CONSIDERING THE QUESTION OF THE INTEROPERABILITY

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Abstract: This article concerns the path taken during my scientific research related to the construction and management of digital assets for the design, development, and management of databases, within the scope of the INET-md in Portugal. Its general objective is to facilitate the interoperability, Web dissemination, search, and retrieval of the INET-md's digital collections. This investigation aims to reinforce the alliance between the areas of Information Science and Computer Science. From the Information Science, it brings the applications used for organization, management, and publication of digital assets collections on the Web; and from the Computer Science, it brings syntactic concepts (metadata and protocols) to communicate and exchange data and semantic concepts (ontologies and semantic annotations) to describe data. Both types of concepts can promote interoperability between distinct digital repositories and platforms, providing improvements in information search and retrieval activities.

Keywords: Digital collections; Digital Humanities; Interoperability; Digital repositories.

Resumo: Este artigo diz respeito ao caminho percorrido durante a minha investigação científica relacionada à construção e gestão de ativos digitais para a conceção, desenvolvimento e gestão de bases de dados, no âmbito do INET-md em Portugal. Seu objetivo geral é facilitar a interoperabilidade, disseminação na Web, busca e recuperação das coleções digitais do INET-md. Esta investigação visa reforçar a aliança entre as áreas de Ciência da Informação e Ciência da Computação. Da Ciência da Informação, traz os aplicativos utilizados para organização, gestão e publicação de acervos de ativos digitais na Web; e da Ciência da Computação, traz conceitos sintáticos (metadados e protocolos) para comunicar e trocar dados e conceitos semânticos (ontologias e anotações semânticas) para descrever dados. Ambos os tipos de conceitos podem promover a interoperabilidade entre distintos repositórios e plataformas digitais, proporcionando melhorias nas atividades de busca e recuperação de informações.

Palavras-chave: Coleções digitais; Humanidades digitais; Interoperabilidade; Repositórios digitais.

1. Introduction

The Institute of Ethnomusicology - Centre for Studies in Music and Dance (INET-md) is a transdisciplinary research unit based at the Faculty of Social and Human Sciences, University Nova de Lisboa (NOVA-FCSH) and three centers located in the Department of Communication and Art, at University of Aveiro (DeCA-UA); Faculty of Human Motricity, at University of Lisbon (FMH-UL); and School of Education, Polytechnic Institute of Porto (ESE-P.Porto). The main goal of INET-md is the research and creation in the fields of music and dance, in collaboration with various interlocutors and institutions.

This study concerns the path taken during the scientific research related to the construction and management of digital assets for the design, development, and management of databases, within the scope of the INET-md, in Portugal. It presents the initial results

obtained by a project conducted inside the research group of Ethnomusicology and Studies in Popular Music of INET-md. The general objective of this study is to facilitate the interoperability, Web dissemination, search, and retrieval of the INET-md's digital collections.

This investigation can be inserted in Digital Humanities (DH) that is an area at the intersection of technologies with the disciplines of the Humanities. DH can be defined as an emerging field that deals with digital technologies and areas related to human, social and applied social sciences (KOLTAY, 2016; CLEMENT and CARTER, 2017). It brings new ways of doing investigations that involve collaborative, transdisciplinary, and computationally engaged research, teaching, and publishing. It also brings digital tools and methods to the study of the Humanities.

Furthermore, this research intends to reinforce the alliance between the areas of Information Science and Computer Science. This investigation presents applications and platforms used for organization, management, and online dissemination of digital assets, from the Information Science; and it brings syntactic concepts to communicate and exchange data and semantic concepts to describe data, from the Computer Science. These concepts can promote interoperability between distinct digital repositories and platforms, providing improvements in information search and retrieval.

Based on the problem approach, this research can be classified as qualitative, in the sense of seeking an understanding of what is behind the investigation through the analysis and the description of the concepts involved. Based on its objectives, this research can be classified as descriptive-exploratory, as it intends to raise and describe characteristics of the problem to be investigated in the light of the literature and research and improve ideas about interoperability between distinct digital repositories.

This text is organized as follows: Section 2 presents the theoretical background that constitutes the basis of this paper; Section 3 presents a case study concerning the digital collections of INET-md; finally, Section 4 outlines the final considerations and future directions regarding the continuity of this research.

2. Theoretical background

First, it is important to note that the term digital collection is being used in this text for expressing any type of digital platform that comprises data and/or documents, that is, a library, repository, museum and current, intermediate, or permanent archive (SEGUNDO, SILVA and MARTINS, 2019). Therefore, other more specific terms such as digital libraries and repositories, digital and/or virtual museums, can also be used, but this reinforces the idea of thinking about collections in a comprehensive and global way.

Some applications currently used for organizing and publishing collections of digital assets are presented in Section 2.1. Besides this, it is important to investigate how to promote interoperability, which is defined in this article as the ability of different systems to communicate transparently with each other, regardless of platform, hardware, or software. Section 2.2 presents concepts regarding syntactic interoperability, while Section 2.3 presents concepts regarding semantic interoperability.

2.1. Organization and publication of digital collections

In this section, some applications used for organizing and publishing collections of digital assets are shortly presented in the following lines. Such tools have in common the fact that they are free and open source, having the capacity to deal with metadata for organization, classification, and search in digital collections. They are: i) Collective Access; ii) Collection Space; iii) Tainacan; and iv) Omeka.

Collective Access (2021) and Collection Space (2021) are applications used for preserving digital collections, maintaining standardized metadata, and providing search services. However, they are less effective when it comes to displaying collections or providing the rich visual context that Web users expect. Both tools are often difficult to implement and expensive to maintain, as they require a team of IT professionals to install and configure their resources. For example, MuSA – the Museum of the University of Aveiro (http://museu.ua.pt/index.php) adopted the Collective Access software to manage its digital collection (MARTINS *et al.*, 2015).

Tainacan is a free software developed by the University of Brasília in partnership with the Federal University of Goiás. The project began in 2014 around the development of a national policy on digital collections for Brazilian cultural institutions. It was implemented in PHP and has WordPress – a CMS[1] platform, as its base architecture. By the way, in practical terms, Tainacan constitutes a plugin for WordPress, which turns it into a digital collection management system (MARTINS e MARTINS, 2020; MARTINS, LEMOS and ANDRADE, 2021).

Omeka (SHINTAKU *et al.*, 2018) offers a collection-focused Web publishing platform, standards adherence, interoperability, and a toolkit for handling digital collections. It also constitutes a lightweight solution when compared to software from traditional institutional repositories, such as DSpace, which requires an IT professional at the institution to support software management and configuration demands (SHINTAKU, 2017; MARTINS, SILVA and SIQUEIRA, 2018). Omeka Classic uses only Dublin Core for metadata, while Omeka-S (Semantics) also supports multiple namespaces, linking to ontologies (GUARINO, 1998), creating dictionaries, and is compliant with Linked Open Data principles (BIZER, HEATH and BERNERS-LEE, 2009). Currently, many institutions use Omeka for applications of digital archiving of different types of digital archives, *i. e.*, not only for written digital objects but also for multimedia content (GILL *et al.*, 2020; POPOVIĆ, ŠKORIĆ and RUJEVIĆ, 2020).

2.2. Syntactic Interoperability

Syntactic (technic) interoperability allows two or more digital repositories/platforms to communicate and exchange data. Investigation about how to allow syntactic interoperability involves the concepts of metadata and protocols, to mention a few. Some definitions are presented in the next paragraphs.

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[1] Content Management System.

In a general way, metadata is data that provides information about other data. The main principles of metadata dissemination, named FAIR principles, are: Findable, Accessible, Interoperable, Reusable. They ensure that metadata is visible, accessible, interoperable, and durable (JACOBSEN *et al.*, 2020). The basic FAIR principle is that data must have at least one unique identifier based on which it can be found in the repository in which they are stored, or in some other repository to which they are linked, and it should, thus, enable the retrieval of data according to a standardized protocol.

There are different metadata standards available, but the Dublin Core Metadata Initiative (DCMI) is the most widely adopted (SEGUNDO, SILVA and MARTINS, 2019). The Dublin Core metadata is a set of fifteen "core" elements or properties for describing resources, which may be digital (videos, images, Web pages, etc.), as well as physical (books, instruments, and works of art).

Protocols are a set of rules for defining communication between systems. There are several protocols that allow the exchange of information, such as the OAI-PMH[2], OAI-ORE[3], ATOM, among others. One way available to service providers to expose metadata so that other systems and/or components can access it is called harvesting, which is a process that enables the direct collection of metadata from documents stored in information systems.

The Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) provides a standard way to harvest metadata records, as well as obtain basic information and supported metadata types. The protocol is based on HTTP, using a common URL with a parameter to select the type of request. The exchange of messages between the data provider's server and the service provider's external robot program for transferring metadata is one-way – the service provider makes requests to the data provider, which responds by sending metadata. To allow as much interoperability as possible, the OAI--PMH protocol recommends using Dublin Core to structure the metadata.

The Open Archives Initiative Object Reuse and Exchange (OAI-ORE) is a protocol that defines standards for the description and exchange of aggregations of Web resources. These aggregations, sometimes called compound digital objects, may combine distributed resources with multiple media types like text, images, data, and video. It provides a similar interoperability mechanism for objects, as OAI-PMH provides for their metadata.

The term ATOM, in the context of interoperability protocols, refers to two related protocols: i) ATOM syndication format (ASF), which is an XML distribution protocol based on RSS, used as a web feed structure, and ii) ATOM Publishing Protocol (APP), which refers to an HTTP-based protocol designed to create, edit, and publish the content of websites that support this protocol.

Despite the importance of disseminating descriptive metadata capable of supporting interoperability, the way in which institutions are implementing Dublin Core in practice is rarely discussed (SEGUNDO, SILVA and MARTINS, 2019). Refining the quality of the metadata remains a huge challenge for interoperability and harmonizing profiles for local

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[2] https://www.openarchives.org/pmh/.

[3] https://www.openarchives.org/ore/.

OAI-PMH implementations, to a significant extent, would support automated harvesting processes (INNOCENTI, VULLO and ROSS, 2010).

2.3. Semantic Interoperability

Investigation about the Semantic Web and how to allow semantic interoperability involves the concepts of ontologies (SACRAMENTO *et al.*, 2010), Linked Data (SACRAMENTO *et al.*, 2012), and Data Mashups (CHEN *et al.*, 2009), for example. Relevant definitions are briefly presented in the next paragraphs.

Semantic (content) interoperability is the ability of computer systems to unambiguously exchange data using a shared meaning, independently of their hardware, software, or platforms. It is concerned not just with the packaging of data (syntax), but the simultaneous transmission of the meaning with the data (semantics). This is accomplished by adding data about the data (metadata) and linking each data element to a controlled, shared vocabulary (ontology).

Ontologies have been used to formally describe the semantics of the data and makes their context explicit (WACHE *et al.*, 2001). They have the same principles of controlled vocabularies, as they work with natural language and delimit terms and relationships. However, the semantics involved in ontology terminology also includes formal axioms that restrict vocabulary usage. Furthermore, ontologies can help the information professional's work when representing documents as, through its formal semantics, they can eliminate contradictions involving concepts and relationships, resulting in an unambiguous specification of the domain, and enabling the search and information retrieval strategies.

Semantic annotation is the process of tagging documents or files with relevant concepts, *i. e.*, attaching metadata and/or ontologies, which makes unstructured content easier to find, interpret and reuse. Sjekavica, Obradovic and Gledec (2013) present an overview of ontologies in general and specialized multimedia ontologies that can be used for semantically rich multimedia annotation.

Fig. 1 shows the interaction of some concepts of the areas of Information Science (cataloging, metadata and controlled vocabularies) and Computer Science (semantic annotation, metadata and ontologies) used in the problem of representing bibliographic and multimedia documents on the Web, revealing that the continuous advance of descriptive cataloging for digital information environments provides improvements in information retrieval systems (LEMOS and SOUZA, 2018; LEMOS and SOUZA, 2019).

Many other articles also researched the integration of these areas. Borges and Siqueira (2020) presented the state of the art of Information Science in Portugal and Brazil. Lemos and Souza (2020) presented an investigation involving ontologies for the description of multimedia content on the Web. Martins and Silva (2017) proposed a set of criteria used by the technical literature in Information Science for the analysis and comparison of information systems aimed at the creation of digital libraries, including the paradigms of social Web interaction and collaboration. Serra and Segundo (2021) presented how library catalogs are currently opaque, without semantic elements, and how they can be enriched with datasets present on the Web. Silva *et al.* (2020) described the semantic relationships included in the elements of the Europeana Data Model (EDM) and the advantages of using this model to represent and retrieve information digitized culture on the Web, allowing the

connection of data from different institutions and the information enriching. Finally, Martins *et al.* (2022) presented the interaction of concepts of the areas of Information Science, Data Science (data preprocessing and machine learning) and Computer Science used in the problem of representing digital collections on the Web.

Fig. 1 – *Representation of bibliographic and multimedia documents on the Web*
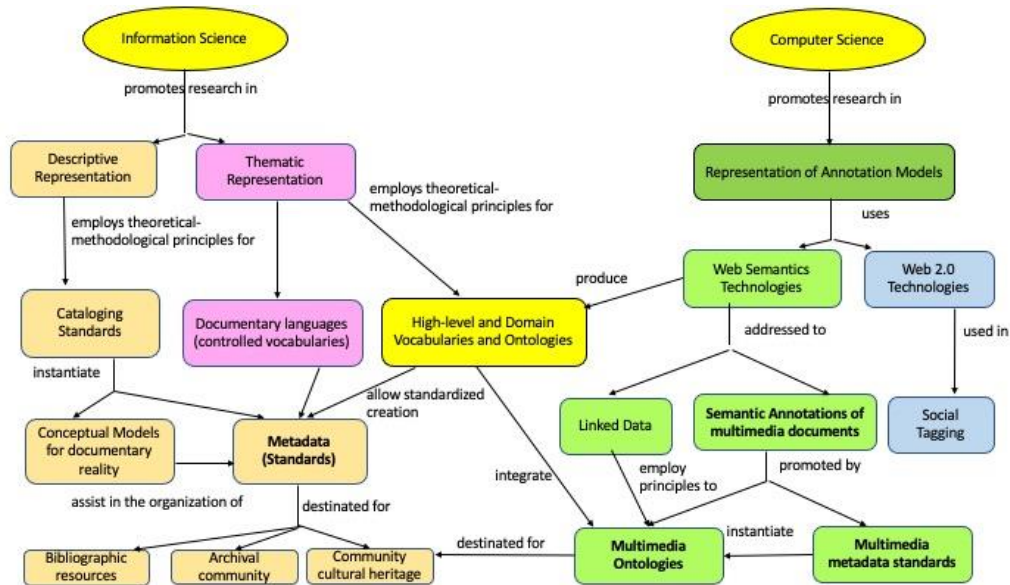
Source: (Adapted from: LEMOS and SOUZA, 2018).

As it was said before, this research intends to reinforce the alliance between the areas of Information Science, bringing the applications used for organization and publication of digital collections; and Computer Science, bringing not only the syntactic of metadata and protocols, but also the semantics of the ontologies and semantic annotations to describe such digital collections.

Although interoperability has been debated for a long time, it is still an obstacle in the processes of integrating data from digital collections, hindering the processes of aggregation and single access to a variety of diverse sources. There is not yet a full interoperability solution or approach that is sufficient to serve the overall needs of organizations and digital systems.

However, only by improving the knowledge about the possibilities of using interoperability resources will teams be able to effectively integrate data from distinct digital collections (MIGUÉIS and NEVES, 2021).

3. Case study

A case study about the INET-md is presented in this section. Section 3.1 presents how this Institute currently stores its data in digital repositories and platforms. Besides this, it is

important to describe how to promote interoperability between these distinct digital collections, presented in Section 3.2.

3.1. Digital repositories and platforms

The initial step of this research was the understanding of the INET-md's structure, goals, main projects, and how its data is made available to the users. After getting to know the website of INET-md and other pages that refer to the data produced by the institute, this investigation was carried out on how this data is stored, in terms of architecture, servers, databases, etc. to understand the current stage and propose the necessary improvements in these structures.

According to this study, INET-md must be able to handle digital collections of documents, but also must be able to support data from multimedia collections (like audio, image, and video), which must be stored in integrated file management systems, as they are more suitable for organizing and managing such collections of assets (CORUJO and GUARDADO, 2019).

The main page of INET-md can be accessed at http://www.inetmd.pt and it was developed in JOOMLA – an Open-Source CMS platform, which allows the rapid availability of content on the Web, with a low learning curve. Currently, the site of INET-md is hosted on IIS[4] web server in a Windows server at the University of Aveiro (UA).

Most of the data is not actually stored in databases. In INET-md at Aveiro, only data from a few projects (e.g., Ecomusic[5] and Mpart[6]) are stored in a relational database (MariaDB[7]). The current volume of data was estimated at 240 GB, including about 1800 video files and about 600 audio files.

To enable the availability of part of INET-md´s data during the COVID-19 pandemic, the page http://inetbase.pt/s/site/page/home was developed using WordPress and Omeka-S. This solution allowed the creation of an Omeka-S instance with the projects' data of the NOVA-FCSH Pole. Omeka uses a relational database to keep metadata and links to data, not real multimedia data. The volume of this multimedia data stored was estimated at 200 GB and contains more than 17.000 files of audios, videos, images, etc.

The INET-md at FMH – UL has two online repositories:

    i)   the TerPsicore file, a database of Dance and Performing Arts, accessible at http://www.terpsicore.pt;
    ii)   the TEPe file, a database of Technologically Expanded Performance, at https://tepe.estudiosdedanca.pt/.

In these repositories, data is persisted on disk, and the metadata is indexed in Apache Lucene for searching and querying. The current volume of data was estimated at 12 GB.

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[4] Internet Information Services.

[5] http://ecomusic.web.ua.pt/.

[6] https://anossamusica.web.ua.pt/.

[7] https://mariadb.org/.

The first application is being migrated to MongoDB[8], and the meta information will be indexed on Elasticsearch. MongoDB is an open-source NoSQL database software that can manage document-oriented information (unstructured documents in JSON[9] format).

Furthermore, some digital collections of data of the UA are stored in RIA – the Institutional Repository of the University of Aveiro (MARTINS, NOLASCO and SILVA, 2013), which is an information system that captures and preserves the research outputs of UA scientific community and make them available online, increasing its visibility and impact. RIA was implemented in DSpace and can be accessed at https://ria.ua.pt.

Most of digital collections of multimedia data of INET-md still come from accounts on Social Networks (Facebook, Instagram, and Linked In) and streaming platforms (SoundCloud, YouTube, and Vimeo). Streaming platforms have been used to make available large-sized audio and video files, as these platforms provide widgets and components that facilitate integration with other sites (embed videos and audios) through their own players in HTML+CSS+JS[10].

Currently, part of the data is being stored using DUnAs – Research Data Repository of the University of Aveiro (NOLASCO *et al*., 2021), whose pilot projects are being made available via the open-source Dataverse[11] platform (ROCHA *et al*., 2021). One of these projects is SOMA - SOunds and Memories of Aveiro, from the INET-md of Aveiro. DUnAs is an open repository for the archiving and publishing of investigation data that support the scientific research, accessible at https://dunas.ua.pt. Furthermore, it is a tool for promoting the visibility, impact, and reproducibility of UA research data. It is aligned with the FAIR Principles and supports the principles and practices of Open Science and compliance with the requirements of science funders in this area.

It is important to notice that both repositories (RIA and DUnAS) facilitate the citation of research's data and outputs through the attribution of a unique identifier (DOI). Finally, they are accessible through the Portal RCAPP (Scientific Open Access Repositories of Portugal), a meta repository that collects, aggregates and indexes open access scientific content existing in the institutional repositories of national higher education entities and other Research and Development entities, available at http://www.rcaap.pt/, OpenAIRE (Open Access Infrastructure for Research in Europe), and DARIAH-EU (Digital Research Infrastructure for the Arts and Humanities), available at https://www.dariah.eu/.

3.2. Promoting interoperability

The interoperability of repositories with other information systems within the institution (and outside it) can be identified as one of the critical factors for success and for researchers' adherence to the deposit in open access scientific repositories (MARTINS, NOLASCO and SILVA, 2013). So, it is necessary to analyze some technical (data

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[8] https://www.mongodb.com/.

[9] https://www.json.org/json-en.html.

[10] HTML (Hypertext Markup Language) + CSS (Cascade Style Sheets) + JS (Java Script).

[11] https://dataverse.org/.

architecture and structure) and functional features (metadata, content formats, technology interoperability, search, and indexing, etc.) of the repositories, to bring them closer, obtaining a set of common features and a mechanism to adapt the different features (SEGUNDO, SILVA and MARTINS, 2019).

According to this research, as the poles of INET-md have independent structures of hardware and software, it is not viable to migrate the entire collection to a common repository. However, they have in common the use of metadata in the format of Dublin Core and the possibility of exchanging data via protocol OAI-PMH, promoting syntactic interoperability.

This study proposes that the repositories and platforms of the INET-md poles allow the automatic harvest of metadata and its aggregation in a common database using OAI-PMH protocol. Furthermore, it proposes to use VuFind[12] as an enhanced discovery tool and an integrator mechanism (Fig. 2).

VuFind is an open-source library search and discovery engine that allows users to search and browse beyond the capabilities of a traditional OPAC - Online Public Access Catalogs (JAYAKANANTHAN and JEYARAJ, 2018). Like Google and other search engines, VuFind offers a single interface for searching of all the items available. It allows users to search from a single search box and then to be able to narrow down the search results by clicking on the various facets of the results, browsing through all the resources.

Fig. 2 – Using VuFind as a search and discovery tool

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[12] https://vufind.org/vufind/.
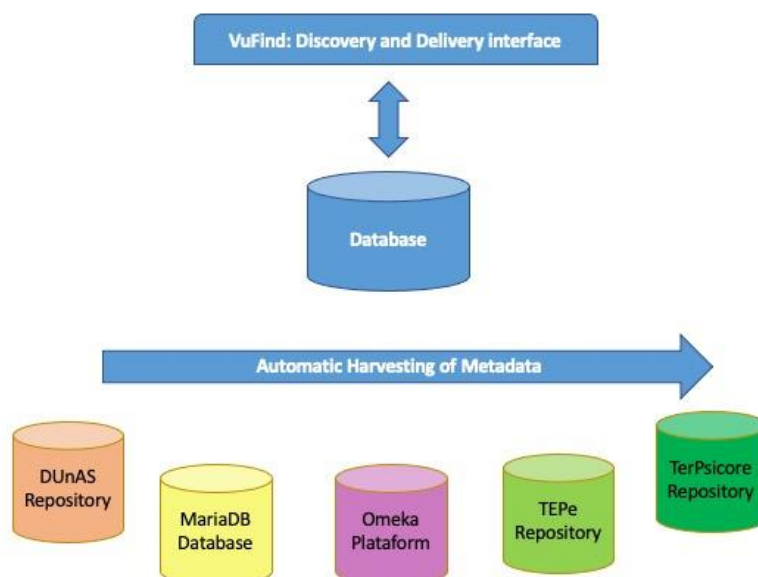
VuFind allows us to collect information from different sources, servers, and incompatible formats. It allows us to import metadata, creating a single searchable index, making possible the integration of all types of interoperating systems and the creation of unique search portals.

Finally, VuFind is already being adopted by UA and is being tested for use as a mechanism for integrating data from the platforms and repositories RIA (DSpace), MusA (Collective Access) and DUnAS (Dataverse), to mention a few.

4. Main conclusions and future work

This research was first inserted in the Digital Humanities area. It wants to favor the alliance between Information Science and Computer Science fields, providing a transversal investigation with the purpose of obtaining advances by approaching distinct technologies and experiences.

In fact, the question of the Interoperability is usually not positioned as a clear priority in many institutions. The main problems found are the inability of systems to operate with each other, the difficulty of teams in creating software complements to effect interoperability and the inappropriate use of metadata standards, or even the existence of eventual inconsistencies in the use of DCMI standards or derivatives thereof. So, there is still a lack of research capable of helping managers and researchers to make decisions in multimedia file management and recovery, despite interoperability issues that have been advocated for several years.

As a future work, it will be important to consider some difficulties encountered by researchers in the self-archiving of data that support scientific projects using DUnAS, such as: creating and defining data and metadata, defining dataset creation rules, and even distinguishing data results in projects with characteristics such as SOMA. Such difficulties are probably transversal to several INET-md projects.

Finally, we also propose to bring not only the syntactic of metadata and protocols, but also the semantics of ontologies and semantic annotations to describe digital collections. It can be said that semantic interoperability was used is an informal way, since the content of each element of DCMI is described informally. A remaining challenge still is to explore the power of the ontologies' axioms for the deduction of information, deriving facts that are not explicitly expressed.

Acknowledgements

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