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An Ontology Design Pattern for Historical Metrological Practices

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Abstract
The field of historical metrology studies past practices for measuring objects (or processes) as well as the transformations of such practices. This perspective leads to research questions that are distinctively different from those raised by the metrology for today's natural sciences and engineering disciplines. In this paper we explain in what way published ontologies for scientific metrology fail to capture metrological practices and their transformations. We propose an ontology design pattern for modeling the practices described in historical metrological sources. We discuss the pattern's conceptual components and link them to use cases from research in history.

Keywords
Ontology Design Pattern, Historical Metrology, Computational Humanities

1. Introduction

Quantitative data form the basis for most types of observations and predictions in the natural sciences and engineering disciplines. It is therefore not surprising that the ontological modeling of metrological knowledge, that is, knowledge about units of measurement, has been studied since the early days of the LOD cloud [1, 2]. Today, researchers and practitioners find several reliable solutions for modeling the quantitative aspects of their data [3]. A prominent example is the Ontology for units of Measure (OM) [4], which has been designed from use cases in the food industry and is currently widely adopted across a range of engineering disciplines [5]. Such ontologies focus on use cases of unit conversion. They also address the issue of dimensional and unit consistency. The formula $f[\mathrm{N}] = m[\mathrm{kg}] \cdot a[\mathrm{km/s}^2]$, for instance, is consistent with respect to the dimensions appearing in it, $f = m \cdot a$, but becomes unit consistent only after replacing km by m [4].

Scholars who study historical practices of measurement describe the specific way in which a defined social group measures a particular quantity. They identify the group (e. g. the guild of tailors in the medieval town of Regensburg) and the details of the measurement process (e. g. the repeated placing of a wooden stick on a woolen cloth). Such a historical description faces problems that are quite different from those of the measurement ontologies in engineering

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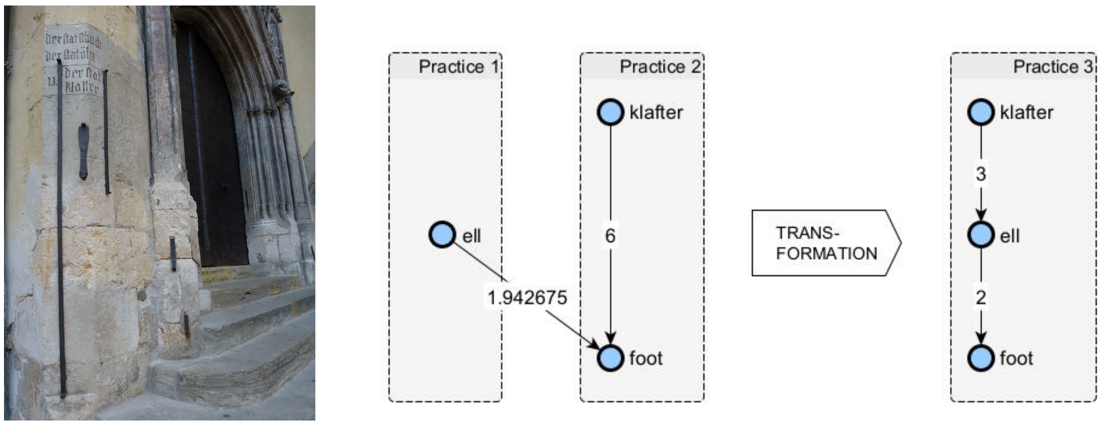

(a) Etalons (b) Transformation of measurement practices

Figure 1: (a) Physical embodiments of three base units for measuring length displayed at the town hall of the city of Regensburg, Germany. Etalons from left to right: klafter (“klafter”), foot (“schuch”), and ell (“öln”). [CC BY-SA 4.0 Hans Koberger, commons.wikimedia.org] (b) Schematic transformation of two measurement practices resulting in a single unified practice (values are fictive)

[e. g. 6, 7]. In comparison with the International System of Units (SI), which we currently use in the sciences, past systems of measurement are less complex in a number of aspects, but considerably more complex in others. They are less complex in the sense that most past practices of measurement refer to simple physical quantity types such as length or weight. There are very few compound units (e. g. velocity, density), which is why the issues of dimensional and unit consistency play a minor role. In contrast, details of the social practice of measurement turn out to be of crucial importance. This involves, for instance, describing the delicate balance between local measurement conditions, the legal regulation of measurement practices, and the latter’s hesitant adoption by the community. In order to avoid confusion, we use the term *scientific metrology* to denote the metrology for today’s sciences, and *historical metrology* for the study of past systems of measurement [6].

When we shift the perspective from scientific to historical metrology, we move the focus of attention from units of measurement to practices of measurement, and from the conversion of units to the transformation of measurement practices. An example illustrates the difference. Figure 1a shows three historical measurement standards, so-called etalons, used in the same trading place, the city of Regensburg, Germany.

The use of more than one etalon for the single physical dimension of length points to a phenomenon which historians have observed all over medieval and early modern Europe as well as in other parts of the world and in different periods (see Section 2.1). Measurement practices vary between trading places and they are often tied to specific trades or goods. The ell from Figure 1a serves for measuring cut goods such as textile fabrics whereas the dimensions of piece goods, such as the length of a table, are measured in feet. In many places, traders of silk, wool and linen used different etalons, thus creating a “wool ell” distinct from the “linen ell” and the “silk ell.” While such measurement practices may look complicated for someone used to the SI system, they are by no means impractical. After all, in the trade of wool, there is no urgent need for comparing the length of a wool fabric to that of a linen fabric.

Historical *measurement practices* are characterized by etalons which define base units. Historical reference works on measurement units identify a practice by the base unit and further descriptors, such as a place descriptor. For instance, Noback and Noback (1851) identify a measurement practice as “Elle” from “Regensburg” [8], Doursther (1840) another one as “Candi” from “Bangalore” [9]. The extraction of knowledge graphs from such reference works provides historical metrologists with a valuable research tool that is much easier to access than the digital scan of the original work and that can be interlinked with other data such as historical gazetteers.

The challenge for the ontology designer consists in modeling the measurement practices as well as their transformations. Figure 1b illustrates what type of transformation a historian might encounter. The measurement practices are described by conversion graphs which show units as nodes and fictive, though plausible, conversion factors on the edges. In this simplified example, two independent measurement practices co-exist at a first stage. Since their base units (ell, foot) are based on different etalons, the conversion factor is determined empirically (1.942675). At a second stage, with the goal of unifying the two practices, one unit (ell) is redefined in terms of the other (1 ell $= 2$ feet). A unified practice using a single etalon (foot) results from the transformation.

The ontology design pattern for historical metrology which we describe in the rest of this paper is based on the ontology for the reference work [8] in the Digital Noback project.[1] The pattern addresses the core task of historical metrology, namely to describe complex measurement practices of the past. In particular, the description includes the application domain (e. g. trade in bulk vs. packed goods; wholesale vs. retail trade) and local conventions (e. g. allowances of the measurement process). Historians are also interested to learn about the *transformation of measurement practices*. Examples for transformations are the substitution of traditional practices by a new legal one (e. g. the introduction of the meter), the differentiation of a practice into two or more special purpose practices (e. g. the creation of etalons for a wool ell and linen ell), or the simplification of a practice by redefining a unit in terms of another unit.

We describe use cases of historical metrological research in Section 2 starting with background information on the transformation of historical measurement practices from which we obtain a list of competency questions. We discuss related work in Section 3, followed by a detailed description of the ontology design pattern in Section 4. We conclude in Section 5.

2. Use Cases

2.1. Transformation of Metrological Practices

Since Antiquity, humans have developed a myriad ways to measure the weight, size and value of commodities, currencies, objects, surfaces, distances and so on. Typically, earlier measurement procedures were valid only in restricted areas and for limited periods. This resulted in a large geographical and temporal variation. In each country hundreds of different units of measurement were in use, mostly with their own, locally defined values [10, 7, 6]. Since

[1] https://www.uni-bamberg.de/en/digihist/projekte/digital-noback-project/

the sixteenth century, numerous accounts of measurement practices have been published in merchant manuals, economic dictionaries, lexicons and encyclopaedia [11, 12, 13]. Prior to the introduction of the meter around 1790, these metrological reference works fixated common knowledge about pre-modern measurement practices. They clarified the relations and ratios between different units of measurement, specified their use, and referenced local or regional measurement regulations. After the introduction of the meter, metrological reference works started to include conversions into metric equivalents (meter, liter, and kilogram) as well.

Based on a large collection of metrological reference works, Jan Gyllenbok has reproduced hundreds of systems of units in tabular form, creating what is in fact a database of unit conversions, published as a book [10]. Gyllenbok argues that systems of units are identified merely by their type and number of base units and aims at an "easy-to-survey compilation of all known metrology systems" [10]. As a result, he neglects the social practices of measurement in historical times. In so doing, Gyllenbok's understanding of historical metrology differs fundamentally from that of the Polish historian Witold Kula [6], who argued that *historical* metrology needs to take into account "(. . .) all the elements associated with measuring: systems of counting, instruments of counting, methods of using these instruments (. . .), the different methods of measuring in different social situations, and finally, the entire associated complex of interlinked, varied and often conflicting social interests." Kula understands every measurement practice as a social institution and thus as a means to further our understanding of "the cultural links between nations and civilizations" [6].

Building on Kula's seminal work, Peter Kramper has produced a detailed qualitative study of the different stages in the long quest for unification of measures as observed and discussed in the natural sciences, politics, and the economy [7]. Kramper has shown that, despite significant advances in the precision of scientific measurement, earlier measurement practices persisted in the commercial sector during much of the nineteenth century. At the same time, novel metrological regulations set in motion processes of assimilation, simplification and unification in metrological systems. These transformations also affected the commercial sector, causing tension between "traditionalists" and proponents of a unified system of measurement. A decisive step towards the latter was taken at the Meter Convention of May 20, 1875, when seventeen countries adopted the meter as standard unit of measurement.

Metrological reference works of the eighteenth and nineteenth centuries continue to be essential sources for the study of past practices for measuring objects (or events) as well as the transformation of such practices. In this paper, we focus on the handbook of weights and measures of the Nobacks [8], a "pocketbook" that consists of 1907 pages bound in two volumes. Ever since its publication, the handbook has been famous for its exhaustiveness, reliability and up-to-date contents. For decades to come, the "Noback" was "(...) by far the best and most informative merchant manual in the German speaking world" [12]. The compilers of [8] aimed at comprehensiveness. The result, which is digitally available to all, is a very dense reference work that provides systematic accounts of the weights, measures, currency relations, exchange rates, formal commercial institutions and informal customs of 954 places and regions around the world — from Aachen (Germany) via Buenos Aires, Calcutta, Nairobi and St. Petersburg, all the way to Zwolle (Netherlands). Each dictionary entry systematically describes the relations and ratios between units as well as the different uses of "larger" and "smaller" units of weight and measure, the persistent use in many areas of international business around 1850 of pre-modern units of weight and measure, and their conversion into metric equivalents. In the following sections, which tackle data modeling issues and present ontological solutions, the "Noback" serves as an exemplar for sources of historical metrology.

2.2. Scenarios and Selected Competency Questions

We present two use case scenarios from the Digital Noback project, which illustrate the type of research problems addressed by scholars in historical metrology. A knowledge graph extracted from the handbook of the Nobacks [8] permits to establish how to convert between units used in different places. In addition, and beyond what a resource such as [10] offers, it is possible to retrieve or infer facts about the social practices of measurement. The first scenario of deprecated measures describes this situation. Enriching the data by linking it to data from historical gazetteers opens further avenues for research. It enables the scholar to spatially explore the data and to search for evidence on complex transformations of measurement practices. A case in point is the imposition of a measurement system under colonial rule as described in the second scenario.

2.2.1. Deprecated Measures Scenario

The introduction of units of measurement by means of legislation and the adoption of the new units by a commercial community are different processes, of which the first not necessarily entails the second. Historians are interested in understanding what factors contribute to the persistence of traditional measurement practices. In our use case, the scholar is studying a geopolitical entity, e. g. the Kingdom of Bavaria around 1850, and tries to identify those dependent entities (cities or territories) where deprecated units of measurement are still in use. The scholar wants to learn whether there exist differences in the level of adoption between places of trade. This transformation of old (traditional) into new (legal) measurement practices is a typical object of study in historical metrology.

2.2.2. Colonial Measures Scenario

Measurement practices are often introduced for the purpose of fostering trade, but they also act as a symbol of sovereignty over a geopolitical entity. Colonial rule was an extreme form of foreign rule, in which the colonizer often imposed cultural practices such as language, religion or, for that matter, the practices for measuring goods. Different forms of European colonial rule on the Indian subcontinent around 1850, for instance, used different policies of imposing measurement practices. One policy consisted in retaining the local name of a unit, e. g. to still measure lengths in "guz," while imposing a fixed relation to a unit of the colonizing power, e. g. by redefining 1 guz = 32 inches. Historians study such transformations of local measurement practices. A "simple" conversion factor provides a first clue for such a policy. Further clues are obtained from written records of measurement practices.

2.2.3. Selected Competency Questions

Competency questions CQ 1 to CQ 5 are about the units appearing in historical measurement practices and the conversion of these units. In many cases, historians ask a question that relates to a particular source or compares several sources.

CQ 1. What type of quantity does the unit "guz" measure in Arungabad in 1850 according to source *S?*

CQ 2. What units were used in Augsburg during the period 1820–1850 for measuring weight according to source *S?*

CQ 3. How does the length unit "guz" used in Arungabad in 1850 convert to the guz used in Delhi at the same time according to source *S?*

CQ 4. Which places have "Schiffspfund" as a measurement unit for weight at some time period according to at least one source *S?*

CQ 5. Do the sources *S1* and *S2* agree on the conversion factors between the different "guz" units used on the Indian subcontinent?

Competency questions CQ 6 to CQ 10 refer to measurement practices and their transformations. CQ 6 for instance, asks for persisting measurement practices. Such cases could indicate problems with adoption, i. e., an incomplete transformation of the traditional practices into the new legal ones. CQ 8 and CQ 10 ask about a different type of transformation, the connection of a measurement practice to another one, a step towards the unification of a system of units.

CQ 6. What were the legal practices of measuring length in Augsburg in 1820–1850 according to source *S?*

CQ 7. For which places in the Kingdom of Bavaria does source *S* report the largest (smallest) number of traditional measurement practices?

CQ 8. For which places in the Kingdom of Bavaria does source *S* report practices for measuring length that are connected by simple unit conversions?

CQ 9. Which places on the Indian subcontinent in 1850 use European measurement practices that have been imposed by a colonial power (according to some source)?

CQ 10. Which types of measurement practices on the Indian subcontinent in 1850 have been redefined and bound to the metrological system of a colonial power (according to some source)?

3. Related Work

Several ontologies have been designed for publishing quantitative data within and outside the LOD paradigm. The evaluation of metrological ontologies by Keil and Schindler [3] compares eight such ontologies. Among these, OM 2.0 describes the largest number of units [4], whereas QUDT has the largest number of measurement dimensions [1]. The comparison is based on an ontology-agnostic relational model which captures common conceptualizations. This model associates the concept of measurement unit (e. g. Newton) with the concepts of dimension (e. g. $\mathrm{mass} \cdot \mathrm{length}/\mathrm{time}^2$), decimal prefix (e. g. kilo), and system of units (e. g. MKSA — meter, kilogram, second, ampere). This conceptualization clearly reflects a late stage in the history of metrology when, starting in the late nineteenth century, several competing proposals were made for universal systems of physical units. The very idea of a system of units presupposes much more conceptual uniformity, understanding of physics and mathematical formalization than what is encountered by historians who study the kind of measurement practices we presented in Section 1.

On the other hand, the idea of a measurement system hides some of the complexity that historical metrology wants to describe. This is not surprising, since the use cases of scientific metrology as specified by [4] overlap only with respect to unit conversions with the use cases of historical metrology which we have described in the preceding section. Historical metrology needs a modeling that is conceptually richer. It has at least (1) to capture the grouping of units into measurement practices, and (2) to handle the distinction between unit conversions and the decomposition or aggregation of units outside the system of decimal prefixes. None of the ontologies for scientific metrology evaluated by [3] serve that purpose.

We finally observe that there is a strand of research on metrological ontologies which is not discussed in the Semantic Web literature because its axiomatization makes use of higher-order logic [14]. Although highly relevant for inferences in the dimensional calculus, the approach, as much as the others, focuses on scientific metrology and seems not to help with our use cases.

4. The Historical Metrology Pattern

4.1. Overview

The Historical Metrology pattern provides a solution for the problem of separately describing measurement practices for which historical sources document independent uses (e. g. foot vs. ell). Practice, Transformation, Unit, and Conversion are the pattern's main components. Figure 2 shows the schema diagram of the pattern. Practice is modeled in the most detail because it is the interaction of this component with the other three that creates the intended abstraction. To put it in a simplified way, Practice and Transformation capture the historical aspects of measurement, Unit and Conversion the physical aspects.

The components Decomposition and Aggregation have a supporting function. They serve to describe the decomposition of units into subunits and the aggregation of units to superunits as operations that are distinct from unit conversions. The schema diagram also includes components that are left unmodeled. We adopt the graphical convention used by [15] and render those components by dashed blue boxes. These boxes denote classes with external dependencies on the ontology in which the pattern is used. They serve as "hooks" to a more detailed modeling.

We provide a formalization of the core components in terms of the OWL axiom patterns described by [16]. These axiom patterns are simple in the sense that they use at most three classes or roles, which is sufficient to express the relevant constraints of the Historical Metrology

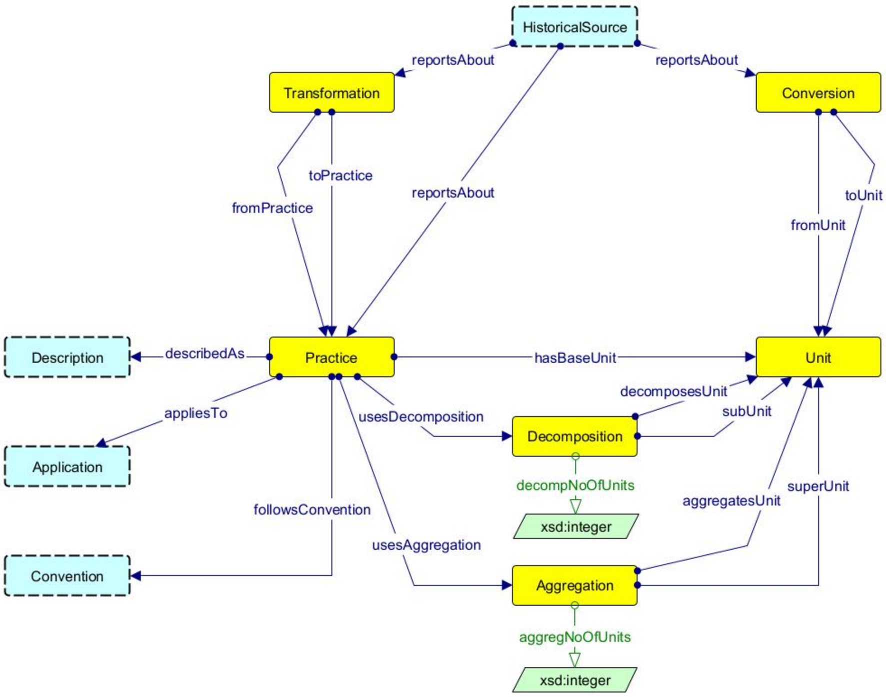

Figure 2: Schema diagram for the Historical Metrology pattern. The yellow boxes show the classes. The blue dashed boxes are "hooks" to potentially more complex modeling. Blue edges are object properties, green edges are datatype properties.

pattern. For quick orientation, we add to each formula the name of the axiom pattern as specified in the above publication. The presentation order of the axioms follows the example of [15]. That is, axioms appear in the section which discusses the source of the arrow in the schema diagram. Axioms using the property hasBaseUnit, for instance, are found in the Section 4.3 that covers Practice. The OWL file of the pattern is published online in the project repository.[2] The pattern has also been submitted to the ODP portal.[3]

4.2. HistoricalSource

Historical research starts with the study of (mostly written) sources. It is part of the work routine of historians to establish whether sources agree or disagree on an assertion about an entity or a process. While sources are at the center of the methodological concerns in history, HistoricalSource is peripheral in the Historical Metrology pattern. The concept of source is left unmodeled because of the complexity of the interpretative process that extracts assertions from sources. Depending on the application, the association of source, interpretation and assertion is modeled with more or less detail. In this context, provenance can be described by means of the EntityWithProvenance pattern from MODL [17]. The Historical Metrology

[2]https://github.com/kulturinformatik/noback
[3]http://ontologydesignpatterns.org/wiki/Submissions:HistoricalMetrology

pattern specifies that sources report about measurement practices, about their transformation, as well as about conversions between units. Note that sources only report indirectly about units, mostly through conversions that define the units in terms of some other units. Applications which deal with sources that make assertions about units without referring to measurement practices or conversions may add the possibility of reporting about units.

4.3. Practice

Historical practices of measurement are characterized by base units. A metrological source has to provide at least this piece of information to be considered a witness for the measurement practice. This is expressed by Axiom 3. In most cases, the property is also functional. While we did not encounter such cases, there might be practices that build upon two or even more base units. Specializations of the pattern can add a functionality axiom if needed.

$$\mathsf{Practice} \sqsubseteq \forall \mathsf{hasBaseUnit.Unit} \quad \text{(scoped range)} \quad (1)$$
$$\exists \mathsf{hasBaseUnit.Unit} \sqsubseteq \mathsf{Practice} \quad \text{(scoped domain)} \quad (2)$$
$$\mathsf{Practice} \sqsubseteq \exists \mathsf{hasBaseUnit.Unit} \quad \text{(existential)} \quad (3)$$

Sources refer to measurement practices by means of a Description or a combination of descriptions. The historical reference works [9] and [8] use descriptions for units and for places when they identify a practice as the one that measures in “guz” from “Bangalore.” Simple descriptions can be modeled by data properties which specify unit names or place names. An obvious choice for more complex spatial descriptors is GeoSPARQL, the Open Geospatial Consortium’s standard for geospatial linked data. Some description is required to identify the practice (Axiom 6). The Application of a practice specifies a field of application, such as measuring lengths in the trade of cut goods or, being more specific, in the trade of woolen cloth. The component is left unmodeled. It could refer to an ontology of historical craft and trade activities. Note that sources may be silent about the domain. For many practices, sources attest a local Convention, e. g. allowances.

$$\mathsf{Practice} \sqsubseteq \forall \mathsf{describedAs.Description} \quad \text{(scoped range)} \quad (4)$$
$$\exists \mathsf{describedAs.Description} \sqsubseteq \mathsf{Practice} \quad \text{(scoped domain)} \quad (5)$$
$$\mathsf{Practice} \sqsubseteq \exists \mathsf{describedAs.Description} \quad \text{(existential)} \quad (6)$$
$$\mathsf{Practice} \sqsubseteq \forall \mathsf{appliesTo.Application} \quad \text{(scoped range)} \quad (7)$$
$$\exists \mathsf{appliesTo.Application} \sqsubseteq \mathsf{Practice} \quad \text{(scoped domain)} \quad (8)$$
$$\mathsf{Practice} \sqsubseteq \forall \mathsf{followsConvention.Convention} \quad \text{(scoped range)} \quad (9)$$
$$\exists \mathsf{followsConvention.Convention} \sqsubseteq \mathsf{Practice} \quad \text{(scoped domain)} \quad (10)$$

In historical measurement practices, the Decomposition of a base unit into subunits is much less uniform and systematic than in the SI system with its decimal factors and prefixes. There is no existential axiom since some units do not have decompositions. Aggregation is treated in an analogous way.

$$\mathsf{Practice} \sqsubseteq \forall \mathsf{usesDecomposition.Decomposition} \quad \text{(s. r.)} \quad (11)$$

$$\exists \mathsf{usesDecomposition.Decomposition} \sqsubseteq \mathsf{Practice} \quad \text{(s. d.)} \quad (12)$$
$$\mathsf{Practice} \sqsubseteq \forall \mathsf{usesAggregation.Aggregation} \quad \text{(s. r.)} \quad (13)$$
$$\exists \mathsf{usesAggregation.Aggregation} \sqsubseteq \mathsf{Practice} \quad \text{(s. d.)} \quad (14)$$

4.4. Decomposition, Aggregation

Decomposition and Aggregation are mirror concepts that specify how exactly a measurement practice decomposes a unit into subunits or aggregates the unit to a superunit. Note that the aggregation of a base unit is not primarily a mathematical operation. It requires handling a measuring device such as a yardstick. The decomposition of a base unit requires a skilled manufacturing process which, for instance, subdivides a yardstick into 32 equal parts. An instance of Decomposition (Aggregation) decomposes (aggregates) exactly one Unit into decompNoOfUnits (aggregNoOfUnits) subunits (superunits). The axioms for aggregations exactly mirror those for decompositions. We omit listing them as they can be found in the published ontology.

$$\mathsf{Decomposition} \sqsubseteq \forall \mathsf{decomposesUnit.Unit} \quad \text{(scoped range)} \quad (15)$$
$$\exists \mathsf{decomposesUnit.Unit} \sqsubseteq \mathsf{Decomposition} \quad \text{(scoped domain)} \quad (16)$$
$$\mathsf{Decomposition} \sqsubseteq \exists \mathsf{decomposesUnit.Unit} \quad \text{(existential)} \quad (17)$$
$$\mathsf{Decomposition} \sqsubseteq \leq 1\ \mathsf{decomposesUnit.Unit} \quad \text{(functionality)} \quad (18)$$
$$\mathsf{Decomposition} \sqsubseteq \forall \mathsf{subUnit.Unit} \quad \text{(scoped range)} \quad (19)$$
$$\exists \mathsf{subUnit.Unit} \sqsubseteq \mathsf{Decomposition} \quad \text{(scoped domain)} \quad (20)$$
$$\mathsf{Decomposition} \sqsubseteq \exists \mathsf{subUnit.Unit} \quad \text{(existential)} \quad (21)$$
$$\mathsf{Decomposition} \sqsubseteq \leq 1\ \mathsf{subUnit.Unit} \quad \text{(functionality)} \quad (22)$$

4.5. Transformation

Historical metrologists are primarily interested in understanding the transformations of measurement practices as well as the factors that drive them. Sources, however, often describe just the status quo at the time of their writing. It is by combining sources from different points in time that a picture of the transformations emerges. This dependence on the application studied explains why it is difficult to come up with a one-size-fits-all model of transformations. The Historical Metrology pattern refrains from specifying details beyond the fact that a transformation starts from and ends in a Practice. Information about start and end may be missing in the sources.

$$\mathsf{Transformation} \sqsubseteq \forall \mathsf{fromPractice.Practice} \quad \text{(scoped range)} \quad (23)$$
$$\exists \mathsf{fromPractice.Practice} \sqsubseteq \mathsf{Transformation} \quad \text{(scoped domain)} \quad (24)$$
$$\mathsf{Transformation} \sqsubseteq \forall \mathsf{toPractice.Practice} \quad \text{(scoped range)} \quad (25)$$
$$\exists \mathsf{toPractice.Practice} \sqsubseteq \mathsf{Transformation} \quad \text{(scoped domain)} \quad (26)$$

4.6. Unit, Conversion

Historical works of reference such as [9] and [8] report conversions for many pairs of units. They do not necessarily agree on the conversion factor or the details of more complex computations, however. The pattern just specifies scoped range and scoped domain axioms for the interaction of conversions and units in order to facilitate the pattern's reuse with different ontologies for scientific metrology.

$$\mathsf{Conversion} \sqsubseteq \forall \mathsf{fromUnit}.\mathsf{Unit} \quad \text{(scoped range)} \tag{27}$$

$$\exists \mathsf{fromUnit}.\mathsf{Unit} \sqsubseteq \mathsf{Conversion} \quad \text{(scoped domain)} \tag{28}$$

$$\mathsf{Conversion} \sqsubseteq \forall \mathsf{toUnit}.\mathsf{Unit} \quad \text{(scoped range)} \tag{29}$$

$$\exists \mathsf{toUnit}.\mathsf{Unit} \sqsubseteq \mathsf{Conversion} \quad \text{(scoped domain)} \tag{30}$$

Concepts closely related to Unit and Conversion are found in ontologies of scientific metrology, for instance, the Unit concept in OM [4]. Other concepts listed in [3] are not aligned as easily. For instance, prefixes imply the uniform decomposition and aggregation of the base unit which historically were only introduced by the metric system, not until the French Revolution.

5. Conclusion and Future Perspectives

While several ontologies have been proposed for the field of scientific metrology, none of them addresses the requirements of historical metrology. As we explain in Section 1 this is due to the fact that until the nineteenth century, the practices of measuring objects in craft and trade vary greatly between the fields of application as well as between the places where they were used. We argue that the central concept for historical metrology is the measurement practice together with the concept of transformation of such practices over time. In support of this view, we describe two use cases from the Digital Noback project as well as a set of competency questions, which historians who study measurement practices intend to address (Section 2). The Historical Metrology pattern is extracted from the ontology created for that project. The pattern allows to express how measurement practices interact with their transformations and how they relate to units of measurement and their conversions. The latter two concepts act as a conceptual bridge to the ontologies for scientific metrology (Section 4).

We formulated the constraints on the pattern in form of OWL axioms, taking care to be as least restrictive as possible. We paid particular attention to incomplete historical knowledge. So it is possible to specify details of a practice without knowing much about how it was transformed. This permissive handling of the constraints should facilitate the reuse of the pattern in existing domain ontologies. Instantiations of the pattern can easily add further constraints if the domain under study warrants it. On the other hand, the pattern underpins important conceptual distinctions. The decomposition of a unit and the aggregation of a unit are treated as operations that are clearly distinct from the conversion between units.

In our future work we plan to optimize the knowledge extraction process from metrological reference works. Some of these works have been published in revised editions for several decades, thereby providing valuable information about changing measurment practices. Extracting and comparing knowledge graphs from different editions could help gaining a better understanding of the transformations of measurement practices. This would probably have an impact on the modeling of transformations as well.

References

[1] R. Raskin, M. Pan, Semantic web for earth and environmental terminology, in: Workshop on Semantic Web Technologies for Searching and Retrieving Scientific Data, 2003.

[2] J. Madin, S. Bowers, M. Schildhauer, S. Krivov, D. Pennington, F. Villa, An ontology for describing and synthesizing ecological observation data, Ecological informatics 2 (2007) 279–296.

[3] J. M. Keil, S. Schindler, Comparison and evaluation of ontologies for units of measurement, Semantic Web 10 (2019) 33–51.

[4] H. Rijgersberg, M. Van Assem, J. Top, Ontology of units of measure and related concepts, Semantic Web 4 (2013) 3–13.

[5] F. Martín-Recuerda, D. Walther, S. Eisinger, G. Moore, P. Andersen, P.-O. Opdahl, L. Hella, Revisiting ontologies of units of measure for harmonising quantity values–a use case, in: International Semantic Web Conference, Springer, 2020, pp. 551–567.

[6] W. Kula, Measures and Men, Princeton University Press, 2014.

[7] P. Kramper, The battle of the standards: Messen, Zählen und Wiegen in Westeuropa 1660-1914, Walter de Gruyter, 2019.

[8] C. Noback, F. Noback, Vollständiges Taschenbuch der Münz-, Maass- und Gewichtsverhältnisse, der Staatspapiere, des Wechsel- und Bankwesens und der Usanzen aller Länder und Handelsplätze, F. A. Brockhaus, 1851.

[9] H. Doursther, Dictionnaire universel des poids et mesures anciens et modernes, contentant des tables des monnaies de tous les pays, 1840.

[10] J. Gyllenbok, Encyclopaedia of historical metrology, weights, and measures, Springer, 2018.

[11] D. Besomi, Crises and Cycles in Economic Dictionaries and Encyclopaedias, Routledge New York, 2012.

[12] M. A. Denzel, J. C. Hocquet, H. Witthöft, Kaufmannsbücher und Handelspraktiken vom Spätmittelalter bis zum beginnenden 20. Jahrhundert, Franz Steiner Verlag, 2002.

[13] J. Hoock, P. Jeannin, W. Kaiser (Eds.), Ars mercatoria : Handbücher und Traktate für den Gebrauch des Kaufmanns, 1470-1820, Schöningh, Paderborn, 1991.

[14] M. Grüninger, B. Aameri, C. Chui, T. Hahmann, Y. Ru, Foundational ontologies for units of measure., in: FOIS, 2018, pp. 211–224.

[15] C. Shimizu, R. Zhu, M. Schildhauer, K. Janowicz, P. Hitzler, A pattern for modeling causal relations between events, in: Proceedings of the 12th Workshop on Ontology Design and Patterns (WOP 2021), 2021, pp. 38–50.

[16] A. Eberhart, C. Shimizu, S. Chowdhury, M. Sarker, P. Hitzler, et al., Expressibility of owl axioms with patterns, in: European Semantic Web Conference, Springer, 2021, pp. 230–245.

[17] C. Shimizu, Q. Hirt, P. Hitzler, Modl: a modular ontology design library, arXiv preprint arXiv:1904.05405 (2019).