Describing and Searching Food Content in Historical Images with the ChIA Vocabulary

Gerda Koch[1][0000-0002-1257-092X], Amelie Dorn[2][0000-0002-0848-8149], Renato Rocha Souza[2][0000-0002-1895-3905], Yalemisew Abgaz[3][0000-0002-3887-5342] and Ramiro Osvaldo Ortiz[1]

[1] AIT Angewandte Informationstechnik Forschungsgesellschaft mbH, Europeana Local AT, Klosterwiesgasse 32, A-8010 Graz, Austria
[2] Austrian Centre for Digital Humanities and Cultural Heritage (ACDH-CH), Austrian Academy of Sciences, Sonnenfelsgasse 19, A-1010 Vienna, Austria
[2] Adapt Centre, School of Computing, Dublin City University, Glasnevin, Dublin 9, Ireland
`kochg@ait.co.at, kochg@europeana-local.at`

Abstract. Through digitization, cultural and historical images (paintings, drawings, photographs, etc.) are transformed from tangible to digital intangible resources and can be made accessible through different platforms. This significantly increases their availability to the general public. However, the transformation mainly focuses on converting the images into their digital representations with generic metadata (e.g. title, creator, date, genre, etc.). The content of the image is often outlined in short descriptions or keywords, but is usually insufficient to support a comprehensive content search. Hence, the ChIA project set out to investigate the integration of semantic technologies and image analysis to improve the retrieval of cultural images related to food. Part of ChIA's goal was to develop a vocabulary of food terms that is particularly attuned to historical and cultural images depicting food. Regarding 'food' as a fairly broad concept, ChIA focused specifically on food that is edible to humans and images that represent it in a cultural setting, which typically includes people, places, objects or a combination of these. Existing thesauri were evaluated and finally reused in the open ChIA vocabulary for image description. The final ChIA food vocabulary has been published online using Simple Knowledge Organization System (SKOS) format and is available for reuse in cataloguing via web services. The use of the ChIA vocabulary is intended to improve the retrieval and linking of cultural images depicting food-related themes. Moreover, the ChIA food concepts and ontology may serve as input for computer vision concepts and automated data enrichment.

Keywords: Ontologies, Vocabulary Alignment, Food Domain, Art Images, Semantic Web, Cultural Heritage.

1 Introduction and Motivation

ChIA - accessing and analyzing cultural images with new technologies [1] is a collaborative scientific project between the Austrian Centre for Digital Humanities and Cultural Heritage (ACDH-CH); the Adapt Centre, Dublin City University; and Euro-

peana Local Austria, an accredited aggregator to the European Digital Library for Culture, Europeana [2]. The project's overall aims are to investigate how images depicting food in a cultural context could be better enriched to be retrieved more easily in an online search and how artificial intelligence can be involved in annotating these types of images. While the Austrian Academy of Sciences brings into the project the digital humanities research aspects, the Adapt Centre concentrates on the semantics and artificial intelligence (AI) aspects, and Europeana Local provides the tailored data access platform for searching, selecting and saving the image resources.

First, it was important to narrow down the research topic of 'food imagery' precisely for this context, and the following definitions were agreed upon:
• A 'cultural food image' is understood to be any type of image from the Europeana collection that depicts one or more types of food in a specific cultural context:
• 'Food' is regarded, in particular, as all types of food that are edible for humans.
• 'Cultural context' refers to the contextual information in which the food(s) is depicted in the image, which provides information about how that food is processed, eaten, served, or interacted with, within a particular society or culture. The cultural context also provides information about the value, status, and associated emotions of the food(s) within that society/culture.
• With 'Society and/or Culture', the ChIA project focuses on European cultures, where culture is understood as being largely associated with country. This focus is chosen given the scope of the project, with the aim of connecting to broader global cultures and societies by extension.

Societies in the western world are increasingly visually driven, and information contained in images is being processed with greater detail by both humans and machines. With the increase in digitization in recent years, came also the need to make information from visual content available in more structured ways to process and analyze them, both quantitatively and qualitatively. In the arts and humanities, there is currently still a lack of methods and computational tools that enables better access to image content.

In this context the question arises as to why there is still so little content description available in cultural image repositories and image metadata catalogues? One reason is certainly that art images are often subject to a wide range of interpretations and textual descriptions can only partially capture the richness and complexity of the semantic content of a visual image. Above all, human indexing of images is very labor intensive and hardly feasible in detail for large databases. When image databases were created for experts in the past, content descriptions were often neglected because, like stylistic genre information, they were considered rather superfluous knowledge for art experts. And even where image providers included subject terms in their art object cataloging, the choice of terms may have been inconsistent [3]. This results from the fact that within the broader history of image-making, there is still inconsistent evidence linking particular commentaries to particular images [4]. 'Iconographic interpretation', which is oriented towards the artist's intention, and 'iconological interpretation', which poses cultural and historical questions, remains ambiguous. As Raymond Drainville (2018) noted '*We rarely hear the voices of those who made pictures, commissioned them, or looked at them, because records of those voic-*

es have rarely survived' [4]. On the other hand, large collections of images often consciously gave priority to capturing the primary iconography. The description of secondary motifs was dispensed with, not only for reasons of practicability, but also to train the eye for the essentials [5].

One aim of the ChIA project was to explore the possible integration and use of existing vocabularies and ontologies for subsequent annotation and use in browsing food content images. The use of vocabularies, thesauri and ontologies enables and improves standardized searching and browsing of online resources. In general, vocabularies provide a set of terms, a controlled list of words that can be used to catalogue and describe resources and when a vocabulary is organized in hierarchies, it is called taxonomy. In contrast, a thesaurus also stores relationship information for terms (e.g. "has related concept", "is related concept"), which additionally allows a term to be linked to another term in a different vocabulary. Ontologies, on the other hand, define relationships and attributes that are specific to a particular domain; ontologies can have their own relationships and attributes, as well as classes of things characterized by these relationships and attributes [6].

For decades, ontologies have already played an important role in the formal representation of metadata associated with images. Recently, ontologies have been exploited to represent the explicit and implicit contents of cultural images by representing objects and recognizing different aspects and orientations of digital images. With the wider applications of computer vision (CV) technologies in GLAMs [7] producing several automatically generated textual labels representing the contents of images, the importance of a unified ontology that allows the integration and consistent interpretation of these labels became crucial. The need for a comprehensive, but highly specialized ontology that integrates concepts from existing vocabularies with further additional concepts added will prove to be crucial for enabling semantic annotation, search and retrieval of images. Such an ontology not only presents the concepts in one repository, but also allows the mapping between existing vocabularies.

2   Related Vocabularies and Ontologies

Food domain ontologies model and represent the domain of food and art history ontologies model subject domains of art history. With the goal of capturing food in images and annotating them with automated procedures in the future, one of ChIA's tasks was to find a vocabulary of food terms applicable for matching with cultural and historical image thesauri. For this purpose, a review of existing vocabularies was carried out from different ontologies, thesauri and classification libraries. The ontologies were chosen according to their fit with the overall ChIA objective, dealing with terms pertaining to food and culture. In order to avoid creating idiosyncratic vocabularies, with ad hoc usage and little dissemination and acceptance, the following existing knowledge sources were selected: FoodOn [8], Iconclass [9], AAT [10] and DBpedia [11]. These specific sources allow greater coverage of food related terms, but also internal diversity, given the different motivations and level of detail of each one of them.

2.1   Art Image Vocabularies

The Art and Architecture Thesaurus (AAT) was established in 1980 and has been supported by the Getty Art History Information Program since 1983 [12]. It is a large and widely used thesaurus that is continuously updated and currently contains around 71,000 records and about 400,400 terms, including synonyms and related terms, relevant for the art domain (December 2020). The terms, descriptions, and other information for generic concepts are related to art, architecture, conservation, archaeology, and other cultural heritage [13].

The AAT concepts are represented in 33 hierarchies [14] and the corpus contains approximately 42,000 generic terms grouped into 8 facets [15]. Unique persistent IDs within AAT identify the concepts and are important, especially in case of homographs, like 'lime' which can represent two distinct concepts a color or a fruit. AAT was released as Linked Open Data (LOD) in 2014 and is published under the Open Data Commons Attribution License (ODC-By) v1.0. The AAT is available in JSON (JavaScript Object Notation), RDF (Resource Description Framework), N3/Turtle and N-Triples formats, as well as in XML and relational tables. The data is refreshed every month. No subsets of the data are provided.

Iconclass was first developed in the early 1950s by Henri van de Waal, Professor of Art History at the University of Leiden. Today it is maintained by the RKD Rijksbureau voor Kunsthistorische Documentatie (Netherlands Institute for Art History). Iconography is the art and science of capturing subjects that often appear in artworks [16] and Iconclass is an iconographic classification system, providing a hierarchically organized set of concepts for describing the content of visual resources in representational Western art (ancient mythology and Christian religious iconography) [17]. It is particularly useful for describing scenes as a whole [18] and when a subject is widely represented in iconography, an artwork can even have the same title as an Iconclass definition [19].

The 28,000 hierarchically ordered Iconclass definitions are divided into ten main subjects and 450 basic categories [17]. The Iconclass alphanumeric classification code (notation) starts with digits ranging from 0 to 9 representing 10 main categories: (0) abstract art; (1-5) general topics; (6) history; (7) Bible; (8) literature; (9) classical mythology and ancient history. They are followed by the description of the iconographic subject (textual correlate) [19]. Text in brackets is used when the user wants to add a specific name outside the hierarchy [15]. Iconclass was also released as LOD (e.g. http://iconclass.org/rkd/25G21%28APPLE%29/ is the semantic URL for 'apple') and is available as RDF and JSON under the Open Database License: http://opendatacommons.org/licenses/odbl/1.0/.

2.2   Relevant Food Ontologies

A number of ontologies for food exist, but most of them have been developed for specific applications. Targeted ontologies have been developed for agriculture, specific popular products such as wine and beer, or related to culinary recipes, cooking, and kitchen utensils. Ontologies have also been created for certain specific health prob-

lems [20] or for recommending meals for specific type of users such as sport athletes [21]. Examples include, AGROVOC [22], a thesaurus of the Food and Agriculture Organization of the United Nations (FAO), the Food Product Ontology [23], or Onto-Food [24] an ontology with dietary rules for diabetics.

The FoodOn ontology was among the first attempts to build an ontology for broader applications, and includes currently nearly 30,000 terms about food and food-related human activities, such as agriculture, medicine, food safety control, shopping behavior and sustainable development [25]. FoodOn describes foods that are known in cultures from around the world and includes human-centric categorization and handling of food [20, 26, 27]. The ontology was developed following the principles of the OBO Foundry and Library and is openly available on GitHub (https://github.com/FoodOntology) under CC-BY-4.0 License. OBO Foundry encourages ontologies to reuse terms from others where applicable [28] and in FoodOn, food-related terms were also imported from existing ontologies, including NCBI Taxonomy for animal, plant, fungal or bacterial source organisms [29], Uberon [30] for parts and types of food, ENVO [31] for environmental context of food, and CHEBI [32] for chemical ingredients and contaminants. In addition, the LanguaL database [33], consisting of 14 food product description facets was used for common names of food sources, preservation methods, and some other facets [28].

In 2019 researchers supported by the Slovenian Research Agency Program and the H2020 project SAAM [34] created the FoodOntoMap resource [26]. FoodOntoMap consists of food concepts extracted from recipes and for each food concept, semantic tags from four food ontologies were assigned. Thus, the FoodOntoMap dataset provides a link between the semantic tags of the Hansard corpus, the FoodOn, OntoFood, and SNOMED CT food ontologies and focuses on foods that are edible for humans.

FoodOn and OntoFood have already been described in this context. SNOMED CT (Systematized Nomenclature of Medicine - Clinical Terms), is a standardized, multi-lingual vocabulary of clinical terms and the Hansard corpus was created within the SAMUELS project and contains almost all speeches given in the British Parliament from 1803-2005 [26]. Finally, each FoodOntoMap dataset or concept corresponds to one of the four semantic resources. As a result of the alignment process, FoodOnto-Map data set consists of a reduced number of 1,459 food concepts that were found in at least two food semantic resources.

3 Developing the ChIA Vocabulary

For the ChIA purposes, we reasoned that a mapping between food and art vocabularies would provide us with a useful mediation platform for cross search and data enrichment. Our aim was to establish an integrated food ontology with a focus on food in cultural and historical imagery. In the context of the Semantic Web, it is important to reuse existing work rather than modify it. Since it is hardly possible to reach domain-wide agreement on common vocabularies, interoperability can rather be significantly improved by creating alignment links from datasets to external reference resources [35]. Therefore, our aim was to add equivalence relations between terms

that occur in the selected different ontologies and refer to the same entity in the world. Differences in the structure of ontologies, like different word uses, coverage, semantics, and semantic relations can be large [36]. In such cases the ontological alignment - identifying equivalent entities and relations - is sometimes only possible at the lower branches of the hierarchies, [37] a fact we also had to face when developing the ChIA vocabulary.

FoodOntoMap normalizes food and nutrition concepts across three different ontologies and a semantic dataset, providing a normalized dataset of food concepts that is very suitable as a basis for matching with other ontologies. Therefore, we used FoodOnToMap as a base for matching concepts and updated and extended this resource with exact and related matches to external art vocabularies and resources. In order to access, assess and align the vocabularies, we developed Python scripts to interact with the Sparql endpoints for AAT, Iconclass and also DBpedia. Based on a curated selection of FoodOntoMap terms as the basis for the queries, a common script was developed and adapted to retrieve, from each triplestore endpoint, the partial matches between the base terms and the existing ones. From the 1,069 original terms selected from FoodOntoMap, we harvested 325,511 related terms in the Getty AAT; 1,806,259 related terms on the Iconclass and 486 fully matching terms on DBpedia. This first matching process was originally made using any partial word match between the base terms, but then we filtered the exact matches (single and only matching word), leaving 978 exact matches with Getty AAT and only one exact match with Iconclass, as concepts in Iconclass tend to be more verbose. The matches with DBpedia were all exact matches.

In the next step, we further refined the matching. From the XML and nJSON files of the AAT and Iconclass, the terms with their respective URLs were extracted and stored in an SQL database. This has allowed additional queries to be performed to match the FoodOntoMap resource. In the case of the AAT, we developed a Python script that selected only those terms whose *Related_Type* field was equal to *concept*. Discarding terms with other *Related_Type* values such as *places*, *agents*, etc. has avoided a lot of undesired matches with homographs. After a new matching process, we retrieved a reduced number of 183 exact and 1,076 related AAT concepts. For Iconclass, only those concepts were extracted that matched the query term exactly, taking into account the possibility of punctuation marks before and/or after each. Now we retrieved 149 exact and 109,359 related Iconclass concepts in the matching process.

The results were exported to files in CSV format and the list of terms was then manually analyzed and cleaned to remove inappropriate terms; plural and singular terms were homogenized and all exact matches were verified. To create the ChIA vocabulary, we used the SKOS (Simple Knowledge Organisation System) standard [38], which provides a format for encoding thesauri, classification schemes, keyword systems and taxonomies in machine-readable form. The following SKOS labels were assigned to the terms: *skos:exactMatch* (http://www.w3.org/2004/02/skos/core#exactMatch) and *skos:relatedMatch* (http://www.w3.org/2004/02/skos/core#relatedMatch). The column was left empty when no match was found.
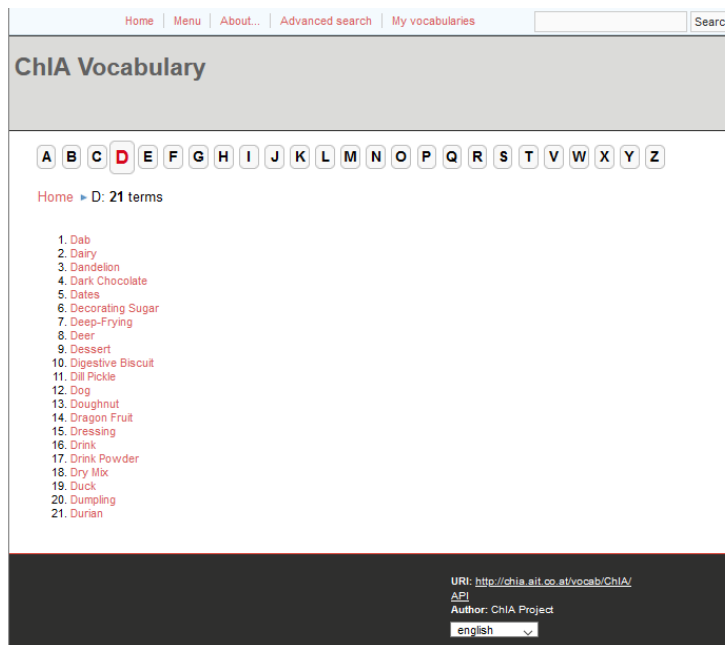
Fig. 1. Screenshot showing the alphabetical display of terms in the ChIA vocabulary.

The final matching result of FoodOntoMap to AAT and Iconclass thus provided the first version of the integrated ChIA vocabulary including 1,003 concepts, 1,508 exact and 1,543 related matches from all processed food and art thesauri and ontologies. Afterwards, a skos.xml file was automatically created to import the vocabulary into the Tematres tool. Tematres [39] is a web application for managing formal knowledge representations, thesauri, taxonomies and multilingual vocabularies on the Internet. It supports the handling of vocabularies in accordance with standard thesaurus norms and allows for import/export of data as simple text files or in SKOS format. In addition, Tematres has a Rest API with which queries can be made from external platforms, such as the ChIA search infrastructure based on OMEKA [40]. Each ChIA Vocabulary term is treated as a concept and its properties are described using SKOS terminology in an RDF style document provided by Tematres. Since April 2021 the ChIA vocabulary is published online [41] and can be reused via web services for cataloguing purposes.

Fig. 2. Screenshot showing the term 'Drink' in the ChIA vocabulary and an exact match from the Getty AAT is highlighted.

4 Integration and Use of the ChIA Vocabulary

Europeana, the European digital library for cultural heritage [2], was launched in 2008 and has so far aggregated more than 58 million objects, of which 52 million objects complying with the standards of the Europeana Publishing Framework [42] can currently be found in the standard search. The data, provided by Europeana, has previously been curated and provided to the joint portal by cultural organizations, including museums, archives, libraries, botanic gardens, cultural research institutions and galleries from across Europe. The descriptive data, originally produced in a wide variety of international data standards (e.g. MARC21 [43], EAD [44], DublinCore [45], Darwin Core [46], Lido [47], CIDOC CRM [48], etc.) is mapped to the Europeana Data Model and the metadata is available under the Creative Commons Zero Universal Public Domain Dedication (CC0). Especially in the case of federated resources, as the case of Europeana, keyword searching is often insufficient for comprehensive information retrieval. Although Europeana uses the Linked Open Data version of the AAT and Iconclass in their search this application is limited to existing AAT and Iconclass URIs in the content providers' data [16].

ChIA has set up an intermediate architecture for access, search and analysis of Europeana images. The search functionality is based on the Europeana Search API and supports the collection of test data sets from the Europeana Collections portal where more than 32 Mio. images are available under different licenses. The tool supports the

creation of individual data collections out of the wealth of (open access) Europeana digital content into sets (baskets). Those sets can be described and saved for further processing, e.g. for testing AI tools on the data sets and creating training sets for Convolutional Neural Networks (CNNs). Within the platform, it is straightforward to quickly download only the metadata (in pdf and JSON format) or any freely available digital assets together with their metadata. An application of the ChIA vocabulary is the semantic expansion of query terms in real time when searching with the ChIA infrastructure.
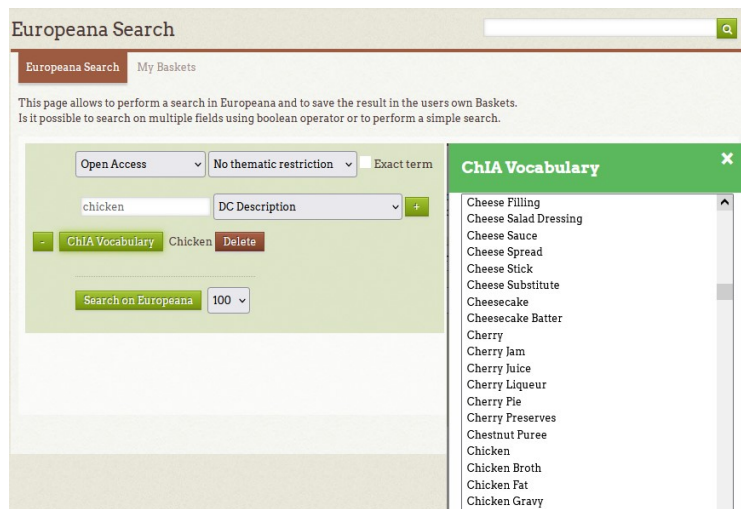

Fig. 3. Screenshot of the Europeana Search API implementation with the ChIA vocabulary selection list.

A query within the ChIA intermediate search platform attaches on user's request the concept identifiers to the textual search terms. The integration of the ChIA vocabulary into the search enables the choice of a conceptual search in addition to the keyword search. This paves way for advanced search strategies, and helps specialize or generalize queries using the concept hierarchy when too many or too few matches are found. With the usage of the ChIA vocabulary when querying, the retrieval of selected test sets for further analysis with CV/CNN/AI tools is further improved.

Fig. 4. Screenshot of a search result with the query expansion highlighted.

5   Conclusion

This work presents a detailed strategy to achieve some degree of harmonization of food concepts in AAT, Iconclass, and selected food ontologies. The aim of our exercise was to create an integrated resource containing exact matches and related matches among these vocabularies, and to reuse existing ontologies as much as possible in this endeavor.

First, we extracted exact and related matches from the art image ontologies via developed matching routines using the terms of the food ontology FoodOnToMap. With the similar terms obtained, an initial vocabulary was created using Tematres software, containing *skos:exactMatch* and *skos:relatedMatch* relationships between the terms of the different vocabularies. The implementation of this work allows the same food data represented in different ways in different data sources (cultural and non-cultural) to be linked to a concept from a basic food vocabulary, facilitating the sharing, combination and reuse of this type of data. Furthermore, the ChIA vocabulary is published online in the standardized SKOS format and can therefore be reused for cataloguing or annotation purposes and image analysis with AI tools.

In a first application, the ChIA platform, which integrates a customized version of the Europeana Search API, supports food concept searches by using the ChIA vocabulary for query expansion. This leads to an improved retrieval of specific sets of cultural images with food content. Next steps for ChIA include the validation of the retrieved related Iconclass concepts for possible integration with the current vocabulary, and additionally also the integration of the DBpedia links into the ChIA Vocabulary. Also of interest would be further tests for alignment with the Getty Iconographic Authority [49], as soon as it becomes available as LOD.

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