The Facets of Intangible Heritage in Southern Chinese Martial Arts: Applying a Knowledge-Driven Cultural Contact Detection Approach

ALESSANDRO ADAMOU, Bibliotheca Hertziana - Max Planck Institute for Art History, Italy
DAVIDE PICCA, University of Lausanne, Switzerland
YUMENG HOU, Laboratory for Experimental Museology, EPFL, Switzerland
PAULA LORETO GRANADOS-GARCÍA, The British Museum, EMKP, United Kingdom

Investigating the intangible nature of a cultural domain can take multiple forms, addressing for example the aesthetic, epistemic and social dimensions of its phenomenology. The context of Southern Chinese martial arts is of particular significance as it carries immaterial components of all these aspects: the technical and stylistic framework of a martial art system; the imagery associated to movements; and the transmission of knowledge orally, practically or through influence, are but examples of intangible characteristics that can and should be captured, not unlike cultural artifacts. The latter case– the one of formalizing cultural influence through its various forms of evidence– is emblematic as well as largely untrodden ground. A previous attempt at detecting cultural influence computationally was made in the context of Roman archaeology, though the binding of that early effort with the domain model was tight; also, there has hardly been any prior dedicated effort to model the martial arts domain through ontologies.

In this paper, we present the realization of the full cycle of a computational approach to investigating cultural contact in Southern Chinese martial arts. The entire approach is predicated upon the usage of standards and techniques of the Semantic Web and formal knowledge. Starting from a modular domain ontology, which models martial arts independently of the goal of capturing cultural influence, we perform knowledge extraction from archival material from the *Hong Kong Martial Arts Living Archive* and generate a dataset of the results modeled after said ontology. Then, we combine the resulting knowledge base with a rule model that represents ways to infer knowledge of potential contact between cultures based on the evidence present in the knowledge base. The results offer an insight into how an inference-based computational model can be applied to detect interesting facts even in the as-yet underexplored domain of intangible cultural heritage. The implemented workflow shows that the full-cycle employment of semantic technologies can offer the ground truth required for largely different approaches, such as statistical and machine learning ones, to operate.

CCS Concepts: • **Applied computing** → **Arts and humanities**; **Digital libraries and archives**.

Additional Key Words and Phrases: intangible cultural heritage, digitization, Semantic Web, embodied knowledge, knowledge representation, ontologies, inferencing

1 INTRODUCTION

Intangible cultural heritage (ICH) is an umbrella term that covers the study, encoding and cataloging of entities that are of relevance to the understanding of a cultural phenomenon that transcends the boundaries of materiality. When we talk about artistic production in the proper sense, that is, the human's ability to create an aesthetic feeling, then art may generate cultural phenomena that are at the same time tangible and intangible. The 2003

Authors' addresses: Alessandro Adamou, Bibliotheca Hertziana - Max Planck Institute for Art History, Italy, alessandro.adamou@biblhertz.it; Davide Picca, University of Lausanne, Switzerland, davide.picca@unil.ch; Yumeng Hou, Laboratory for Experimental Museology, EPFL, Switzerland, yumeng.hou@epfl.ch; Paula Loreto Granados-García, The British Museum, EMKP, United Kingdom, pgranadosgarcia@britishmuseum.org.

1556-4673/2023/7-ART
https://doi.org/10.1145/3606702

UNESCO convention gave a quasi-extensional definition of ICH, with examples considered intangible due to being conceptualizations of – often collective – human intellect.[1] On closer inspection, however, the intangible aspects that Digital Humanities studies strive to capture may be multifarious, co-occurring in one domain, and potentially independent of one another [22]. Consider for example the art of sensorial theater, which incorporates scent in its performances [2]: the involvement of sensory stimulation that modern technologies are only beginning to capture and represent [29]; the Proustian symbolic association of the olfactory experience; the reliance on documented human experience as a form of evidence; and the instability of the discipline by lack of systematic transmission, are cohabiting forms of ICH within this one art.

The above example alone showcases aspects of ICH which reside in the aesthetic, semiotic, poietic and social realms of culture. Similarly, martial arts offer a unique environment for these aspects to be singled out and captured, being at the crossroads of art (*techne*) manifested indeed as knowledge of the end to strive for, and practice of the best means to achieve it. Indeed, one way of viewing a martial artist under a cultural lens is, to put it in Plato's terms, a *technician* who knows the right measure of things, where the measure is fundamentally an aesthetic act [36]. There is then a close relationship between the aesthetic act and the social act: each cultural and social group shares their own aesthetic form. This holds even truer when it comes to kinetic arts, of which martial arts are arguably eminent representatives and which, even when coming from an Eastern tradition, share a cultural trait very similar to the Platonic inheritance, in which the aesthetics of movement also constructs a socially shared cultural object.

Concepts such as style, experience, tradition and, as a consequence of the latter, cultural contact, have all been individual subjects of study in ICH research. Martial arts, especially when downscaled to a context like the Southern Chinese one, provide an opportunity to observe the compenetrations of these aspects: a martial art is expressed in styles and techniques; manifested in forms, combat and training; symbolically and aesthetically represented through mental images arising from observation and experience [38]; transmitted across small communities through means like oral history and rituals; and influenced by partly traceable cultural changes. Accordingly, the human body becomes an essential vehicle for intangible cultures, where poses, gestures, and movements are information carriers through which the artistic manifestation can be analyzed. While material evidence may occasionally compound the immaterial one [7] - as do weapons and training tools, they may also attempt to document it in context through multimodality [26].

This paper presents a study, backed by an inferential computational model acting upon knowledge graphs, and aimed at understanding how a complex art form like martial arts generates intangible cultural and social objects. The challenge posed here is thus twofold. We attempt, on the one hand, to semantically capture intangible elements, such as movement and its aesthetic production; on the other hand, to study how these elements contribute to creating objects of social tradition. For the latter, we chose to extract and represent the social reality of contact between cultures, thus addressing the research question: *How can we design a computational model to detect suitable candidates for occurrences of contact between cultures in a martial arts knowledge base?*

A prior study exemplified how the application of an inference-based computational model, namely statement generation rules over Linked Data, could make new knowledge emerge about cultural contact: it was first carried out in the context of early Roman provinces of Spain using sculptural, epigraphic and numismatic evidence, as an example of inferring intangible cultural traits and their influences out of material evidence: coin series and the characteristics of their depictions; sculptural evidence and the characteristics of the iconography represented; and languages or scripts used in the messages recorded in the epigraphic evidence [30]. In this work, instead, we set out to infer similar intangible elements of cultural contact from evidence that is largely immaterial, of which styles, techniques and symbolic allegories are examples. This paper shows how to realize a full cycle of the computational model, from the knowledge organization of the evidence to the generation of new knowledge.

[1] *What is intangible cultural heritage?*, https://ich.unesco.org/en/what-is-intangible-heritage-00003

Consequently, both ends of the spectrum – most of the starting evidence and the generated knowledge – are in our case intrinsically representative of ICH.

There are three cornerstones to this study. First, the ontological landscape was analyzed in its capability to model martial arts, which prompted the building of an ontological model, bottom-up from the source material, and with the goal to capture martial arts independently of cultural, ethnic or spatio-temporal coordinates. Second, the proposed ontological model was used for the knowledge organization of the (meta-)data that represent the evidence, present in the *Hong Kong Martial Arts Living Archive* (HKMALA), thus generating a group of datasets that are part of a knowledge graph. Third and final, to exemplify the validity of the model, the ontology was combined with a distilled version of an existing Cultural Contact Ontology and with a system of inference rules based upon it. These rules, once executed on the knowledge graph, materialize interesting facts attesting to potential cultural contact, effectively using the HKMALA dataset as evidence. Every model or meta-model used is available online as open data.

The product of this study offers an insight into a computational method for the detection of ICH traits, using a cultural contact ontology as vehicle, from a mixed body of tangible and intangible objects. This demonstrates the potential value of immaterial but catalogable entities as sources of evidence. In the longer run, we expect this study to be useful to address the challenge of formalizing the "porosity" of cultural traditions, not only from a social point of view, but also from that of the dimensions from which a tradition itself is constituted.

The paper is structured as follows: after an overview of the materials and methods from related work in Section 2, we describe our proposed martial arts ontology in Section 3 and how it was used to generate the HKMALA knowledge graph (Section 4). A validation of the model, based on standard ontology metrics (Section 5) and on the case study of cultural contact detection (Section 6), is then presented, followed by an overview of the resulting online resources (Section 7) and a discussion of the outcomes (Section 8). An outlook on potential future work concludes the paper.

2 MATERIALS AND METHODS

At the time of the 2003 UNESCO Convention for the Safeguarding of Intangible Heritage, establishing and protecting the value of ICH became the center of international attention and the aim of numerous initiatives across the globe to celebrate, research and protect it. In many of these endeavors, however, ICH was configured merely in opposition to its tangible equivalent, thus formulating the concept as the representation of antithetical ideas: tangible/intangible, material/immaterial, static/dynamic, and so forth. This caused cultural heritage to be regarded as something to be classified according to two different and opposed categories, which were artificially configured and do not necessarily fit into material and intellectual perceptions of heritage across history and groups. It also hinted that the safeguard of ICH should require bespoke methods covering all its aspects.

In the latest years, the dichotomy between tangible and intangible is slowly fading into a more fluid understanding that celebrates the inseparability of both concepts. These approaches underline the embodied and lived character of heritage and mostly sustain that heritage should not be considered and framed by its materiality or lack thereof, but rather by its meaning in a broader cultural context, and how this meaning is enacted by our daily interaction with it. On the other hand, through the principle of *reification*, the Semantic Web teaches us that not only people, places and works of art are worthy of being named, referenced and described: through proper modeling, entities like events, styles and experiences acquire identity and expressivity, and as such they can be captured and cataloged for future studies [20]. By this analogy, it is therefore through the methods and tools of the Semantic Web, such as Linked Data and ontologies, that we choose to organize the knowledge of the martial arts domain which, as exemplified earlier, requires a fluid understanding of the facets of cultural heritage.

2.1 HKMALA: The Hong Kong Martial Arts Living Archive

China has a long history of martial arts traditions. Originated as methods of combat and self-defense, these practices have, since at least the Zhou dynasty (ca. 10th Century BC), acquired a humanistic dimension, thus becoming instruments for "whole-person education" [9]. Chinese martial arts nowadays are practiced in countless groups at various organizational levels, ranging from "families" to "schools" and "sects", each with their own philosophies, concepts, techniques, and training systems [34]. With these groups as the hives of cultural transformation, Hong Kong has acted as a vibrant center for Southern Chinese martial arts throughout the 20th century due to its role first as a major port and trading center, then as a safe haven for refugees across China [9]. There are a tremendous wealth of martial arts resources and elite practitioners who represent the highest authority for their respective lineages or styles. However, these treasured cultural practices, made internationally famous by the movie industry, are being endangered by factors like rapid urban development, population growth, cultural transformation, and the aging of the masters.

The *Hong Kong Martial Arts Living Archive* (HKMALA) originated as a heritage project in 2012, to archive Hong Kong's rich and diverse kung fu styles with traditions [9]. The HKMALA project has been a longitudinal research collaboration between the International Guoshu Association, the Laboratory for Experimental Museology (eM+) at EPFL, and the City University of Hong Kong. It encompasses a comprehensive analysis of digital strategy, including motion capture, motion-over-time analytics, 3D reconstruction, high-speed and panoramic video shooting, and photographic archiving of the masters involved. Its datasets represent one of the world's largest motion archives for intangible cultural heritage, spanning over 130 sets of empty-hand and weapon sequences, or *taolu*, covering 19 styles with performances by 33 elite practitioners. The archive is accompanied by extensive contextual documentation, such as ritual descriptions and multimodal digital records of physical objects like weapons and training tools.

The current, implicit, logical organization of resources in HKMALA reflects how they are assembled for exhibitions around a designated theme. Extracting open-access learning and study resources from the archive and exhibitions will enhance their role in the preservation, re-activation and revitalisation of traditional martial arts [34], as well as the basis for future educational programs [24]. However, realizing this requires a knowledge organization system that has both the flexibility to accommodate content in the diverse South Chinese martial arts spectrum, and awareness that said content is a carrier of ICH elements like tradition, style and influence. Part of this study was to survey the ontological landscape in search for what ontologies model, or could support a model of, martial arts in general, filling any gap over the course by ourselves.

2.2 The semantics of movement and culture

In contrast to tangible material practices naturally embedding cultural identities in physical objects, ICH is defined through its reliance on tacit and embodied practices inextricably linked to people. These are usually bodily, performative, expressive, symbolic, rule-based, non-instrumental, and subject to a dynamic process [25, 47]. One of the critical channels where cultural expressions occur is *kinesthesia* - the movement. Through the perception of the body, physical qualities acquire significance in the presentation of culture. Relevant studies have been carried out in the field of dance, arguably the best-known performative discipline that values motion, perception and interpretation, which either reveal the source of inspiration for a given technique, or provide a means to facilitate its transmission. Similar considerations also hold in martial arts: examples include techniques developed through the alliances with Japanese warriors to counter piracy incursions, or the osmosis between military and civilian martial arts, causing the latter to employ makeshift weapons or simulate them with hand techniques due to government prohibition to bear arms.

While there was no expectation that an existing formal data model would cover the nuances of Southern Chinese martial arts, still no validated ontological framework could be found to even only represent martial

arts under general or limited aspects: the only online resource that was found is UMAO, an attempted ontology that does not seem backed up by experimentation or publications and, in the author's stated intentions, merely constitutes a modeling exercise.[2]

A litmus test further attesting to such lack of representational coverage is the scrutiny of how martial arts concepts are represented in general-purpose knowledge bases: to richly authored English and Chinese Wikipedia articles on the Fujian White Crane style[3][4] corresponds a Wikidata representation that hardly covers anything more than the style's geographical origin.[5] Wikis are indeed among the key manifestations of interest in structured knowledge on martial arts, as corroborated by the *Wiktenauer* one on Western martial arts curated by the Historical European Martial Arts Alliance [46], whose information wealth is also not backed by a knowledge organization based on formal semantics.

We acknowledge, on the other hand, that the solution to part of the modeling problems in a transversal domain are to be found in how connected domains are modeled. In that sense, it is useful to look at models such as the Muninn Military Ontology [45] for what concerns its representations of weaponry or of regimental hierarchy, if anything, for alignment purposes. Likewise, foundational ontologies are able to provide the basic framework whereupon to lay descriptive models of the physical, social and normative ramifications of the domain [40].

Following a similar reasoning, it makes sense to look at ontologies that model kinesthetic, movement-centered arts. One way of building these is by information-intensive knowledge mapping, in which performative movements are described by a dense sequence of micro-movements [31]. In recent years, there have been several attempts to capture and model movement expressions in performing arts. For example, Raheb et al. proposed an ontology that allows users to annotate classical ballet videos with a domain-specific vocabulary implementing the functionality of "motion concept search", through which a user searches for specific movements performed within each video [15]. Kannan et al. focus on modeling dance video objects at multiple levels of detail by implementing the Dance Video Semantic Model (DVSM) [23]: this vocabulary attempts to combine and interconnect the underlying semantics between songs and movements. Chaudhry et al. propose an ontology to classify complex movements for folk Malaysian dances [10]. Finally, Lagrue et al. propose an ontology and web-based dance video annotation system for representing the semantics of dance videos at different granularity levels [27]. The above models are all very specific to the dance domain, providing only basic concepts for a martial arts ontology to align to and not always with a formalization that is openly available online. However, the use case of annotating performance media in a nonlinear, multilayered fashion has been retooled as part of the knowledge organization of HKMALA media, which falls beyond the remit of cultural contact detection and is described separately [35].

These few examples show a common problem being faced: the simultaneous capture, through an ontological model, of a kinesthetic aspect such as movement and a more static aspect such as intangible cultural tradition. On the one hand, the ontology must be able to express the modeling of kinesthetic processes. On the other, it should also make the cultural aspect visible, which such movement is intended to express [15]. On that, we argue that the cultural aspects of movement, style, technique or influence do not need to be rendered explicitly in the ontology, rather, they can and should emerge from the interplay of the domain ontology with a cultural one, whereupon a computational method is applied. In other words, cultural aspects should be a connotation, rather than a denotation, of an ontology of martial arts. This allows us to still avail ourselves of cultural heritage models [39], like the widespread CIDOC-CRM [13] and the emerging ArCo, the latter being the first to offer the basis for an intangible cultural framework [8]; only, the usage of these ontologies, and by extension the classification of

[2]Upper Martial Arts Ontology (UMAO), https://github.com/PR0CK0/UpperMartialArtsOntology.

[3]Wikipedia contributors, Fujian White Crane (en), https://en.wikipedia.org/w/index.php?title=Fujian_White_Crane&oldid=1095566038 (retrieved 21/8/2022).

[4]Wikipedia contributors, Fujian White Crane (zh), https://zh.wikipedia.org/w/index.php?title=%E7%99%BD%E9%B6%B4%E6%8B%B3&oldid=71148387 (retrieved 21/8/2022).

[5]Wikidata contributors, Fujian White Crane, https://www.wikidata.org/w/index.php?title=Q803758&oldid=1136192384 (retrieved 21/8/2022).

domain features as cultural traits, is deferred to the application of the computational model, which in our case are the inference rules for detecting potential cultural contact. The knowledge representation device through which martial arts become evidence of cultural interaction is the CuCoO (Cultural Contact Ontology) ontology. CuCoO establishes a set of concepts and relationships that allow the description of contacts between cultures and their identification in the evidence. It enables the modeling of the cultural context itself, as well as the establishment of potential cross-cultural connections between the entities [30].

2.3 Forms of cultural contact

The question of cultural contact has been rooted in literature since the early attempts at defining it over the past three decades [11]. While disciplines like sociology and anthropology offer the opportunity to explore the context and impact of this phenomenon in living communities, others like archaeology have to rely on the close examination of the material evidence to identify potential cultural traits that can be considered as evidence for cultural transmission. Although some may consider these as two different forms of exploring and understanding the potential outcomes of cultural contact – whether its effects are on people or on things –, they actually rely on the same idea, which is to identify cultural traits that are exercised, perceived and assimilated and can then be manifested in the material realm or not.

It should be borne in mind that cultural contact is not synonymous with influence: more often than not, this is the case and the evidence of it can be found in the characteristics of material manifestations of those cultures, or of their habits. Anything from the curvature of a weapon to the way an attack technique is named can bear such evidence. However, just as not every context of contact is pacific and may have been enforced through e.g. conquest, so does not every process cause the incorporation of traits from one culture into another. These latter ones are cases of *impermeable cultural contact* [41] and are characterized by the lack of evidence in cultural heritage, which is therefore to be sought in the historical discipline. Typical examples include the foundation of a colony, or the resistance to modernizing trends, an example of which is found in the way martial arts in Zhangzhou developed, hardly ever amalgamating with more recent or international arts since under the Qing rule. In addition, permeable contacts may develop traits that appear in opposition to, rather than acceptance of, the culture that comes in contact with another, of which the development of unarmed martial arts, following the prohibition of weapons by conquering rulers, is an eminent example.

The previous attempt mentioned earlier aimed at identifying cultural traits that would have been exchanged and manifested in the material evidence of Southern Roman Spain. Using the same principle, this study explores the potential of an inference-based computational model to pinpoint evidence of interaction between cultures manifested in embodied knowledge and practices, rather than in material artifacts. In addition, we also attempt to assess whether the factors that made sense in that study, e.g. (im)permeability and contexts of trade or conquest, suffice or should be expanded to accommodate the complexity of Southern Chinese martial arts history and, potentially, other historical disciplines.

Identifying which salient features of a setting are traits of a particular cultural identity or phenomenon is inherently a classification problem. As such, it naturally lends itself to supervised machine learning approaches which, however, are built upon models trained on a significant portion of curated gold-standard data [16] that, at the time of this paper, are not openly available. Our work veers towards bootstrapping the construction of this ground truth as a byproduct.

3 A CULTURALLY-ORIENTED MODULAR ONTOLOGY FOR MARTIAL ARTS

Because the ontological landscape in the modeling of martial arts *tout-court* has proven unsatisfactory (cf. Sec. 2.2), the first step was to actually construct such a formal ontology. Added to the original goal of having a model for the knowledge organization of HKMALA metadata, there is a further goal of enabling multi-faceted cultural

studies on the domain of martial arts *per se*. The identification of culturally relevant traits of the martial arts domain should not be explicit in the ontologies but, as will later be shown, are a byproduct of this modeling effort.

Developments of our martial arts ontology system are being made openly available[6] online. An earlier version of these ontologies [1] was since further refined, based on the internal feedback loop arising from the effort of modeling HKMALA data after it [35]. The results of such refinement are presented in the following sections.

3.1 Design considerations

Our stated intent when designing a martial arts ontology was not to constrain it to the use case of cultural contact detection, but to ensure its usefulness in multiple potential use cases, such as finding common and distinguishing traits between styles, or publishing sports competition statistics as open data. However, ontology development methodologies that advocate modularization do allow for rationales that partition the landscape on the basis of the role that individual modules play in a driving use case [14]. By drawing inspiration from the NeOn Methodology, one of the most recently established scenario-based frameworks with reuse and modularity in mind [43], we based our knowledge engineering effort on a series of competency questions, of which the salient ones are reported below:

- **CQ1.** *What techniques does a martial art style use?*
- **CQ2.** *What type of weapons are employed in armed martial arts?*
- **CQ3.** *Which martial arts feature a hand technique that simulates wielding a weapon?*
- **CQ4.** *Which styles, techniques or forms are symbolically represented by a being of nature?*
- **CQ5.** *In what group types (families, clans, schools, sports federations) is a certain martial art being taught?*
- **CQ6.** *What aspects of a martial art style must be mastered to acquire a certain grade?*
- **CQ7.** *What belt color in a grading system corresponds to a grade in another system for the same martial art?*

It is worth reminding how none of the above CQs are predicated upon explicit cultural indicators, though related considerations can be drawn from most if not all of them. This is a precise design choice: a user of this ontology must be given the tools to single out and highlight the entities with a potential to contribute to the use case at hand if needed.

Based on these design considerations, the martial arts ontology was developed as an ontology network that satisfies these requirements:

(1) *Modularity*. Rather than as a monolithic ontology, organize the model in a modular structure with clearly defined epistemic roles for each module, to favor reuse of parts of the overall ontology.
(2) *General purpose*. Aside from the driving use case, the model should be general enough to be adapted to most martial arts, with extension points to partly model non-combative kinetic performing arts.
(3) *Inference of cultural aspects*. Cultural traits will not be made explicit in the model: as many as are the entities with a potential to act as manifestations of a culture, they only materialize as such when reasoning is performed on data built upon the ontology.
(4) *Reuse of other ontologies*. The model should be built up to the level where the entities are able to specialize those of a designated upper ontology. Said ontology will be an overarching dependency of the martial arts model. Alignments with, and reuse of, other domain ontologies will be performed when possible.

From a modularity perspective, the ability to single out relevant groups of terms is similar to the principle of ensuring that the subsumption hierarchy of a single class be as self-contained as possible, which is intended to be applied to the modularization of an existing ontology [12]. For instance, classes that subsume `WeaponType`, say, `MeleeWeaponType`, should belong in the same module, however, if parts of the human anatomy are considered

[6]Issued under the Creative Commons Attribution License 4.0.

default	http://crossings.github.io/term/
arco	https://w3id.org/arco/ontology/arco/
crm	http://www.cidoc-crm.org/cidoc-crm/
cucoo	http://www.semanticweb.org/paulagranadosgarcia/CuCoO/
data	*(arbitrary namespace for instance data)*
dc	http://purl.org/dc/terms/
dul	http://www.ontologydesignpatterns.org/ont/dul/DUL.owl#
rdfs	http://www.w3.org/2000/01/rdf-schema#
skos	http://www.w3.org/2004/02/skos/core#
wd	http://www.wikidata.org/entity/

Table 1. Prefix mappings used throughout the paper.

akin to weapons in an offensive capacity (see e.g. CQ3), they should also belong together. Also, properties that connect classes (e.g. declarations of domain or range) should belong either in the same ontology as both classes, or in ontologies that depend on one another. By following these principles, we obtain an organization of the Martial Arts Ontology into modules that happen to also play defined roles in the cultural categorization of an art by different facets, whether tangible or not.

Based on the above competency questions, requirements and design principles, the martial arts ontology network was structured along three modules: the *kinesthetic*, *stylistic*, and *social* modules. These, in turn, reflect three possible dimensions and lenses for highlighting cultural phenomena.

To fulfill requirement #4 while taking #2 into account, we chose a foundational ontology as the base model to relate our key concepts to, namely DOLCE UltraLite (DUL) [17]. This upper ontology provides fundamental notions such as agents, qualities, norms and methods, which proved fitting for the organization of the martial arts terminology. We can therefore defer any mappings to cultural heritage models, such as CIDOC-CRM and ArCo, to the stage where the characterization of martial arts entities as cultural objects occurs.

The remainder of this paper assumes the prefix mappings defined in Table 1.

3.2 Modules and terminology

The starting documentation for this modeling effort is the corpus of panel texts and media captions for the exhibitions that were established for HKMALA through the years, as well as multimedia subtitles of interviews to masters and their technique explanations. The base terminology was lifted from the corpus by project members and engineered as classes and properties. The resulting key concepts are synthetically shown in Fig. 1, with nodes for classes and edges for properties relating them through either domain and range, or class restrictions.[7] The figure reflects the organization into modules denoting the principal cultural dimensions, with classes serving as contact points between them.

3.2.1 Kinesthetic module. The features that describe the qualities and articulation of the human body, or weaponry, when performing a manifestation of a martial art, are grouped in this module. While primarily a kinetic model, it is complemented with kinesthetic concepts, i.e. related to the perception of movement, that are not quantifiable in themselves, but are manifested and perceptible through kinetic means.

The key concepts of this module are as follows.

[7]For the sake of simplicity, properties that establish a *has-* association with a member of a class, though may appear in examples, are omitted. Also, property names that contain the objects have been shortened.

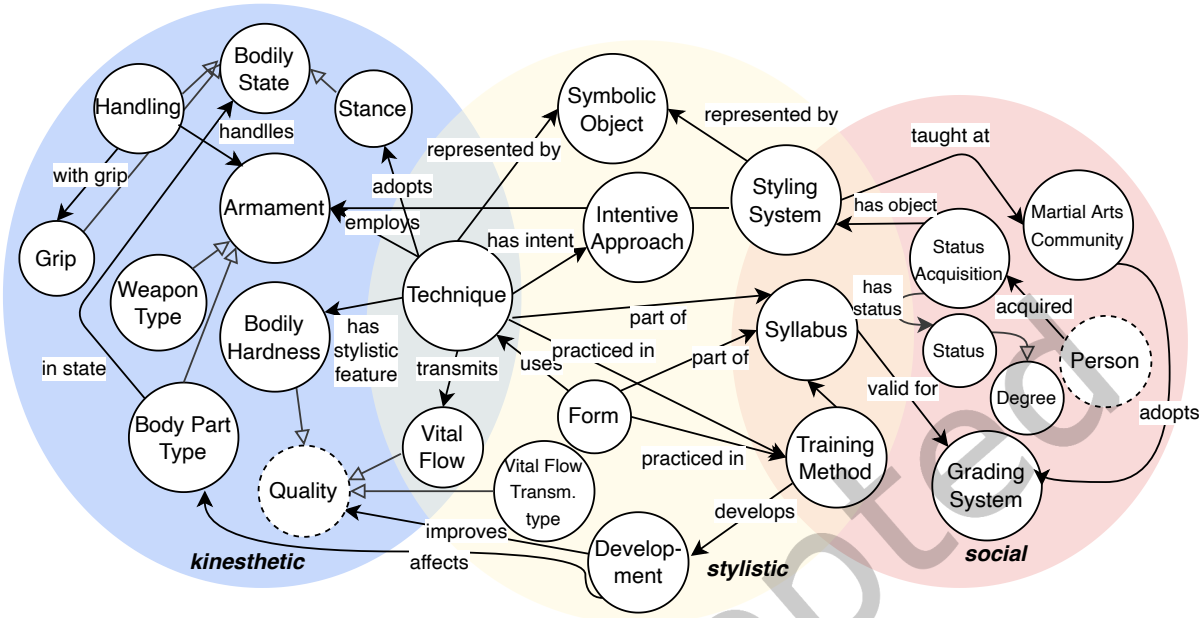

Fig. 1. Key concepts of our martial arts ontology network, structured according to three principal cultural dimensions: kinesthesia, styling and social. For legibility, property names that contain the objects have been shortened (e.g. `employs` as short for `employsArmament`). Dashed nodes indicate reused classes (from DOLCE).

class `Armament`. Anything that plays a role, or potential role, as a vehicle of offensive, defensive or otherwise performative acts in some martial art is a member of this class. That includes actual weaponry (e.g. the *gim*, a Chinese double-edged straight sword), human limbs or other types of body part, for which subclasses `WeaponType` and `BodyPartType` are defined. Note that their instances, such as "hand" or "double-edged sword", are abstract, rather than tangible, material individuals, hence the suffix `-Type` in the class name.

class `BodilyState`. An instance of this class denotes a single characteristic, or combination thereof, of the state the body or a body part needs to be in, for a technique to be executed: subclasses include `Stance` (e.g. low, feet two hip widths apart), `Handling` of armament (e.g. swift), or the `Grip` (e.g. one- or two-handed) on an object or opponent.

class `BodilyHardness`. A qualitative measure of how a body is able to withstand blows - and, under certain conditions, deliver them. This is an example of physical `Quality`, as defined in DUL. Base instances could be as simple as "hard" and "soft", but more may be specified for martial arts like Judo, based on the principle of *Jū* (gentleness).

class `VitalFlow`. Again a non-measurable `dul:Quality`, it indicates a physical, mental or spiritual input by the practitioner: for example, the *ki/qi* (energy) or *yi* (intent). Because some traditions distinguish different ways of conveying and receiving this input, such as at the point of impact (external) or through the entire motion of the body (internal), an instance of this class can be associated to an instance of `VitalFlowTransmissionType`.

object property `handles`. Associates the characteristics of an instance of `Handling` to an instance of `WeaponType`, and can be used to represent statements such as "Handling a double sword requires a two-handed grip and slow swing".

object property `inState`. Associates an instance of `BodyPartType` to an instance of `BodilyState` that part is or must be in, e.g. that the lower body is in a wide `Stance` when defending. Note that this is not intended to model body conditioning, which actually concerns attaining qualities (e.g. through training).

object property `withGrip`. Associates the characteristics of an instance of `Grip` to an instance of `Handling`, effectively linking two bodily states to each other.

3.2.2 Stylistic module. This module describes the way combinations of the aforementioned kinesthetic features culminate in something that acquires a methodological identity: this can be a technique, choreography (or form, e.g. *kata* or *taolu*), an actual martial art or a style of one. This module also comprises an epistemic component, since it is also responsible for encoding the symbolic associations that either inspire or are used to identify and transmit such methods. These typically arise from human experience - such as observing a drunkard's erratic moves or the stance of a crane in a pond - thus encoding another important ICH element. The key concepts are:

class `Technique`. A subclass of `dul:Method`, whose instances combine kinetic features to serve a single purpose within context, such as a (counter-)attack. This class is specialized insofar as the hierarchy remains general, thus being subsumed with classes like `EmptyHandTechnique`, `FrontalTechnique` or `OffensiveTechnique`, which are not shown in Fig. 1 for the sake of conciseness.

class `Form`. Also a subclass of `dul:Method`. Forms demonstrate one or more `Techniques` within a simulation. Examples include the *kata* of Japanese arts, the Chinese *taolu*, and the Korean *hyung*, yet these do not appear as terms in the ontology due to their culture-specific nature. A `Form` `uses` one or more `Techniques`: for instance, the Nanquan *taolu* demonstrates the back leg sweep technique in a performative context.

class `StylingSystem`. Also a subclass of `dul:Method`, intended as a collective methodological framework that denotes a martial art or style thereof. "Southern Praying Mantis (Kung Fu)" or "Brazilian Jiu-Jitsu" are example instances.

class `Development`. A cause-effect relationship with a connotation either pedagogical (e.g. the mastery of a `Technique`) or focused on improving a physical or mental condition, such as the upper body resistance to impact. This is an n-ary relation that can be used to represent, for example, that the conditioning drill of punching the *makiwara* (padded striking pad) develops the hardness of hand knuckles: the instance of `Development` is therefore connected to one of `dul:Quality` via the property `improves`, and to one of `BodyPart` via the property `affectsBodyPart`.

class `TrainingMethod`. A subclass of `dul:Method` whose purpose is a certain `Development`. It may consist of a single exercise. Multiple instances can be combined into a `TrainingSet`, such as the rice bucket conditioning drills.

class `IntentiveApproach`. Indicates the martial artist's disposition when performing a `Technique`. Instances may denote the intent to attack, defend or distract. It can be subclassed with approaches that require the hardening or loosening of the body during a performance.

class `SymbolicObject`. Anything that is used as an allegory or mental image for a technique or style, such as the praying mantis, drunken man, or even a weapon (e.g., the *nukite* simulates a spear strike in karate). Most likely, these are worldly things described in other domains, where they could be modeled as classes, individuals, or more

simply concepts (e.g. in thesauri). Moreover, one is unlikely to think of these as symbols in their own domains.[8] The monkey may not evoke imagery in zoology as it does in martial arts: in ontology parlance, this means that one should not expect it to be assigned the `SymbolicObject` type assertively, but instead by type inference, because of being used in association with a style or technique. We therefore choose not to be prescriptive in the ways these entities should be modeled, as they most likely originate in external datasets agnostic to the martial arts domain.

object property `belongsInSystem`. Associates an instance of `Technique` to an instance of `StylingSystem` (be it a martial art or style thereof) where that technique is practiced and developed.

object property `develops`. Connects an instance of `TrainingMethod` to one of `Development`.

object property `practiced in`. Connects an instance of `Technique` or `Form` to one of `TrainingMethod`: for example, a certain *taolu* is practiced in a mirror drill.

object property `hasIntent`. Associates an instance of `Technique` to one of `IntentiveApproach`.

object property `employsArmament`. Associates a `dul:Method` to an `Armament` that is required for implementing that method, whether a technique, style or form.

object property `representedBy` *and its inverse* `symbolicallyRepresents`. Associates any of the above subclasses of `dul:Method` (forms, styles or techniques) to something which consequently becomes a `SymbolicObject`. For example, we can connect the "chasing the wind" sword technique to the concept of wind as modeled in Wikidata, as in this example from the HKMALA dataset (see Sec. 4):

```
data:chasing_the_wind_sword :symbolicallyRepresents wd:Q8094    # The wind
```

object property `hasStylisticFeature`. A super-property that groups those that characterize styles or techniques, such as `employsArmament` and `symbolicallyRepresents`.

3.2.3 Social module. This module implements the system that describes how martial disciplines are taught, learned, assessed and disseminated. This module is more lightly axiomatized than the others, the reason being that the ontological landscape is much richer in modeling social agents, their interactions and activities, and pedagogical and agonistic frameworks,[9] which can be employed directly. We only therefore describe the key concepts that contribute domain-specific knowledge to existing models. The key concepts are:

class `MartialArtsCommunity`. Any collective social agents where martial arts teaching, training, assessment or dissemination takes place, e.g. a school, clan, sect or sports federation. Classification by this type is expected to occur either by assertion or by inference.

class `GradingSystem`. The `dul:Norm`s in place within a `MartialArtsCommunity` to assess the technical level of a practitioner, and where a formal status or `Degree` can be attained. Examples include the different belt color systems.

class `Syllabus`. A `dul:Norm` that organizes methods in the stylistic model, such as techniques, forms and training exercises (whereupon these become `Requirements`), to represent the bundle of knowledge required for a martial art, style, or degree therein. A `Syllabus` is `validFor` a `GradingSystem`.

[8] This is part of the reason why this class is not aligned with `E90 Symbolic Object` in CIDOC-CRM.
[9] Examples: http://linkedscience.org/teach/ns for teaching, or BBC Things for sports, https://www.bbc.co.uk/things/.

class `StatusAcquisition`. A `dul:Event` whereby a practitioner acquires a `Status` (e.g. that of a master in the discipline), which may or may not be measured by a `Degree`.

object property `acquiredStatus`. Denotes that a person completed a `StatusAcquisition`. The object of the acquisition (e.g. a style or art) and the status attained in it (e.g. a formal title or salutation) are connected to it via the `acquisitionHasObject` and `acquisitionHasStatus` object properties.

object property `adopts`. Associates an instance of `MartialArtsCommunity` to one of `GradingSystem` that is used for assessing students.

object property `taughtAt`. Associates an instance of `StylingSystem` to one of `MartialArtsCommunity` where that style is taught.

Note the absence of a *tout-court* martial artist class. While a person (from DOLCE) could be classified as such by a variety of criteria, including having practiced an art, acquired a status in it or participated in competitions, consensus of who may be universally classified as a martial artist is hard to reach.

Also note that no specific commitment is made to the HKMALA context: any notions specific to Southern Chinese martial arts will require the ontologies to be specialized or instantiated (req. #2). Also, to ensure enough flexibility to develop rule systems upon the ontologies, we aimed at an implementation within the OWL 2 RL profile[10] (req. #3). Such rule system will be necessary to be able to classify e.g. an experienced practitioner as a Master – a status recognized in the social dimension – or a piece of `Armament` or other object as a training tool.

4 INSTANTIATION OF THE ONTOLOGY: THE HKMALA KNOWLEDGE GRAPH

The Martial Arts Ontology illustrated earlier, despite showing an expected bias towards the source documents whereupon it is based, as well as its attempt to generalize, is not committed to rendering entities in the domain of Kung Fu or of Southern Chinese martial arts. This is an objective of the datasets that instantiate this ontology by providing what is called an assertional knowledge base, or ABox [19], to the terms of the ontology.

The HKMALA knowledge graph, being created as part of our work, is a collection of datasets in RDF format. Its data schema uses the Martial Arts Ontology together with its aligned ontologies and commonly used vocabularies like Dublin Core and SKOS [3]. There are datasets that cover all the three modules of the ontology, and specific ones for equipment and training tools. The workflow that generates and updates the data is curated and only partly automated, owing to the goal of constructing a ground truth for future cognitive computing approaches.

The construction of the datasets, schematically represented in Figure 2, employed a variety of source materials from the HKMALA archive, including exhibition panel texts and exhibit cards; referenced glossaries and literature; manifest files that orchestrate assemblies of archive content into exhibitions; and transcripts of interviews to masters. Further details on how the data are generated are found in a prior publication [35], whereas information on data availability is provided in Section 7 of this paper.

The snippet below, in quasi-Turtle[11] syntax, is taken from the knowledge graph and illustrates how a technique, known as “Sticky Hands”, is described. The technique involves either hand and, due to its gentle motions, is deemed not to transmit its *qi* at the point of impact, which in local cultures is considered an “internal” transmission type.

```
data:technique/nian_shou a :Technique , skos:Concept
  ; skos:prefLabel "Sticky Hands"@en , "Nian shou"@pny
  ; :hasFlowTransmission data:type/flowtrans-internal
  ; :contactsThrough data:type/bodypart-hand
```

[10] OWL 2 Profiles, https://www.w3.org/TR/owl2-profiles

[11] Prefixed names with slashes in the suffix are normally not allowed in Turtle: they are shown in these snippets for the sake of legibility.

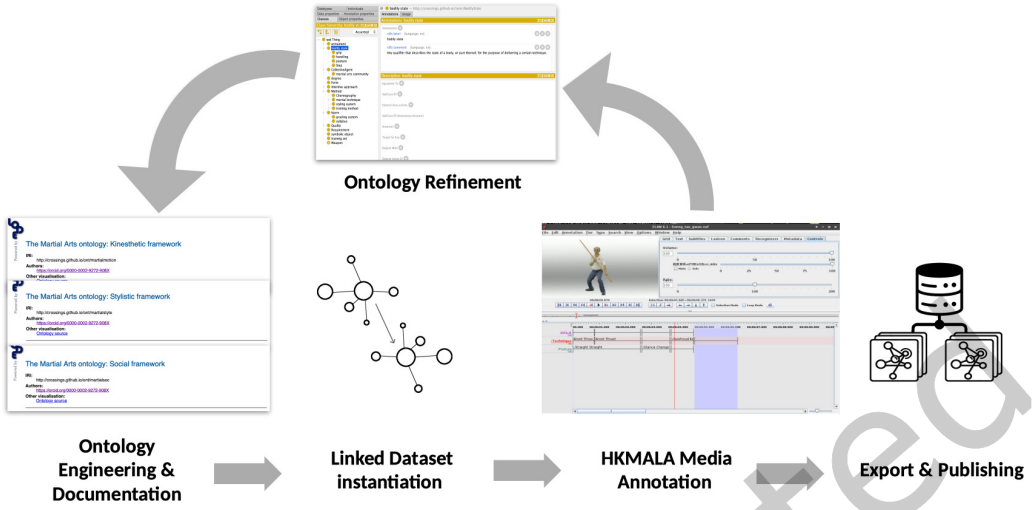

Fig. 2. Pipeline of HKMALA knowledge organization (taken from [35]).

```
.
data:type/flowtrans-internal a :FlowTransmissionType , skos:Concept
  ; skos:prefLabel "Internal flow transmission"@en
  ; dc:description "The power of a blow comes from a part of the body
    that does not match the point of impact."@en
.
data:type/bodypart-hand a :BodyPartType , skos:Concept
  ; skos:prefLabel "Hand"@en
  ; dc:description "Any one hand: can be used when the technique
    applies to the left or right one indistinctly."@en
.
```

Another example, which will be reprised in the remainder of this paper, represents a type of sword, used in some weapon-based Southern Chinese martial arts, that is single-edged and must be held with both hands.

```
data:weapon/shuangshoudao/handling a :Handling , skos:Concept
       ; skos:prefLabel "handling of the two-handed saber"@en
       ; :handles data:weapon/shuangshoudao
   ; :withGrip :TwoHandedGrip
.
data:weapon/shuangshoudao a :WeaponType , skos:Concept
       ; skos:prefLabel "two-handed saber"@en , "Shuang Shou Dao"@pny
       ; skos:broader  data:weapon/singleedgedsword
.
data:weapon/singleedgedsword a  :WeaponType , skos:Concept
       ; skos:prefLabel "single-edged sword"@en
.
```

As the dataset is intended to serve as a gold standard for future efforts, linkage with external datasets is for the most part curated. Due to the scarcity of available domain datasets, most links reference Wikidata. In cases where

the linked entity belongs to a domain beyond the remit of martial arts, as in the case of `SymbolicObject`s, reuse is direct, as in the early example of the "chasing the wind" technique; otherwise, linking is by alignment, as in this weapon example:

```
data:gim skos:closeMatch wd:Q1284919       # A double-edged straight sword
```

The version of the Martial Arts Ontology presented in Section 3 incorporates the results of the feedback loop originating from the data transformation process. Particularly, in order to represent the data appropriately in the knowledge graph, it was necessary to reify some entities that were not modeled as classes earlier. Reification took the form of n-ary relations, i.e. entities that relate three or more things together. Examples include the `Development` class, which connects a training exercise, the affected body part and the quality it improves; a `Handling` type over a type of weapon or equipment, separate from the type of `Grip` involved; and the `Acquisition` of a creditable status such as that of master.

One byproduct of this knowledge organization worth mentioning is that the generated data can be used to semantically annotate HKMALA media content. This was carried out by annotating video files of technique demonstrations in the EAF annotation format [42]. The reason this is worth mentioning is that EAF is multi-tiered, and that our chosen tier structure adopted the same criterion as the one that caused the ontology to be partitioned into three modules. This effectively allows the three core dimensions - kinesthetic, stylistic and social, to coexist on the same media timeline.

5 VALIDATION

While the ways of evaluating ontologies, especially domain ontologies, remain to this day an open problem [32], there are some quality metrics that the knowledge engineering community has accepted over time, and that will be reported and discussed in this section. At the same time, recent scholarly debate on the validity of an ontology has veered towards understanding its suitability for being selected to fulfill a specific task, which ties in with scenario-based development methodologies [44]. It is therefore sensible to validate the Martial Arts Ontology over a use case where it is selected along with other ontologies. Our study on a computational model to infer cultural contact offers such a use case.

5.1 Qualitative and quantitative metrics

Each module of the Martial Arts Ontology was submitted to the *OOPS!* service for pitfall detection [37]. While no critical issues with the ontologies were detected on the outset, some that are deemed important on the OOPS! scale, such as the explicit declaration of disjoint siblings, were subsequently addressed. The only exception is on the explicit indication of domain and range definitions for each property, primarily due to some of them whose domain was deemed not entirely predictable, unless one commits to an explicit fallback to the `owl:Thing` top concept.

In order to quantitatively measure the Martial Arts Ontology, we rely upon the criteria offered by the OntoMetrics framework [28]. The salient statistics from the OntoMetrics report on information richness are summarized in Table 2.

From the contrast between the two richness figures, it can be observed that the model relies significantly more on the class hierarchy to convey its information, than on property structures. This is primarily due to the fact that most properties exist for the primary purpose of providing one single connection between instances of two classes. A property hierarchy is currently only present to group properties of styles and techniques and is not foreseen for others in future developments, though it would boost relationship richness. Class inheritance richness, on the other hand, contributes to justifying why each class exists as an information carrier in its own right, which also explains their low tangledness score, i.e. there is little multi-class inheritance. Because we directly reuse

Schema metrics		Graph metrics	
Metric	Value	Metric	Value
Inheritance richness	0.8	Average depth	1.89
Relationship richness	0.507	Maximal depth	4
Equivalence ratio	0.023	Average breadth	3.22
Axiom/class ratio	6.09	Maximal breadth	17
Inverse relations ratio	0.25	Ratio of leaf fan-outness	0.71
Class/relation ratio	0.617	Ratio of sibling fan-outness	1.0
		Tangledness	0.16
		Average number of paths	11.3

Table 2. OntoMetrics statistics of the Martial Arts Ontology as of February 2023.

foundational terms from DOLCE, and only use equivalence links to other third-party terms, the equivalence ratio is naturally low. As the ontologies are lightly axiomatized with universal or existential restrictions, as well as disjointness axioms for sibling classes, the axiom/class ratio is noticeably high. Lastly, the fact that subclassing is partly delegated to potential extensions of the ontology - we do not intend, for instance, to enumerate all the body part types that may serve as armament - explains why the dispersion measure, i.e. the fan-outness of the ontology, approximates one.

We have likewise verified that the Martial Arts Ontology and its closures with DOLCE UltraLite and with the HKMALA knowledge graph all return as OWL2-consistent, as of the time of writing, when run through the HermiT description logic reasoner [18].

5.2 Suitability evaluation

According to ontology development methodologies based on competency questions, prototypical queries that encode these questions can be used as unit tests for the ontology itself [6]. In the following, we list prototypical SPARQL queries able to answer the competency questions illustrated in Section 3.

CQ1. What techniques does a martial art style use? This has a straight answer in SPARQL for all known styles.

```
SELECT DISTINCT ?style ?technique WHERE {
  ?technique a :Technique
    ; :belongsInSystem ?style .
  ?style a :StylingSystem .
}
```

Listing 1. SPARQL query for CQ1

CQ2. What type of weapons are employed in armed martial arts? Because the domain of `employsArmament` is `dul:Method`, therefore subjects can be techniques or styles, the solution to CQ2 concatenates the property to an optional inverse of `belongsInSystem` to ensure the propagation of weapons used only in some techniques .

```
SELECT DISTINCT ?style ?weapontype WHERE {
  ?style a :StylingSystem
   ; ^:belongsInSystem?/:employsArmament ?weapontype .
  ?weapontype a :WeaponType .
```

```
}
```

Listing 2. SPARQL query for CQ2

CQ3. Which martial arts feature a hand technique that simulates wielding a weapon? CQ3 makes the reasonable assumption that a technique does not use a human body part to simulate another, therefore `?weapontype` will be bound to types of actual weapons.

```
SELECT DISTINCT ?style ?weapontype WHERE {
  ?style a :StylingSystem
   ; ^:belongsInSystem [
     a :Technique ;
     :employsArmament :Hand ;
     :symbolicallyRepresents ?weapontype
   ] .
  ?weapontype a :WeaponType .
}
```

Listing 3. SPARQL query for CQ3

CQ4. Which styles, techniques or forms are symbolically represented by a being of nature? CQ4 makes two assumptions: (a) natural beings are reused from, and described in, an external dataset like Wikidata; (b) that dataset contains the knowledge that the object is a natural being, so it needs to be queried in federation to answer the competency question. We also do not explicitly indicate the `SymbolicObject` type, which is intended to be inferred. Also recall that styles, techniques and forms are all subclasses of `dul:Method`.

```
SELECT DISTINCT ?method ?t ?symbol WHERE {
  ?method a dul:Method , ?t           # ?t values include more specific types
    ; :symbolicallyRepresents ?symbol .
  SERVICE <http://query.wikidata.org/sparql> {
    ?symbol wd:P279+ wd:Q29651224     # (recursive) subclass of natural object
  }
}
```

Listing 4. SPARQL query for CQ4

CQ5. In what group types (families, clans, schools, sports federations) is a certain martial art being taught?

```
SELECT DISTINCT ?martialart ?grouptype WHERE {
  ?martialart a :StylingSystem
    ; :taughtAt [ a ?grouptype ]
}
```

Listing 5. SPARQL query for CQ5

CQ6. What aspects of a martial art style must be mastered to acquire a certain grade? Here, by 'aspect' it is meant a form or a technique, which form the values to be bound to `?requirement`.

```
SELECT DISTINCT ?grade ?requirement WHERE {
  ?grade a :Degree
    ; :hasRequirement/:expectsMasteryOf ?requirement
}
```

Listing 6. SPARQL query for CQ6

CQ7. What belt color in a grading system corresponds to a grade in another system for the same martial art? A belt color is a Degree. Here we assume that equivalent degrees in different grading systems require mastery of the same syllabus.

```
SELECT DISTINCT ?grade1 ?gradingSystem1 ?grade2 ?gradingSystem2 WHERE {
  ?syllabus a :Syllabus ; :validFor ?gradingSystem1 , ?gradingSystem2 .
  ?grade1 a :Degree
    ; :awardedInSystem ?gradingSystem1
    ; :hasRequirement/dul:isPartOf ?syllabus .
  ?grade1 a :Degree
    ; :awardedInSystem ?gradingSystem2
    ; :hasRequirement/dul:isPartOf ?syllabus .
  FILTER (?gradingSystem1 != ?gradingSystem2)
}
```

Listing 7. SPARQL query for CQ7

6 CASE STUDY: DETECTING CULTURAL CONTACT

Recall from Section 1 that one goal that warranted the development of the Martial Arts Ontology, and the knowledge organization of the HKMALA, is to investigate how a computational model can detect potential candidate forms of contact between cultures through martial arts. We attempt this approach by transfer from another domain.

Supposing such an attempt had been made over a knowledge base for one cultural domain, it would then be plausible that a similar methodology could be reapplied to another *ceteris paribus*, that is, by keeping all the elements of the model that are not tightly bound to the domain, whereas the domain model is replaced. In our case, an earlier attempt to use an ontology to classify culturally relevant traits, phenomena and evidence in a domain took place in the context of the early Roman age, using sources of evidence ranging from epigraphic to sculptural and numismatic. That previous work generated a cultural contact model in the OWL ontology language, complemented it with inference rules, and applied them to an RDF dataset that described Roman inscriptions, coinage (including legends, series and mints) and sculptural representations in the Roman province of Ulterior/Baetica in Southern Spain [30]. Within the original scope of that work, domain-specific cultural identities (e.g. Roman or Phoenician), forms of evidence (e.g. coin faces, inscriptions or mints) and traits (e.g. hairstyles, vestments or language) were tightly coded into the monolithic ontology. Our work builds upon that endeavor, with a goal of not only reapplying it to the domain of Southern Chinese martial arts, but also making the model general-purpose. This effort, however, required a tuning and repurposing of the formal knowledge employed in that study.

6.1 Using CuCoO: The cultural contact ontology

CuCoO[12] is a monolithic (non-modular) ontology whose main goal is to identify entities that manifest cultural traits that have been related to two or more different cultural identities. For example, hand-to-hand combat techniques in Southern Fujian (an area primarily populated by Minnan and Hakka people) during the mid-Qing period testify to a reaction against the state-imposed proscription of arms by a rule of Manchu ethnicity. In another example, single-edged two-handed swords show features inherited from the alliances with Japanese *ronin* to contrast piracy, whereas the staff-fighting techniques that emerged afterwards are the result of a contact with Japanese culture that is of an antagonistic nature, once Wokou (Japanese pirates) incursions intensified. For a better understanding of the case study implementation, we provide a brief description of the key concepts of the ontology.

`cucoo:CulturalIdentity` is an upper class that signifies a "self-conscious association of a group or person with a culturally-constructed group identity".[13] The Chinese Minnan or Hakka, or the Muromachi-period Japanese, are example instances of a primarily ethnic subclass of this class, but more subclasses, grounded on e.g. religious or gender identity, are contemplated.[14]

Another upper class, `cucoo:CulturalContactFeature`, describes the phenomenology of a cultural interaction in three forms, each encapsulated by a subclass as follows:

`cucoo:CulturalContactContext` refers to "the context in which the situation of cultural contact takes place" (for example in a context of migration). It is intended to be subsumed by a controlled vocabulary of possible phenomenological classes, of which the original study proposed those relevant for its remit, such as `Conquest`, `Trade`, `War` or `Migration`.

`cucoo:CulturalContactAspect` refers to "the main feature that defines the cultural contact phenomenon", thus assigning a connotation to it. Only the `Linguistic` and `Iconographic` aspects were contemplated by the study that the ontology initially aimed at, however, other taxonomies can be attached by subsuming the main class.

`cucoo:CulturalContactTrait` allows the identification of cultural traits in the evidence or in the actors of the cultural phenomenon. Once again, it should be regarded as an extension point through which the base model reaches into the cultural domain. Some of these traits, such as material, measure, carving, appearance, weight, iconography, or text, were hardcoded into the original ontology; however, another controlled vocabulary could be associated to it, whether the membership of classes is asserted or inferred.

Cultural contact traits are "characteristics of human action which are acquired and transmitted by any kind of communication in a situation of cultural contact". The object property `cucoo:isAssociatedWith` relates a trait (e.g., a type of material or the grip over a weapon) with a cultural identity (e.g. Roman, Phoenician, Minnan or Feudal Japanese), without restrictions, whereupon the former is classified as a cultural trait. For example, a Latin inscription in a sculpture can be associated with the Roman cultural identity because it is written in Latin, in the same way as it could be related to the Iberian cultural identity if it were to record an Iberian name in Latin script. In another example that will run through this section, the Shuang Shou Dao saber could be associated to either Feudal Japanese or Anglo-Saxon cultural identities, because two-handed swords belong in both (but not natively in South China), however, the fact that it is single-edged helps resolve the ambiguity in favor of the association to Feudal Japan.

By applying inference rules to CuCoO and to a domain dataset, it is possible to identify cultural contact traits of diverse provenance, each trait being one entity in the dataset. This is done by connecting an instance of

[12]The Cultural Contact Ontology, https://github.com/paulagranados/CuCoO.

[13]Full-text definition of terms are given as annotations within the CuCoO OWL source code.

[14]Being aware of the critical debate around the very notion of cultural identity, we report that CuCoO allows for instantiating cultural identities whose granularity is subjective, and can be more specific than anything commonly recognized as an identity. This shall be further elaborated upon in Section 8.

`cucoo:CulturalTrait` to one of `cucoo:CulturalIdentity` (or of a subclass of it) through the property `cucoo:isAssociatedWith`. In this way, the objects that present cultural traits related to different cultural identities are considered in CuCoO as evidence for cultural contact.

6.2 Modularization of the CuCoO ontology

One potential pitfall of using an ontology-based approach to detect culturally relevant aspects in data is that, when reusing arbitrary domain ontologies to describe the context, pinpointing these aspects in those ontologies would be both restrictive and unsustainable. While it is plausible that features identified in Roman coins, such as the clothing worn and weaponry wielded by those depicted on them, be culturally relevant in the martial arts domain as well, making it explicit may give rise to knowledge representation issues, such as saturating the assignment of types to entities. CuCoO, the cultural contact model we adopted, is structured in such a way, therefore we took it upon ourselves to generalize it so that it would serve the needs of, among others, the Southern Chinese martial arts domain.

Because the present study required the association of contexts, aspects and traits of cultural interaction beyond those originally defined, and in a way that cannot always be predicted in an ontology engineering phase, we aimed at improving the versatility of CuCoO while preserving its fundamental framework. Taking advantage of the existing modularization techniques mentioned earlier [12, 14], we created a separate, modular derivative of CuCoO. The resulting version used in this study is so partitioned:

- *Core.* This module now only contains the basic model of cultural contact, stripped of any relationship with specific types of trait. The notions of cultural identity, trait, contact and feature and the properties that related them have been moved to this module.
- *Alignments.* All mappings to third-party ontologies of interest have been moved to this module, to place CuCoO in the landscape of cultural ontologies. Existing mappings to CIDOC-CRM have been preserved, while the `CulturalContact` class itself now subsumes `crm:E92_Spacetime_Volume`, thus becoming part of the CIDOC-CRM phenomenological framework. Alignments with ArCo were introduced for types that denote cultural traits and contexts.
- *Traits.* While the original CuCoO already separated instances specifically from the Early Roman domain into another module, definitions of traits like clothing, hairdo, material or language still survive in the main ontology. These have been moved to an ad-hoc module since, although biased by the original study, some traits such as clothing are expected to be relevant in other cultural heritage domains, including the Southern Chinese martial arts one. We did not add new ones, though, out of expectation that entities like technique, symbolic association or weapon grip, will be classified as cultural traits by the inferencing process.

Only the Core module of the reengineered CuCoO is necessary for the purpose of this study. Nevertheless, it is also useful to keep track of cultural traits to verify which ones correspond to features detected by the inference-based computational model described in the following. The alignments can be utilized if one wishes to, for example, materialize the inference as a cultural heritage dataset based upon CIDOC-CRM.

6.3 Inference-driven cultural contact detection

To detect potential characteristics of cultural contact found in the evidence of our domain dataset, we formalize inference rules, run them over the dataset, and materialize the new statements being generated by their execution.

Semantic Web technologies offer several means of expressing inference rules upon data in RDF format, including ontology rules in the SWRL language, SPIN rules, and CONSTRUCT queries in plain SPARQL language. To avoid language overheads for the comprehension of our computational model, we chose the last form, though all of them are for the most part interchangeable [5]. Our use case implementation, informed by the tools available for

the construction of rule-based inferential models (cf. Sec. 2.2) and with generalizability in mind, consists of the following steps:

(1) Write inference rules that use terms from both the martial arts domain ontology and the modularized CuCoO, but otherwise as independent of the HKMALA data as possible.
(2) Set the scope of each inference rule to a data table that lists the known associations of features to cultural identities; being instance-based, these tables may reference terms from the HKMALA datasets.
(3) Execute the rules over the HKMALA knowledge graph and materialize the resulting inferences, that is, produce them as RDF triples in the query output.

Writing the inference rules as indicated in step (1) allows them to be written with the sole knowledge of the domain model for the rule antecedent (i.e. the WHERE clause in the case of SPARQL CONSTRUCT) and of the cultural contact model for the rule consequent (i.e. the graph patterns in the actual CONSTRUCT clause). The data table in step (2) is as simple as a SPARQL VALUES clause that can be inserted into the rule to give it the desired scope.

We demonstrate the above through examples extracted from the six inference rules used for this study. Listing 8 shows a rule that generates CuCoO cultural associations out of martial art styles, possibly through techniques of them (line 11, `^:belongsInSystem?`), that employ a weapon of some type that must be handled (line 13, `^:handles`) in a way that has certain characteristics (the `[ ?feature ?featureValue ]` pair). At this stage, it is not yet known which features, such as grip or swing, will actually be considered: these features, as well as their values and the styles returned in output by the rule execution, will all be bound to entities from the HKMALA knowledge graph.

```
1  CONSTRUCT {
2    # Feature-based association
3    ?style cucoo:hasCulturalAssociation ?assoc .
4    ?assoc a cucoo:CulturalAssociation
5      ; cucoo:isAssociatedWith ?uident
6      ; cucoo:hasCulturalContactTrait ?feature
7      ; cucoo:value ?featureValue .
8  } WHERE {
9      # If a style uses a weapon either directly or through a technique
10   ?style a :StylingSystem
11     ; ^:belongsInSystem?/:employsArmament ?weapon .
12   ?weapon skos:broader+ ?weaponType
13     ; ^:handles [ ?feature ?featureValue ] .
14
15   {%feature_table%}
16   ?featureValue a ?featureType .
17
18   # Functions to build new entities
19   BIND (URI(CONCAT(STR(?style),"/assoc/", labelify(?ident) ,"/", REPLACE(
20     LCASE(STR(?feature)), '^.+/', '') )) AS ?assoc)
21   BIND (URI(CONCAT("http://data.unil.ch/cultural_identity/crossings/",
22     LCASE(?ident) )) AS ?uident)
23 }
```

Listing 8. Inference rule, in SPARQL construct form, to detect cultural traits from weapon handling.

What the weapon types, cultural identities, or handling characteristics are should not be hardcoded into the rule, however, the available knowledge in that regard must be taken into account. This is the reason why, in listing 8, there is (line 15) `{%feature_table%}` as a placeholder that can be substituted at runtime with a VALUES clause, which encodes the table of possible cultural associations. In our example, the following data table provides the scoping: it indicates that swords which are held with two hands are a trait of the Japanese Muromachi culture if single-edged (line 2) and of the Anglo-Saxon cultures if double-edged (line 3).[15]

```
1 VALUES (?weaponType ?featureValue ?ident) {
2   ( data:SingleEdgedSword :TwoHandedGrip wd:Q334845 )  # Q334845 is Muromachi Japan
3   ( data:DoubleEdgedSword :TwoHandedGrip wd:Q784963 )  # Q784963 is Anglo-Saxon England
4 }
```

Listing 9. VALUES clause complementing the rule in Listing 8.

At this stage, one does not yet know what such weapons and styles are, or if they even exist. Applying the rule in Listing 8, scoped using the data table of Listing 9, attempts to detect cultural traits and to trace them back to the evidence that warrants them. At the time of writing, their execution over the HKMALA knowledge graph generates the following RDF statements.

```
1  data:martialart/minnan_martial_arts
2    cucoo:hasCulturalAssociation
3       data:martialart/minnan_martial_arts/assoc/muromachi/weapon ,
4       data:martialart/minnan_martial_arts/assoc/muromachi/withgrip
5  .
6  data:martialart/minnan_martial_arts/assoc/muromachi/weapon
7    a  cucoo:CulturalAssociation ;
8    cucoo:hasCulturalContactTrait  :WeaponType ;
9    cucoo:isAssociatedWith  wd:Q334845 ;
10   cucoo:value  data:weapon/shuangshoudao
11 .
12 data:martialart/minnan_martial_arts/assoc/muromachi/withgrip
13   a  cucoo:CulturalAssociation ;
14   cucoo:hasCulturalContactTrait  :withGrip ;
15   cucoo:isAssociatedWith  wd:Q334845 ;
16   cucoo:value  :TwoHandedGrip .
```

Listing 10. Inferred statements from the application of the above rule to the HKMALA dataset.

The snippet in Listing 10 tells us that the martial arts of the Minnan people have two possible associations to the Muromachi-period Japanese culture (`wd:Q334845`, lines 9 and 15): one through the *Shuang Shou Dao* (a single-edged bladed weapon) and one through the typically Japanese custom of holding swords with both hands. Verification with HKMALA text documentation confirms these claims[16] with the explanation that inhabitants of the Southern Chinese coast partnered with Japanese *ronin* warriors to counter regular pirate incursions. We also note that an object property, `withGrip`, is used in the data as the predicate for `TwoHandedGrip`, therefore the

[15]The example is obviously simplified for the sake of clarity, as finer-grained rules should take into account combinations of more factors, such as the material and curvature of the blade.

[16]Granted that the wielding of swords with both hands most likely needs to be relaxed to cover a broader context than the Muromachi period alone.

rule in Listing 8 automatically identifies that property (line 14) as the cultural contact trait to be associated to Muromachi Japan.

In another example, we create a rule that states that, if a martial arts style (e.g. Southern Praying Mantis or Fujian White Crane) or a single technique (e.g. Lock hand) are associated to a symbol, then this may be indicating cultural influence.

```
1  CONSTRUCT {
2    ?subject cucoo:hasCulturalAssociation ?assoc .
3    ?assoc a cucoo:CulturalAssociation
4      ; cucoo:isAssociatedWith ?identity
5      ; cucoo:hasCulturalContactTrait ?p
6      ; cucoo:value ?symbol
7  } WHERE {
8    # Any of these properties can be used to build a symbolic association
9    VALUES (?p) {
10     (:symbolicallyRepresents)
11     (:mimics)
12   }
13   {%feature_table%}
14
15   # A single technique or an entire style can bear imagery
16   { ?subject a ma:StylingSystem } UNION { ?subject a ma:Technique } .
17   ?subject ?p ?symbol
18
19   # Functions to build new entities
20   BIND (URI(CONCAT( STR(?subject),"/assoc/", MD5(STR(?identity)) ,"/",
21     MD5(STR(?symbol)) )) AS ?assoc)
22 }
```

Listing 11. Inference rule to detect cultural traits from weapon usage

In Listing 11, this time we fix (lines 9-12) the imagery-related properties we are interested in, and leave to the data table only the responsibility of associating symbols to cultures. The `{%feature_table%}` is therefore substituted with the following, which has been simplified for example's sake:

```
1  VALUES (?symbol ?identity) {
2    ( wd:Q25365 data:identity/zhangzhou/qing> )
3  }
```

Listing 12. Minimal slice of a VALUES clause complementing the rule in Listing 11.

In Listing 12, Wikidata entity `wd:Q25365` is the crane, and the corresponding cultural identity is a spatio-temporal framing tailored around the Zhangzhou province inhabitants during the Qing rule (modeled separately), arguably the first people known to have used the crane imagery in their styles, which has since trickled down to other martial arts.

7 RESOURCES

To provide a reference implementation of our cultural contact detection approach, we strive to make as much of its data and models as possible available under open data or otherwise permissive licenses.

The code repository of the Martial Arts Ontology modules is available on GitHub[17] under a Creative Commons Attribution 4.0 license. The corresponding GitHub Pages frontend[18] provides a way to make the ontology URIs resolvable. The entire network can be imported by loading a single root module for convenience.[19]

Likewise, the modularized version of CuCoO is available under its same license yet with a different attribution.[20] A root module to use for loading the entire networked ontology is also provided.[21]

The datasets that constitute the HKMALA knowledge graph are available on a rolling-release model,[22] i.e. with continuous delivery of updates regardless of their packaging into releases.[23] Restrictions on the use of HKMALA archive content limit the data that can be made available to the extent of what has been publicly released by the "300 Years of Hakka Kung Fu" project[24] and its rights holders. However, the RDF datasets, EAF media annotations and data tables for the inference rules, which are based on documentation made available internally, are also part of the data repository. Because of the aforementioned limitation, the license of the knowledge graph data is Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0).

Most of the inference rules we used are packaged with the knowledge graph repository. The project does not require bespoke software to execute its cultural contact detection rules: once the VALUES clauses are integrated with the inference rules in SPARQL CONSTRUCT form, which is attainable with a simple shell command, they can be executed on any RDF store with a SPARQL engine where the ontologies and datasets are stored.

8 DISCUSSION

In the process of validating the Martial Arts Ontology, our focus was to seek confirmation of hypotheses. This is manifested both through satisfaction of the requirements expressed in the competency questions and through confirmation, by means of the inferencing model, of facts known *a priori*. In other words, the inference rules and data frames providing the scope were designed to infer knowledge previously gathered form the HKMALA documentation in the least constrained way possible. Its precision is therefore high by design, also considering that this study was not meant to take into account the serendipitous inference of unexpected facts. While this computational model would be perfectly capable of doing so with an expanded dataset and ruleset, our goal is to construct a curated gold standard implementation of the model.

From an anthropological perspective, supporting computationally an investigation on the porosity of ethnic cultures opens up opportunities for a structured approach towards turning the results into data, albeit with caveats towards a totally unsupervised strategy. Identifying the point of transition from one culture to another has been a lively debate for long years and, despite repeated attempts, the effort to find one has gradually waned, prompting anthropologists to assert that a culture always belongs to multiple cultures [21, 33] and that, therefore, associations to cultural identities should not be sought with certainty. In fact, the concept of cultural boundary has taken on different meanings over the years, to the point of being strongly criticized and its very existence being called into question [4].

Besides their ability to organize and reproduce themselves, the most striking characteristic of cultures is their dynamic character, asymmetry and continuous search for balance through cultural exchanges. The border is one of the drivers of this dynamism, and yet, it is not clear to anthropologists which terms are used to define the boundaries of a cultural group. While there are solid cores that define an ethno-cultural group, even more

[17] GitHub code repository, https://github.com/CROSSINGS/ont
[18] Martial Arts Ontology GitHub pages, https://crossings.github.io/ont/
[19] Martial Arts Ontology root, https://crossings.github.io/ont/martialarts
[20] Code at https://github.com/CROSSINGS/CuCoO/, resolvable GitHub pages at https://crossings.github.io/CuCoO/
[21] CuCoO root, https://crossings.github.io/CuCoO/cucoo
[22] GitHub, https://github.com/CROSSINGS/kg, DOI http://doi.org/10.5281/zenodo.5886867.
[23] Note that the Zenodo data repository still creates individual DOIs for each update pushed to it.
[24] http://www.hakkakungfu.com/

truly these cores have a degree of porosity and permeability that is extremely marked, to the extent that the core itself is modified. Our work is part of a larger attempt at modeling culture as a set of articulated and hierarchical elements, joined together through the set of relationships between these features. Our way of acknowledging the debate described above in our work is to represent cultural identities no longer through a pre-organized vocabulary, which is somewhat easier to attain in the Ancient World context the CuCoO ontology originally operated in, but as a combination of anthropological features that serve as their coordinates.

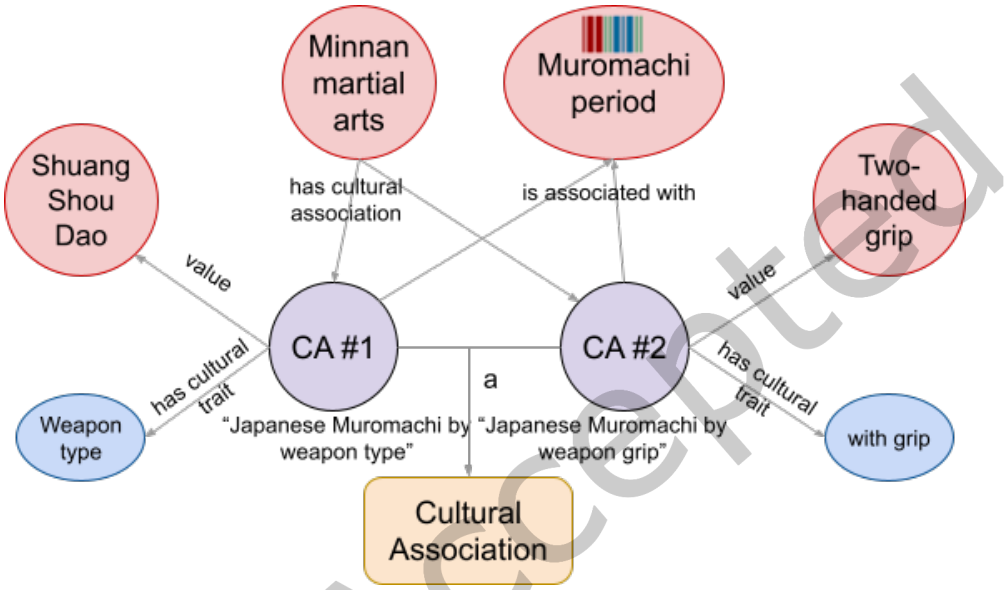

Fig. 3. Knowledge-driven inference of potential cultural contact based on evidence, combining tangible and intangible factors. Dataset entities are indicated in red, materialized entities in purple, domain ontology terms in blue and CuCoO terms in yellow.

Taking the example of Fig. 3, depicting the Chinese cultural tradition of "Shuang Shou Dao", the single-edged saber held with a two-handed grip, we showed in Section 5 how its derivation from Japanese culture required some features to be present in combination. Such permeability between the two cultures in question is eminently represented in our domain ontology, which was crafted to capture such elements independently, however, anthropological transmission requires a culture-aware model to be combined with it.

This work also demonstrates the benefits of making ontologies interoperate, which were developed in separate contexts and each with its independent focus. Without the ontological support of CuCoO striving to become independent of historical/cultural context or relevant cultural traits, it would not have been easy to represent links between cultures. The intertwining of traditions was made possible by the representational synergy of the Martial Arts Ontology with CuCoO. The latter provides the necessary modeling layer for capturing elements that, by transcending the cultural boundaries of a civilization, become true anthropological elements.

9 CONCLUSION

The documentation that accompanied HKMALA exhibitions over the years references multiple contexts where a form of influence took place, e.g. Japan to China or military to civilian, and the traits where it is manifested, such as weaponry or the imagery behind a technique or style. In that light, we have illustrated how a full cycle of an

inference-based computational model can be realized in order to associate factors of cultural contact to evidence that can be either tangible, such as weapons, or intangible, such as techniques or symbolism.

Investigating the application of this largely curated approach allowed us to demonstrate that, even when ICH elements are at both ends of the computational model – first in the domain definition, then in the formalization of cultural contact, which is in itself intangible – interesting results can be gathered. These, in turn, are expected to serve as a ground truth for further approaches, not necessarily logical but also statistical, as are most modern-day machine learning approaches, to be employed semi-automatically and at scale. One limitation to the ability of providing proper training data, is that it is hard for this approach to produce the necessary negative examples: the case of impermeable cultural contact is characterized by a lack of evidence (cf. Sec. 2.3), which in this setup makes it easy to be mistaken for lack of cultural contact at all. Overcoming this limitation, whether by revising the rule system, or by rethinking the notion of permeability in a way that can be encoded into an inferential model, is matter for future investigation.

While, therefore, we have a domain ontology, whose purpose is to represent the salient features of a specific cultural manifestation, the introduction of a somewhat transversal ontology as is CuCoO makes it possible to capture the elements of anthropological congruity between different cultures, thus tracing a form of cultural ontogeny and phylogeny: a process that, from the standpoint of the sheer martial arts domain, takes place virtually unawares. The intuition to apply an existing formal model that had been conceived for a completely different domain in ancient history, while presenting reusable abstract features, offers an opportunity for the expansion of that same model. For one thing, the categorization of forms of cultural contact should be expanded from those that were devised for Ancient Roman history: as the late Imperial history of China had it, there have been subtle and intricate forms of counterreaction to political rule or ethnic prevarication - recall the aforementioned examples of prohibitions to bear arms or pirate incursions. These cannot be adequately captured through the simple permeable/impermeable dichotomy that is in CuCoO, which calls for future work to revise its more general foundation.

Moreover, the potential of Linked Data is demonstrated by the need for our domain-specific dataset to interoperate with general-purpose ones such as Wikidata, if anything, because the introduction of the symbolic aspect calls for a need to connect to concepts that serve as inspiration to techniques or to entire styles. Because these concepts may come from virtually any domain, like nature or East-Asian societies, a domain-specific effort simply cannot take upon itself to model them.

In a separate yet dependent effort, the datasets modeled after the Martial Arts Ontology, which constitute the HKMALA knowledge graph, are being used to annotate individual segments of motion capture and video resources: the ultimate goal of this task is to enable the fine-grained querying of the entire archive, or of any part of it that the rights holders should choose to openly release, through the knowledge graph.

Cultural studies experts in the project team have attested to the intrinsic value of our findings of the cultural contact detection approach, which has been implemented by other members. The fact that the inferences are confirmed by the texts used as the primary corpus for creating the knowledge graph shows promise. However, how interesting the findings are to historians of martial arts and scholars in Chinese history remains to be assessed. A complete knowledge organization of the original archive would be feasible following a renewed funded partnership with its rights holders, whereupon it would be possible to involve domain experts from the International Guoshu Association for an appraisal of their relevance and usefulness, and of the degree of serendipitous knowledge being extracted.

ACKNOWLEDGEMENT

This work was supported by CROSSINGS - Computational Interoperability for Intangible and Tangible Cultural Heritage, a project in the Collaborative Research on Science and Society (CROSS 2021) programme. The authors

would also like to thank the *Hong Kong Martial Arts Living Archive*, a heritage project co-launched by Mr Hing Chao and Professor Sarah Kenderdine in 2012, and a longitudinal research collaboration between the International Guoshu Association, the Laboratory for Experimental Museology at EPFL, and the City University of Hong Kong.

REFERENCES

[1] Alessandro Adamou, Yumeng Hou, Davide Picca, Mattia Egloff, and Sarah Kenderdine. 2021. Ontology-Mediated Cultural Contact Detection Through Motion and Style in Southern Chinese Martial Arts. In *Semantic Web and Ontology Design for Cultural Heritage (SWODCH 2021) (CEUR Workshop Proceedings, Vol. 2949)*. CEUR-WS.org. http://ceur-ws.org/Vol-2949#short2

[2] Igor Areh and Barbara Jenic. 2021. The Art of Immersion with Smell and Sensorial Theatre Language. *Amfiteater* 9, 2 (2021), 102–118. https://doi.org/10.51937/Amfiteater-2021-2/100-119

[3] Thomas Baker, Sean Bechhofer, Antoine Isaac, Alistair Miles, Guus Schreiber, and Ed Summers. 2013. Key choices in the design of Simple Knowledge Organization System (SKOS). *J. Web Semant.* 20 (2013), 35–49. https://doi.org/10.1016/j.websem.2013.05.001

[4] Ira Bashkow. 2004. A Neo-Boasian Conception of Cultural Boundaries. *American Anthropologist* 106, 3 (2004), 443–458. http://www.jstor.org/stable/3567610

[5] Nick Bassiliades. 2018. SWRL2SPIN: A tool for transforming SWRL rule bases in OWL ontologies to object-oriented SPIN rules. *CoRR* abs/1801.09061 (2018). arXiv:1801.09061 http://arxiv.org/abs/1801.09061

[6] Eva Blomqvist, Karl Hammar, and Valentina Presutti. 2016. Engineering Ontologies with Patterns - The eXtreme Design Methodology. In *Ontology engineering with Ontology Design Patterns - Foundations and applications*, Pascal Hitzler, Aldo Gangemi, Krzysztof Janowicz, Adila Krisnadhi, and Valentina Presutti (Eds.). Studies on the Semantic Web, Vol. 25. IOS Press, 23–50. https://doi.org/10.3233/978-1-61499-676-7-23

[7] Nicola Carboni and Livio De Luca. 2016. Towards a conceptual foundation for documenting tangible and intangible elements of a cultural object. *Digit. Appl. Archaeol. Cult. Heritage* 3, 4 (2016), 108–116. https://doi.org/10.1016/j.daach.2016.11.001

[8] Valentina Anita Carriero, Aldo Gangemi, Maria Letizia Mancinelli, Ludovica Marinucci, Andrea Giovanni Nuzzolese, Valentina Presutti, and Chiara Veninata. 2019. ArCo: The Italian Cultural Heritage Knowledge Graph. In *The Semantic Web - ISWC 2019 - 18th International Semantic Web Conference, Auckland, New Zealand, October 26-30, 2019, Proceedings, Part II (Lecture Notes in Computer Science, Vol. 11779)*, Chiara Ghidini, Olaf Hartig, Maria Maleshkova, Vojtech Svátek, Isabel F. Cruz, Aidan Hogan, Jie Song, Maxime Lefrançois, and Fabien Gandon (Eds.). Springer, 36–52. https://doi.org/10.1007/978-3-030-30796-7_3

[9] Hing Chao, Matt Delbridge, Sarah Kenderdine, Lydia Nicholson, and Jeffrey Shaw. 2018. Kapturing Kung Fu: Future proofing the Hong Kong martial arts living archive. In *Digital Echoes*. Springer, 249–264.

[10] Huma Chaudhry, Karim Tabia, Shafry Abdul Rahim, and Salem BenFerhat. 2017. Automatic annotation of traditional dance data using motion features. In *2017 International Conference on Digital Arts, Media and Technology (ICDAMT)*. 254–258. https://doi.org/10.1109/ICDAMT.2017.7904972

[11] James G. Cusick (Ed.). 1998. *Studies in culture contact : interaction, culture change, and archaeology.* Center for Archaeological Investigations, Southern Illinois University, Carbondale, IL.

[12] Mathieu d'Aquin, Marta Sabou, and Enrico Motta. 2006. Modularization: a Key for the Dynamic Selection of Relevant Knowledge Components. In *Proceedings of the 1st International Workshop on Modular Ontologies, WoMO'06, co-located with the International Semantic Web Conference, ISWC'06 November 5, 2006, Athens, Georgia, USA (CEUR Workshop Proceedings, Vol. 232)*, Peter Haase, Vasant G. Honavar, Oliver Kutz, York Sure, and Andrei Tamilin (Eds.). CEUR-WS.org. http://ceur-ws.org/Vol-232/paper2.pdf

[13] Martin Doerr, Christian-Emil Ore, and Stephen Stead. 2007. The CIDOC Conceptual Reference Model - A New Standard for Knowledge Sharing. In *Challenges in Conceptual Modelling. Tutorials, posters, panels and industrial contributions at the 26th International Conference on Conceptual Modeling - ER 2007. Auckland, New Zealand, November 5-9, 2007. Proceedings (CRPIT, Vol. 83)*, John C. Grundy, Sven Hartmann, Alberto H. F. Laender, Leszek A. Maciaszek, and John F. Roddick (Eds.). Australian Computer Society, 51–56. http://crpit.scem.westernsydney.edu.au/abstracts/CRPITV83Doerr.html

[14] Paul Doran. 2009. *Ontology modularization : principles and practice.* Ph. D. Dissertation. University of Liverpool, UK. http://repository.liv.ac.uk/1306/

[15] Katerina El Raheb, Nicolas Papapetrou, Vivi Katifori, and Yannis Ioannidis. 2016. BalOnSe: Ballet Ontology for Annotating and Searching Video Performances. In *Proceedings of the 3rd International Symposium on Movement and Computing* (Thessaloniki, GA, Greece) *(MOCO '16)*. Association for Computing Machinery, New York, NY, USA, Article 5, 8 pages. https://doi.org/10.1145/2948910.2948926

[16] Marco Fiorucci, Marina Khoroshiltseva, Massimiliano Pontil, Arianna Traviglia, Alessio Del Bue, and Stuart James. 2020. Machine Learning for Cultural Heritage: A Survey. *Pattern Recognit. Lett.* 133 (2020), 102–108. https://doi.org/10.1016/j.patrec.2020.02.017

[17] Aldo Gangemi, Nicola Guarino, Claudio Masolo, and Alessandro Oltramari. 2003. Sweetening WORDNET with DOLCE. *AI Mag.* 24, 3 (2003), 13–24. https://doi.org/10.1609/aimag.v24i3.1715

[18] Birte Glimm, Ian Horrocks, Boris Motik, Giorgos Stoilos, and Zhe Wang. 2014. HermiT: An OWL 2 Reasoner. *J. Autom. Reason.* 53, 3 (2014), 245–269. https://doi.org/10.1007/s10817-014-9305-1

[19] Thomas R. Gruber. 1993. A translation approach to portable ontology specifications. *Knowledge Acquisition* 5, 2 (1993), 199–220. https://doi.org/10.1006/knac.1993.1008

[20] Nicola Guarino and Giancarlo Guizzardi. 2016. On the Reification of Relationships. In *24th Italian Symposium on Advanced Database Systems, SEBD 2016, Ugento, Lecce, Italy, June 19-22, 2016, Ugento, Lecce, Italia*, Mario A. Bochicchio and Giansalvatore Mecca (Eds.). Matematicamente.it, 350–357.

[21] Linda Hantrais. 2013. *A Handbook of Comparative Social Policy, Second Edition.* Edward Elgar Publishing, Cheltenham, UK, Chapter 12: Crossing cultural boundaries, 227–242. https://doi.org/10.4337/9781782546535.00022

[22] Yumeng Hou, Sarah Kenderdine, Davide Picca, Mattia Egloff, and Alessandro Adamou. 2022. Digitizing Intangible Cultural Heritage Embodied: state of the art. *Journal on Computing and Cultural Heritage (JOCCH)* (2022). https://doi.org/10.1145/3494837

[23] Rajkumar Kannan and Balakrishnan Ramadoss. 2010. Modeling and Annotating the Expressive Semantics of Dance Videos. arXiv:1001.0442 [cs.MM]

[24] Sarah Kenderdine. 2012. Embodied Museography. *About the Culture Academy Singapore* 23 (2012), 37–41.

[25] Sarah Kenderdine. 2020. Reenactment and Intangible Heritage Strategies for Embodiment and Transmission in Museums. *Volkskunde* 121, ARTICLE (2020), 415–+.

[26] Sarah Kenderdine and Jeffrey Shaw. 2017. Archives in Motion: Motion as Meaning. *Museum and Archive on the Move: Changing Cultural Institutions in the Digital Era, edited by Oliver Grau Wendy Coones and Viola Rühse* (2017), 211–233.

[27] Sylvain Lagrue, Nathalie Chetcuti-Sperandio, Fabien Delorme, Chau Ma Thi, Duyen Ngo Thi, Karim Tabia, and Salem Benferhat. 2019. An Ontology Web Application-Based Annotation Tool for Intangible Culture Heritage Dance Videos. In *Proceedings of the 1st Workshop on Structuring and Understanding of Multimedia HeritAge Contents* (Nice, France) *(SUMAC '19)*. Association for Computing Machinery, New York, NY, USA, 75–81. https://doi.org/10.1145/3347317.3357245

[28] Birger Lantow. 2016. OntoMetrics: Putting Metrics into Use for Ontology Evaluation. In *Proceedings of the 8th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management (IC3K 2016) - Volume 2: KEOD, Porto - Portugal, November 9 - 11, 2016*, Ana L. N. Fred, Jan L. G. Dietz, David Aveiro, Kecheng Liu, Jorge Bernardino, and Joaquim Filipe (Eds.). SciTePress, 186–191. https://doi.org/10.5220/0006084601860191

[29] Pasquale Lisena, Marieke van Erp, Cecilia Bembibre, and Inger Leemans. 2021. Data Mining and Knowledge Graphs as a Backbone for Advanced Olfactory Experiences. In *Proceedings of Smell, Taste, and Temperature Interfaces (STT2021)*. Yokohama, Japan (online).

[30] Paula Loreto Granados-García. 2020. *Cultural contact in early Roman Spain through Linked Open Data.* Ph. D. Dissertation. The Open University. http://oro.open.ac.uk/73887/

[31] R. Luca, S. I. Bejinariu, and H. N. Teodorescu. 2014. An ontology of human walk for autonomous systems. In *2014 18th International Conference on System Theory, Control and Computing (ICSTCC)*. 488–493. https://doi.org/10.1109/ICSTCC.2014.6982464

[32] Melinda McDaniel and Veda C. Storey. 2019. Evaluating Domain Ontologies: Clarification, Classification, and Challenges. *ACM Comput. Surv.* 52, 4 (2019), 70:1–70:44. https://doi.org/10.1145/3329124

[33] Liviu Papadima, David Damrosch, and Theo D'haen. 2011. *The canonical debate today: crossing disciplinary and cultural boundaries.* Internationale Forschungen zur Allgemeinen und Vergleichenden Literaturwissenschaft, Vol. 149. Rodopi.

[34] LO Patrick. 2015. *Preserving Local Documentary Heritage: Conversations with Special Library Managers and Archivists in Hong Kong.* City University of HK Press.

[35] Davide Picca, Alessandro Adamou, Yumeng Hou, Mattia Egloff, and Sarah Kenderdine. 2022. Knowledge organization of the Hong Kong Martial Arts Living Archive to capture and preserve intangible cultural heritage. In *Digital Humanities 2022 - Conference Abstracts, 25-29 July 2022, Tokyo, Japan.* https://dh2022.dhii.asia/abstracts/files/PICCA_Davide_Knowledge_organization_of_the_Hong_Kong_Martial.html

[36] Plato. 2005. *Statesman.* Liverpool University Press. http://www.jstor.org/stable/j.ctv1228h63

[37] María Poveda-Villalón, Asunción Gómez-Pérez, and Mari Carmen Suárez-Figueroa. 2014. OOPS! (OntOlogy Pitfall Scanner!): An on-line tool for ontology evaluation. *International Journal on Semantic Web and Information Systems (IJSWIS)* 10, 2 (2014), 7–34.

[38] Bruno Sartini, Valentin Vogelmann, Marieke van Erp, and Aldo Gangemi. 2022. Comparing Symbolism Across Asian Cultural Contexts Using Graph Similarity Measures. In *Digital Humanities 2022 - Conference Abstracts, 25-29 July 2022, Tokyo, Japan.*

[39] Isabelle Savard and Riichiro Mizoguchi. 2016. Ontology of Culture : A Procedural Approach for Cultural Adaptation in ITSs. In *Proceedings of the 24th International Conference on Computers in Education (ICCE 2016). Think global act local : Contextualizing technology-enhanced education.* Asia-Pacific Society for Computers in Education, 64–69.

[40] Daniela Schmidt, Cássia Trojahn, and Renata Vieira. 2019. Matching BFO, DOLCE, GFO and SUMO: an Evaluation of OAEI 2018 Matching Systems. In *Proceedings of the XII Seminar on Ontology Research in Brazil and III Doctoral and Masters Consortium on Ontologies, Porto Alegre, Brazil, September 2nd-5th, 2019 (CEUR Workshop Proceedings, Vol. 2519)*, João Paulo A. Almeida, Marcello Bax, Rita Berardi, and Fernanda Baião (Eds.). CEUR-WS.org. http://ceur-ws.org/Vol-2519/paper7.pdf

[41] Boas Shamir and Yael Melnik. 2002. Boundary Permeability as a Cultural Dimension: A Study of Cross Cultural Working Relations between Americans and Israelis in High-Tech Organizations. *International Journal of Cross Cultural Management* 2, 2 (2002), 219–238. https://doi.org/10.1177/1470595802002002250

[42] Han Sloetjes and Olaf Seibert. 2016. New Facets Of The Multimedia Annotation Tool ELAN. In *11th Annual International Conference of the Alliance of Digital Humanities Organizations, DH 2016*, Maciej Eder and Jan Rybicki (Eds.). ADHO, 888–889. http://dh2016.adho.org/abstracts/161

[43] Mari Carmen Suárez-Figueroa, Asunción Gómez-Pérez, and Mariano Fernández-López. 2015. The NeOn Methodology framework: A scenario-based methodology for ontology development. *Appl. Ontology* 10, 2 (2015), 107–145. https://doi.org/10.3233/AO-150145

[44] Marzieh Talebpour, Martin Sykora, and Tom Jackson. 2018. The Evaluation of Ontologies for Quality, Suitability for Reuse, and the Significant Role of Social Factors. In *Knowledge Discovery, Knowledge Engineering and Knowledge Management - 10th International Joint Conference, IC3K 2018, Seville, Spain, September 18-20, 2018, Revised Selected Papers (Communications in Computer and Information Science, Vol. 1222)*, Ana L. N. Fred, Ana Salgado, David Aveiro, Jan L. G. Dietz, Jorge Bernardino, and Joaquim Filipe (Eds.). Springer, 161–177. https://doi.org/10.1007/978-3-030-49559-6_8

[45] Robert Warren. 2012. Creating specialized ontologies using Wikipedia: The Muninn experience. *Proceedings of Wikipedia Academy: Research and Free Knowledge (WPAC2012)* (2012).

[46] Wiktenauer contributors. 2018. Wiktenauer. online. https://wiktenauer.com/

[47] Christoph Wulf. 2020. Performativity and dynamics of intangible cultural heritage. In *Ritual, Heritage and Identity*. Routledge India, 76–94.