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Nobili on Mobile! When the scientific instruments exhibitions are at your fingertips

ABSTRACT

This paper presents a general view of a proposal for a digital reinterpretation of a collection of scientific instruments belonging to the Physics Cabinet of the Science Museum of the University of Coimbra. In this cataloging, the local and global aspects of each instrument are inventoried and represented by a semantic network of concepts, facts, ideas, and narratives, resulting in a knowledge base about scientific physics instruments. This knowledge base will be made available to students, researchers, and the general public through a mobile phone application. The article also offers a review of the transformations of the conceptual models of material culture studies related to scientific instruments and adds some contributions to this field of study.

Keywords: history of science, scientific instruments, communication in science museums, sematic web, wiki

Słowa kluczowe: historia nauki, instrumenty naukowe, komunikacja w muzeach nauki, sieć semantyczna, Wiki

Introduction

Why do we collect artifacts from the material culture of science? How to expose collections of scientific instruments and introduce them with contextualized information about the history of science and help people understand how science works? How can we propose content about scientific instruments, which are in glass cabinets and cannot be touched? Would science museums have a role in providing consistent and historically contextualized information about scientific instruments that could be a reliable source of information for researchers and students to generate knowledge? These questions challenged us to think not only about the role of collections of scientific instruments in general but also ways of reinterpreting collections, precisely that of scientific instruments of the Physics Cabinet of the Science Museum of the University of Coimbra.

Science Museums are non-homogeneous arrangements, within the diversity of definitions and classifications that museological literature offers, both have are being oriented to communicate, educate and interpret knowledge related to science, its method, its transformations, its experiments, and its instruments that allow to know and describe natural phenomena. However, in the context of many museums similar to the one we examined, these instruments are untouchable, usually displayed inside a glass cabinet, so what would be the best way to approach them?

Museums are also perceived by the public as reliable information providers and are sources of research for knowledge generation.[1] The support for this role of museums are so important as the objects they preserve and display, and this means it is relevant to provide all the information existent in their archives about the collection's items. Today, in the vast majority of museums, these archives are digitized and often accessible via the Web.

It is in this context of digital museum collections that we propose to think about ways of presenting and interpreting collections of ancient scientific instruments, within a perspective of the History of Science, emphasizing how the conception of these artifacts articulate relations between theories and experiments. We intend to provide the visiting public with access to a narrative that favors the perception of science as a social venture in continuous transformation, with its uncertainties, and its results as a consensus of the scientific community, till new knowledge breaks it.

The proposal under development sought to research and collect information about the scientific instruments belonging to the Physics Cabinet of the Science Museum of the University of Coimbra (GF), organizing them in a knowledge base, improving and complementing information already cataloged and generating new information. Interpretations about the collection. The GF has a digital catalog that can be accessed via the web, but offers only basic descriptions of the instrument, some information about its operation, origin, and has less than 20% of the artifacts recorded in images.

The current virtual collection is structured in a database and information about its items can be retrieved by different search forms: by a general listing; by a general search using a word or phrase; by search-oriented according to the expressions – Who, What or When; by a specific research that enables the construction of a query cross-section; and by a guided research, which from six categories – Scientific instrument; Scientific instrument\Accessory; Scientific instrument\Measuring instrument; Scientific instrument\Didactic model; Scientific instrument\Instrument holder and Furniture. These searches can return three types of responses: list, album, and summary. The information structure presented is restricted to necessary information about the instruments such as

[1] This subject is deep explored by J. Griffiths and D.W. King, *InterConnections: The IMLS National Study on the use of libraries*, Museums and the Internet. Institute of Museum and Library Services, 2008, http://www.interconnectionsreport.org/reports/IMLSMusRpt20080312kjm.pdf [accessed: 19.01.2018].

inventory number, object designation, title, description, authorships, categories, materials, measurements, and inscriptions.

The virtualization project of the University of Coimbra Science Museum (MCUC),[2] followed a common trend in the first decade of the millennium (2007) to customize existing database management systems and relational database software, in this case, Microsoft SQL Server, with the front end developed in ASP.NET.[3] Thus, as in many other similar museums, collections made available online do not provide a specific interpretation context for the objects they display, they provide access only to basic description and composition information of instruments and in some cases information about their operation. Without historical contextualization and inadequate interpretation to accompany these objects, these online collections are insufficient as research sources, providing only superficial visualization experiences. Museums need to address this information gap to justify their status as valuable educational and research institutions.

Cataloging scientific instruments collections: Building a scientific instruments knowledge base

How to make the vast mass of factual knowledge about scientific instruments manageable for researchers and students? It means gathering, disseminating, and making available content from a broad universe of available information and the inherent difficulties of a coherent organization that facilitates its retrieval. In the computational domain, databases are tools to accomplish this task of storing and retrieving information, but the current methodology of relational data modeling is inadequate to represent the various relationships that may exist in an application. Classification strategies and semantic modeling are some of the ways to overcome these deficiencies.

Classification systems are ways of describing objects, managing chaos, placing an order to understand, learning, and essential for the early retrieval of registration in cataloging processes. The classifications reflect practical concerns and theoretical assumptions about the nature of specific populations and certain domains. Therefore, information management and information organization are essential parts of a knowledge base, but it is not restricted to that alone. If we limit ourselves to the organization of information and exclude other manifestations of knowledge, we also limit what we can achieve.[4]

Semantics is the study of meaning. It focuses on the relationship between signifiers, such as words, phrases, signs and symbols, and what they represent, their denotation. It is a broad subject within the general study of language. An understanding of semantics is essential to the study of language acquisition (how language users acquire a sense of meaning, such as speakers and writers, listeners, and readers) and of language change

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[2] The website is at http://museudaciencia.inwebonline.net/ [accessed: 15.01.2018].

[3] ASP.Net is the acronym to Active Server Page, a Microsoft Web Programing Language.

[4] P. Lambe, *Organising knowledge: Taxonomies, knowledge and organisational effectiveness*, Oxford 2007.

(how meanings change over time). It is essential to understand the language in social contexts as it is likely to affect meaning and understand varieties of English and style effects. It is, therefore, one of the most fundamental concepts of linguistics. The study of semantics includes the study of how meaning is constructed, interpreted, clarified, obscured, illustrated, simplified, negotiated, contradicted, and paraphrased.

In the case of collections of scientific instruments, the problematization begins with the term 'scientific instrument', which in itself seems clear but is somewhat generic and brings together a myriad of objects that could not correctly be called instruments. Moreover, the term is the subject of different understandings, as it encompasses a long line of devices dating back to the eighteenth century and the concept of science would only emerge in the mid-nineteenth century, coined by the historian of science William Whewell (1794–1866), thus being scientific instruments would be a mid-nineteenth-century term.[5]

Given the diversity of types, purposes, and functions, some authors suggest classifications for scientific instruments based on the classification suggested by G.L.E. Turner, in *Elizabethan instrument makers: The origins of the London trade in precision instrument making* which emphasizes the 'use' criterion to subdivide scientific instruments into three categories: research and action; professional and industrial; and education and didactics,[6] involved the use of objects, including instruments, models, gadgets, and tools. Their duties would include observation, measurement, experimentation, and replication, as well as demonstration, dissemination, education, and indoctrination.[7]

Most collections tend to be cataloged in a well-structured hierarchy, following the best archiving standards. Classification schemes are designed to group related things, so that is possible to find something within a category; it is easy to find other related things in that category. However, sometimes we find inconsistencies in the terms used for archiving, lack of standardization across institutions, and a broader discussion of the terms used for cataloging collections of scientific instruments is needed.

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[5] There is evidence, however, that in France, in 1787, Étienne Lenoir, 'ingénieur du Roi', described the objects he manufactured as 'les instrumens à l'usage des sciences'. Also the term "wissenschaftliche instrumente" would have been used in Germany in the 1830s, and by 1850 it was already commonly used by some manufacturers. The concept 'instrument' would relate to tools and devices, and that by joining the term 'scientific' would result in the notion of a tool or device used by scientists to investigate nature, qualitatively or quantitatively. In addition, the author argues that the term 'scientific instrument' was coined in the late eighteenth century and was widely used until the mid-twentieth century by manufacturers, dealers, patent office staff to meet the taxonomic or interpretative expectations of the curators. museums. Since it was created in the period mentioned, a movement of production and distribution of objects called scientific instruments, but often during the nineteenth century, these artifacts were called by their manufacturers, as instruments of 'mathematics' or 'optical,' or 'philosophical,' according to their manufacturing practices and due commercial and mercantile considerations, and that the terms 'natural philosophy' and 'philosophical instruments' have also given rise to contemporary expressions 'science' and 'scientific instruments.' In: L. Taub, *On scientific instruments*, "Studies in History and Philosophy of Science" 2009, No. 40, pp. 337–343.

[6] P. Brenni, *The evolution of teaching instruments and their use between 1800 and 1930*, "Science & Education" 2012, No. 21, pp. 191–226.

[7] L. Taub, *op.cit.*

In this sense, we emphasize and adopt in our project the result of the work developed by museological teams from Portugal and Brazil, which resulted in the Thesaurus of Scientific Collections in Portuguese Language,[8] which is an efficient tool for standardization and terminological control for categorizing museum collections and is continually being updated. A thesaurus is a classification system used to control preferred term(s) to describe an object, oriented to meet the needs of collection managers, researchers, and academics.

This Thesaurus has the following categories for classifying scientific instruments:

- Scientific instrument
  - Scientific Instrument for Calculation and Processing
  - Scientific instrument of design
  - Scientific instrument of measurement
  - Scientific Observation Instrument
  - Scientific Instrument of Preparation and Assembly
  - Scientific Registration Instrument
- Demonstration and Study Instrument
  - Instrument of Demonstration and Contemplative Study
  - Demonstration and Operative Study Instrument
- Machine
- Reference Object
  - Scale
  - Standard
- Utensil.

This Thesaurus defines a more 'top-down' classification, and often each object representing a class can have its internal classification according to different criteria such as components, functions, and methods involved in its operation. Classification and serialization in the study of scientific artifacts is presented with an exploratory combinatorial data analysis technique to reorder objects in a sequence along a one-dimensional continuum, so as to reveal regularities and standardizations across the entire series of objects and also it allows detecting relationships that may exist between elements, subsets or sets and aspects that the given instrument shares with equivalent or similar artifacts such as contemporary instruments of the same type, or instruments produced by the same manufacturer.[9]

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[8] Thesaurus de Acervos Científicos em Língua Portuguesa – The website is at http://thesaurusonline.museus.ul.pt/default.aspx [accessed: 23.05.2018].

[9] An example of a classificatory analysis of a scientific instrument is presented by V.N. Krutikov in his study on radiators. The author defines two classes of this device according to the fundamental principles that determine their operating mechanism: thermal radiation receivers and photon radiation receivers. With these two class, he builds two chronological trees: one for the development of thermal radiation receivers and other for photon radiation receivers. The author highlights the importance of the genealogy for the organization and understanding of the technological transformations of an instrument throughout its life cycle. In: V.N. Krutikov, *The history of development and the present state of radiation receivers as primary converters of optical quantities, signals, and images*, "Measurement Techniques" 2002, Vol. 45 (9).

In addition to this categorization, the starting point of our research, we sought in the specialized literature studies on conceptual models or data models developed within the scope of material culture studies oriented to museological collections to guide our information modeling.

Why a knowledge base and not a database?

Knowledge comprises concepts and propositions, including concept propositions that deal with learning strategies and conduct investigation methods, and also includes the affective dimension of experience associated with concepts and proposition.

Knowledge Base is a relational database that specializes in a particular subject or accumulated knowledge about a particular subject so that its content can be used to solve specific problems. It can aggregate different inference tools, intelligent agents based on Artificial Intelligence (I.A.) logic, thus constituting accurate expert systems. It can contain different formats of information, such as articles, videos, audios or materials in other formats organized according to the mental model of the expert, and which allow quick access to answers to frequent problems demanded by users.

A knowledge base should be able to ask and answer questions through inferences that are answered as if an expert were answering them. Its promotes the idea that a knowledge base is a tool that is beyond just sharing information – it could be considered as an expert system where users have the opportunity to expand their knowledge, and category experts have the opportunity to share it.

There is ongoing confusion about database management systems and knowledge management systems. It is crucial first to demarcate the differences between knowledge and information. Knowledge refers to relevant and objective information gained through experience, means the familiarity and awareness of a person, place, events, ideas, questions, ways of doing things or anything else, which is gathered through learning, perception or discovery. It is the state of knowing something with knowledge through an understanding of concepts, study, and experience. In short, knowledge connotes the confident theoretical or practical understanding of an entity, along with the ability to use it for a specific purpose. Combining information, experience, and intuition leads to knowledge that has the potential to draw inferences and develop insights based on our experience and thus can assist in decision making and action making.

The term "information" is described as structured, organized, and processed data presented in context, which makes it relevant and useful to the person who wants it. Data means raw facts and numbers relating to people, places, or anything else, which is expressed in the form of numbers, letters, or symbols. Information is data that is transformed and classified into an intelligible form that can be used in the decision-making process. In short, when data becomes meaningful after conversion, it is known as information. It is something that informs, in essence, gives an answer to a particular question.

The overly simple distinction between tacit and explicit knowledge helps to increase this confusion because it is elementary to assume that information is explicit knowledge. In the context of building a knowledge base on scientific instruments, the demarcation of the various domains of know-what, know-how, know-why, and know-who come together to form and build a vast network involving the demonstrations of use and functioning of instruments, as well as the historical and theoretical narratives that these objects involve.

Is crucial to shift that a graphic representation of knowledge is becoming ever more critical in applications that deal with large amounts data, like museum with their role to research, interpret and sharing meaningful information, and one of the options is stepped back in the path about studies about model of knowledge and matrix of information about museum collections.[10]

Conceptual models for the study and cataloging of scientific instruments

In the context of the History of Science, the interest in the study of scientific instruments has a mark stone with the publication in 1953 of Maurice Daumas *Les Instruments Scientifiques aux XV IIe et XVIIIe Siecles*, but studies based on material culture gain emphasis on a group of historians and philosophers of science at the University of Edinburgh in Scotland, who propose a social history of scientific practice, culminating in the 1980s with the publication of the study *Leviathan and the air-pump: Hobbes, Boyle, and the experimental life*, by Steven Shapin and Simon Schaffer, where the authors take advantage of the debate between Boyle (1627–1691) and Thomas Hobbes (1588–1679) on Boyle's air-pump experiments in the 1660s, to construct a narrative focused on the scientific apparatus emphasizing the thesis that the problems of knowledge linked to the issues of social order.

In the context of the collections of scientific instruments of science museums, studies of material culture and scientific practices are used to describe a history of museums through 'biographies of objects' in their collections, accompanying their manufacture, uses and movements until the incorporation into a collection when it is classified categorically, analytically or exhibitory. Material culture is a mode of the investigation focused on the object as primary data and can be considered a branch of cultural history or cultural anthropology. Its fundamental purpose is the search for cultural belief systems, the belief patterns of a particular group of people at a given time and place. In this way, scientific production considered as an aspect of culture, and a network of social relations.[11]

Studies of material culture have flourished in the field of anthropology, being a discipline that is close to social and cultural history and characterized by its interdisciplinary aspect in investigating the past in order to engage the dialogue between historians, archaeologists, sociologists, folklorists and anthropologists, as well as museum and antique curators, among others.

The material culture research object is concerned with the everyday life and material circumstances of ordinary people. It is a field of knowledge with a theoretical structure in continuous reformulation and with methodological issues still being debated, such as, how people's relationships with objects in the past are reconstructed. Also, how it is possible without resorting to texts and documents that enable the understanding of this

[10] M. Nisheva-Pavlova, N. Spyratos, P. Stanchev, *Conference: UNESCO digital presentation and preservation of cultural and scientific heritage*, Vol. 4p, Veliko Tarnovo, Bulgaria 2014.

[11] S.J.M.M. Alberti, *Objects, and the museum*, "Isis" 2005, No. 96, pp. 559–571.

relationship. These reconstructions are based on hypotheses and deductions constructed from the theoretical models.

Within this context, the proposed model by E. McClung Fleming in *Artifact study: A proposed model*, appeared in "Winterthur Portfolio," an academic journal published by the University of Chicago Press, which deals with studies on the arts and the historical context in which they were developed. A few years later, the study of Jules Prown, *Mind in matter: An introduction to material culture and method* in the same journal, tried to establish also, a methodological foundation for the studies of material culture.

The method proposed by Fleming, named Winterthur's Method, was developed to guide the study of art artifacts in museums and emphasized the examination of the physical properties of objects; comparisons with other related or similar purposes; the cultural context of manufacture and use, i.e. the links between the artefact and its original culture; and in the current meaning, in the relationships between the artifact and the contemporary cultures of the public. The method consists of a structure with five basic properties that seek to include and interrelate all the significant facts about an artifact through four operations (Identification, Evaluation, Cultural Analysis, and Interpretation) proposed for each of these five basic properties: History, Material, Construction, Design, and Function.[12]

A recent study in the field of material culture seeks to document historical and scientific instruments belonging to museums highlighting the relationships of instruments with scientific theories that gave rise to them. This study sought to add to the model proposed by Fleming the research on the material, bibliographical, written sources and iconographic, and organizing the data according to two dimensions – temporal and similarities. The temporal dimension presents the chronological dichotomy, which seeks to distinguish the synchronic aspects of the artifact by direct inspection and the diachronic elements related to its history. The dimension of similarity also presents two factors: the dichotomy of classification, which is the distinction between the individual instrument and the class of devices that share the same designation. The notion of temporality and classification result in a four-quadrant structure, composed of mutually dependent issues and requiring different sources and methods for their response. The four quadrants combined provide a research program consisting of four parallel and interdependent tasks: the individual material instrument being studied; his biography; the group of similar surviving devices and their scientific function; and local and global narratives in the history of science where these instruments played a role.[13]

The absence of information related to provenance, acquisition and other data related to the use of the scientific instruments of the collection, drove to the necessity to research through documents "Minutes of the Collegiate" and "Purchasing Notes"

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[12] J.D. Prown, *Mind in matter: An introduction to material culture theory and method*, "Winterthur Portfolio" 1982, Spring,Vol. 17 (1), pp. 1–19.

[13] M. Lourenço, S. Gessner, *Documenting collections: Cornerstones for more history of science in museums*, "Science & Education" 2014, No. 23, pp. 727–745, doi: 10.1007/s11191-012-9568-z.

in the University of Coimbra Public Archives, to unveil a little of the past of these instruments.

Also was made bibliographical research related to the instrument and its inventor. Were consulted the 'Physics Manuals' and in the 'Vendors and Manufacturers Catalogs,' allowed us to construct a historical narrative about the studied object, to emphasize both its 'local dimension' and the artifact of a museum collection, as well as its 'global dimension,' as an instrument related to scientific culture.

From a computational standpoint, these conceptual models are information structures, and the model proposed by Gessner and Lourenço[14] will become our basic structure for the representation of knowledge about scientific instruments, and from it we developed a semantic ontology, graphically represented, so as to allow the visualization of all the possible connections that the instruments may present, whether of their inventors, manufacturers, materials, components and even other instruments and so on, with the purpose of establishing a specialized information network featuring a knowledge base on scientific instruments.

Representing knowledge: The relational dimension of the conceptual model

In the context of the History of Science, the study of material culture allows us to look at the scientific instruments belonging to the teaching collections, as a way to construct a historical narrative of science teaching practices in nineteenth-century schools, as well as the relations of social and economic order, which involved, among manufacturers, producers of informational catalogs, promotional fairs and the vast network of consumers of what represented the essence of modernity: science.

Thus, we develop an ontology about scientific instruments, considering the instruments as 'entities,' the inventors, the manufacturers, the sellers, the users (teachers, preparers, and students), the collectors; finally a vast interconnected network that is the substratum of the meaning of that object on display. Such an object is represented as a network of relationships within the 'scientific culture'. From a technical point of view, semantic modeling explicitly operates relationships, and semantic data models are generally complete in that the user extracting any information from the database always obtains a set of related facts.[15]

Whether the entry is a subject or object search, the result will always be a corollary of information relating to one another. Relevance relations are explained in which terms function as conceptual connectors, such as: 'invented by'; 'made by'; 'used in'. The use of abstractions in semantic data models allows the user to view information as layers at

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[14] *Ibidem.*

[15] Semantic modeling uses Resource Description Framework (RDF) technology, which is a graph-based data model specifically designed to represent and interconnect information on the Web. RDF is based on a triple pattern of relationship between a subject or an entity, a predicate and an object. In: A. Uzun, *Semantic modeling and enrichment of mobile and WiFi network data*, London 2018.

many different levels. The possibility of graphical visualization of this information is a differential compared to conventional databases.

Wiki as a knowledge base

Many museums display their collections in searchable online databases. However, these online collections do not provide full context and interpretation for the objects they display. Most collections offer only basic levels of identification of the objects they own. Without the proper context to track these objects, online collections do not serve as proper search sources and only provide shallow viewing experiences.

The causes of this sparse content offer are multiple, such as lack of research resources, technological limitations, and computational resources. One option to circumvent these restrictions would be to use a low-maintenance, easy-to-use resource with incredible potential that has already become one of the most significant global benchmarks in shared knowledge management, the Web Wiki resource. Wikis can be applied for cataloging museum collections to improve the depth and availability of museum information online. Wikis promote the exploration of knowledge through their linked articles. With a Wiki, it is possible to reveal the relationships between artifacts in collections.

The Web Wiki feature allows documents to be edited collectively with a simple and effective markup language using a web browser. Since the vast majority of Wikis are web-based, the term wiki is usually sufficient. One of the definitive advantages of the Wikis is the ease to create, change and maintain the Wikis pages. There is usually no review before modifications being accepted, and most Wikis are open to all or at least all people who have access to the Wiki Server. Not even user registration is required on many Wikis.

On the Web, we could find some projects involving Wiki technologies to catalog and document museum collections like WikiProject Digital Preservation, a project designed to improve Wikipedia's coverage of digital preservation and the organization of information and articles on this topic. The Haggin Museum in Stockton, CA, a pilot project that introduce the collection of Albert Bierstadt paintings.[16] The OpenGLAM Project is an Open Knowledge initiative to promote free and open access to the digital cultural heritage of galleries, libraries, archives and museums; the Astrolabe Explorer, a collaborative experiment sponsored by the Oxford Museum to explore and catalog existing astrolabes in public and private collections; also by the same Oxford Museum Collections Explorer, which is an experimental service for browsing some items from the Yousef Jameel Center for Islamic and Asian Art, Bodleian Digital and Pitt Rivers Museum, as well as additional features such as the Benezit Artists Dictionary, the List Getty Union Names (ULAN), Early Modern Letters Online, the University of Oxford Research Archive (ORA), Nomisma, VIAF, GeoNames and Wikimedia Commons.

[16] More information about this project can be found in detail at: M. Schlesinger, *The Museum Wiki: A model for online collections in museums*, "Master's Projects and Capstones" 2016, No. 456, https://repository.usfca.edu/capstone/456 [accessed: 15.05.2018].

Semantic Wiki and other projects

Although ordinary wikis are restricted to content as data, semantic wikis add more layers, and, data that can be used for human or automatic processing, or computer-only data that is not easily understood by humans.[17] We chose to use the MediaWiki feature with the Semantic MediaWiki (SMW) extension, which uses semantic web technologies (OWL,[18] RDF) so that the wiki environment, in addition to hyperlinked browsing, has a structure susceptible to be understood by machines. Allows articles (and links) to have relationships, attributes. Thus, SMW can help in searching, organizing, browsing, improving, and sharing wiki content. Because it is an extension, no part of MediaWiki is overwritten, so it can be incorporated into fully functioning wikis without much migration cost.

Several successful projects that use Semantic Web technologies to provide access to cultural heritage collections already exist. Among the most popular are the projects:

- REACH,[19] Reach is an independent online space open to the contribution of the entire Heritage Research community to offer a set of multi-disciplinary and multimedia approaches for the exchange of knowledge and experience between people and institutions.The site gathers links to project data, documents, and websites from the EU and from outside Europe. Information is indexed by keywords, theme categories, and date of publication for easy user access.
- MuseumFinland,[20] a portal that integrates collections from three Finnish museums, and the CultureSampo,[21] a system that creates a collective semantic memory of a country's cultural heritage, which provides unified viewpoints into the heterogeneous collections of over 20 Finnish cultural heritage institutions. Both are part of the Linked Data Finland[22] initiative, which is a Live Laboratory of action and research, to make life easier for publishers and consumers of structured data on the web. It is conducted by the Aalto University Semantic Computing Research Group in collaboration with the University of Helsinki and a large consortium of Finnish organizations and public companies.
- Amsterdam Museum,[23] an open data set of the Amsterdam Museum, that consists of the metadata and images of the collection of the city of Amsterdam. All object descriptions (metadata) are made available under CC0[24] and the images (content)

[17] F. Bry, M. Eckert, J. Kotowski, K. Weiand, *What the user interacts with: Reflections on conceptual models for Semantic Wiki*, "CEUR Workshop Proceedings" 2009, pp. 60–72.

[18] OWL – Ontology Web Language is a Semantic Web language designed to represent rich and complex knowledge about things, groups of things, and relations between things, https://www.w3.org/OWL/ [accessed: 15.05.2018].

[19] The website is at https://www.reach-culture.eu [accessed: 15.05.2018].

[20] The website is at http://www.museosuomi.fi/, https://www.ldf.fi/dataset/mufi/ [accessed: 15.05.2018].

[21] The website is at http://www.kulttuurisampo.fi/?lang=en [accessed: 15.05.2018].

[22] The website is at https://www.ldf.fi/index.html [accessed: 15.05.2018].

[23] The website is at https://www.amsterdammuseum.nl/open-data [accessed: 15.05.2018].

[24] CCO – Cataloging Cultural Objects, a metadata standard developed by the Visual Resources Association, an international organization for image media professionals, founded in 1982 by slide librarians (visual resources curators) who were members of the College Art Association (CAA), the South Eastern Art Conference (SECAC), the Art Libraries Society of North America (ARLIS/NA),

are Public Domain. This means that the data may be copied, changed, distributed and executed without permission from the Amsterdam Museum. The museum appreciates being mentioned as a source of information.
- The British Museum Semantic Web Collection Online[25] that provides access to the same collection data available through the Museum's web presented Collection Online but in a computer-readable format. The current version is beta and development work continues to improve the service.

Some projects that, although not using semantic technologies, were relevant references because the organization of their content and the strategies used to interact with the public became essential references for us, such as the pioneering project Epact 2003.[26] Epact is an electronic catalog of instruments from medieval and renaissance scientists belonging to four European museums: History of Science Museum, Oxford; Institute and Museum of Storia della Scienza, Florence; British Museum, London and Boerhaave Museum, Leiden. Together, these museums house the best collections of the world's first scientific instruments. Epact consists of 520 catalog entries and a variety of support material. All European instruments from the four manufacturers museums that were active before 1600 were entered in the catalog. They include astrolabes, armillary spheres, sundials, quadrants, nocturnes, compendia, topographic instruments, and so on. Examples range from ordinary everyday instruments to the most extravagant and often luxurious pieces intended for princes's Cabinets.

The other valuable reference is the project "The Virtual Laboratory: Essays and Resources on the Experimentalization of Life"[27] – a platform maintained by the Max Planck Institute of History of Science, where historians publish and discuss their research on experimentation in the life sciences, art, and technology. Virtual Laboratory collects and presents texts and images on various aspects of life experimentation, such as instruments, experiments, places, and people. The section on experiments links scientists to instruments, a manufacturer, and a vast repertoire of related information accessed by eight categories: Essays, Experiments, Technology, Objects, Sites, People, Concepts and Library. It is a platform partially open to employees, restricted to specific requirements.

On the Web you can find some portals that provide references and research on scientific instruments, here I highlight the Youtube channel of Fondazione de Scienza e Tecnica de Florence,[28] directed by Prof. Paolo Brenni where a variety of experiments with the ancient scientific instruments pertaining to this institution's collection are demonstrated, exemplifying the workings of many devices. It is essential to emphasize the importance of this material that adds the dimension of tacit knowledge to the instruments, indispensable to a knowledge base. Also, an important source of information for scientific instruments

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and the Mid-America College Art Association (MACAA). The association is concerned with creating, describing, and distributing digital images and other media; educating image professionals; and developing standards. The Visual Resources Association Foundation, a 501 C-3 organization created by the VRA, supports research and education in visual resources and provides educational, literary, and scientific outreach to the archival and library community and the general public.

[25] The website is at https://old.datahub.io/dataset/british-museum [accessed: 15.05.2018].

[26] The website is at https://www.mhs.ox.ac.uk/epact/ [accessed: 15.05.2018].

[27] The website is at http://vlp.mpiwg-berlin.mpg.de/index_html [accessed: 15.05.2018].

[28] The website is at https://www.youtube.com/user/florencefst [accessed: 15.05.2018].

is the Scientific Instruments Commission website which connects a multitude of other institutions and provides links to two databases: the Websters' Instrument Makers Database and the Scientific Instrument Makers in the Netherlands. The first provides information collected by Roderick and Marjorie Webster, longtime curators of the scientific instrument collection at the Adler Planetarium & Astronomy Museum in Chicago; and the second provides biographical data on instrument makers that were active in the Netherlands from a card index used at the Museum Boerhaave — equally inspiring the Museum Optischer Instrumente,[29] which feature a fantastic detailing of photos of optical instruments, and handy organization of references of these instruments.

All these projects are essential references in the field of information on scientific instruments and were the result of initiatives by many people, institutions, and resources. They form the core of what we are trying to fulfill, and sometimes our documents point to information referenced on these sites. Moreover, yet, as the volume of documents that we offer for prospecting information grows can be greatly facilitated with the use of graphical data visualization feature. Some graphical data visualization tools allow the visualization of complex data networks, and we use the Topic Maps tool, with which the navigation by topic nodes expand to the intensity of the research and the desire to deepen the topic, which has been shown a handy resource for navigating large amounts of information as a Wiki-based knowledge base.

Topic Maps for Content Navigation

Topic Maps was initially developed in the late 1990s as a way to represent back-of-the--book index structures so that multiple indexes from different sources could be merged. Topic Maps represents information using topics, representing any concept, from people, countries, and organizations to software modules, individual files and events, associations, representing hypergraph relationships between topics and occurrences, representing information resources relevant to a specific topic. Topic Maps are similar to 'Concept Maps' and 'Mind Maps' in many ways, although only Topic Maps are ISO standards. The ISO standard is formally known as ISO/IEC 13250: 2003.[30] Topic Maps are a form of semantic web technology similar to RDF.[31]

[29] The website is at https://www.musoptin.com [accessed: 15.05.2018].

[30] For more details and the entire course of discussion done until you reach the referenced standard and its subsequent revisions (2006 and 2007) at http://www.isotopicmaps.org/tmrm/ [accessed: 15.05.2018].

[31] Resource Description Framework (RDF) is a standard model for data exchange on the Web. RDF has features that make it easy to merge data even if the underlying schemas differ, and specifically support schema evolution over time, without requiring all data consumers to be changed. RDF extends the web linking framework to use URIs to name the relationship between things as well as the two ends of the link (this is often called "triple"). Using this simple model, it allows structured and semi-structured data to be mixed, exposed and shared across different applications. This linking structure forms a labeled, directed chart, where the edges represent the named link between two features, represented by the chart nodes. This graphic view is the easiest possible mental model for RDF and is often used for easy-to-understand visual explanations.

The VIKI Extension for MediaWiki draws a network graph from links between Wiki pages allowing for viewing it as a Topic Maps. Its adds an intuitive interface for users to effectively navigate the Wiki framework and make it possible to find information relevant to their tasks.[32] Topic Maps provides an overview of the structure of the Wiki organization. Topic Maps can be viewed at different levels of detail so that users can control the amount of information presented to them. Topic Maps lets understand the network of relationships an object can have with several others. When we think of extensive collections with more than 1,000 pieces, resulting in dozens of internal links to each page, leading to the exponential growth of topics and pages available for reference, the Topic Maps feature thus becomes a strategic option for prospecting information.

In order to make the information contained in the knowledge base more accessible, we decided to make it available through a mobile application (app), for its ubiquity and its power of penetration of all ages. We use a strategy of delivery of knowledge in a fragmented or granular way, so that it is possible to deepen into the knowledge about the scientific instruments on display, according to the user's interest. The app features a range of functions and aims to provide an informal, active learning environment to explore knowledge in depth and push the boundaries of the Physics Cabinet exhibit.

Mobile and museums

Why mobile? We make this justification by appropriating the words of Nancy Proctor who points out that "mobiles are changing science communication in the research institutions." For her, mobiles have a "disruptive power," once they allow an "individual, immediate and omnipresent access," connecting people in global social communities and networks, being "private and public, personal and political." This technology would be changing the way that museums do business. She points out the profound disruption that this technology has brought to museums since the use of radio broadcasting for the first audio tour at the Stedelijk Museum in Amsterdam in 1952.[33]

Also, technology has always been an ally of museums, in the 1980s microcomputer had an impact not only on the managerial sectors of museum collections but also on new ways of exposing and interpreting such collections through the use of multimedia

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[32] VIKI (Visualization and Knowledge Integration) is a D3-based directed force layout graph visualization of the structure of a wiki. In a VIKI graph, graph nodes represent individual wiki pages or web pages, while links between nodes indicate page links (i.e. one page has a hyperlink to another page, e.g. of the form [Other Page]). These links are directional, where the direction of the link indicates which page links to which. If two pages link to each other, the link is bidirectional. We say two pages are linked on a VIKI graph if there is a link between their nodes on the graph, i.e. either of the two pages links to the other, or they link to each other. Some wiki pages also have hyperlinks to external web pages; these pages are also displayed on the VIKI graph (with a generic wi-fi icon), but interaction with these pages is limited. The graph is pannable and zoomable using either the mouse scroll action or the zoom bar located at the bottom of the graph. Individual nodes may be dragged around and rearranged as well; the D3 graph automatically revises node positions to a local equilibrium state whenever nodes are dragged.

[33] N. Proctor, *Mobile apps for museums*, The AAM Press, American Association of Museums, Kindle Edition, 2011.

in kiosks and terminals. If already previously some museums used the videos cassettes for the projection of films, documentaries, making off, with the digital technology the possibilities of interaction with the public and the way to think the objects in the exhibition were extended. In the late 1990s, the Web became a worldwide phenomenon making the site global. The museums have a presence in the world through the Web, ensuring in their domains their institutional identity, allowing access to their collection remotely, providing research and education, and more significant interaction with the target public, with registered visitors and all the resources that would follow Web 2.0.

Mobile applications for museums can only have an institutional character, be like a business card with necessary information about the institution, contacts, and directions, but they can contemplate much more than this. They can function as audio guides and also, once they are 'geospatially aware' they can provide flexible audio-guides and support research, communication, and collaboration. Mobiles would be an integral part of a network of platforms that connect communities of interest and facilitate conversations between different audiences, and with the museum itself. The possibilities of an application as 'a mobile guide,' distributed by the museum, could become an excellent tool to meet the challenge of publicizing museums and mediation of exhibitions when there are limited budgets and human resources[34].

Museums on the Web are moving away from the "curator of highlights" approach to a model in which the entire collection is available for research, navigation, and filtering. Many multimedia projects in museums would not meet the demands of the target audience if they were based on the demands of the target audiences of traditional audio guides. They are different requirements and different needs.[35]

To provide a knowledge base related to scientific instruments, belonging to the Physics Cabinet of the Science Museum of the University of Coimbra, for a different audience who visits, has visited the museum or not a museum collection, we developed a prototype of an application. A mobile phone that allows multiple ways to access information about the instrument, which may be on display or stored in the technical field. For visitors, information can be accessed by reading QRCode printed on exposed object identifiers. Necessary information about the instrument at the touch of the screen can be deepened by navigating through the links offered, accessing other information screens, according to the user's interest. All navigated route and instruments visited in the application, when registered, allow us to know a little about the interest of visitors--users. The system also offers search lists and Topic Maps navigation, always accessing a Wiki page, the knowledge base.

Last, we believe that a mobile application can overcome the mobile guide to the extent that it enables interactivity beyond the passivity of hearing audio guides as well as being a learning technology with a great potential recently started to explore and above

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[34] Sh. Wang, *A mobile guide app platform prototype with front-end evaluation and potential business model for museums in Finland*, "Proceedings MWA" 2013; *Museums and the Web ASIA 2013*, The Conference of Museums and the Web in Asia, 2013.

[35] K.J. Smith, *The future of mobile interpretation* [in:] *Museums and the Web 2009*: *Proceedings*, eds. J. Trant, D. Bearman, Toronto, 31 March 2009, http://www.archimuse.com/mw2009/papers/smith/smith.html [accessed: 15.06.2018].

all we look to the student public and researchers who wish to deepen their knowledge about scientific instruments.

Conclusions

The present work is a proposal in the development of digital cataloging of scientific instruments belonging to the collection of the Physics Cabinet of the Science Museum of the University of Coimbra. Besides the visual register of objects, we also intend to reinterpret these objects by associating them to an information structure based on studies of the material culture of scientific instruments. We are using a Wiki tool to catalog all information about each device and its local and global properties. We are using a Topic Maps tool to retrieve information registred on Wiki. This tool allows the visualization of a network of relationships that each device may have with others, in whatever their domain, global or local.

As part of the development of this project, we are planning to apply a user test. We will be offering to randomly selected visitors to use the app on a mobile device while visiting a temporary exhibition with some chosen objects. A pretest will be applied to these volunteers and a posttest. An another group of visitors who will not make use of the app will apply the same pre and post-tests. It aims to realize the effectiveness of providing information about objects in promoting learning about concepts and topics related to the instruments on display.

In our content, we emphasize the museum visitor understands science as an institution in continuous transformation, with its uncertainties, its results and as part of a social endeavor, and not just minds and dates. We were also intent that this app could have the possibility of have been applicable as curricular themes of physics in several schools of Portuguese language, joining on a network to provide more and more sources of scientific information of easy access.

With an interdisciplinary perspective, the present project intends to make modest contributions to different areas, such as material culture research, using computational tools to expand models for the study of scientific instruments. Within the scope of museum studies, to advance the use of semantic tools in the cataloging of collections and to test the effectiveness of mobile applications in delivering properly structured content relating to the instruments on display to guide visitors and promote non-formal science learning.

We concern that, despite the growth of more museums and science and technology exhibition centers than ever before, the data points out to a growing public increasing in these spaces, which leads to the conclusion that there is apparently a considerable public 'hunger' to know about science and technology, but, paradoxically, this growth of widespread interest and the expansion of supply of information on science and technology has been accompanied by a growing concern with scientific illiteracy and prevalent disinformation about Science and Technology (S & T), in which the historian of science John Pickstone[36] called the 'twentieth century S & T paradox.'

[36] J.V. Pickstone, *Ways of knowing: A new history of science, technology, and medicine*, Manchester 2000.

Much remains to be done; content building depends on research, research, and more research! We believe that our main contribution to this project would be the development of a relational cataloging model for the development of a knowledge base on scientific instruments that we hope will be expanded with the experience of using the knowledge base interfaced by the use of Topic Maps in others museum collections.

Finally, our app and its content should contribute to building a consciousness of science as experimentation, and as Macdonald & Basu[37] warns, if contemporary scientific practices are based on experimentation, the objects on display at a Science Museum would be permanently an ‘experimentation’, and so will be our app, a technological instrument to integrate the individual with the science and technology, allowing the acquisition of scientific experimental know-how.

For what Nobili has to do with mobile besides an “almost” heteronym, is that at the touch of your finger you can see in detail, on your mobile, the scientific instruments designed by Leopoldo Nobili (1784–1835), the Italian physicist who invented a series of critical instruments to investigate thermodynamics and electrochemistry, such as the Nobili-type projection galvanometer manufactured by Ruhmkorff, the Nobili thermoelectric cell manufactured by EM Clarke, which are part of the of our Physics Cabinet of Coimbra University Science Museum. Check it.

Bibliography

Alberti S.J.M.M., *Objects, and the museum*, “Isis” 2005, No. 96, pp. 559–571.

Brenni P., *The evolution of teaching instruments and their use between 1800 and 1930*, “Science & Education” 2012, No. 21, pp. 191–226.

Bry F., Eckert M., Kotowski J., Weiand K., *What the user interacts with: Reflections on conceptual models for Semantic Wiki*, “CEUR Workshop Proceedings” 2009, pp. 60–72.

Griffiths J., King D.W., *InterConnections: The IMLS National Study on the use of libraries, Museums and the Internet*. Institute of Museum and Library Services, 2008, http://www.interconnectionsreport.org/reports/IMLSMusRpt20080312kjm.pdf [accessed: 19.01.2016].

Krutikov V.N., *The history of development and the present state of radiation receivers as primary converters of optical quantities, signals, and images*, “Measurement Techniques” 2002, Vol. 45 (9).

Lambe P., *Organising knowledge: Taxonomies, knowledge and organizational effectiveness*, Oxford 2007.

Lourenço M., Gessner S., *Documenting collections: Cornerstones for more history of science in museums*, “Science & Education” 2014, No. 23, pp. 727–745, doi: 10.1007/s11191-012-9568-z.

Macdonald Sh., Basu P., *Introduction: Experiments in exhibition, ethnography, art, and science* [in:] *Exhibition experiments*, eds. S. Macdonald, P. Basu, Oxford 2006, https://www.york.ac.uk/media/sociology/introduction.pdf [accessed: 9.01.2016].

Museums and the Web ASIA 2013, The Conference of Museums and the Web in Asia, 2013.

Nisheva-Pavlova M., Spyratos N., Stanchev P., *Conference: UNESCO digital presentation and preservation of cultural and scientific heritage*, Vol. 4p, Veliko Tarnovo, Bulgaria 2014.

[37] Sh. Macdonald, P. Basu, *Introduction: Experiments in exhibition, ethnography, art, and science* [in:] *Exhibition experiments*, eds. S. Macdonald, P. Basu, Oxford 2006, https://www.york.ac.uk/media/sociology/introduction.pdf [accessed: 9.01.2018].

Pickstone J.V., *Ways of knowing: A new history of science, technology, and medicine*, Manchester 2000.
Proctor N., *Mobile apps for museums*, The AAM Press, American Association of Museums, Kindle Edition, 2011.
Prown J.D., *Mind in matter: An introduction to material culture theory and method*, "Winterthur Portfolio" 1982, Spring, Vol. 17 (1), pp. 1–19.
Schlesinger M., *The Museum Wiki: A model for online collections in museums*, "Master's Projects and Capstones" 2016, No. 456, https://repository.usfca.edu/capstone/456 [accessed: 3.06.2018].
Smith K.J., *The future of mobile interpretation* [in:] *Museums and the Web 2009*: *Proceedings*, eds. J. Trant, D. Bearman, Toronto, 31 March 2009, http://www.archimuse.com/mw2009/papers/smith/smith.html [accessed: 15.06.2018].
Taub L., *On scientific instruments*, "Studies in History and Philosophy of Science" 2009, No. 40, pp. 337–343.
Uzun A., *Semantic modeling and enrichment of mobile and WiFi network data*, London 2018.
Wang Sh., *A mobile guide app platform prototype with front-end evaluation and potential business model for museums in Finland*, "Proceedings MWA" 2013.