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Chapter 6
Modeling and Visualizing Storylines of Historical Interactions
Kubler's *Shape of Time* and Rembrandt's *Night Watch*††

Abstract
The Golden Agents research infrastructure enables analyses of interactions between/within the creative industries of the Dutch Golden Age by bringing various heterogeneous (un)structured datasets of cultural heritage institutions together in linked open data. One of the challenges is the modeling of ontologies for the historical processes of the interactions between various branches, and between the production and consumption of these industries. These processes are described as multiple narratives for which we use the concept "storifying data." Here we try to demonstrate that current attempts to model temporality of historical data in linked data such as CIDOC-CRM, OWL-Time or PeriodO are too limited and that we might learn from historical conceptualisations of periodisation and duration. In particular, we will focus on George Kubler's *The Shape of Time: Remarks of the History of Things* (1962) and claim that his approach of the history of art as a system of linked historical sequences of formal relations is still relevant for modeling time and historical processes in ontologies and standards. The model "storylines of historical evidence" and the relevance of Kubler's views on duration and sequence will be demonstrated by the very rich case of the (re-)uses of Rembrandt's *Night Watch*.

1.0 Golden Agents: Creative industries and the Making of the Dutch Golden Age

During the Dutch Golden Age, Amsterdam developed into the world's center for trade, science and art, and was known for the size and scale of its creative industries, especially for paintings and book production (Rasterhoff 2017; Pettegree and Weduwen 2019). Until now, monographs have been written on famous artists and authors, but information on lesser known professions such as silversmiths, playwrights or appraisers in that period is still oblivious. We are even less informed about the consumption of cultural goods in Amsterdam during the Dutch Golden Age.

The project Golden Agents: Creative Industries and the Making of the Dutch Golden Age by using a combination of semantic web and multi-agent technologies aims at developing a sustainable infrastructure to study relations and interactions between 1) the various branches of the cultural industries and 2) between producers and consumers of creative

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goods across the long Golden Age of the Dutch Republic, in particular in Amsterdam. The project will link distributed, heterogeneous resources (both existing and new) on the production of the creative industries in the Dutch Golden Age from heritage institutions such as the Rijksmuseum, KB National Library of the Netherlands, and the RKD: The Netherlands Institute for Art History, and of academic institutions such as the data bases of painters in the Low Countries, ECARTICO and of theatre productions in Amsterdam in the 17th century ONSTAGE, both produced by the University of Amsterdam. Consumption remains an under-investigated topic with regard to the creative industries in the Dutch Golden Age. The digitisation of the enormously rich collection of the notarial acts (more specifically the probate inventories) in the Amsterdam City Archives, will provide data on the possessions of cultural goods by the inhabitants of all layers of society in Amsterdam as one of the most important global centers in the world in the 17th century. Finally, we believe that these big data of the production and consumption can provide more insight in concepts of creativity and innovation in the Dutch Golden Age and potentially contribute to the history of taste. For instance, Angela Jager (2[illegible]), in her PhD research, was able to nuance the view in the historiography of Dutch painting of the Dutch Golden Age that history paintings were the most expensive and the highest praised works of art. On the basis of prices mentioned in a few probate inventories in the notary acts she revealed that much cheaper versions were produced for the lower end of the art market. This revelation is promising because the Golden Agents has the intention of opening up the contents of 2,000,000 scans of notarial deeds such as baptism, marriage and burial registries, and other document types of the Amsterdam City Archives that give insight into the households of the more common Amsterdamer and not just of the elite culture during the Dutch Golden Age. This allows us to (partially) construct storylines about inhabitants of Amsterdam and the (type of) objects they possessed or traded.

2.0 Storifying data: Modeling historical knowledge

> Historical Truth, because it has nothing to correspond with, can only be defined as coherence with the understanding of the past (documents, including material culture) and the concepts we share with our predecessors and interlocutors (Shaw 2010, 6-7).

The Golden Agents research infrastructure enables analyses of interactions within the creative industries of the Dutch Golden Age by bringing various heterogeneous (un)structured datasets of cultural heritage institutions together in linked open data (LOD). One of the challenges is the modeling of ontologies for the historical processes of the interactions between various branches, and between the production and consumption of these industries. These processes are described as multiple narratives for which we use the concept "storifying data" (Zamborlini, Betti and Heuvel 2017).

These multiple stories developed over time in parallel orders, for instance the order in the making of an object (from idea to final product), the order of an object in the artistic life or oeuvre of its maker, the order between the original object and copies and transformations hereof and finally the order of the object within history or in fictional time depicted in paintings or described in stories. The parallel development of these multiple stories over time can be described in events to capture the historical discourses of that expanding cultural world in ontologies.

Ryan Shaw, in his Phd dissertation *Events and Periods as Concepts for Organizing Historical Knowledge*, stated eloquently that knowledge organisation (KO) is not applied to history, but that history is a form of KO. Historians produce knowledge of the past by organizing the past, by organizing documents, concepts and the systems that facilitate the processes of KO (Shaw 2010, 2 and 94). This requires not only an understanding of the applied ontologies, but also of how the historical concepts in the Golden Agent projects are organised. Shaw distinguishes three senses of the word "history:"

1) history-as-past i.e. all actions and happenings before the present time;

2) history-as-portrait as referring to some organised structure to represent the past in the form of a narrative –a story; and,

3) history-as-practice that refers to history as a discipline.

The latter also encompasses the ways historians engage with the cultural heritage of material culture and documents. Shaw rightly stresses the risk that we develop systems that portray history rather than supporting doing history. This in his view requires describing the concepts historians construct in order to describe the past and of the documents they use to describe them: i.e., history as conceptualisation (Shaw 2010, 4-5). In a recent paper Igor Frank (2019) advocates an applied ontology for digital history informed by philosophy of history to make the conceptualisations of historians explicit. His applied ontology approach to represent historical reality is directed at: 1) grasping historical processes; 2) representing multiple perspectives of different actors involved in historical events; and, 3) representing views according to different historical sources. Although all these facets of this multi-perspectival representation of knowledge make part of the Storifying Data Model, in this chapter we will in particular discuss the modeling of historical processes by focusing on time and periodisation that is not included in his discussion.

2.1 Periodisation and events in historical discourse

Frank's ([6]) warning not to commit "cliocide" by modeling away all the crucial subtleties of historical reality is well taken. However, if we follow the observation of Shaw, history itself is a form of KO (and not just applied to history); it is not sufficient to model the representation of that reality from multiple perspectives, but characteristics of history of KO should be modelled as well. One important, if not the most important, characteristic of history as KO is the preoccupation of historians with the organisation of events in time, that is, the representation of historical events in a temporal order.

The representation of time and temporal order in linked data (LD) goes beyond the common practice in applied ontology in digital history of mapping a historical event in a given place to the right (Georgian, Julian, Chinese etc.) calendar. Important is the PeriodO initiative to create a gazetteer of period definitions. However, it is not sufficient to map vague period names to more precise chronological coordinates as confined events. More flexible at first sight seems the development of the ChronOntology gazetteer (iDai.chronontology) that connects temporal (and spatial) information of "types." (Schmidle et al. 2016). In this way, for instance, the type "painting" as an object of material culture of the Italian Renaissance could be linked as (space-time) to an area described as Renaissance regardless of what we know about its extent. This allows periods, such as the "Renaissance" to take place at different times and in different regions, for instance the Renaissance in Low Countries. However, all these valiant attempts to create time models that can handle some fuzziness in periodisation in practice (regardless from the question of

how relevant it is to stylistic classifications for periodisation as we will discuss in the next section) are still calendar-focused and lack a conceptualisation of time itself. Recently, the theoretical physicist Carlo Rovelli (2018, 103) in *The Order of Time* argued that there is no need to choose a privileged variable and call it time. It would suffice to have a theory of dynamic relations that tells us how the things we see in the world vary with respect to each other. Probably these different world views and various perceptions of time in different cultures explain why so many philosophers, scientists and historians have tried to get a grip on periodisation and temporality in their disciplines. Toyoshima (2019) tried to describe the foundations of an ontology of time with a practical function in the domain of the digital humanities and opted on the comparative analysis of adherents of presentism, eternalism and the so-called growing block theory for the latter because it acknowledges in the temporal ontology the past (unlike) presentism, but not the future (unlike the eternalists).

Kauppinen et al. (2010) tried to explain the relevance of imprecise temporal intervals for information retrieval in the domain of cultural heritage. Although both studies provide some points of reference for annotation of cultural objects in cultural heritage applications in more or less precise time intervals, problems remain with the ontological representation of the co-occurence of multiple natural/real and fictional/abstract time intervals. Galton (2018) brings such problems to the front in a comparative analysis of the treatment of time in the upper ontologies BFO, DOLCE and GFO in which he points to their respective inconsistencies in modelling space-time with Einstein's relativity theory. This might seem far-fetched as bridging the gap between insights of physical theories and philosophical debates about the nature of time is not the aim of our model. However, we need to get a grip on issues of realism versus conceptualism of time and of multi-dimensional representations of space-time, with abstract or fictional notions of time when we try to model concepts of events or durations in (the making of) cultural objects. How do we model for instance the co-occurence of time of Gustave Courbet's symbolic portrayal of "L'Origine du Monde" with his depiction in close-up of the vagina of a naked woman in his provocative painting of 1866? Or how do we model the multiple events of the story of another famous painting, that of the *Adoration of the Magi* of Gentile da Fabriano of 1423, in which the three kings are appearing and disappearing behind rocks to express the (narrative) time of their journey in a (as art historians in the German language call it beautifully) "kontinuierende Darstellung" in one framed panel. We cannot discuss all these conceptualisations of time. Only those will be referred to that are relevant for modeling our concepts of events, narration and historical evidence.

One of the most classical examples of periodisation in the historiography of the historical disciplines is Fernand Braudel's conception of serial history in events (very short term); conjuncture or cyclical time (intermediate duration) and "longue durée" (structural change) that dominated the French historiography of the Annales School (Tomich 2012). Braudel's notion of time, i.e., of plural time, is interesting because it unites multi-layered geophysical-social space and historical time. His concept of conjuncture borrowed from economics that integrates correlations observed across multiple quantitative time series is of particular interest for the discussion further below of Kubler's *Shape of Time*. However, Braudel's model of time is also problematic because events are not necessarily short happenings but can vary in time and also be read in terms of narratives (Ricoeur 1980 and 1984; Shaw 2010, 53). Moreover, this interpretation of an event as something that happened over a very short period of time does not coincide with the use of historical events within the semantic

web paradigm. To this end Shaw (2013), on the basis of his dissertation, proposed a semantic tool informing users about events in historical discourse and formulated the requirements and criteria to individuate them. He distinguishes between events as concrete individual things and events as abstractions from narratives. Shaw finally defines an event as "something that happened" and stresses the point that unlike other definitions it does specify a change of state or a distinction of events from states or processes.

2.2 Narration and visualisation of historical events and processes

In the context of our model Shaw's semantic tool is not only of interest for its definition of events in relation to temporality and periodisation, but also for its role in selecting events in relation to documents. In Shaw's view (2013, 42) a document can be both a portrayal of an event and provide some evidence for some event, i.e., document-as-evidence. A document can become historical evidence after a historian has studied and made some assessments about the status of the document as a less or more trustworthy representation of the past. The latter is only possible by a portrayal or narration of the event. Since events are not explicitly named, the kind of relationship between document and the event needs to be visualised by putting it into context. In short, events need to be linked to time, place and related concepts, as well as put in the context of narratives. For understanding the historical discourse, a variety of (one may add sometimes conflicting) stories need to be told about the past (compare Shaw 2013, 45).

While the modeling of periods and events in standards such as CIDOC-CRM is not always straightforward, capturing the role of narratives in historical discourse and the role of documentation as source of evidence is even more difficult. Standards developed in the cultural heritage domain such as CIDOC-CRM support the structuring of the metadata of material artefacts and documents as cultural or bibliographic objects quite well. However, they are not always suitable for modelling (meta-)data for historical research. Frank (2019) for that reason set up a case study using Ontology Design Patterns in combination with DOLCE to explain the procedure of "colligation" to trace and to classify the relations between events based on chronological relations, mereological relations and causal relations (visualised in UML diagrams) in order to locate them in their historical context. At the same time, he explained that his Description and Situations Ontology Design Patterns (DnS) all can be expressed in CIDOC-CRM classes as well.

Similar attempts bring historians together in the DataforHistory.org consortium. It was created during a two-day meeting (23-24 November) in 2017 in Lyon on the initiative of Francesco Beretta and George Bruseker with the aim to develop ontologies for history that are complementary to the CIDOC-CRM, but still fully comply to this standard in order to guarantee optimal interoperability between the data of historical research projects and of cultural heritage institutions.

Within the Data for History consortium a working group concentrates on the modelling of storylines.[1] It was brought together by Charles van den Heuvel and includes members of the very interesting Narratives in Digital Libraries project (Bartalezi, Meghini and Metilli 2017) that models and connects narrative events in literature, but unfortunately does not allow for representing multiple time-sequences. Promising is the multiple strata (material, cultural, institutional) approach of life cycles of cultural goods that Karl Pineau presented at the 3rdData for History meeting (Pineau 2019). Alex Butterworth organised a panel at the Digital Humanitites (DH) 2019 conference in Utrecht that discussed alternative

ways of visualizing literary and historical narratives and chronotypes. (Butterworth et al. 2019). In the context of the development of our model of storylines that provide insight in historical evidence the work of another member of this working group, Regina Varniene-Janssen is relevant. She contributes to the Virtual Electronic Heritage Information System VEPIS project that develops long-term strategies to support interoperability regarding the authenticity and provenance of digital content of the National Library of Lithuania with other cultural heritage institutions such as Europeana (Varnienė-Janssen and Kuprienė 2018).

Although the creation of the model storylines of historical evidence started before the creation of the Data for History.org consortium it brings together several of the features that the "storylines" working group members are developing separately in the context of their own projects. Similar to the Narratives in Digital Libraries it connects narrative events but differently it allows for representing multiple time sequences. The latter is also the case in the life cycles of the cultural goods model of Pineau, but our model is not restricted by his three material, cultural and institutional strata, or Butterworth's macro, meso and micro levels that resonate Braudel's model of duration. Our storyline model includes in principle infinite parallel time sequences. The visualisation of these storylines is not only intended to explore and to switch between events and narratives, but also as an instrument of critical inquiry to assess the quality of the data and discourses on the basis of their provenance. In that regard we try with the model to explore the potential of the graphic arts to query knowledge production in a critical way from a humanist perspective as advocated by Drucker (2009 and 2014). However, we do not try in the model to distinguish these graphical explorations from more technical, analytical models of KO, but rather to reconcile them.

For the development of the storylines of historical interactions model, we were inspired by the work of George Kubler, *The Shape of Time: Remarks of the History of Things* (1962). This study is not only interesting for bringing in views on temporality, periodisation and narration in historical discourse in addition to those of authors discussed by Ryan Shaw (2010) in the rich historiographical overview when discussing their interpretations in his conceptualisation and modeling of periods and events in organizing historical knowledge. Kubler's *Shape of Time* is of particular of interest for our model because his discussion of the concepts of temporality, periodisation and narratives is more closely related to our aim to develop an infrastructure that can be used by researchers to use cultural heritage data and that allows cultural and art historians to deal with questions concerned with style and innovation, but also of replication to explain the boom of the creative industries of the Dutch Golden Age.

3.0 Kubler and *The Shape of Time*

> The "history of things" is intended to reunite ideas and objects under the rubric of visual forms: the term includes both artifacts and works of arts, both replicas and unique examples, both tools and expressions- in short, all materials worked by human hands under the guidance of connected ideas developed in temporal sequence. From all these things a shape in time emerges (Kubler 1962, 9).

3.1 The *Shape of Time*: Remarks on the history of things

In the preamble of the *Shape of Time* (1962), Kubler explains the motivation of his provocative work in the history of art. Instead of focusing on the work of art as a symbolic

expression of which its meaning needs to be explained, Kubler proposes another definition of art "as a system of formal relations." While in his view no meaning can be conveyed without form, structural forms can be perceived independently from meaning. The purpose of *The Shape of Time* is to (viii): "draw attention to some of the morphological problems of duration in series and sequence." Kubler's work is so much discussed by art historians because it questions and even dismisses the usefulness of their commonly used words to describe the arts, such as "style" which both is used to group objects with similar characteristics over a longer period of time and to describe often several successive changes in features within the oeuvre of an individual artist during his lifetime. In the context of the discussion above it is also interesting that Kubler discusses problems related to narration such as the limitations of biographies describing the lives of artists to describe the talent and the genius of artists. To paraphrase Kubler, both Leonardo and Raphael were talented; Romano was as well, but as a follower just had "bad luck" (7). Kubler proposes an alternative history, i.e., a history of things that consists of ideas and of objects ranging from unique artifacts to replicas all connected in temporal sequence. It is the task of the historian, similar to that of the astronomer, to collect "ancient signals" and transformations hereof in order to develop compelling theories about distance and composition. To order and class events extracted from these signals and to verify and test all their evidence is the principal task for the historian (20-21). Kubler classes things in formal sequences not so much as objects in time, but as sequences of solutions. In his example of churches built between 1140 and 1350 in Northern Europe, Kubler states (37): "The formal sequence is not 'cathedrals'. It is more like 'segmented structures with rib vaults.'" This allows him to distinguish fashions with a very brief duration as being without substantial change in the connected chain of solutions (39). The challenge is to individuate to find such sequences of solutions to find the things that shape time.

3.1.1 Things

> There are prime objects and replicas as well as the spectator's and the artist's views of the situation of the work in time (Kubler 1962, 39).

Things in Kubler's model include not only objects and ideas, but perceptions from multiple perspectives hereof as well. He distinguishes between prime objects and replications. Prime objects are similar to prime numbers that have no divisors as themselves and therefore cannot be decomposed in entities. Replications on the other hand comprehend an entire system of replicas, reproductions, copies, reductions and other derivations of an important work of art. Since a formal sequence can only be deduced from things we need an understanding from this system of prime objects and replications. While the number of prime objects for their uniqueness is very limited, our knowledge of sequences has to be mainly based upon replications. Therefore, most of our evidence is based on copies or other derivatives. This system of prime objects and replications has a logical order in the sense that a replication can never precede the prime object. This object however, can live on over a long period of time in all sorts of derivatives. For that reason, Kubler speaks (55) of a "systematic age of each item in a formal series according to its position in the duration." Old and new series of things coexist simultaneously at every historical moment, save the first. The reason for this is historical change in which the conditions and circumstances alter from one moment to the other. However, these processes of change and in our attitudes

towards them, shape the occurrence of things. As Kubler explains it eloquently (62): "We cultivate 'avantgardisme' together with the conservative reactions that radical innovation generates." He propagates things in processes of invention, repetition and discard. The propagation of things as processes of invention, repetition and discard needs to be measured in time.

3.1.2 Time

> Calendar time indicates nothing about the changing pace of events (Kubler 1962, 83).

Like most historians, philosophers and scientists that try to define time, Kubler tries to distinguish between absolute or solar time on the one hand and time ordered by mankind on the other. For the latter he deplores the lack of sound theories of temporal structure and speaks of "few old ways of grouping events" (96). Nevertheless, these ways of grouping events are not random, but can be measured systematically, hence the aforementioned term "systematic age." Within the historical disciplines Kubler is not so much interested in divisions in calendar time that arrange one event after the other. Similarly, he sees decades or centuries as arbitrary intervals and prefers the length of human generation as a unit. For that reason, Kubler bases his measurements not on numbers but on relations between events that express variations in duration in the lives or successive generations of artists. He analyzes variations in pace, differences between slow and fast happenings of events in tribal or urban cultures or in the lives of individual artists (86):

> The pace and tone of an artist's life can tell us much about his historical situation, although most artist's lives are uninteresting. They fall usually into routine divisions: apprenticeship, early commissions, marriage, family, mature work, pupils and followers. Sometimes the artist travels, and occasionally his path crosses those of more colorful persons.

Of particular interest are for Kubler the shape and forms of durations that last longer than a single human life (more to the point, the working life of the ma[illegible] art) or which require the time of more than one person for which he uses the term collective durations. He proposes to use "indiction" as the module. It is of course an approximation, but Kubler bases this module on a time span of ca. 50-60 years as the usual duration of an artist's life which can be subdivided in four stages—preparation, early, middle and late maturity—of about 15 years. Certain time intervals of linked events in the history of art—for instance to describe technical developments such as the early history of the rib-vaulted construction of Gothic architecture—according to Kubler, take intervals of doubled 60 years duration. Kubler calls it an empirical description of sequences in the history of art that allows us to avoid talking about styles of art, but instead to analyze the history of special forms among related examples occuring in limited regions (101-3). Kubler introduces new classes of duration when the series of successive events temporarily are interrupted, the so-called intermittent classes. There are two kinds of intermittent classes: those which lapse inside the same cultural grouping and those that span different cultures. In the history of art, the first kind of intermittent class is important for understanding the revival of specific forms within a specific culture, for instance the re-use of the classical architectural language in the Italian Renaissance. The second kind of intermittent class, that of transcultural diffusion, is of particular interest for the Golden Agents projects to describe the period of the cross-fertilisation between decorations on Chinese porcelain and Dutch earthenware when the art market of Amsterdam in the Golden Age opened up to the Far East. Finally, Kubler distinguishes between wandering and simultaneous series. An example of the first series is

the re-use of the same architectural ornaments of the Italian Renaissance in a later stage in the Dutch Republic that for instance were transmitted by examples in treatises and model books. Simultaneous series describe the opposite, that is different classes of specific forms in the same time interval. In short, Kubler does not provide a periodisation of one continuous timeline (compare Braudel's events, conjuncture and "longue durée") but his systematic age consists of relationships between changing classes of forms and changing classes of duration in multiple sequences.

3.1.3 Visualing the *Shape of Time*

> Instead we can imagine the flow of time as assuming the shapes of fibrous bundles with each fiber corresponding to a need upon a particular theatre of action, and the lengths of the fibers varying as to the duration of each need and the solutions to its problems (Kubler 1962, 122).

It is surprising that Kubler's art-historical analysis with the title *The Shape of Time* has only one tiny image hidden away in a footnote to the text. It concerns a visualisation of a directed graph (that is a network in which the relations (links) between the nodes are not reciprocal) provided to Kubler by his colleague at Yale University, the mathematician Øystein Ore, one of the pioneers of graph theory with whom he corresponded about the concept of series and sequences. We do not know exactly what Kubler asked but Ore's reaction was supportive, but at the same time somehow critical (33-34 n3):

> In attempting to give a systematic presentation of so complex a subject matter one would be inclined, as in the natural sciences, to look to the mathematicians for some pattern to serve as a descriptive principle. The mathematical concepts of series and sequences came to mind but after some thought these appear to be too special for the problem at hand. However, the less known field of networks or directed graphs seems to be considerably more suitable. We are concerned with the variety of stages in the creativity of the human race ... There are a variety of directions that may be selected. Some represent actual happenings. Others are only possible steps among many available ones. Similarly, each stage may have occurred among several possible steps leading to the same result ... The graphs shall be a-cyclic, that is, there exists no cyclic directed path returning to its original stage. This essentially corresponds to the observation about human progress that it never returns to the previous conditions.

The quotation from Ore's reply to Kubler (only partly represented here) is a long one, but we include it for two reasons. First of all, it is a direct reference to the expectations of the potential of graph theory in the future that we use now to model the data and agents of the Golden Agents project using semantic web and artificial intelligence technologies to which we will return later when we discuss the implications of using Kubler's model of time for our ontologies and mappings to existing ontology standards. Second, Ore's reply reveals how Kubler tried to legitimise his alternative model of time in art history with expertise from other disciplines such as, in this case, mathematics. However, it can be questioned whether he fully understood the implications of Ore's picture of the mathematical concept of directed graph or network. This might even be the reason perhaps why he just left the discussion of the network as a note. Kubler certainly imagines his model of time, at least part of it, as a network when describing the sequence of forms in duration (37-8):

> The closest definition of a formal sequence that we now can venture is to affirm it as a historical network of gradually altered repetitions of the same trait. The sequence might therefore be described as having an armature. In cross section let us say that it shows a network, a mesh or a cluster of subordinate traits; and in long section that it has a fiber-like structure of temporal stages, all recognizably similar, yet altering in their mesh from beginning to end.

When we try to envision Kubler's description it becomes clear that it is quite different from Ore's picture of a directed network. In that respect recent 3-dimensional timeline tools such as that developed by Matt Jensen (2006, fig. 4) for NewsBLIP might express Kubler's idea better (our Figure 1).

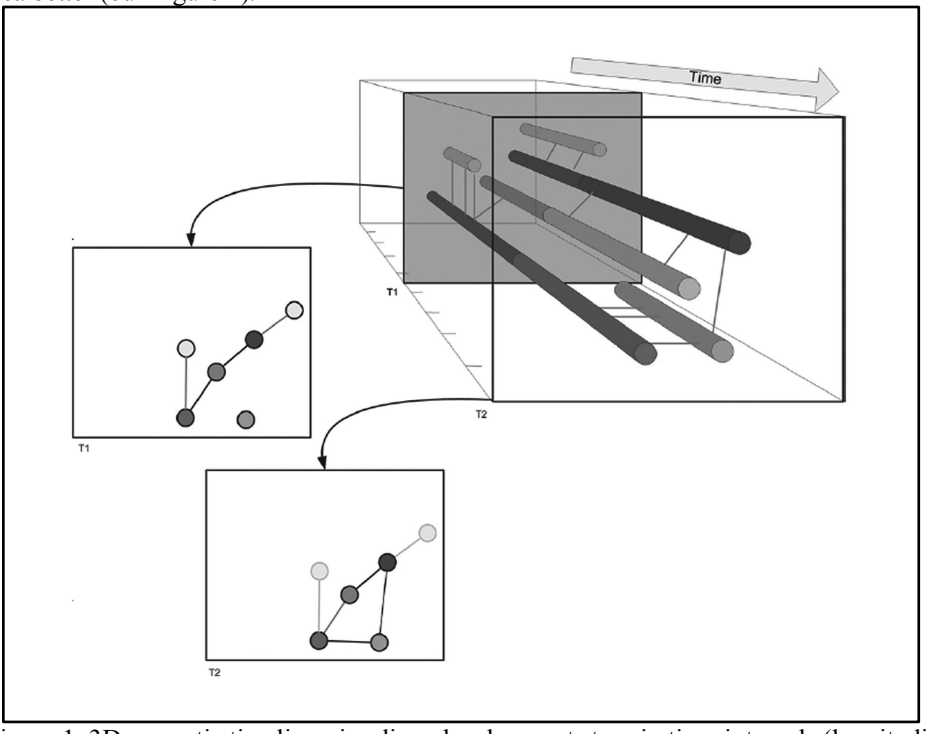

Figure 1. 3D semantic timeline-visualises development story in time-intervals (longitudinal) and network of relations between storylines (transversal) similar to Kubler's description of fibers of duration and networks in cross-section (Jensen 2006).

The limitations of Kubler's different reading of the role of networks could have in his model of duration compared to Ore's interpretation thereof becomes apparent when he tries to juxtapose his fibers of duration with the circular lenses of followers of "Strukturforschung" that tend to read the expressions of poets and artists of one place and time as radial or central patterns varying in thickness according to their antiquity (27 and 121-2). It seems that Kubler was not able to grasp the full potential of Ore's explanation of the directed network of his model by reading the formal sequences of durations just in longitudinal and transversal ways (i.e. strictly flat) instead of exploiting the full potential of the graph in which the longitudinal and transversal allow for traversing pathways in more than two dimensions.

3.2 The *Shape of Time* reconsidered: Kubler on style and historical time

> Style is like a rainbow. It is a phenomenon of perception governed by the coincidence of certain physical conditions .... Whenever we think we can grasp it, as in the work of an individual painter, it dissolves into the

farther perspectives of the work of that painter's predecessors or his followers, and it multiplies even in the painter's single works (Kubler 1962, 129).

Directly after its publication Kubler's *Shape of Time* received much attention in the world of art history, anthropology, linguistics, philosophy and other disciplines. We cannot discuss all the reviews. For our model it is interesting to see how he reacted to the various comments. Twenty years after its publication, Kubler wrote a comment (1982) with the title "*The Shape of Time* Reconsidered." In this comment he replied to some of his critics such as Priscilla Colt (1963) who had questioned whether the study of style necessarily is precluded by the study of formal sequences. In reply to her critical remarks, Kubler referred to his later publications (Kubler 1967 and [1979] 1987) with elaborations on his view on style. These later works are of interest because Kubler published herein additional "axiomas" (1967) later turned into reduced "postulates" ([1979] 1987) to explain his views on style in relation to those of art historians. Kubler formulated the following special postulates about visual style ([1979] 1987, 167).

- Style comprises acts undergoing change
- Style appears only among time-bound elements
- No human acts escape time
- Different styles coexist at the same time
- Style is more synchronic than diachronic, consisting of acts of undergoing change

Styles in the view of Kubler are historical configurations that are neither perpetual nor in random change. Style is only identifiable among time-bound elements. However, because the components are always in change the relation among them is a changing one. Although all human action has its styles, their configurations are more instantaneous and synchronic, than extended in duration. For that reason, it is best adapted to static situations in cross-cut or synchronous sections. It is unsuited to duration, because of the changing nature of every class in duration. (Kubler 1967: 855). We do not know whether Priscilla Colt was satisfied with Kubler's elaborations of the relations between style and formal sequences in historical time. It seems that Kubler, although he nuanced the tone of his formulations somehow, just tried to bring in additional arguments in particular from the natural sciences to support his case. Priscilla Colt's (1963, 79) main reservation with Kubler's theory was that it was mainly concerned with the problems of describing change rather than with explaining it. Moreover, she deplored that Kubler did not alter the methods at hand. Kubler indeed in the preamble of his *Shape of Time* immediately had set aside studies that focused on symbolic expressions and the meaning of art instead of formal relations. However, also our ontological model of storylines of historical evidence is in the first place descriptive instead of explanatory. It supports in the first place the semantic web and multi-agent technologies to link and to query data of the distributed collections of the infrastructure that allows researchers of the creative Dutch Golden Age in Amsterdam to ask questions and to test hypotheses for further interpretations and explanations.

4.0 Modeling Rembrandt's *Night Watch* in Storylines

4.1 Rembrandt thinking and painting: The *Night Watch* as a prime object

While the Golden Agents project tries to break with the canon of art history by analyzing the consumption of cultural goods in all layers of society instead of in elite culture, for the modeling the most famous painter of the Dutch Golden Age, Rembrandt, and his most famous painting *The Night Watch* of 1642 were chosen. We opted for a painter with many

pupils and copyists, for a work of art with multiple archival sources of commissions and provenance (Dudok van Heel 1987 and 2006; Remdoc), with a rich material history of production, re-use and restoration and with contemporary copies and later derivatives in other formats to make a rich model that includes as many past and present stories and perspectives as possible. Rembrandt and his *Night Watch* meet those requirements for an inclusive model.

The Rembrandt Research Project that run from 1968 until 2014 under the guidance of the expert Ernst van de Wetering and resulted in *A Corpus of Rembrandt Paintings* (Bruyn et al. 2015) in six volumes in which attributions to master and pupils changed continuously made gradually clear that connoisseurship based on stylistic criteria did not suffice and that additional material research based on methods of the natural sciences was needed to establish the corpus of 340 paintings by Rembrandt. However, additional publications by Van de Wetering, *Rembrandt the Painter at Work* (2009) and *Rembrandt The Painter Thinking* (2016) confirm the view of Kubler (things are ideas and objects) that thinking about and the practices of making paintings cannot be separated from the materiality of the painted objects. Using contemporary sources about painting materials, methods and art theory, Van de Wetering reconstructs and contextualises Rembrandt's working practices and exploration of the foundations of the art of painting in his time and explains that changes in his way of working cannot simply be attributed to stylistic evolution in his work.

Without doubt the *Night Watch* is Rembrandt's most famous and replicated work. In the traditional historiography this masterpiece might be called, in Kubler's definition, a primal object that denotes a principal invention. Several authors, referring to the comments of contemporary and later critics underlined Rembrandt's break with tradition in the composition of group portraits that focused on the faces of the individual people as recognisable entities. For instance, Rembrandt's pupil Samuel van Hoogstraten, in his *Inleyding tot de hooge schoole der schilderkonst: anders de zichtbare werelt* of 1678, praised the overall composition in which figures on the foreground were more roughly painted while those in the back more neatly draw the attention of the viewer to the whole instead of to individual parts (Wetering 2009, 181-5). However, recently Middelkoop nuanced this view (2019, 190) and stated that other lesser known painters, such as Ketel, Badens and De Keyser already used aspects of Rembrandt's composition techniques. *The Night Watch* stands in a long tradition of the so-called institutional group portraits that were produced in Amsterdam between ca. 1525 and 1850. Apparently, it was a very popular genre in the 17th century. Between 1617 and 1650, 80% of the 600 regents, guilds or arquebusiers active in Amsterdam were portrayed in such portraits (Middelkoop 2019, 717). Kubler's observation that in the wake of prime objects a whole system floats of replica's, reproductions, copies, reductions, etc., that are so important to understand the original better because they provide more evidence, seems also to be the case when we unpack the history of the *Night Watch* in multiple storylines.

4.2 *The Night Watch* in Storylines

4.2.1 Stories of *The Night Watch*: The original object

The Night Watch is not only a grand work; it is a big object which measures of 379.5 cm x 453.5 cm (149.4 x 178.5 inches), and it used to be even bigger. When *The Night Watch* changed ownership from the militia of Frans Banning Cocq who had commissioned the

work to the city of Amsterdam it was cut in 1715 to move it from its original location from the Kloveniersdoelen to the Townhall of Amsterdam.

We do not know exactly its original measurements but the system of derivatives, in Kubler's words, allows us to infer this information. A drawing in the family album of Frans Banning Cocq, a painting of 1647 attributed to the contemporary copyist Gerrit Lundens, in the Rijksmuseum on loan from the National Gallery in London, and an etching after the original of Lambertus Antonius Claessens of 1797 (see Figure 2) provides crucial contextual information to understand the original depicted scene and *The Night Watch* as an object. The copy of *The Night Watch* attributed to Lundens was painted on panel instead of canvas and was smaller in size, but it shows which parts of the scene were cut, which figures were added later and what the dimensions of the original must have been. Moreover, the smaller copy attributed to Lundens was used to make a virtual reconstruction of *The Night Watch*.

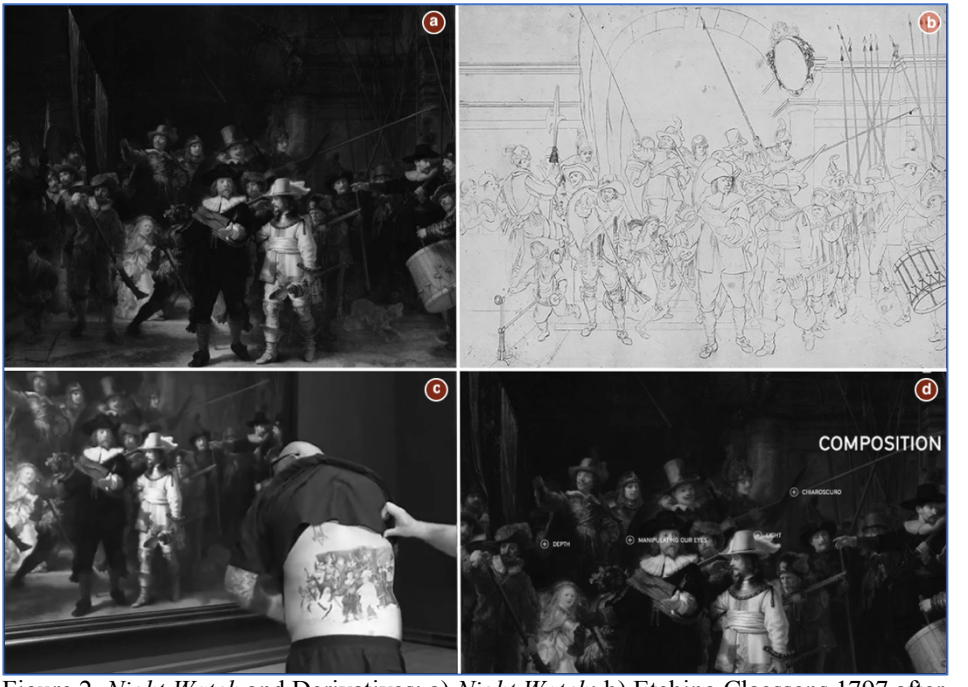

Figure 2. *Night Watch* and Derivatives: a) *Night Watch*; b) Etching Claessens 1797 after original; c) Tattoo of *Night Watch* on back Marko Bak during visit to the Rijksmuseum on 18th of May, 2019; and, d) storytelling about the composition of *The Night Watch* by the Rijksmuseum).

The research photographer Rene Gerritsen on commision of Ernst van de Wetering combined x-ray images made by Guido van der Voorde in the 1970s with digital photographs of Lundens' copy to reconstruct *The Night Watch* in its original dimensions and with a representation of the figures that Rembrandt had included in his work (Gerritsen n.d.; Middelkoop 2019) The digital *Night Watch* in its original dimensions was one of the 340 reproduced works, including those damaged and stolen included at the virtual exhibition

"Discover Rembrandt: His Life and all his Paintings" (https://www.discoverrembrandt.com/en/) that opened in the RAI Amsterdam Convention Centre on the 5th of July 2019.

This attention to the original dimensions of *The Night Watch* might seem farfetched, but for the making of group portraits as Middelkoop has demonstrated, the architectural setting, or more specifically the availability of space on the wall, often determined the commissions. In the case of *The Night Watch* its original size makes part of a larger debate between art historians whether Rembrandt could have painted this big object on location in the Kloveniersdoelen or in the house at Jodenbreestraat (now the Rembrandt House Museum) that he bought shortly before the commission, or in a gallery built as an extension to this house in its courtyard. It is the beginning of a long storyline that traces the long material history of *The Night Watch* that since it was cut in 1715, was overpainted, attacked by a knife in 1911 and 1975, sprayed with a chemical in 1990 and restored several times. As we write this story, *The Night Watch* is since July 2019 once again in restoration which can be viewed live by visitors to the Rijksmuseum or by followers on line of "Operation *Night Watch*."

4.2.2 Stories of *The Night Watch* in Derivatives

Apart from this material history of the painting, the story of *The Night Watch* lived on in many other media. It inspired, for instance, Peter Greenaway to make a film, Mikhail Dronov and Alexander Taratynov to cast the arquebusiers in freestanding bronze statues and finally a theater company to bring The Shooting Company of Frans Banning Cocq to live midst the shopping public in Amsterdam as a part of a commercial for a Dutch bank. Endearing is the story documented on the 18th of May 2019 on YouTube (https://www.youtube.com/watch?v=WJAKFjn0ODk) of the 51 year-old trucker Marko Bak, who in the making of a tattoo of *The Night Watch* on his back together with his tattooist Richard van Meerkerk, visited the Rijksmuseum to compare it with the original. Although at that time still two or three tattoo-sessions of seven hours were needed to complete the copy, the tattoo already differed considerably since Bak had asked to change some of the faces of the figures on the painting to those of his own family members and friends. Marko's mother who up to now always lamented her son's tattoos was finally proud of this one because her portrait would be included.

The sources of evidence of the very rich story of the production, re-use and restoration of *The Night Watch* with its many copies and derivatives in other media is just one of the many stories of the history of this painting that allows us to storify data in related, partially overlapping timelines as input for modeling historical processes in knowledge graphs.

An example of how these stories of *The Night Watch* in copies and adaptations in terms of production and consumption relate to each other is visualised in Figure 3. In this figure and similar figures following, the horizontal arrowed lines represent storylines for certain entities. The arrows represent continuity (for undetermined time) in one or the other direction. The curved symbol that may connect the lines represents events in which the covered entities participate, and which are described with balloons. For convenience, some entities may be omitted, such as who resized *The Night Watch* in 1715. Observe that the events concerning the copies and adaptations (in orange) of the Night Watch are preceded by consumption events (in dark blue).

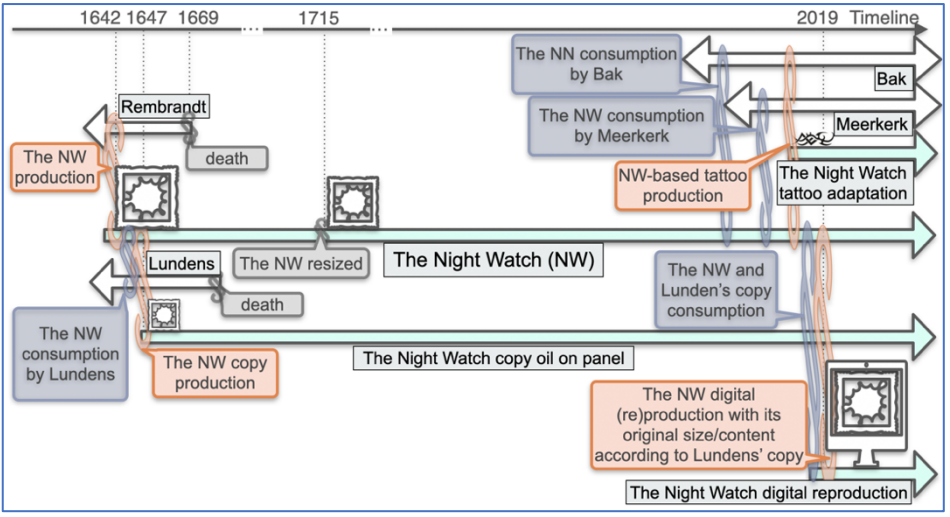

Figure 3. Storylines of the production and consumption of *The Night Watch* in copies, adaptations and digital reproductions hereof.

Additionally, we can zoom in or out on the longitudinal sections of storylines. As depicted in Figure 4, the zooming feature here proposed does not regard expanding or reducing the time frame under scrutiny, but rather allows the view more or fewer details for a particular entity, in this case, *The Night Watch*. On the left-hand side we zoom in into the details of the painting to observe the storylines of its material and immaterial parts. On the right-hand side, we zoom out to observe the Night Watch in the context of more or less contemporary paintings of Rembrandt.

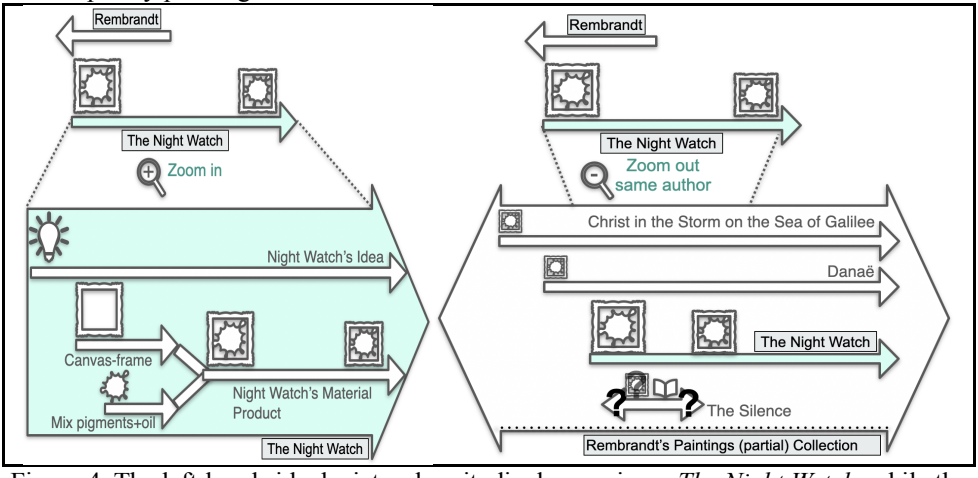

Figure 4. The left-hand side depicts a longitudinal zoom in on *The Night Watch*, while the right-hand side depicts a longitudinal zoom out showing *The Night Watch* among other paintings by Rembrandt.

We can then zoom in on the longitudinal sections of certain timelines of *The Night Watch* and its copies and adaptations, for instance, for visualizing in more detail production and consumption events regarding immaterial and material aspects of the Night Watch (Figure 5).

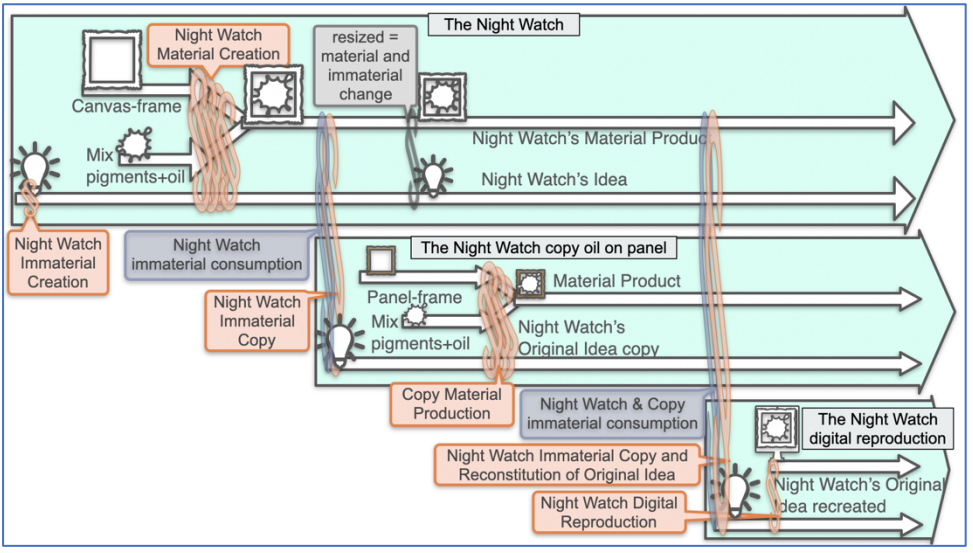

Figure 5. Zooming in on immaterial and material aspects of the production of *The Night Watch* and copies or adaptations thereof.

In cross section such longitudinal zoomings will also result in less or more detail depending on the question of whether we can see all the ends of these storylines at the same time (synchronous snapshot), or whether we get only a transversal view of some ends of these storylines, which can only be read in a meaningful way (as will be explained in more detail below) in combination with past and/or future events (asynchronous crossing). A snapshot of the unfinished tattoo of Bak on the 18th of May during his visit to Rijksmuseum can only be understood by the past and present of *The Night Watch* and by the future filling in of the blank faces for Van Meerkerk on request of Bak to make portraits of his family and friends.

4.3 Views of Rembrandt *Night Watch* and a kaleidoscope for Kubler

Earlier we noted that Kubler imagined his shape of time as a bundle of fibers instead of lenses as adherents of Strukturforschung and iconologists had done. Just now we described two moments relatively close to each other in the long history of Rembrandt's *Night Watch* in all of its contexts: the 18th of May 2019 when Marko Bak was filmed in the Rijksmuseum with the tattoo of *The Night Watch* on his back and the moment a month and half later, on the 5th of July, when the doors opened to the virtual exhibition "Discover Rembrandt: His life and all his Paintings" in the RAI, where for the first time since 1715 *The Night Watch* could be seen in its original dimensions. How would we be able to see these moments according to Kubler's *Shape of Time*? Kubler (1962, 28) describes a moment in his bundle of fibers of duration as follows:

> By this view the cross-section of the instant, taken across the full face of the moment in a given place, resembles a mosaic of pieces in different developmental states and of different ages, rather than a radial conferring in meaning upon all the pieces.

It is clear that Kubler tries to explain that if we make a slice in time we do not get a coherent picture of the whole, but rather an amalgamation of pieces that for the greater part differ in meaning because they are composed of the profiles of fibers (in our case storylines) in different stages of development. In that regard his mosaic metaphor is misleading. We can read representations of Greek gods or ferocious animals in figurative mosaics and will even be able to recognise regular patterns in non-figurative ones. The metaphor of the circular lens, varying in thickness according to the antiquity of the patterns that Kubler (122) dismissed, or the use of multiple lenses such as in a telescope, would at least allow for seeing more detail of the pattern in question. However, instead it would even be better to replace Kubler's mosaic metaphor by the one of the kaleidoscope, to explain the potential of his *Shape of Time* for the representation of the aforementioned moments in the storylines of Rembrandt's *Night Watch*.

The advantage of the kaleidoscope metaphor is that it gives depth (an extra dimension) to the view of the desired pattern. In a kaleidoscope light rays that enter from the back of the tube are reflected on mirrors that are tilted to each other in such a way that when one or more (parts of) objects are moved by rotating parts of the tube until they are aligned on one end of these mirrors these can be seen as a regular pattern.

When we return to Rembrandt we can explain and visualise Kubler's cross-section and our interpretation of his longitudinal bundles of fibers of duration as a kaleidoscope using the history of all his paintings as an example. For our visualisation in Figure 6, we include of course *The Night Watc*h and his *Danea* that stand for all his paintings that are in public or private collections in the world. However, for this historical overview it is important to realise that not all original works of Rembrandt survived. For instance, there are archival sources that point to his work that we have never seen, such as a painting with the title *de Stilte*" (*The Silence*) mentioned in a notary deed in the City Archives of Amsterdam (Dudok van Heel 1982). And there are his paintings of which we have images, but of which we do not know whether they still exist. A famous example is Rembrandt's *Storm on the Sea of Galilee* that was stolen in 1990 from the Isabella Steward Gardner collection in Boston.

Now observing the storylines (Kubler's bundle of fibers) for Rembrandt's collection transversally rather than longitudinally, we use views that could be synchronous (Kubler's cross-section) or asynchronous (kaleidoscope). Figure 7 illustrates, on the left-hand side, two ways for traversally visualising the storylines presented in Figure 6: a synchronous view as a straight line cutting the storylines in 2019, and an asynchronous view as a combination of cuttings in the storylines at the moment of their creation. The resulting views are presented on the right-hand side. The synchronous view or snapshot depicted on the top right side, only provides information on the present state of *The Night Watch* and *Danae*, meaning that *The Christ in the Storm* and *The Silence* are not accessible. In other words, it is equivalent to being able to have access to the existing paintings (in a physical sense) of Rembrandt at a chosen moment, in all public and private collections in the world.

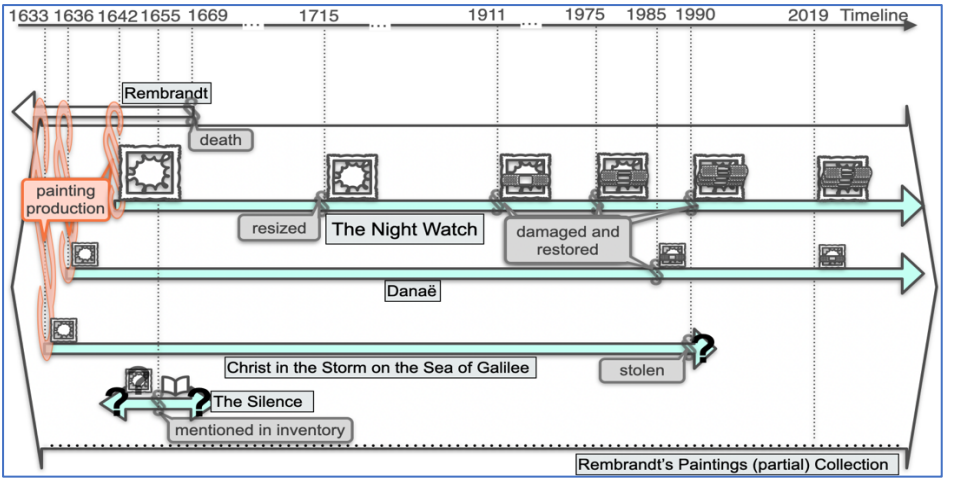

Figure 6. Storylines of Rembrandt's paintings based on information available in 2019.

Conversely, the asynchronous or kaleidoscope view of Rembrandt's painting collection as depicted on the bottom right hand side of figure 7 provides information on the state of the paintings at chosen moments in the past, which implies that *The Christ in the Storm* can be represented, as well as referred to previous paintings we only have documentary evidence of such as *The Silence*. It is equivalent to being able to have access to all paintings of Rembrandt, as close to their original version as the available information/knowledge allows for, regardless of their current condition. Hence, in this kaleidoscope view one can access all four selected paintings, including *Christ in the Storm* and *The Silence* (clearly not in the physical sense). However, using the latest virtual reproduction techniques, the exhibition "Discover Rembrandt" allowed us to virtually see the paintings resulting from a kaleidoscope view, since the paintings by Rembrandt were digitally represented and sometimes reconstructed in their original dimensions, such as *The Night Watch*. *The Silence* could not be digitally reproduced because there is no record of its appearance.

One could also consider the virtual exhibition to be a cross-section (synchronous view) of the digital reconstructions, that is historically founded in a kaleidoscope view (asynchronous view) of Rembrandt's originals. This, for the reason that the virtual reconstruction of *The Night Watch* in its original dimensions that was projected on the wall can only be understood by the historical evidence that the work was cut in 1715 and was reconstructed digitally with information about the lost part of the painting derived from the copy of Lundens. However, the pixels with which this image is built up is just an approximation of the materiality of *The Night Watch*. To get a better understanding of the materials Rembrandt used we have to manipulate the kaleidoscope—make a new alignment—in such a way that we for instance can see the pigments in the lab of the Rijksmuseum that provide evidence of other material aspects of *The Night Watch*.

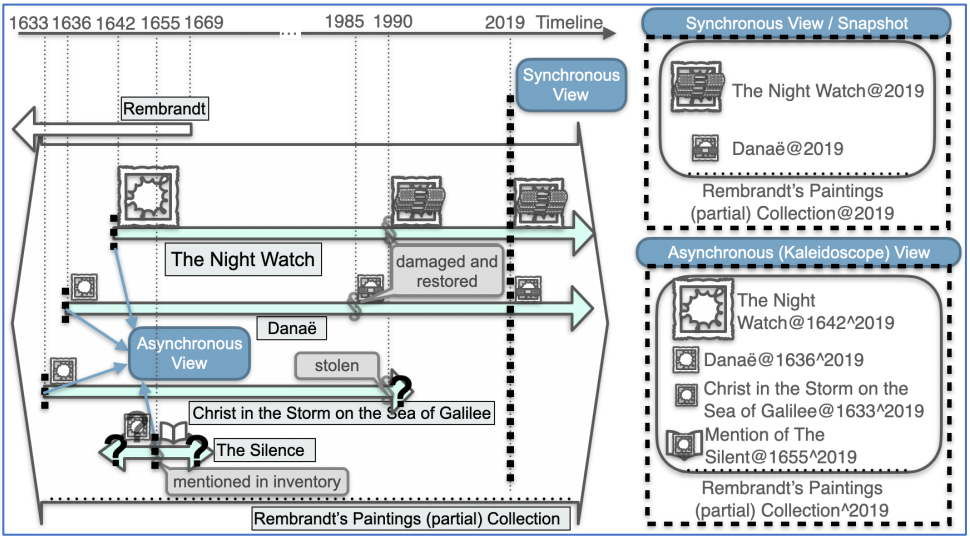

Figure 7. Storylines (longitudinal) on the left-hand side and cross-sections on the right-hand side. The one on top is a snapshot (synchronous cross-section) of Rembrandt's existing paintings in 2019 whilst the one at the bottom is a kaleidoscope view (asynchronous cross-section) of Rembrandt's paintings according to information available in 2019, similar to the digital reconstruction hereof for the Virtual exhibition "Discover Rembrandt: His Life and all his Paintings."

Similarly, the composition of the Night Watch can immediately be recognised in the tattoo on Bak's back. However, when we have a closer look at the faces of this group portrait, the photo-album of his family and friends probably provides far better contextual information to understand this dissimilarity of the tattoo with the painting. This phenomenon, that two meaningful patterns can be recognised simultaneously when aligned with multiple perspectives, is probably what Kubler tried to capture with the term "the plural present" and brings him to the conclusion that the principal object of the art historians is "to suggest other ways of aligning the main events" than style (Kubler, 1962, 129-30).

The limitations of aligning periods and events according to style and the advantages of using the kaleidoscope view of alignments of what Kubler (39) had called sequences or "chains of solutions" become evident when analysing and visualizing the term "chiaroscuro" that is often used to describe a main characteristic of several of Rembrandt's works. The term, that literally means light-dark, is comprehensive and complex. It has been used in the context of style, such as caravaggism after the Italian painter Caravaggio. This for instance to define "i caravaggisti" in Italy such as Giovanni Baglioni (accused for plagiarism by Caravaggio) or the female painter Artemesia Gentileschi but also to describe common characteristics of the Utrecht school of caravaggists with painters such as Hendrik ter Brugghen and Jan van Bijlert (*The Concert* 1635-40) or followers in France such Simon Vouet (*Fortune Teller* ca. 1620) and Georges de la Tour. It has been associated with the sub-genres of portraits and still-lifes in which faces and objects often in nocturnal scenes

are lit up against dark backgrounds by candlelight. Dirck van Baburen and Gerrit van Honthorst (*The Matchmaker* 1625) as members of the Utrecht school made small group portraits in that genre or Georges de la Tour in France who made a whole series of candle-lit portraits such as *Magdalena* with the smoking flame (c 1640). However also Rembrandt lit up portraits of himself or others—often in the act of reading or writing—by candlelight. Finally, the term chiaroscuro has been described as a technique to enhance the dramatic effects in storytelling such as in the *Crucifixion of Saint Peter* by Caravaggio (1601) or in the depiction of the same saint in prison by Rembrandt (1632), but also in far less dramatic ways such as in the composition on his *Night Watch*. The latter is important because it demonstrates that a certain technique can be applied in other styles or genres. It is generally accepted that Rembrandt who never was in Italy was indirectly influenced by Caravaggio via his teacher Pieter Lastman who visited the Mediterranean country approximately between 1604 and 1607. Nevertheless, if we compare Rembrandt's earlier work in chiaroscuro, such as *Three Singers* (1624) it differs far more in style from Caravaggio than the depiction of the musicians by Van Bijlert thirty years later in his *The Concert* produced between 1635 and 1640. Chiaroscuro is far more prominent and persistent in the sub-genres of individual or small group portraits than in the large, institutional group portraits. *The Night Watch* is one of the few exceptions in these long series of militia group portraits. Nevertheless, the contrasts between light and dark are used compared to the caravaggisti in a far subtler way (Figure 8).

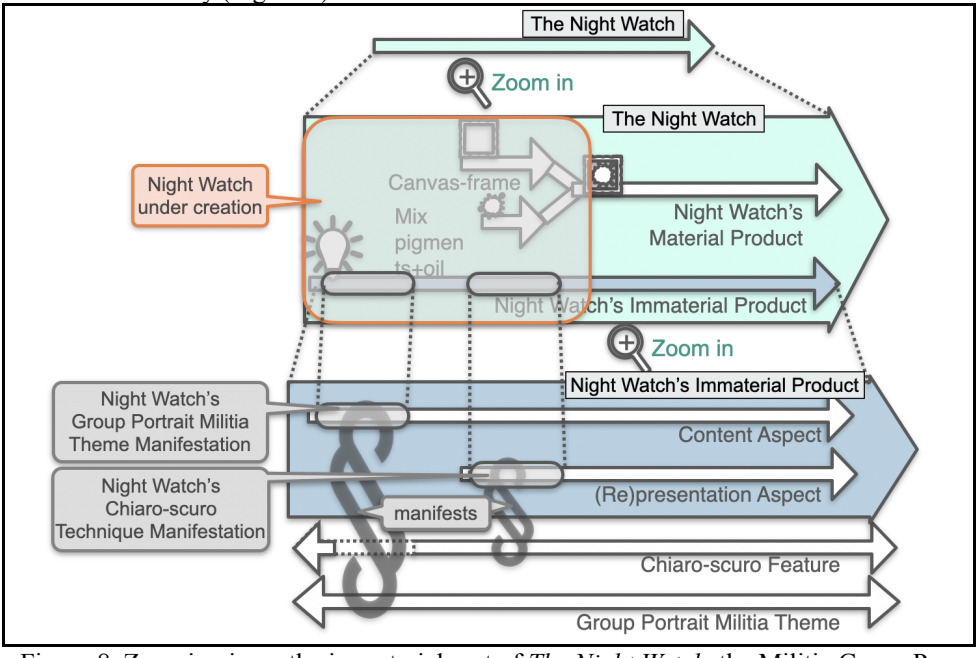

Figure 8. Zooming in on the immaterial part of *The Night Watch*, the Militia Group Portrait theme manifests as its content aspect, while the chiaroscuro Feature manifests as its (re)presentation aspect.

In short, there are overlaps between style and genre in the application of chiaroscuro, but their inconsistent sequences in time and place, as we have seen, demonstrate that they both have limitations for periodisation in the arts. Kubler is correct when he states that rather than using periods of styles (he does not discuss artistic genres in his *The Shape of Time*), it would be better to speak of chains of solutions. While only few of Rembrandt's works in which he applied chiaroscuro have some overlap with the caravagist style or the candle lit (sub-)genre, all works of Rembrandt in which he used the technique of chiaroscuro can be linked to a long chain of solutions in the use of light-dark contrasts that runs from Leonardo's *Virgin of the Rocks* (1483-86) to Stanley Kubrick's use of candle lights in the film *Barry Lyndon* (1975), to the chiaroscuro in the photographs of Christy Lee Rogers such as *Rapture* (2011). Common manifestations in genre, style, and technical solutions can be aligned (Figure 9).

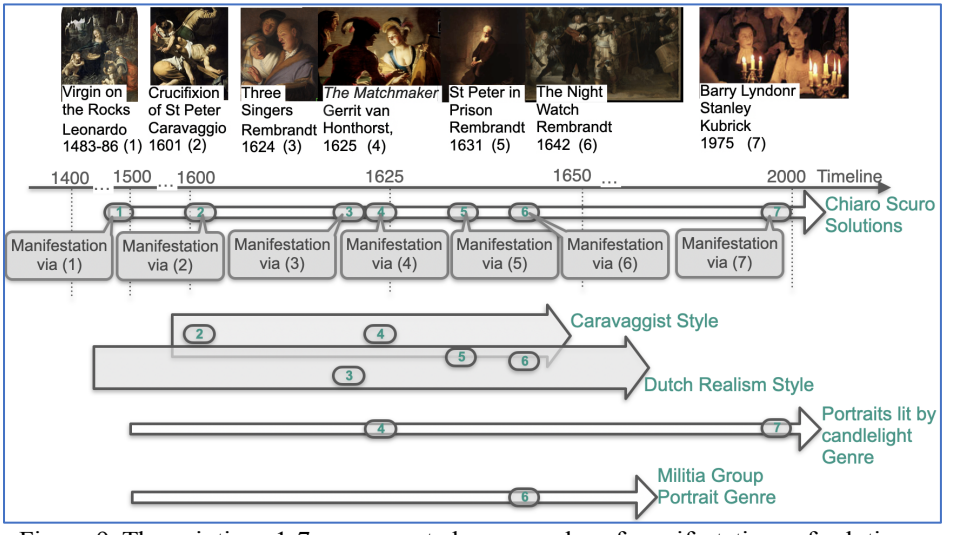

Figure 9. The paintings 1-7 are presented as examples of manifestations of solutions, styles and genres.

Some historians argue that such alignments in the kaleidoscope of history are arbitrary. For instance, Paul Veyne (1979; compare Miller ([1993] 2000, 152 and note 107) when describing Michel Foucault's approach of the past as a kaleidoscope states that the last pattern is "neither more true nor more false than those that preceded it." Indeed, with every turn of the tube a new pattern will occur. Some fragments that we observe might seem to be less relevant than others. However, similar to the idea that most people like the symmetrical patterns of the kaleidoscope for esthetic reasons, the historian in this metaphor might also be more content with one pattern over another.

In our example of chiaroscuro, the caravagist style, candlelight genre and the use of strong dark-light contrasts as a technique or "solution" can all three be aligned to explain the main characteristics of *The Matchmaker* of Gerrit Honthorst (1625). Rembrandt's *Night Watch* could only partially be aligned with the style of the "caravaggisti" given the strong

overlap with the Dutch realistic style (and be recognisable of course in the so-called Rembrandt style of followers, in the same way as Caravaggio directly corresponds with the style of the "caravaggisti"). It would fit a completely different genre, that of the militia groups running according to Middelkoop approximately between 1525 to 1800, but would fit in with all his other works in which he used light-dark contrasts in the long series of "chiaroscuro solutions" from the end of the 15th century to the present.

The use of the kaleidoscope view is not necessarily limited to visual analysis. The historian might look for fragments that fall in place when they connect to past historical evidence. Such as we have seen in our example of Rembrandt's work *The Silence,* of which we probably will never know how it looked, but which original existence still can directly be traced back to archival documents. The use of the kaleidoscope just implies dealing with less or more uncertainty in the meaning of visual patterns or in historical evidence in the interaction with these various fragments when making alignments until the moment that we recognise patterns that are deemed to be meaningful.

5.0 Toward a knowledge interaction model of historical interactions

5.1 Framework: Knowledge interaction versus KO

The Golden Agents project develops an infrastructure to analyse interactions between the production and consumption and among the various branches of the creative industries of the Dutch Golden Age. In short it should support the study of interactions. However, interactions are not only the object of study. If we follow Shaw's statements that KO is not applied to history, but that history is a form of KO and that the emphasis should not be on a (organised) portrayal of history but on supporting historians in doing history, we can argue that interactions also have methodological implications. We need a model that supports the analysis of historical knowledge interactions and interactions with historical knowledge. In earlier studies attempts have been made to formulate a theoretical framework for the analysis and visualisation of knowledge interaction between concepts in general (van den Heuvel and Smiraglia 2013; Smiraglia and van den Heuvel 2013 and 2011; Smiraglia, van den Heuvel and Dousa 2011). Similar to the way that Shaw described the requirements of a semantic tool that supports historians in the process of conceptualisation of historical discourse, we need a dynamic model to describe, analyse and visualise the interactions within the creative industries of the Dutch Golden Age. a model that we can use actively as an instrument to interact with interpretations of that past and with the documents that are used to portray historical events and to underpin those portrayals with historical evidence. The part of the ontological model that deals with historical evidence based on archival resources and expressions of uncertainties is still work in progress, but first results are and will be demonstrated (Idrissou et al. 2018 and 2019; Engelse and Wissen 2019; Zamborlini, Wissen and van den Heuvel 2020; Wissen et al. 2020; Wissen and Zamborlini 2020; Zamborlini and Wissen 2020).[2] In this chapter we focus on parts of the model that allow for describing and interacting with historical processes and discourses with the emphasis on conceptualisations of temporality and periodisation. This model needs to meet the following requirements:

Requirement 1) The model provides a framework for interactions of historical knowledge as an object of study and as a methodological instrument to interact with historical knowledge.

Requirement 2) The model supports the study of interactions between production, consumption and branches of the creative industries.

Requirement 3) The model supports conceptualisations of historical interactions with temporality and periodization.

5.2 Storifying data: Modeling historical narratives and conceptualisations of things in space/time

In a model that supports conceptualisations of interactions with historical knowledge, in our case of the creative industries of the Dutch Golden Age, things (ideas and objects) need to be linked to time, place and related concepts, as well as put in the context of narratives. Modeling things in space and time (space/time) has a long history that goes back to antiquity (Bliss 1929). In the early history of library and information science Ernest C. Richardson (1935) used the universe of knowledge metaphor to class things (which could be both ideas and physical objects) in space and time. This metaphor was followed by the universe of concepts (Ranganathan 1957; Miksa 1992; Beghtol 2008) and concepts in spacetime in the multiverse of knowledge (van den Heuvel and Smiraglia 2010; Smiraglia, van den Heuvel and Dousa 2011). van den Heuvel and Smiraglia (2010) extended the metaphor of multiverse knowledge to the laws of physics in those spaces. The "gravitational forces" in these knowledge universes were used metaphorically to explain two important concepts in the theory of classification: "likeness" and "likeliness" (Hjørland 2003; van den Heuvel and Smiraglia 2013). The latter concepts might be of interest for the understanding of the stories we tell about the st[illegible] we tell about history. The tattooist of the Night Watch was drawn between the "likeness" with the composition and colours of the painting and with the portraits of Bak's family. The "likeliness" of a meaningful pattern in the narratives depends on the weight we address to the various pieces of evidence of the relations between, in Kubler's terms, primal objects and the many different sorts of replications. The Bak's back tattoo tells multiple stories simultaneously, some finished a long time ago, others like the making of the portrait of his mother that still was a future idea for the tattoo in May 2019. This example demonstrates that the model needs to be able to handle narratives of relationships between things both in real and in fictional time in a multidimensional space for which we introduced the kaleidoscope metaphor. As Shaw states, several historians treat events as phenomena, as actual things that existed in the past. From that perspective one sees the history of the past as a kind of fabric woven of these events, and history-as-practice as the study of that fabric. According to this "unreflective view of events" historians simply describe events as a historical portrait by comparing them to an independent standard "what really happened." However, the past does not exist anymore and for that reason the best historians can do is to compare various portraits of narrations of the past. In doing so they accept or reject new and old ideas that are shaped by newly discovered documentation and that are changed by cultural changes (Shaw 2010, 45-46). This is congruent with Kubler's *Shape of Time* in which processes of change and in our attitudes towards them, shape the occurrence of things in often imprecise time intervals. It implies the remodeling of events as part of a dynamic system with sequences in different rhythms of duration instead of in calendar time (which as Kubler stated indicates nothing about the changing pace of events) and concordances hereof such as in PeriodO. However, to allow for interoperability of LD within the semantic web paradigm the remodeling of temporality of historical events must allow for mappings to other standards such as CIDOC-CRM, OWL-Time and PeriodO:

Requirement 4) In the model that supports interaction with historical knowledge, things (i.e. ideas and objects) need to be linked to time, place and related concepts, as well as put in the context of narratives.

Requirement 5) In the model that supports interaction with historical knowledge, multiple narratives of developments of ideas and objects must be represented simultaneously in a multi-dimensional way.

Requirement 6) In the model that supports interaction with historical knowledge, ontologies of events purely based on calendar time and concordances hereof need to be remodeled to describe events as part of a more empirical system based on practices of historical research. The model is calendar-agnostic.

Requirement 7) The model needs to be interoperable with ontologies/SKOS of time that are used as standards in cultural heritage.

5.3 Visualizing storylines of historical interactions

Kubler, possibly inspired by Ore as we noted, did see historical patterns as networks. Moreover, we claimed that Kubler's reading of a time instant in the fibers of duration as a mosaic perhaps better could be imagined as a kaleidoscope. In the context of this latter observation it is interesting to note that the kaleidoscope is already used as a metaphor to explore the semantic web and knowledge graphs (Haase 2019). Mackeprang et al. (2018) developed a prototype of an RDF-based data analysis tool using semantic web technologies to explore and annotate upcoming associations and ideas interactively and to link them to concepts from external knowledge graphs such as Wikidata. It is a user interface in which customizable colored dots, that function as markers of ideas generated by each SPARQL query, are distributed over a grid-pane. Unfortunately, it is therefore a two-dimensional user-interface that does not do full justice to its name, because the kaleidoscope metaphor that we envision to model and visualise our concept of storifying data inspired by Kubler's *Shape of Time* entails interactions with data in a multidimensional spacetime model. A fake news post in the satirical journal *Onion* on the 16th of July 2018 described and illustrated a $200 billion Hubble Space Kaleidoscope with brilliantly colored interlocking and rotating diamond things that captured the first images of a nebula. Such a kaleidoscope that can be used to explore the pattern of the universe does not exist. However, a combination of telescopes including the NASA/ESA Hubble Space Telescope[3] was able to produce kaleidoscope images of a galaxy cluster that reveals the effects of a phenomenon that is known as gravitational lensing. The dark matter of this observed cluster bends the light of background objects in such a way that it acts as a magnifying glass and enables astronomers to find galaxies that existed relatively shortly after the big bang. These observations make part of the Hubble Frontiers Fields program[4] that started in October 2013 when for the first time the gravitationally lensed image of a supernova was arranged four times after the alignment with a galaxy in the cluster to which it belonged. This phenomenon of gravitational lensing is of interest in the context of the aforementioned metaphor of gravitational forces in knowledge interaction based on "likeness" and "likeliness" in which alignments from multiple perspectives with "things" that are alike, increases the likelihood that patterns will be recognised that we deem to be of interest. If we replace the entering light rays of the origins of the universe that are distorted by forces but are aligned with the astronomer's recognised patterns by Kubler's fibers of historical duration we get a similar effect. By interacting through alignments with parts of history that are reflected to us we can create a pattern of the past that in a certain moment of time has a meaning that is coloured by our interactions with parts of that past. It is important to realise that we see a pattern, and not an image as in the mosaic metaphor. It is not its context in the same dimension, but the

multidimensional spacetime of history that provides the contextual information to understand this pattern. Similar to the huge task that the Time Machine project set for itself, the development of an interactive kaleidoscope to explore the multidimensional spacetime of history is still a future dream. However, there are already more concrete explorations of user interfaces that would allow us to visualise and to interact with historical storylines that actually reflect Kubler's ideas quite well. We already observed that Kubler's *Shape of Time*, consisting of a longitudinal bundle of happenings of shorter and longer duration and a transversal view of a network, could be visualised by three-dimensional timeline tools, such as Jensen's TimeVis (compare Figure 1).

Other relevant examples of multidimensional semantic timelines combined with graph visualisations are the visualisations of time in "Time-Shadows" and "Time Beads" (Morawa et al. 2014). They are of interest because these shadows and beads respectively combine interactions in zoom based on overviews with various time shapes to visualise the display of qualitative and quantitative data in different classes of durations. Similarly, the user interface to interact with time in LD as part of the EU project Smart Museum (Kauppinen et al. 2010, Figure 5) is of interest. It deals with fuzziness and uncertainty in time intervals and allows for annotations of the relevance of time periods in relation to their queries.

Requirement 8) The model allows for the visualisation of synchronous and asynchronous multiple things (ideas and objects) over time and the relations between them can be expressed in networks.

Requirement 9) The model allows for the visualisation of the multidimensionality and dynamics of these networks of things.

Requirement 10) The model allows for the visualisation of events in precise and imprecise time intervals. The GUI allows users to interact with the settings and to annotate the preciseness of the boundaries of the time intervals and to assign the relevance of time periods in relation to their queries.

6.0 A model for time in storylines of historical interactions

This section presents a conceptual model aimed at addressing most of the aforementioned requirements while leaving place for others in future work. In particular, the proposed model is meant to be calendar-agnostic but also "truth-agnostic," in the sense that it enables events to be expressed in any existing calendar regardless of its veracity, as well as in the "future" or in fictional "calendar-time," such as an Elvish Calendar. As long as one can provide a mapping from one calendar to another or create explicit formal relations among the events (such as before or during) then they can be related or compared. In future work we plan to address veracity by allowing for reported events to be provided with evidence, so that it can be believed to be true or false or even just likely, but also to address the representation of events as explicitly hypothetical or fictional.

The proposed model builds on top of a general-purpose ontology called Unified Foundational Ontology (UFO) (Guizzardi 2005; Guizzardi et al. 2013 and 2015) and its variation gUFO (Almeida et al. 2020), of which the ontological commitments are precise but also flexible enough to support our requirements. It incorporates developments from other foundational ontologies such as GFO and DOLCE in a coherent way. They are compatible with the conceptualism theory in which concepts and individuals are described according to perception. Naturally, other existing models such as CIDOC-CRM, Web Ontology Lan-

guage (OWL) and its extension for time OWL-Time, Simple Event Model (SEM) and PeriodO also partially address our requirements. The similarities and differences with respect to our proposal are discussed and reconciled when possible.

The model is presented here in several UML-like class diagrams, including some UFO concepts (in a dark-gray shade) plus newly proposed concepts (in a light-yellow shade). They also include colored references to similar concepts present in other models, which when preceded by an asterisk mean an approximation not an equivalence. Dotted lines indicate relations that are not explicitly defined in that particular diagram, but in others or in the text. Moreover, in the text the concepts will be referred to by using as prefix an acronym of the model to which it belongs (e.g. *prefix*:Concept). This is important to avoid their free interpretation as a commonsense word but also because sometimes the same term means different things in different models. For example, the reading of *UFO:*Objects should be such that, according to the UFO, a person is an object. In particular, we use the prefix *ga* (for golden agents) when describing the concepts of the model here proposed.

6.1 Perdurants and temporal extents are calendar-agnostic

Figure 10 presents some main concepts as follows: the concept *UFO*:Entity, aligned to *CIDOC:E1-CRM-Entity* and close to *owl:Thing* (which does not include literals). It comprises the universe of discourse (roughly, anything one may want to "talk about") and is divided into *UFO:Concrete* and *UFO:Abstract* entities, where the former are entities that can be "placed" in space and time directly or indirectly (e.g., a language can be situated in space and time through the people who speaks it), while the latter is not (e.g., a number).

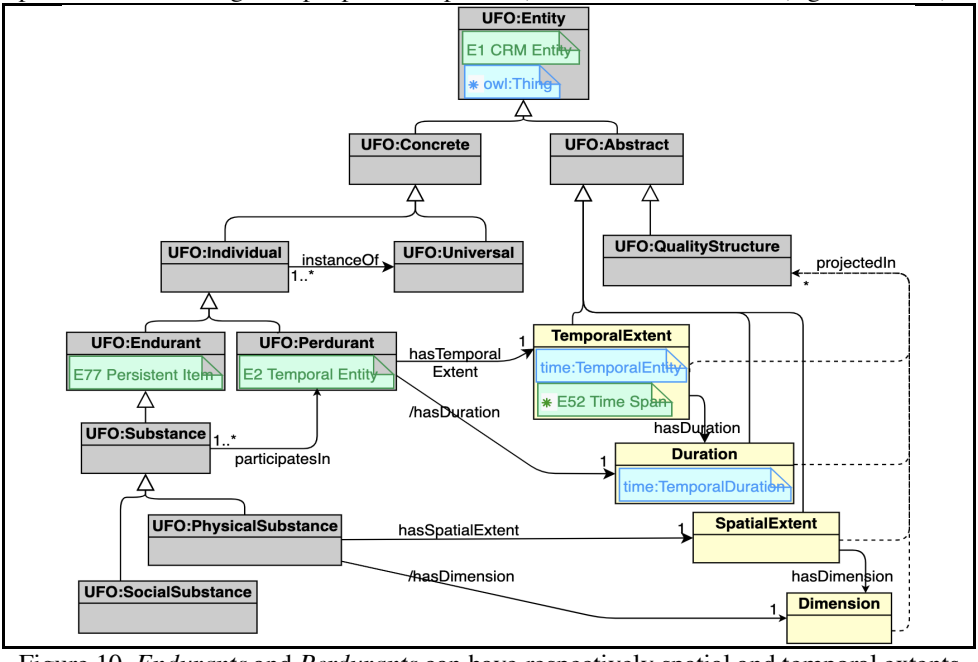

Figure 10. *Endurants* and *Perdurants* can have respectively spatial and temporal extents which are independent of a specific quality structure and can be projected in one or more

of them, e.g., someone's birth date can be projected in both Gregorian and Chinese calendars.

UFO:Concrete entities are then split into *UFO*:Individual and *UFO*:Universal. The former are entities of interest (e.g., Rembrandt, *The Night Watch* or Rembrandt's role as a master instructing his pupils) while the latter, roughly, comprise ways of classifying and/or providing identity to the former (e.g., person or painting). *UFO:Individual* is split into *UFO:Endurant* and *UFO:Perdurant*. The former are entities whose essential parts are always present (e.g., a painting) while the latter's parts are not present altogether (e.g., the creation of a painting). These concepts align respectively as *CIDOC:E77-Persistent-Item* and *CIDOC:E2-Temporal-Entity*.

A particular type of *UFO:Endurant*, *UFO:Substances* are existentially independent entities said to participate in *UFO:Perdurant*. It can be split into *UFO:Physical-Substance* and *UFO:Social-Substance*. While the latter are *IMMATERIAL* entities (e.g., language), the former are *MATERIAL* entities that occupy a space, i.e. that have a *ga:Spatial-Extent* and also a *ga:Dimension*. Similarly, *UFO:Perdurant* entities have a *ga:Temporal-Extent* and also a *ga:*Duration, which is derived from the duration of its extent. Those concepts are *UFO:Abstract* entities that can be projected in a certain *UFO:Quality-Structure*, such as a calendar or a space coordinate system (to be discussed in the next subsection). Those entities are in principle independent of a quality structure, e.g., the temporal extent of a perdurant exists independently of a particular *CALENDAR SYSTEM*. Moreover, it exists regardless of our knowledge, i.e., the fact that we cannot precisely determine when an event happened does not make its temporal extent imprecise. On the other hand, some would argue that some entities' boundaries are essentially vague, such as those of a language or genre. Both cases require means to account for *UNCERTAINTY,* such as to state that the temporal extent of a language includes a smaller-precise one and is included by a bigger-precise one, thus expressing its "imprecise boundaries." Finally, observe that a perdurant is not the same as its temporal extent, since several perdurants can have exactly the same temporal extent, which is an abstract entity, meaning they happen at the same time, similarly to the manner in which several persons can have the same age or height.

Although only *UFO:Physical-Substances* and *UFO:Perdurants* are directly connected to respectively space and time, both can be indirectly connected to respectively time and space. *UFO*:*Substances* are indirectly situated in time through the perdurants in which they participate, while perdurants are indirectly placed in space through the *UFO*:*Substances* that participate in it. Naturally, in this paper we focus on perdurants and their ways of measurement.

The *OWL-Time* ontology actually concerns exactly the representation of *ga:Temporal-Extent*, where it is called *owl-time*:*Temporal-Entity*, while it does not concern perdurants or events *per se*. It does, however, consider that any entity (*owl*:*Thing*) can be attributed a temporal extent, which is not necessarily incompatible with our view if one considers that the endurants/substances can be indirectly placed in time. In turn, the "similar" concept *CIDOC:E2-Temporal-Entity* actually refers to a *UFO:Perdurant*, meaning that "temporal entity" does not mean the same in *OWL-Time* and *CIDOC*. Instead, the concept *CIDOC*:*E52-Time-Span* is close but not exactly the same as the *ga*:*Temporal-Extent* or *owl-time:Temporal-Entity*, since it does incorporate uncertainties.

6.2 Periods and durations in calendars

In Figure 11 the *UFO:Abstract* is more detailed to explain how the temporal extent and the duration are projected into a particular quality structure or, more specifically, a calendar, besides how to reconcile different interpretations of the concept period.

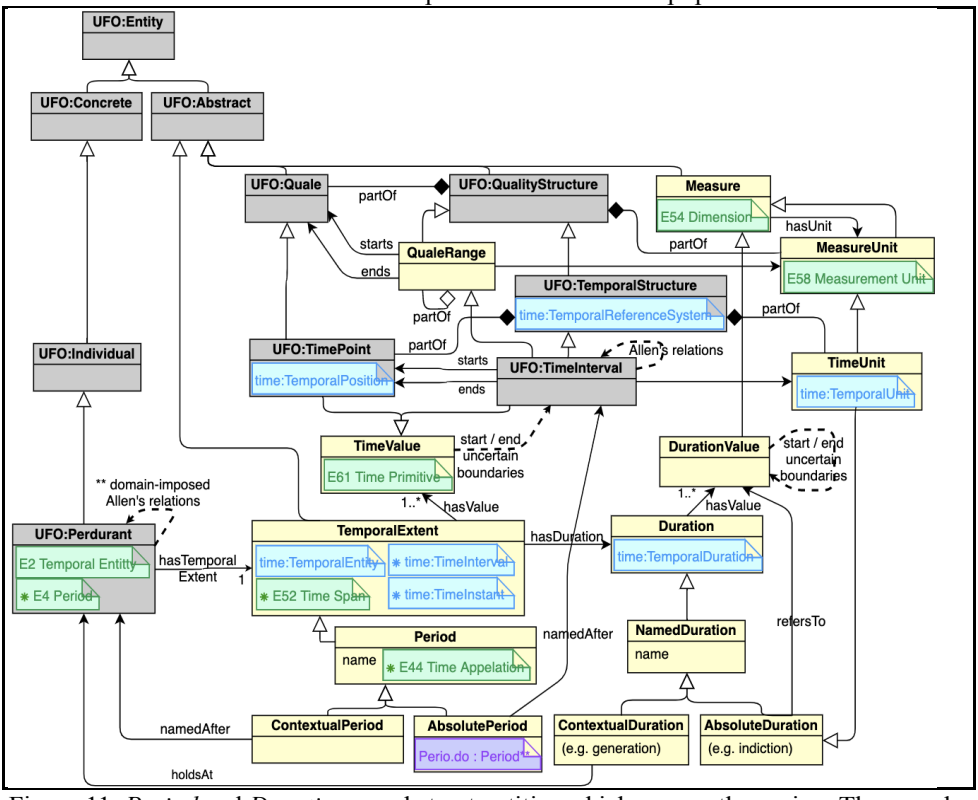

Figure 11. *Period* and *Duration* are abstract entities which are worth naming. They can be named after a specific event, e.g., the 2nd World War, or may refer to a particular time interval within a calendar, such as the 1960s or the year of the rooster.

First, a *UFO:Quality-Structure* is composed of *UFO:Quale* entities, which stands for each point in the quality structure. In a *UFO:Temporal-Structure*, which aligns with *owl-time:Temporal-Reference-System*, a quale is a *UFO:Time-Point*, which aligns with *owl-time:Temporal-Position*. In its turn, a *ga:Quale-Range* represents a subset of *UFO:Quales* and can be defined by a start- and an end-quale, e.g., a *UFO:Time-Interval* is a subset of time points. The union of time points and intervals in whatever calendar is called *ga:Time-Value*, which aligns to *CIDOC:E61-Time-Primitive*, and can be attributed to (calendar independent) *ga:Temporal-Extents*. When several values are attributed to an extent it means either projections of the extent in different calendars or a discontinuous extent. Finally, the concept *owl-time:TimeInterval* is a subset of *owl-time:Temporal-Entity* and therefore is equivalent to a subset of *ga:Temporal-Extent* whose values are *UFO:Time-Interval* in any calendar.

Special temporal algebra applies among *UFO:Time-Intervals*, also known as Allen's relations defined by Allen (1983), namely: during, starts, finishes, is equal to, overlaps, meets and takes place before. These relations can be derived between two intervals given their values. Naturally, the same relations apply to *UFO:Temporal-Extents*, although their calculation requires being able to project the extents into the same calendar system. Furthermore, equivalent relations can be inherited by perdurants/events. They can also be imposed by domain restrictions, such as a birth event must happen before the baptism. The domain restrictions allow us to state formal relations among events without knowing exactly when they have happened.

One way to allow for uncertainty is to attribute uncertain boundaries to the ga:Time-Value of a *ga:Temporal-Extent*. This allows one to express as much as is known about an event, such as the lastest start point. The *Simple Event Model* (*SEM*) provides such relations to hold between any *sem:Core* entity and a specific calendar value: *has-Earliest-Begin-Time-Stamp*, *has-Latest-Begin-Time-Stamp*, *has-Earliest-End-Time-Stamp*, h*as-Latest-End-Time-Stamp*. *CIDOC* provides a relation called *P82-at-some-time-within* describing the maximum period of time (*E61-Time-Primitive*) within which an *E52-Time-Span* falls.

A *ga:Period* is roughly a *ga:Temporal-Extent* worth naming. When the name is given after a relevant event, its temporal extent is called *ga:Contextual-Period*. Otherwise, when it is based on a time interval it is called *ga:Absolute-Period*. The latter is the case in the gazetteer *PeriodO*, where the concept period is a subset of *owl-time:Temporal-Entity*, hence a temporal extent, to which a name and other values are attributed, e.g., 1960 to 1969 is called the 1960s. However, the concept in *PeriodO* is not explicitly connected to any particular event, even if the period is called World War II. Conversely, *CIDOC:E4-Period* is a *CIDOC:E2-Temporal-Entity* which aligns with *UFO:Perdurant*. Therefore, *CIDOC:E4-Period* does not mean the same as *ga:Period*, but they are the *UFO:Perdurants* of which temporal extents are named *ga:Contextual-Periods*, such as in the previous example. Another concept called *CIDOC:E44-Time-Appelation* allows for using names to refer to a *CIDOC:E52-Time-Span*, although it is not itself a *CIDOC:E52-Time-Span* but an objectification of the naming. Finally, a *ga:Contextual-Period* can be associated to a place through the *UFO:Perdurant* after which it is named, while a *ga:Absolute-Period* has no clear connection to space.

A *ga:Measure* is an amount of *UFO:Quales* given in terms of *ga:Measure-Unit*s, which are names given to pre-defined amounts of *UFO:Quales*, e.g., *ga:Time-Units* like a second or a year. In particular, a *ga:Duration-Value* is a *ga:Measure* that values a *ga:Duration* that can represent the extension of *ga:Temporal-Extents*. In a similar fashion to *ga:Temporal-Extent*, as their *ga:Time-Value* can have uncertain boundaries, so can the *ga:Duration-Value* of a *ga:Duration*. Moreover, the *ga:Duration* can also be named either after a specific duration value, called *ga:Absolute-Duration* or yet after a certain duration that may change in time, called *ga:Contextual-Duration*. The former comprises all *ga:Time-Units* in any calendar such as a decade (10 years), or also Kubler's term indiction (duration of 15 years). The latter in turn comprises terms such as (human) generation, which is independent of a calendar and also may change in time, i.e., a generation 100 years ago might not correspond to the same amount of time as 100 years from now.

6.3 Modeling storylines: Fibers of duration and networks

Even though the *UFO* often uses *Perdurant* and *Event* interchangeably, we find it convenient to present them separately, since there are different correspondents in other models such as *CIDOC*. Figure 12 elaborates those concepts as well as storyline related concepts.

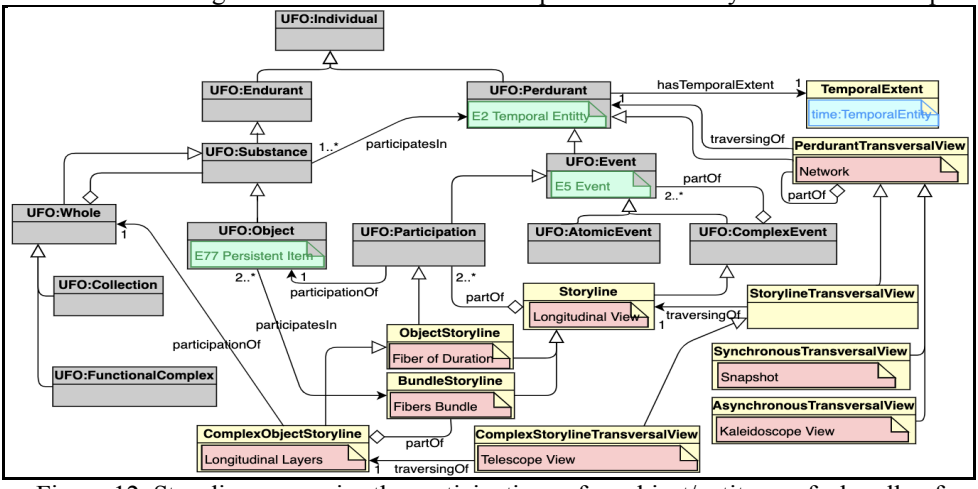

Figure 12. Storylines comprise the participations of an object/entity or of a bundle of them in events through time. A storyline transversal view is a static view or a network, which can be a synchronous view in time (e.g., Figures 2 and 7 top right) or it can be an asynchronous view (e.g., Figure 7 bottom right) as to connect objects that participate in related events at different points in time.

A *UFO:*Event, which aligns with *CIDOC:E5-Event*, is a perdurant that can be split into *UFO:ComplexEvent* and *UFO:AtomicEvent*, where the former is composed of two or more events and the latter is not. Moreover, a *UFO:Participation* is an event that conveys the participation of one single *UFO:Object*. The latter is a type of *UFO:Substance* that has a unity criterion, complementary with amount of matter, which will not be discussed in this paper.

A *ga:Storyline* is a *UFO:ComplexEvent* that can be split into (i) *ga:Object-Storyline*, which is composed of participations of a single *UFO:Object*, and (ii) *ga:Bundle-Storyline* (Kublers' "fibers of duration"), in which two or more *UFO:Objects* participate. Considering the storyline of *The Night Watch*, one can see it as a single *ga:Object-Storyline* describing only the events/participations concerning this painting (when it has been commissioned, produced, delivered, transferred, altered, etc.) or one can see a *ga:Bundle-Storyline* such as in Figure 3 connecting *The Night Watch*'s storyline to others such as Rembrandt's storylines as its creator, Lundens' copy in oil on panel, Bak's tattoo or its digital reproduction in 2019.

Furthermore, a *UFO:Object* can be a *UFO:Whole*, which means that it has two or more parts. While in a *UFO:FunctionalComplex* each part has a different "function," such as material and immaterial parts of a product, in *UFO:Collection* instead each part has the same "function," such as a collection of coins or a collection of paintings by Rembrandt. Hence, a *ga:Complex-Object-Storyline* is a *ga:Object-Storyline* as the participations of a single *UFO:Whole*, while it is itself composed of *ga:Bundle-Storylines* in which the parts

of the whole participate. This means that a particular storyline can provide a longitudinal zoom in and out from the whole to the parts and back. Since one whole-object can have parts that are themselves whole-objects several zoom levels can exist. In an example given in Figure 5 on the left-hand side, by zooming in on *The Night Watch* storyline one could see a more detailed bundle of storylines comprising both its immaterial part and the materials that were used, such as the preparation of the canvas or the pigments (more details about material versus immaterial in the next section). On the right-hand side, by zooming out from *The Night Watch* storyline, one can see the storylines of other paintings that are part of the same "whole-collection of Rembrandt's paintings."

Finally, another way to observe *UFO:Perdurants* is via a *ga:Perdurant-Transversal-View*, resulting in a "static" view of an event of interest that Kubler calls a network. It can be either (i) a *ga:Synchronous-View*, e.g., observing all the entities involved in an event at the same time like a snapshot; or (ii) a *ga:Asynchronous-View* that allows for "statically" observing a network of entities that participate in an event of interest but at different points in time, which we called a kaleidoscope-view since it allows motion back and forth through time independently for each storyline. Naturally, a *ga:Storyline-Transversal-View* is the crossing of a *ga:Storyline*. For example, Figure 7 depicts on the left-hand side the storylines of Rembrandt and some of its collection of paintings, which are crossed in two ways: (i) on the top right a snapshot of Rembrandt's painting collection in 2019, while on the bottom right a kaleidoscope view of his paintings at the time of their creation. In particular, the crossing of a *ga:Complex-Object-Storyline* allows one to zoom in and out on the parts of the whole-object but now in a transversal zoom instead of a longitudinal one, which we could call a telescope-view. For example, a transversal zoom in on the aforementioned kaleidoscope view could show the combination of the original materials used by Rembrandt in 1642 to create *The Night Watch*, while a zoom in on the snapshot of 2019 would show also the materials added due to restorations.

6.4 Modeling storylines of production and consumption

We already discussed and visualised (compare Figures 3 and 4) storylines of the production and consumption of *The Night Watch* itself and in copies and adaptations and zoomed in and out on immaterial and material aspects hereof in other paintings of Rembrandt. With these examples in mind we here model these production and consumption storylines and discuss them in relation to CIDOC CRM.

The *ga:Storyline* of a *ga:Product* is called a *ga:ProductStoryline*, which is composed of events like *ga:ProductUnderCreation* and *ga:ProductUnderConsumption* as the *UFO:Participations* of the *ga:Product* respectively in the processes of *ga:Production* and *ga:Consumption*, as depicted in Figure 13. A *UFO:Agent* is a type of *UFO:Object* with intentionality to perform actions, such as a *ga:Producer* and a *ga:Consumer*, which approximates to a *CIDOC:E39-Actor* representing (a group of) people to perform intentional actions.

For all the mappings made to CIDOC in this model, one important difference to bear in mind is that CIDOC is human centric, in the sense that all the actors are necessarily humans and the products human-made. This can be seen as a special case of our model which does not impose such restriction, so that it could cover for instance situations (real or fictional) in which art could be created by an animal or by artificial intelligence. The CIDOC concepts are therefore subclasses of the concepts here proposed.

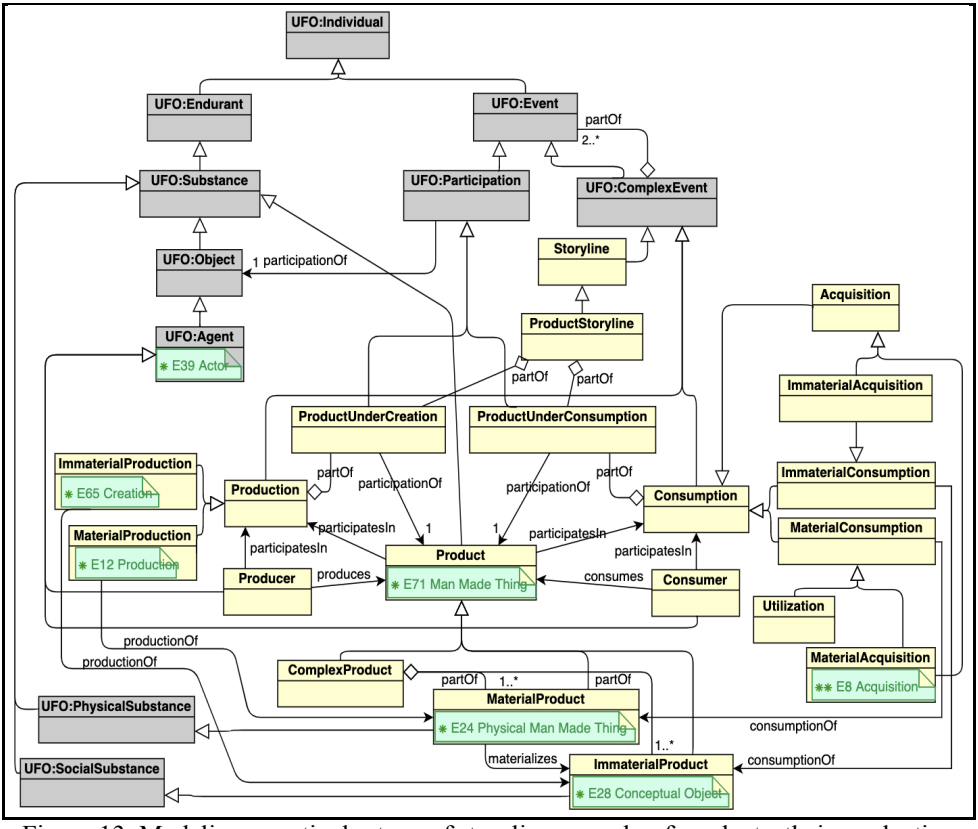

Figure 13. Modeling a particular type of storyline, namely of products, their production and consumption, material or immaterial.

A *ga:Product* can be either *ga:MaterialProduct*, *ga*:ImmaterialProduct or *ga:Complex-Product*, where the latter has as parts entities of the former two types. Consequently, both *ga:Production* and *ga:Consumption* processed may regard some or all of those types of *ga:Product*. While *ga:Product* corresponds to *CIDOC:E71-Man-Made-Thing*, a *ga:Material-Product* corresponds to *CIDOC:E24-Physical-Man-Made-Thing* and a *ga*:ImmaterialProduct corresponds to a *CIDOC:E28-Conceptual-Object*. The *ga:MaterialProduction* is a *CIDOC:E12-Production* whilst the *ga:ImmaterialProduction* is a *CIDOC:E65-Creation*. Regarding *ga:Consumption*, the *ga:MaterialAcquisition* approximates to *CIDOC:E8-Acquisition*, except for the latter including loss of title due to destruction of the item.

With *The Night Watch* and its derivatives in mind the various production and consumption storylines both in an immaterial as in material sense can be modeled as follows:

(1) As a *ga:Material-Product*, the storyline starts with the materials used to create the painting, comprising the preparation of the canvas and the process of mixing the pigments and oil, the materialisation of the painting until the final touches, followed by the cuts made in order to make the painting fit into the city hall. The

derivatives also have their parts as a *ga:Material-Product* which are the materialisation of their immaterial counterpart described next (see Figures 4 and 5).

(2) As a *ga:Immaterial-Product*, the storyline starts with the first conception of the idea for the painting by Rembrandt, probably after hearing the requirements set by the commissioners about its genre and who should be included in the painting, and includes the usage or adaptations of techniques such as how to mix the pigments to produce a certain effect. The immaterial part is consumed before it is copied or adapted, such as Lundens did for copying *The Night Watch*, expressing its content using different materials, or Bak's tattoo that partially preserved the content aspect, since he chose to include the faces of members of his family therefore telling a story other than that meant by Rembrandt. Finally, for the digital reproduction of the exhibition in 2019, it was necessary to includes the immaterial consumption of both the current version of *The Night Watch* and the copy by Lundens, so that the digital image could faithfully express the original *Night Watch* (see Figures 4 and 5).

(3) As a whole *ga:ComplexProduct* of which both (1) and (2) are part, as zooming out from the details in such a way that the *ga:Production* may encompass both *ga:MaterialProduction* and *ga:ImmaterialProduction*, and the *ga:Consumption* may encompass *ga:MaterialConsumption* and/or *ga:ImmaterialConsumption* (see Figure 3).

6.5 Modelling Kubler's views of periodisation via storylines of styles and solutions

According to Kubler, styles do not constitute themselves as periods as a style often cannot be represented as a single timeline (or fiber) but as multiple (parallel) ones of which the beginning and end may differ, for example, by taking the location into account for the time-period associated with the Renaissance style, which is different in Italy and in the Netherlands. In this section we discuss how this account can be addressed in our model alongside with Kubler's proposed alternative of representing chains of solutions, as depicted in Figure 14.

First of all, a *ga:Period* is the temporal extension of a *ga:Storyline* (or *UFO:Event*) that is worth naming, therefore to discuss periodisation we need to project styles and solutions into storylines. Second, since a *ga:Storyline* combines participations of entities in certain events, we need to decide which entities and which events form the storyline of styles or solutions. Clearly, it cannot simply be the collection of their exemplary products, as the storylines of the products extend throughout their existence, while the time-frame for styles and solutions is constrained around the time in which the products were created.

Regarding the nature of style and solution, when and why does something get to be called as such? Our hypothesis is that they are themselves *ga:Immaterial-Products* and *ga:Pattern-Features* that manifest by the creation of more than one *ga:Product*. This means no feature can be considered a style or solution if it is manifested only once. A (immaterial) *ga:Product* has inherent *ga:Content-Aspects* and *ga:Presentation-Aspects*, which are *UFO:Aspects* that inhere in *UFO:Objects*. While a *ga:Content-Aspect* manifests features such as a *ga:Story* or a *ga:Theme*, e.g., portrait lit by candlelight, a *ga:Presentation-Aspect* manifests features such as a *ga:Presentation-Technique*, e.g., chiaroscuro. If a technique is recurrently manifested, it can be called a *ga:Solution*, e.g., chiaroscuro. Finally, a *ga:Style* is a combination of *ga:Solutions*. In that sense, if someone creates today a painting manifesting the set of solutions that defines the caravaggist style, it is manifesting this style (with no interference in periodisation issues).

However, deciding whether a style is being manifested might not be as straightforward as for solutions. First, since the style is composed of a number of solutions, it might bring

some uncertainty regarding its manifestation, for example, on paintings that do not manifest all the expected solutions. In addition, it seems important to have as evidence a connection of the painter with other paintings of that style (assuming it is not the one who has created the style), more precisely a *ga:ImmaterialConsumption* event directly or indirectly via a teaching master. For instance, *The Night Watch* is not clearly a manifestation of the caravaggist style, but still could be somehow associated with that given (1) the chiaroscuro solution in common and (2) the knowledge of Rembrandt about other paintings in the caravaggist style, such as those of his teacher Pieter Lastman. Conversely, a painting by Leonardo da Vinci could never be taken as caravaggist since Caravaggio was not born yet nor the style created by him.

Now, how to compose the storyline(s) of a style or solution? The participation of the product in its creation, *ga:ProductUnderCreation*, comprises the creation of its content and presentation aspects. When they manifest a solution or style, this participation also includes (the creation of) their manifestation. We refer to the creation, since some may interpret the manifestation as extending through the whole existence of the product, while we need to restrict the time-frame. Therefore, their storyline consists of composing the events in which a solution or style is manifested, *ga:SolutionManifestationCreation* and *ga:StyleManifestationCreation*. As a side note, while some technique is always manifested by the time of the creation, a style or solution may be retrospectively applicable since they may be "defined" later in time, e.g., caravaggist style was not defined by the time Caravaggio was creating his paintings.

Although the aforementioned is the basis for their storyline(s), other constraints may be necessary in order to support the historical analysis. For example, one could split the storyline of a style based on the location of the products' creation, resulting in multiple storylines for a style. An additional constraint may regard a limited time-gap among manifestations, so that an isolated caravaggist painting would not interfere in the analysis.

Ergo, once one or more meaningful storylines are created for a style, their temporal extension can be considered worth naming, for example as Italian Renaissance or Utrecht Caravaggism. In other words, even though Renaissance or Caravaggism are not themselves periods, they can support the identification of relevant time-frames for historical analysis, eventually worth naming as a period. Therefore, the use of style for periodisation can, in fact, result in different periods, even different beginning-end for a period such as Italian Renaissance depending on how strict one uses the aforementioned constraints.

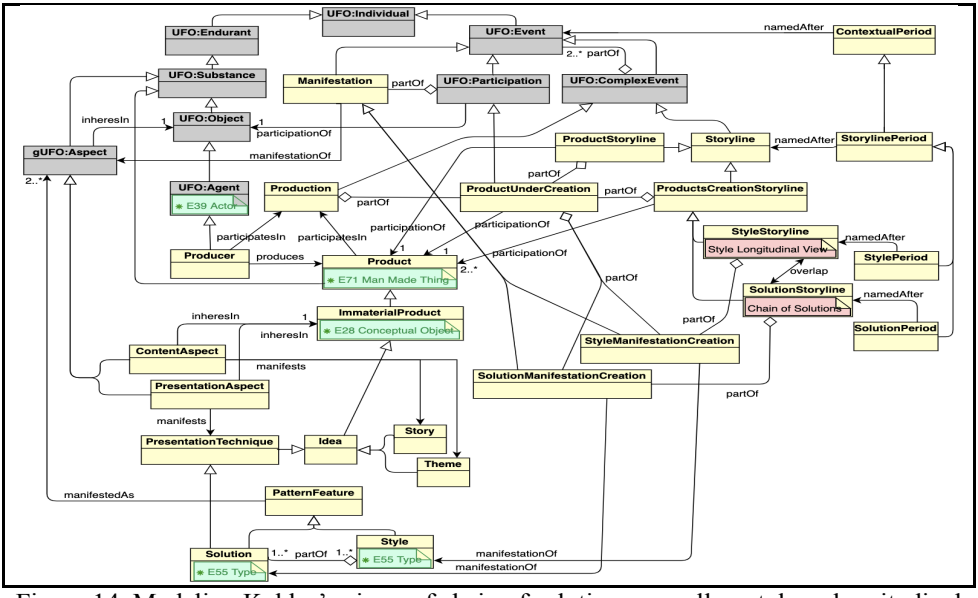

Figure 14. Modeling Kubler's views of chain of solutions as well as style as longitudinal views over the creation of products that manifest a solution or style.

CIDOC does not have specific concepts for style and solution but it does suggest means to represent them. Regarding style, two interpretations are possible according to the documentation: (1) as a *E4-Period*, which has been criticised by Kubler, and (2) as morphological object types that fall under *E55-Type*. The property *P32-used-general-technique* also has as range the *E55-Type*, which suggests that a technique (or solution) is also accounted for as such. This is compatible with our view of pattern feature, since a type is an abstraction of features expected from its instances, e.g., the type *Child* implies all its instances present as a pattern to be under a certain age limit. Finally, the concept *E55-Type* is an *E28-Conceptual-Object*, which is an *E71-Man-Made-Thing*. This means their interpretations in CIDOC are compatible with our hypothesis of them as immaterial products. Future work is to find out how human-made *CIDOC:E55-Type* relates to the supposedly equivalent *UFO:Universal*.

However, according to Kubler, a style could be better analysed via synchronous cross-section rather than longitudinally (storylines/periods). We argue that it is possible to visualise styles as storylines, although it is indeed not trivial and might not produce a unique view, as previously discussed (see Figure 9). It is not only possible, but necessary if one wants to use it for shaping the time. Nonetheless, we can also investigate how to produce Kubler's synchronous views of styles and our kaleidoscope (asynchronous) views, as well as for solutions in a similar fashion. Even though the storyline of a style or solution cannot be the storyline of its corresponding painting collection, as previously discussed, the transversal views make more sense for the latter than the former (Figure 7 illustrates transversal views). To this end, we introduce (Figure 15) the concepts *ga:StyleCollectionStoryline* and *ga:SolutionCollectionStoryline*, which are the collection of products that manifest those features. A synchronous or snapshot view of those storylines would list, at a certain time,

all (existing) products that manifest a feature, for example, all the paintings that manifest the caravaggist style in 1625 or the chiaroscuro solution in 1610. Conversely, an asynchronous or kaleidoscope view allows for accessing any of these products at different points in time, including those that were lost, for example all the paintings that were known or believed to have manifested the caravaggist style or the chiaroscuro solution at their creation time. By doing so, one could include, for example, the lost painting *The Silent* by Rembrandt in an asynchronous view of chiaroscuro solutions, if it is believed to have manifested this solution, or even the lost Caravaggio painting *Nativity with St. Francis and St. Lawrence* to a caravaggist style view.

Another interesting way that Kubler proposes is to analyse styles in terms of artists' life. This is his idea of indiction as a module of duration corresponding to the phases of an artist's life—preparation, early, middle and late maturity—lasting approximately 15 years each. Certain styles could be measured by multiple indictions of durations that are longer than single human lives or which require the time of more than one person as collective durations (Kubler 1962, 99). Naturally, it will not hold for all the cases, but we can still accommodate in the model the cases for which it does. To this end, we introduce (Figure 15) the *ga:IndictionBasedStoryline*, which has as temporal extent with a *ga:IndictionBasedDuration*, e.g., 1 indiction or 4 indictions, whereas for a style we have *ga:IndictionBasedAStyleStoryline*, corresponding to indiction-sized style storylines such as those lasting one or two successive human lives (i.e., 4 to 8 indictions, approximately 60-120 years). For example, readings of developments in Rembrandt's style in periods, such as in H.W. Janson's classic *History of Art* (1962) as middle (1636-1650) and late (1650-1669) can be compared to Kubler's indiction based on modules of maturity and late maturity. Furthermore, they can be described as (sub)storylines (parts of Rembrandt's storyline) as they last 1 indiction each (approximately 15 years). Finally, it more or less corresponds to Janson's periodisation of his outdated term "Dutch Baroque style," in his publication of the same year as Kubler's *The Shape of Time* in which he positioned Rembrandt, between ca. 1610 - 1675 as it lasts 4 indictions. Given the fact that Rembrandt's "style" hardly could be associated with the caravagist style, Janson's very arbitrary Dutch Baroque style or the very generic term Dutch Realism we can indeed question how useful it is to model style on the level of periodisation as Kubler demonstrated, although the concept "style" is still in use by art historians to get a grip on changes in the history of taste.

In conclusion, we present in Figure 15 a model that summarises the presence of Kubler's concepts (marked with a **K**) and our related adaptations/interpretations. According to Kubler, a *Fiber of Duration* or a *Bundle* of them are *Longitudinal Views* of entities through time. They can also be observed transversally as a (synchronous) *Network* or Cross-Section. He argues the latter is suitable to observe styles producing a *Style Cross-Section*, while solutions are better observed longitudinally as a *Chain of Solutions*. Other complimentary concepts are presented according to our interpretation (marked with a **GA**). A *Network* can be either *Synchronous* or *Asynchronous Transversal Views*, where the former is a *Snapshot* and the latter a *Kaleidoscope View*. In addition, a *Fiber* can consist of several "sub-fibers" that we call *Longitudinal Layers* as a *Complex Object Storyline.* This can be zoomed in and out on the layers that represent the 'internal' *Bundle of Fibers* of the parts of an object. As a consequence, a transversal view on those layers produces a *Telescope View* from which more or less details/parts can be observed. Similar to Kubler's *Chain of Solutions*, a style can also be observed in a *Style Longitudinal View* obtained by

the (relevant) manifestations of the feature during the products' creation. Their transversal counterparts, however, are obtained over the storylines of the collection of (relevant) products, for which we proposed a *Style Kaleidoscope View* complementary to *Kubler's Style Cross-Section*. And finally, Kubler's idea of *Indiction* can be used as a measure unit for storylines and their parts.

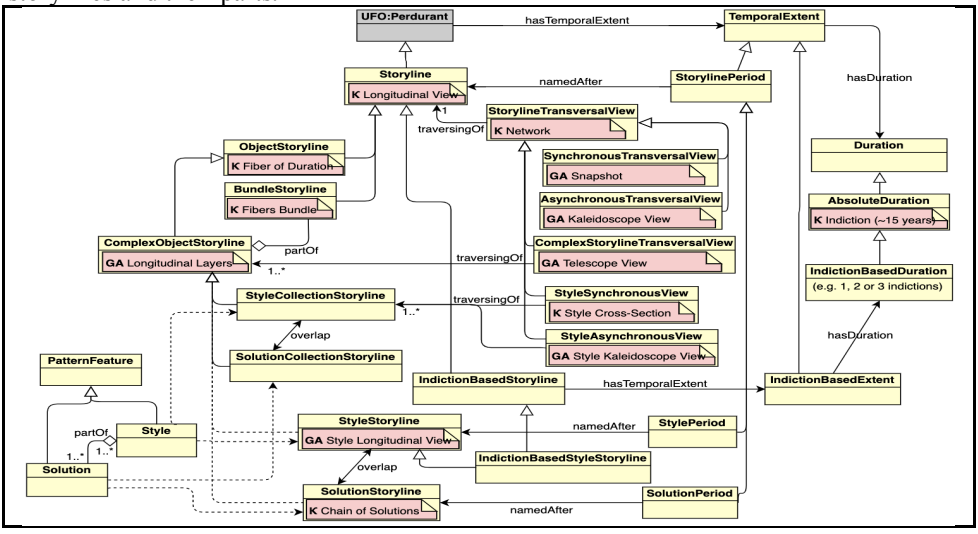

Figure 15. Modeling of Kubler's concepts and complementary interpretations related to storylines and their transversal views.

7.0 Conclusion and future work

In the context of the Golden Agents project that models historical processes of interactions between and within the creative industries of the Dutch Golden Agents as multiple narratives using the concept of "storifying data," we recognised an interesting parallel with the views on Kubler in his *Shape of Time* of 1962 on periodisation of creative production as fibers of duration based on artistic solutions instead of style. Instead of simply applying existing models of periods and events in standards such as CIDOC-CRM or PeriodO, we argued that conceptualisations of time and historical processes by historians such as that of Kubler should be taken as a point of departure for the modeling to support researchers in understanding, analysing and interacting with historical processes. We were inspired by Kubler's controversial view in the history of art that "style" is unsuitable for periodisation because different styles coexist at the same time and are in continuous flux and therefore can only be captured in an instantaneous cross-section that he described as a network. Here, we argued that Kubler had not fully grasped the potential of networks reading them in two instead of multiple dimensions and suggested for that reason to replace Kubler's own mosaic metaphor by that of a kaleidoscope to visualise his model of periodisation. Furthermore, we were interested in Kubler's empirical model of periodisation based on the life cycles of single and successive generations of artists that he brought back to modules (indictions) of (approximately) 15 years. Finally, we explored how Kubler's concept of prime objects and derivatives might be used to model the (im)material production and consumption of cultural goods in storylines in the Golden Agents project. Kubler's ideas have been

shown to be very a l, as many points are still under-addressed or partially addressed in scattered literature. Although we did not agree with all of Kubler's views they turned out to be insightful.

Therefore, we visualised Kubler's and our own perspectives using the rich history of the life and works of Rembrandt, in particular of *The Night Watch*, as a test case to formulate in total 10 requirements for our knowledge interaction model of historical interaction. Following these requirements, this historical interaction model was built on top of Unified Foundational Ontology UFO. Modelling decisions are guided herein by the rule that each introduced concept needs to fit its system of categories that makes the nature of that concept explicit. Where possible, relevant classes of CIDOC-CRM or PeriodO were mapped in the UML diagrams of the UFO-based historical interaction model. From these mappings, it became clear that several existing standard ontologies and vocabularies, such as CIDOC-CRM, OWL Time, Simple Event Model (SEM) and PeriodO did not meet our requirements in full. We believe that this not only has implications for our case study but for many semantic web applications in the humanities domain that favor data integration. One aim of our work was to find ways to reconcile concepts from the models mentioned on the basis of the formulated requirements.

All requirements for the model could be met in the parts of the historical interaction model that were visualised in UML diagrams. However, the provided visualisations of the storylines of the life and works of Rembrandt that illustrate our test case for the model of historical interaction are still static. We hope in the future to turn these static visualisations into a dynamic user interface to allow researchers to interact with the storylines in an LD paradigm including some annotation features, similar to those discussed in the cited literature on knowledge graph visualisations.

Naturally, as the proposed historical interaction model is a first attempt to materialise Kubler's ideas of time combined to our requirements, the application in practice to real data and further theoretical discussions may point out welcome improvements necessary to the model. As it is proposed, the model is truth agnostic in the sense that real or fictional events, participants and even calendars can be stated and analysed seamlessly. Important consequences of this choice are (i) likely events, as so often happens in history research for which we are not sure, can be expressed so that they can be part of the analysis that may endorse or reject them; (ii) knowingly fictional stories often mention real events or participants, which may also provide relevant input for historical research. Naturally, this position begs for (1) ways to connect the statements to one or more evidence-sources and (2) explicitly adding an epistemological layer in which statements can be taken as more or less likely facts according to someone's beliefs. An account for (1) particularly targeting archival resources are currently being developed and some preliminary results called ROAR++ can be found in van Wissen and Zamborlini 2020. The creation of an epistemological layer (2) is also under investigation for which a solution will also be proposed and published in the future.

Therefore, the conceptual model here proposed does not constitute the whole "storifying data model," which is still in development. It does provide all its different views on style, events and periodisation in relation to existing standard ontologies and vocabularies, which may require some complex modelling decisions to make important distinctions explicit. It is important to realise, however, that not all this complexity may be needed for the implementation, which will be provided in OWL also as future work.

Notes

1. The group consists of Charles van den Heuvel (Huygens ING/UvA Amsterdam, Veruska Zamborlini (University of Amsterdam), Vanessa Bartalezi Lenzi and Carlo Menghini (CNRS-Pisa), Alex Butterwoth (University of Sussex), Karl Pinneau (UTCompiegne) and Regina Varnierne-Janssen (Vilnius University).
2. For some of these papers, abstracts have been submitted but the review process has been delayed due to the coronavirus. Wissen, Latronico, Zamborlini, Reinders and van den Heuvel. 2020. "Unlocking the Archives: A Pipeline for Scanning, Transcribing, and Modelling Entities of Archival Documents into Linked Open Data." Abstract for DHBenelux2020, submitted 24 March 2020; Zamborlini, Wissen and van den Heuvel. 2020. "Reconstructions and Observations in Archival Resources: Modelling Persons, Objects and Places in the Golden Agents research Infrastructure."
3. https://www.nasa.gov/image-feature/goddard/2016/hubble-looks-into-a-cosmic-kaleidoscope
4. https://frontierfields.org

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