g. related to dating arguments, into account[1]. Another option which has become increasingly important in recent years is the use of machine learning, including (ML) artificial intelligence (AI). In a classification task, such as determining the origin of an object, an ML model provides a likelihood value that can be added to the object entry (e.g. 56 % probability the object is a coin). However, these values are intrinsically tied to the model employed; they are only stable and reproducible if the exact same model and (training) parameters (for non-deterministic models, this also includes, e.g., the seeds) are known.

[1] https://www.sheffield.ac.uk/mps/research/maths/queade

Therefore, the model version alongside all relevant parameters should also be added as additional information. However, most current AI models are so-called black boxes, which means that users have little to no insight into how the input data (e.g. the photo) is turned into the prediction and its probability. Therefore, such results can be difficult to understand and explain, and users are often forced to either accept or reject the prediction. This problem is further exacerbated as training data and parameters of most commercially available models are unknown - this is also true for most large language models, which are dominantly employed for text or data analysis. Therefore, foremost explanatory methods and if possible, insight into the training data should also be offered for the prediction of models and the probability statement for a better understanding of the results. While adding such explanations for the ML models seems at least feasible, this is difficult to imagine for the probabilities given by human experts.

Community Definition: Uncertainty

Below we list examples of different definitions that can be found in literature. We start with a definition generated during our collaborative TWG meetings.

Definition §U.1: NFDI4Objects TWG Community Definition

"Uncertainty refers to the limited confidence with which a particular interpretation, identification, or attribution can be made due to incomplete, ambiguous, or indirect evidence. Uncertainty arises when conclusions cannot be established with full certainty, such as when data of objects, features, etc. is assigned a specific interpretation like authority, period, place, or function, etc." (FuzzyWobblySW TWG)

Definition §U.2

"Uncertainty stems from statements that are either true or false and it acts like a probability of the statement's truthfulness." (Weigel 2024)

Definition §U.3

"Unsicherheit: Korrektheit einer Information ist nicht bekannt, aber die Aussage muss entweder wahr oder falsch sein. Beispiele: Glühbirne ist an, Maus ist tot, Mainz05 gewinnt am Samstag gegen Köln, In 1 von 5 Fällen wird es morgen regnen In 4 von 5 Fällen wird es morgen nicht regnen." (Unold & Bruhn 2017)

Definition §U.4

"Bei Unsicherheit ist gänzlich unbekannt, ob die getroffene Aussage überhaupt wahr ist. Trifft der Wetterbericht beispielsweise die Aussage »Morgen regnet es mit 75 %-iger Wahrscheinlichkeit«, dann handelt es sich um eine unsichere Aussage. Sie sagt aus, dass in drei von vier Fällen die Kernaussage wahr ist, es also morgen regnet und in einem von vier Fällen falsch ist, es also morgen nicht regnet." (Unold et al. 2019, sec. 3)

Definition §U.5

"Within uncertainty, it is completely unknown whether the statement is true at all." (Thiery & Mees 2023)

Definition: fuzziness/wobbliness

Background and Explanation

As previously stated, uncertainty can co-occur with vagueness. An indication that is not only vague (Weight: approx. 5.5 g) but also uncertain (Weight: approx. 5.5 g?) is almost unusable for scientific evaluation. Another case is the specification of a value with an upper and lower limit with an 'uncertain' note. This can be read to mean that the expert was unsure of the exact position of the value between the upper and lower limits of the weight. The other possible interpretation is that the uncertain note casts doubt on the entire weight entry. In this case, a simple 'uncertain' note is no longer sufficient and would have to be replaced by a more precise indication of the uncertainty.

As with vagueness, the solutions of individual information systems must also be evaluated. When an object is entered into a database, the uncertain entry of several authorities who may have commissioned the object must not suddenly become a certain entry, because the database allows only one authority to be entered. This is a significant challenge in digitisation and data integration, because removing local context is an important part of making larger, integrated data collections efficient and useful for further processing. While drilldown back to the original sources and their context can work in some use cases (such as aggregated object data from museums), it will not in others (such as many LLMs).

While vagueness and uncertainty got defined above and are rather clear. In real-world situations it is not always clear why and where exactly problems occur. It could be a combination of vagueness and uncertainty. Alternatively, instability in data interpretation or structure might also happen; for example, database constraints can force a single "certain" value from originally uncertain or vague input. Also, precision and accuracy can be introduced by different levels of systems and/or humans. Since this overall might be very complex, we propose to combine all those cases under the umbrella term "fuzziness/wobbliness" (can be seen as a root class) also including the previous cases "uncertain" and "vague".

Overall, it is hard to imagine cultural heritage research and other disciplines without the concept of fuzziness/wobbliness. This fact is fundamental to the handling of research data and the research based on it by scientists from all disciplines. In order to avoid possible misunderstandings that could arise when exchanging data and research results (LOD), it would be advantageous to introduce a common standard for labelling and modelling cases of fuzziness/wobbliness. At least to a certain level where according information is available and potentially useful for the data users. This also includes mapping and alignment as part of data integration processes. The Simple Knowledge Organization System (SKOS) offers mapping properties, but apart from skos:exactMatch, the interpretation is not semantically clear. In the context of Wikidata, there exist various qualifiers that can be used with the property sourcing circumstances (P1480). These include, for example, circa (Q5727902), presumably (Q18122778), possibly (Q30230067), disputed (Q18912752), estimate (Q37113960), and no earlier than (Q110290991). You can also tag a value in Wikidata as "no value" or "unknown value".[2] However, the significance of such qualifiers is sometimes questionable.

[2] https://www.wikidata.org/wiki/Wikidata:Data_model#No_value_and_unknown_value

Community Definition: fuzziness/wobbliness

Below we list examples of different definitions that can be found in literature. We start with a definition generated during our collaborative TWG meetings.

Definition §FW.1: NFDI4Objects TWG Community Definition

"*Fuzziness/wobbliness is an umbrella term combining uncertainty and vagueness where they can not be distinguished from each other in statements or data entries. It also covers any unclear situation, like ambiguous mapping of instances, properties or classes between ontologies or unreproducible statements, e.g. from literature.*" (FuzzyWobblySW TWG)

Definition §FW.2

"*Fuzziness/wobbliness also contains database expressions such as "A or B or C* ***?****" which is a combination of uncertainty and vagueness, not stated if the question mark is for the whole statement or just one element within the string. All of this may result in a degree of connection*" (A.W. Mees & F. Thiery, via Mees & Thiery 2026; Thiery et al. 2022)

Definition §FW.3

"*Fuzziness/wobbliness also contains accuracy/precision/standard deviation in measurements that express the 'doubt' in numbers.*[3]" (Thiery 2026a, sec. 2.6, 3.5)

Definition §FW.4

"*Fuzziness/wobbliness also contains human-made categories, e.g. likely or little chance, that can also be described in digits*" (Nation 2017)

Definition §FW.5: fuzzy-sl Wikibase

"*Fuzziness/wobbliness also contains* uncertain expressions combined with precision information, certainty levels (high, medium, low, dubious) and method information depending on the source, e.g. within the fuzzy-sl Wikibase as the "Four-Level Mapping Model" (Thiery 2026a, sec. 2.4, 2026b; Thiery et al. 2026, fig. 4; Thiery et al. 2024; Mees & Thiery 2026, sec. 3.4)

Definition §FW.6: Quantitative normalised SKOS Extension/Alignment

"*Fuzziness/wobbliness also contains rankings/categories as certainty levels that can be aligned to SKOS mappingProperties based on the concept of a degree of connection d ∈ [0, 1], which expresses the strength of a semantic mapping relation, e.g. high-low scales or star levels using the Gradual Semantic Alignment for SKOS (GSAS) framework*" (Thiery 2026a, 2026b).

[3] https://github.com/Research-Squirrel-Engineers/GSAS/tree/main/skos_perceptions

Definition §FW.7: Wikidata

"*Fuzziness/wobbliness - in Wikidata - also contains a combined modelling, i.e. sourcing circumstances (P1480) and determination method or standard (P459), within Wikidata to express the uncertain/vague statement of e.g. coordinate location (P625)*[4]." (F. Thiery)

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[4] cf. https://t1p.de/ofb8p

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