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Semanticizing Sociability: Documenting Relationships in the Context of Cultural Heritage

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Abstract. Museums are increasingly leveraging the relationships between actors to guide their work and uncover new socio-cultural networks. Better socio-cultural network modelling based on CIDOC CRM—which is not specifically concerned with actor networks but remains the most widely used ontology in the heritage community—would contribute to the discovery, dissemination and enhancement of museum information and would promote inter-institutional collaboration. To achieve this, models must consider complex networks of inter-entity relationships and ways of inferring and representing such relationships. Various ways of representing actors in networks are already available (Bio CRM, Linked.Art, etc.), but none (based on CIDOC CRM) seem to focus on modelling the network itself. This article, after a critical analysis of relationship patterns in relevant models that offer them, proposes a CIDOC CRM-based approach to representing the events that concretize social interactions and relationships. This is done by representing actors' roles within events, with patterns that are non-hierarchical (one actor does not take precedence over another) and multi- or bi-directional (links between actors are reciprocal) in order to provide a more detailed description of socio-cultural networks.

Keywords. Semantic Modelling, Actors Roles Semantics, Social Networks, Linked Open Data, CIDOC CRM.

1. Introduction

Recent debates on the (re)definition of museums, most notably at the International Council of Museums, illustrate a trend towards an increasingly social contextualization of objects. This is in part signaled by an increased emphasis on active collaboration with communities to record diverse understandings of the world:

> *"Museums [...] work in active partnership with and for diverse communities to collect, preserve, research, interpret, exhibit, and enhance understandings of the world, aiming to contribute to human dignity and social justice, global equality and planetary wellbeing."* [1]

This socially-involved stance and focus on safeguarding diverse memories indicates a shift in what is traditionally recorded to encompass the cultural perspectives and individual stories objects carry with them. This social function compels heritage institutions and practitioners to pay attention not only to the recording of data about physical items, but also to that pertaining to social artefacts. Hence, public figures' (inter)actions (as opposed to the notable episodes of their lives) are becoming a relevant field of inquiry for the heritage community. This shift in the nature of the questions asked about persons and groups from information on the actors *themselves* to questions about the relationships *between them* is in line with examinations of the extent to which a person's social network has bearing on their cultural production, identity and history [2].

Heritage practitioners are thus paying increasing attention to the various social moments of creative activity (production, mediation, reception), to the actors they involve, and to the implications of the interactions between these actors. This interest first emerged in the academic community where philosophers and sociologists [3–7] as well as heritage theorists [8–10] became interested in the matter. It is now spreading through the methodologies of the heritage community, where documentation, conservation, and exhibition practitioners must deal with the fluctuating context of artefacts, which is itself an issue of collective memory [11]. Hence, better understanding and cataloguing heritage figures' (inter)actions is of prime importance both for heritage documentation and research.

Concurrently, the exponential growth of the amount of data currently generated by and about humans is leading to a substantial change in the nature and amount of information collected about individuals and groups [12]. Whilst heritage practitioners have limited access to these massive datasets about persons at the moment, it is reasonable to expect that they will eventually do. Not only could actors want to make their data public, but such information artefacts will eventually be in the public

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historical domain. The conservation, documentation and processing of such data thus raise many social, ethical, legal and heritage-related questions [13], one of which is how to best formalize or even define such relationships.

Relationships[4] and interactions[5] are most often only summarily recorded in relational databases. Such databases and data structures provide summary documentation of explicitly recorded exchanges between actors (i.e. manifest exchanges) by connecting the records of the parties concerned. This allows cultural organizations' current minimum search needs to be addressed by summarily recording information about actors' interactions.

Yet, there is an increasing demand for information on interactions that are often not explicitly recorded [14,15] but need to be uncovered and formalized in order to properly contextualize data. This is something that is especially important in the case of previously ignored corpora, such as those by people from marginalized communities[6], or "weak" relationship networks[7] where the context in which an individual or group operates must be properly catalogued to be adequately understood [18].

From this perspective, it is no longer sufficient to record only manifest exchanges between individuals; rather, interactions must be documented and described so that the actors' relationship to the world around them can be better understood. This would enable, for example, the visualization of the dissemination of scientific knowledge, the identification of an individual's or a family's networks of influences, or provide information on a company's growth processes [19].

There is hence a distinction to be established between three fundamental elements:

- what *actually* exists, namely the relationship between the parties as it is embodied in the world;
- what is *recorded*, namely the information that is documented in the relational database;
- what is *searched* for, namely the information that is relevant to the work of practitioners and about which they make queries.

Because of the previously alluded to massification of datasets and of the concurrent evolution in what is searched by practitioners, the information recorded by them is also currently undergoing substantial changes in the form of a greater focus on actors' relationships. These make the structure of conventional databases inefficient (either because of the complexity of the links between data, or because of the sheer amount of it). This inefficiency in turn drives the development of alternatives to traditional relational databases, notably in the form of semantic graphs.

2. Different Approaches to Structuring Relationships: Properties and Instances as the Locus of Meaning

An examination of the main standards[8] used in the cultural sector to describe networks of actors provides an overview of the data currently catalogued by libraries, archives and museums. Although there does not seem to be a consensus on the definition of database fields pertaining to relationships, nor on how they are typically interconnected, there is consensus around the fact that actual relationships are manifold and that searches about them abound as well. At the moment, a summary assessment indicates that relationships recorded by the heritage community mainly pertain to the following four clusters: authority relations (e.g. X is Y's boss), temporal relations (e.g. X is Y's predecessor), family relations (e.g. X is Y's uncle) and associative relations (e.g. X is Y's business partner). Accounting for the manifold nature of these relationships requires conceptualizing them beyond current records of manifest exchanges and actions to think of the function of these actions in the context of the relationship in which they occur.

There are various possible approaches to modelling relationships between actors, and the methodological principles in doing so vary accordingly [20,21]. In the context of heritage aggregation, the main objective of modelling is to achieve a balance between faithful representation of the data submitted by contributors and standardization of this data for interoperability purposes. From this perspective, certain methodological principles—in addition to the usual best practices of clear definition of concepts, design consistency and model scalability—take on greater importance; three of them are identified below.

First, to ensure a model's effectiveness, it is important to limit the technological and human resources needed to implement it. A model must therefore be confined to the needs of the field of expertise it represents

[4] Relationships are understood, in the context of this article, to be the direct or indirect interactions between individuals or groups of individuals.

[5] Interactions are understood, in the context of this article, to be the concrete and definite "micro" contacts or exchanges between actors that, put together, form a relationship.

[6] Marginalized communities or populations are those "excluded from mainstream social, economic, educational, and/or cultural life [...for example due to] race, gender identity, sexual orientation, age, physical ability, language, and/or immigration status" [16].

[7] Weak relationships or "ties" are un-frequent or transitory social relations that nonetheless have an influence on persons because they carry with them novel information or opportunities [17].

[8] This study examined the relationship fields of the following norms: the Visual Resources Association's *Cataloging Cultural Objects: A Guide to Describing Cultural Works and Their Images*, the Getty Vocabulary Program's *Categories for the Description of Works of Art* (CDWA), the Getty Vocabulary Program's *Editorial Guidelines*: *Union List of Artist Names (ULAN)*, the *International Standard Archival Authority Record for Corporate Bodies, Persons and Families* (ISAAR (CPF)) of the International Council on Archives, *Resources Description and Access* (RDA) of the Joint Steering Committee for RDA and the Committee of Principals (CoP), and the *Rules for Archival Description* (RAD) of the Canadian Committee on Archival Description.

[20], and it must limit the inclusion of patterns[9] that address technological rather than informational imperatives (limitation of encoding bias) [21]. This depends in part on the absence of superfluous or unduly restrictive classes and properties so that the classes provided can be easily specialized by third parties (limitation of ontological commitment) [21]. Such an approach, based on the *rationalization of ontological patterns*, provides detailed modelling that meets the limited needs of particular fields of knowledge but is still interoperable and implementable. This type of exploration is central to teams that are collaboratively developing ontological models for specific, expert purposes. Consequently, it appears best to reuse existing models, as many of them were developed with a wide variety of use cases in mind. In addition, the use of such pre-existing classes and properties makes it possible to limit the resources allocated to the creation of new ones.

Although the creation of new refined classes and properties is also encouraged by some authoritative institutions, the use of a vocabulary to categorize generic entities is becoming more widespread. It is mainly so because it requires less resources to rely on external vocabularies than to maintain and manage specialized entities internally [22]. Moreover, the use of external vocabularies facilitates interoperability between models as the reconciliation of specialized entities amongst different models is more complicated than that of high-level entities.

Second, a model is always a logical abstraction whose objective is to get as close to reality as possible. In this context, maintaining structural parity between the actors so that the subject of the documentation does not take precedence over its relational counterpart is essential [20]. Even if, from the standpoint of available data, the actor being documented will continue to have precedence over its counterpart, it appears essential not to make this predominance *structural* (i.e. at the pattern level) since *recorded* information on actors (i.e. documented data) might become more egalitarian as a result of increased documentation efforts, or as additional reasoning functionalities (such as inference or linguistic analysis) may uncover relationships that are not currently apparent.

Fostering *structural parity* in patterns relies on acknowledging that the nature of one's relationship to their counterpart is particular to themselves and can differ from that of their counterpart to them (e.g. a student's relationship to their teacher is not symmetrical to the teacher's to the student). The nature of this relationship is heavily tied to the standpoint from which it is considered (that of either one of the persons involved), a standpoint that determines two elements: the function or role the person endorses in the relationship (e.g. student) and the directionality that derives from that standpoint (e.g. student *to* their teacher). Maintaining patterns that account for the role[10] and directionality[11] of all parties involved in a relationship pattern is a way to better reflect the perspective each adopts on it, and thus to foster structural parity when developing models. This in turn constrains structural biases that would favour subject actors to the detriment of their relational (object actors) counterparts, and encourages the adequate documentation of both parties.

Actual relationships between individuals necessarily involve several standpoints from which roles and directionalities emanate not unilaterally from one actor to another, but from each actor to their counterpart. Acknowledging this matter of fact when modelling relationship patterns is essential to eventually yield—by inference and through alignment of the data (most often using controlled vocabularies)—additional information about the interactions that had remained latent up to that point. This, combined with a more granular recording of interactions heritage data, is what would amount to raising structural parity to an informational level (i.e. new searchable and usable information is produced) through *logical consistency* in the patterns and vocabularies [21].

These three principles—rationalization of ontological patterns, structural parity, and logical consistency—are important criteria for studying and building on existing models that account for relationships. Information science, sociology, museology, linguistics, and prosopography all offer formalizations of such relationships through data models or ontologies, either by:

- Considering the relationship itself as an inter-actor property whose function is to represent the actors' interaction (minimalist methodology);
- Embodying the crux of the relationship in a distinct class instance whose function is to federate the actors' interactions with what surrounds them and transform those interactions into describable instances themselves (expressive methodologies);
- Formalizing the relationship both as a property and as a class (dual methodology).

2.1. Minimalist approach

The fundamental structural component of the minimalist approach is the inter-actor property which embodies the nature of the relationship between actors. Because there is no other structural component to represent the relationship itself, both directionality and function must be accounted for in the property itself through precise, numerous, and dedicated properties. This approach is

[9] A pattern is a representation of a part of the ontology or data model that identifies the classes and properties used to implement a specific theme.

[10] The parts, activities, functions, and duties endorsed by a person or group with regards to another person or group with which they have dealings ranging in duration from brief to enduring. These reflect a set of connected behaviours, rights, obligations, beliefs and norms expected from both parties and reflected in the contacts between them as well as the way they behave towards each other.

[11] The quality of an interaction of being conceptualized from the standpoint of a person or group in relation to another person or group.

described as "minimalist" because it has a simple structure that generates few triples (since it records limited data on the relationship itself) and therefore requires relatively little technological power and resources from its users. For example, [12] the property `:studentOf` is used to indicate that Marie Skłodowska Curie was the student of Jonas Ferdinand Gabriel Lippmann:

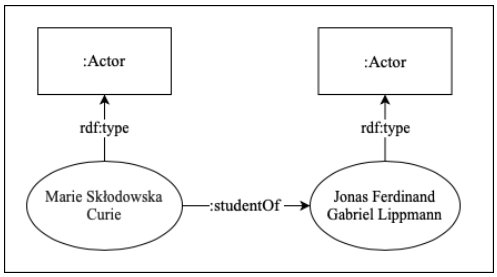

Figure 1. Diagram of the Minimalist Approach

The minimalist approach has been adopted in models such as RiCo (Records in Contexts) of the International Council on Archives, and FOAF (Friend of a Friend) [23,24]. Whilst RiCo structures its properties hierarchically from the vaguest relationships, such as `rico:isAgentAssociatedWithAgent`, to the most precise relationships, such as `rico:hasTeacher`, FOAF structures its properties by characterizing the inter-actor connection with properties such as `foaf:members` or `foaf:knows` [25].

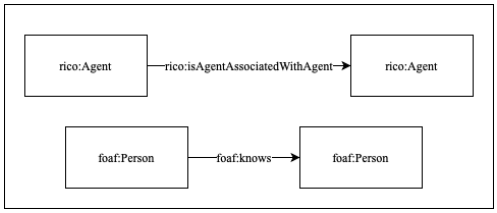

Figure 2. Diagram of the relationship pattern in FOAF and RiCo Ontologies

The minimalist approach, however, displays three significant disadvantages. First, any new type of relationship that does not fit easily into the established structure requires the development of new properties, which contravenes the rationalization criterion established above.[13]

Second, the properties represent the relationship from the single standpoint of one of the actors involved in it. To remedy this, *inverse* properties can be used to infuse bi-directionality to relationships that are of the same nature no matter the standpoint adopted (e.g. friend to friend) [27]. However, this does not always amount to structural parity because some relationships are non-reciprocal, such as the relationship of a student toward a person that might be a tutor just as much as a teacher. Because a minimalist approach relies on properties to embody non-reciprocal relationships as well, inverse properties are not sufficient. To ensure structural parity, the relationship would have to be documented from the counterpart's viewpoint, which would require the creation of another triple to avoid one party having structural precedence over its relational counterpart. Although this is not impossible, it remains a bulky solution that is more problematic to implement because of the specific properties that must be specifically generated for each situation.

Third, it is impossible to infer substantial information from these relationships because the latter cannot be sufficiently documented for logical rules to be applicable or for those rules to be verifiable. As such, the mosaic of relationships that are *actually* embodied in the world is confined to their limited *recording* structure, which in turn limits the queries, so that such a structure both enables and restricts the *research* by practitioners. In addition, because a new property is created anytime a new relationship is recorded, there is a multiplication of properties that must be handled using logical assertions rather than (as would be the case with a controlled vocabulary) hierarchical ordering. This significantly complexifies both the recording (identifying what warrants the creation of a new property), aggregating (determining what logical rules characterize an expanding number of properties and aligning the latter), and searching (making sure all relevant properties are included in a query) processes. For these reasons, the minimalist approach appears unsuitable to the documentation of relationships in the context of heritage aggregation.

2.2. Expressive Approaches

The main structural component of expressive approaches is an instance that embodies the relationship distinctly (whilst the minimalist approach solely employs a property to link two actors together). Because the instance denoting the relationship can become subject to other triples, each social interaction can be further documented, which is why such methods are described as expressive.

Expressive approaches enable better documentation of the relationship itself by associating contextual data with it (such as dates that situate it in time, or types defining its nature).

Expressive approaches can be categorized into two:

- The uni-directional expressive approach, which solely entails modelling interactions between

[12] The following examples are not based on any specific model; they simply represent the principles of the minimalist approach in general.

[13] This is a challenge FOAF faced when the need to document non-reciprocal relations emerged: properties unrelated to the interactions themselves became necessary to account for the variety of ways people consider their relationships to others. Such properties do not pertain to the interaction itself so that they are somewhat inconsistent with the ontology from a design perspective, but are essential to its functional implementation. These include properties such as `foaf-x:ambivalentOf`, `foaf-x:ancestorOf`, `foaf-x:influencedBy`, `foaf-x:knowsByReputation` or `foaf-x:wouldLikeToKnow`. For an analysis of the issues and problems that this structure entails, see [26].

actors using class instances and pairs of properties to embody relationships;
- The multi-directional expressive approach, which further documents the actors within the relationship by modelling their roles.[14]

2.2.1. Uni-directional expressive approach

A uni-directional expressive approach uses class instances to distinctly embody relationships and link such instances to actor instances through symmetrical subject-object properties that mirror each other. Yet, such properties account for the interpretation of the relationship from the perspective of the subject actor towards the object actor, thus forming a unidirectional pattern (hence the name). For example, the `:studentOf` property (used above in the minimalist approach to link Marie Skłodowska Curie and Jonas Ferdinand Gabriel Lippmann) is here a documentable instance of the relationship class (`:StudentOf`) with which two mirror properties (`:hasSubject` and `:hasObject`) are associated:

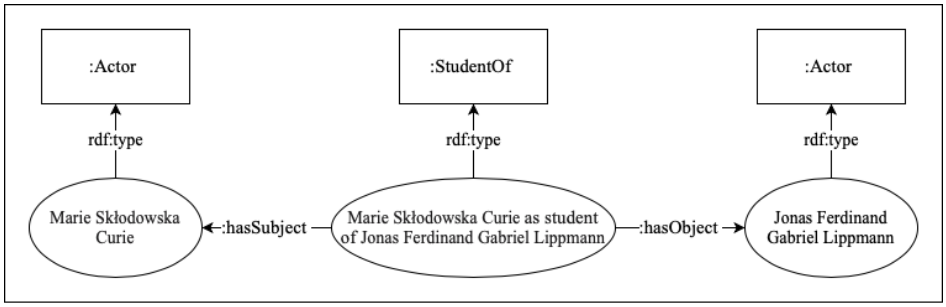

Figure 3. Diagram of the Uni-directional Expressive Approach

However, *actual* relationships encompass a variety of facets and characteristics that would make the creation of a new class for each and every iteration problematic at the recording stage (bulky model) as well as at the search stage (numerous classes that complicate practitioners' queries). To remedy this, a single overarching class can be created with each instance of that class being qualified by a controlled vocabulary term. This solves the problem of adequately accounting for the *actual* manifold nature of relationships at the *recording* stage through the use of controlled qualifiers that facilitate cross-dataset searches. For example, the relationship between Marie Skłodowska Curie and Jonas Ferdinand Gabriel Lippmann can be modelled using an expressive class called `:Relation`, and the instance of that `:Relation` class can be categorized by a vocabulary term "Student of":

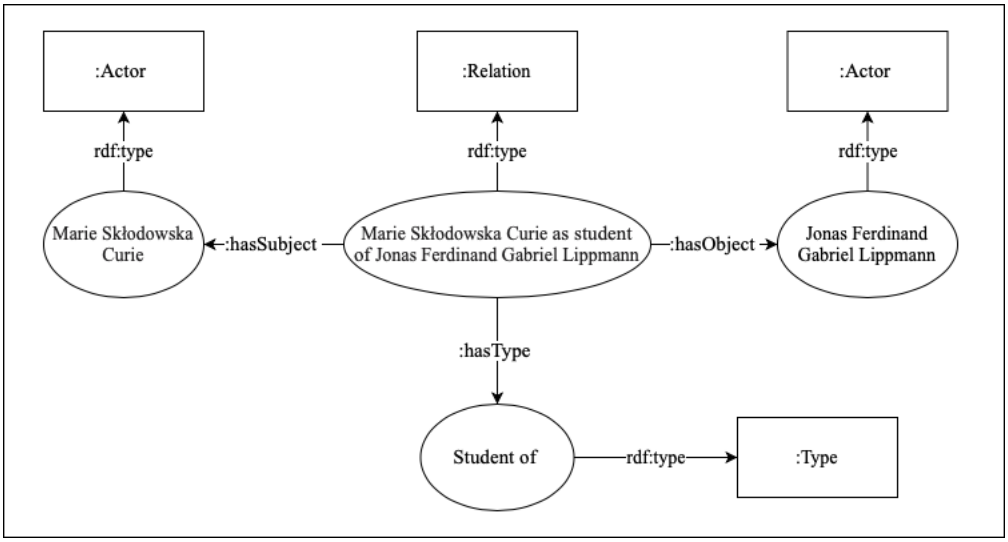

Figure 4. Diagram of the Uni-directional Approach relying on the use of types to categorise relationships

This approach is used in models such as those currently developed by Linked Art or the Swiss Art Research Infrastructure (SARI) which both document relationships using classes categorized by vocabulary terms (instances of the class `crm:E55_Type`), instead of relying on singularized properties.

[14] Roles amount to the parts, activities, functions, and duties endorsed by the main actor instance with regards to a related actor instance with which they have dealings ranging in duration from brief to enduring. These reflect a set of connected behaviours, rights, obligations, beliefs and norms expected from both parties and reflected in the contacts between them as well as the way they behave towards each other. It amounts to an organized model of behaviour pertaining to the position and function an entity endorses in the context of a relationship [28].

The Linked.art Data Model "does not aim to capture all of the possible information about a Person or Group, or their relationships to other people, objects, places or activities" [29] so that there are little documented discussions dedicated to the modelling of social relationships on their platform. Still, Linked.art suggests the use of a class (`crm:E13_Attribute_Assignment`) to model the relationship of an actor with another [30]. The actor instance subject of the relationship can be linked to an instance of `crm:E13_Attribute_Assignment` using the property `crm:P140_assigned_attribute_to`, whilst the actor instance that is the object is linked to this same instance of `crm:E13_Attribute_Assignment` using a `crm:P141_assigned` property. This relationship ensemble can then be qualified using an instance of `crm:E55_Type` linked to the `crm:E13_Attribute_Assignment` instance by a `crm:P177_assigned_property_type` property.

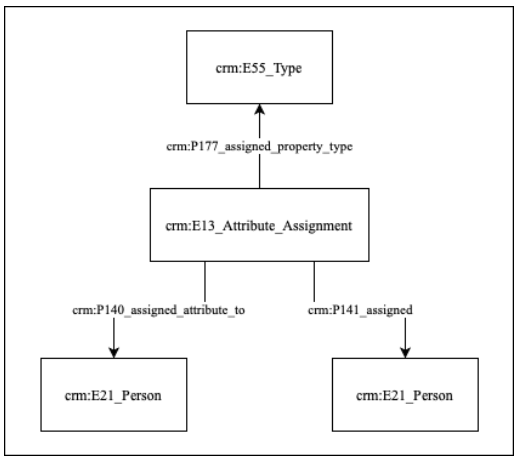

Figure 5. Diagram of the relationship pattern in Linked.art Data Model

For their part, SARI [31] uses a series of property classes—classes developed by the CRM SIG for the reification of properties that are the subject of another property (.1 in CIDOC CRM specification) to facilitate RDF implementation [32] [15] — and their associated properties to embody relationships. These property classes are the domain of two properties: `crm:P01_has_domain` and `crm:P02_has_range`, respectively linking the domain and range of the reified property.

SARI uses the root class of those reified properties, `crm:PC0_Typed_CRM_Property`, and creates a new subclass called `sari:SRPC3_in_social_relationship` with the `crm:P01_has_domain` and `crm:P02_has_range` properties to embody the relationship. This instance of the class `sari:SRPC3_in_social_relationship` is then linked to an instance of `crm:E55_Type`, which qualifies the nature of the relationship represented using controlled vocabularies.

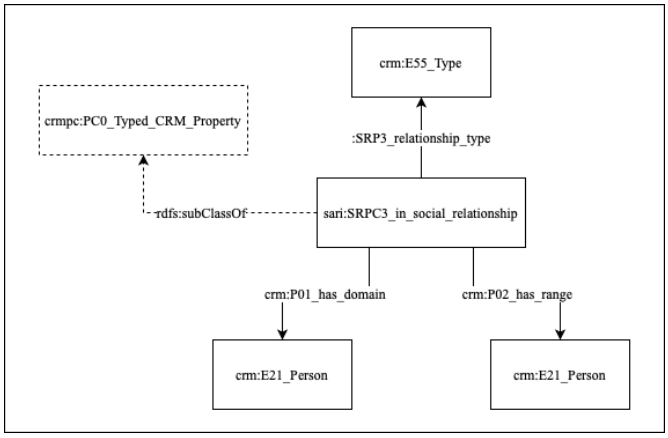

Figure 6. Diagram of the relationship pattern in the SARI Reference Data Model. The dotted lines indicate the super- and sub-classes in the ontology

Both these models mobilize an autonomous class instance qualified by a type thanks to the use of independent controlled vocabularies. The use of this autonomous instance simplifies the reasoning process so that *actual* relationships are *recorded* and categorized in a standardized manner through controlled vocabularies, thus facilitating the *querying* process on the part of practitioners, as it has been discussed above.

[15] For example, the property `crm:P144_joined_with` can be replaced by an instance of the property class `crm:PC_144_joined_with` so that it can be linked to an instance of `crm:E55_Type` using the property `crm:P144.1_kind_of_member`.

The documentation's subject and object actors can then be linked to this instance with mirror properties such as assigned_attribute_to - assigned (`crm:P140_assigned_attribute_to` and `crm:P141_assigned`) or domain - range (`crm:P01_has_domain` and `crm:P02_has_range`). Such an approach, however, confers precedence to the subject actor over its object counterpart as this relationship pattern remains unidirectional (from-to). The relationship pattern thus continues to account for a single standpoint (that of the subject actor, namely the `crm:E39_Actor` linked with the properties `crm:P140_assigned_attribute_to` or `crm:P01_has_domain`). In the case of reciprocal relationships (e.g. friends), this again can be remedied by creating inverse triples validated by logic rules. Still, in the case of non-reciprocal relationships (e.g. student-teacher), inverse relationships cannot be deduced logically (as with Marie Skłodowska Curie and her thesis supervisor Jonas Ferdinand Gabriel Lippmann) and, as such, a structural inequality remains (as was the case with the minimalist approach).

2.2.2. Multi-directional expressive approach

This difficulty to represent multi-directional relationships from an egalitarian perspective explains various working groups' recent interest in better documenting actors' part in relationships by recording their roles[16]. Such groups instantiate actors' roles within relationships so that each involved actor can be symmetrically documented (rather than from the sole perspective of a single actor). This multi-directional and expressive approach can account for more than two actors (hence its multi-directional name) although it is most often used for bi-directional relationship patterns, which will be the focus of this article although its conclusions apply to larger groups.

2.2.2.1. Bio CRM

One model employing such a multi-directional expressive approach is Bio CRM [33,34], an unofficial extension of CIDOC CRM developed by the Semantic Computing Research Group at Aalto University. It uses a `bioc:Actor_Role` class to specify the roles of actors documented within the relationship pattern.

Figure 7. Diagram of the relationship pattern in the Bio CRM ontology. The dotted lines indicate the super- and sub-classes in the ontology

Instances of this new `bioc:Actor_Role` class are linked to instances of `bioc:Person` (an indirect sub-class of `crm:E39_Actor`) through the property `bioc:inheres_in`, and are connected to instances of a relational event `bioc:Event` (sub-class of `crm:E5_Event`) with the CIDOC CRM property `crm:P11_had_participant`. From a semantic standpoint, this means the instances of

[16] An organized model of behaviour relating to the position and functions that an actor assumes in a relationship; this model is correlative to the expectations of the other parties involved.

bioc:Actor_Role are the ones participating in the relationship event, rather than instances of bioc:Person themselves, which makes it possible to document non-reciprocal relations between actors with bi-directionality and structural parity in mind.

However, the Bio CRM ontology presents some alignment challenges that prevent its effective implementation in a heritage context because of the semantic disconnect it entails. Indeed, the bioc:Entity_Role class is a direct sub-class of bioc:Entity which is associated in CIDOC CRM to crm:E1_CRM_Entity, a class that cannot be used as the range of crm:P11_had_participant which mandates as its range an instance of crm:E39_Actor. Because of the hierarchical positioning of bioc:Entity_Role in CIDOC CRM, there is no way to link instances of bioc:Event to instances of bioc:Actor_Role without contravening the semantics of CIDOC CRM itself. As such, the Bio CRM ontology poses implementation challenges to the egalitarian representation of roles, which would require the creation of new Bio CRM properties to link the bioc:Event to the bioc:Actor_Role, or the reclassification of bioc:Actor_Role as an rdfs:subclassOf of crm:E39_Actor.

2.2.2.2. DOLCE+DnS Ultralite (DUL)

In the domain of Linguistics and Cognitive Engineering, an ontology called Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) has been developed by the Laboratory for Applied Ontology (LAO). This foundational ontology has been extended to include the Description and Situation (DnS) framework [35], formalized in OWL by the Semantic Technology Lab of the National Research Council (Italy). Called DOLCE+DnS Ultralite (DUL), this ontology further develops the DOLCE concept of roles by fleshing out the representation of relationships themselves through a connection with those that enact them (i.e. actors) [36].

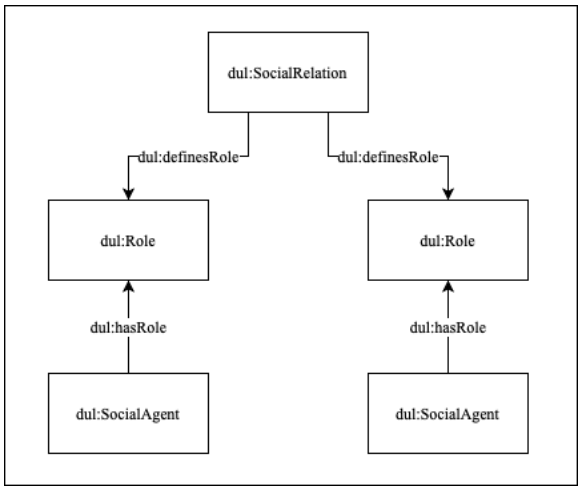

Figure 8. Diagram of the relationship pattern in the DOLCE+DnS Ultralite Ontology

A dul:SocialRelation class is used to embody the interactions between actors by linking an instance of it directly to instances of dul:Role through dul:definesRole properties. This dul:Role class is mobilized in several patterns, one of which is the carrying out of activities by actors who are, in DUL, represented using dul:SocialAgent class instances. These dul:SocialAgent instances can thus be linked to the dul:Role in the relationship pattern described above, which is done symmetrically for each instance of dul:SocialAgent in order to reflect their particular standpoint. [17] As such, the ontology proposes multidirectional patterns that support a precise documentation of relationships. However, there is no alignment between DUL and CIDOC CRM (as this ontology is intended for use in the linguistics and cognitive engineering field), which complexifies and hinders its use in a heritage context.

2.2.2.3. Factoid Prosopography Ontology (FPO)

The Factoid Prosopography Ontology (FPO) developed by King's College, University of Oxford, also proposes to specify the nature of inter-actor relationships using roles [37].

[17] Because there is no scope note specific to this class, it remains unclear whether this instance should identify the *role* an actor plays, or the *actor themselves in that role*. In addition, whether dul:Role instances are specified using a hierarchy of sub-classes (which is most likely, with roles such as "student", "friend", etc. to choose from) or qualifiers (which is least likely but nonetheless possible, with terms extracted from a vocabulary used to determine the precise role an actor embodies) remains undetermined as well.

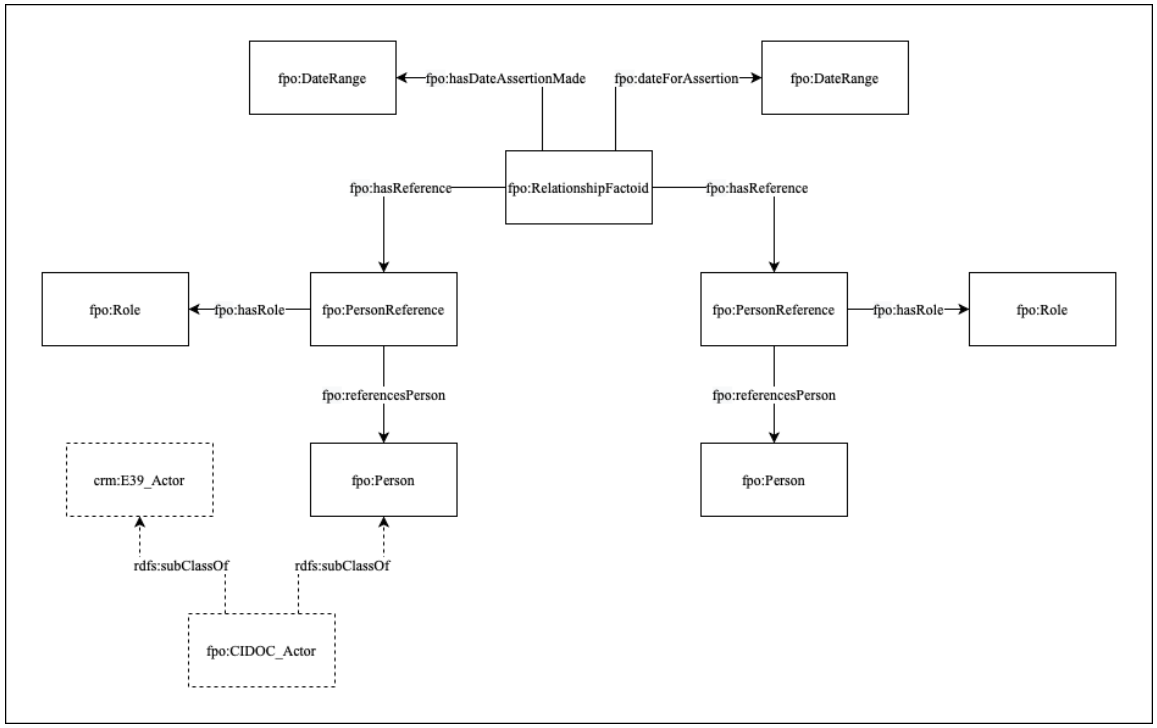

Figure 9. Diagram of the relationship pattern in FPO. The dotted lines indicate the super- and sub-classes in the ontology

The central element of FPO is the "factoid" concept, a kind of "prosopographical assertion that centers on statements made by an historical source. It is a structured interpretation of something that an historical source says about an individual." [38]. Relationships documented by historical sources are considered factoids in this ontology and can be modeled with the class `fpo:RelationshipFactoid`. Such instances of `fpo:RelationshipFactoid` are then linked to instances of the class `fpo:PersonReference`, which "links an assertion / factoid to a person or a geographic location [...] and provides a place that can capture information about [...] what their role was in the factoid" [39]. Each instance of the class `fpo:Person` is thus linked to a shared instance of `fpo:RelationshipFactoid` through an instance of `fpo:PersonReference`. This pattern, similar to the multi-directional expressive approach, documents both actors' perspective on the relationship.

However, FPO's main purpose to record *historical assertions* rather than the reality they detail inherently differs from that of CIDOC CRM which aims to describe *material reality* [22]. Even though some links can be established between FPO and CIDOC CRM (e.g. the class `fpo:Person` is linked to the class `crm:E39_Actor`), their fundamental structures are incompatible because FPO is object-based rather than event-based (as CIDOC CRM is). Because the field FPO covers is specific and because it does not leverage CIDOC CRM—which remains the primary heritage ontology—it is difficult to implement in a broader heritage aggregation context.

2.2.2.4. Analysis

The Bio CRM, DUL, and FPO models, even though they are not seamlessly applicable to the CIDOC CRM ontology, still illustrate the necessity of role modellization in the context of social relationship patterns. They demonstrate that a multi-directional expressive approach enables the modellization of relationships with structural parity in mind, using contextual data. For example, the relationship between Marie Skłodowska Curie—as a student—and Jonas Ferdinand Gabriel Lippmann—as a thesis supervisor—can be expressively modelled using a shared relational class instance (`:Relation`), with the functions assumed by each party in the relationship indicated as roles (`:role`):

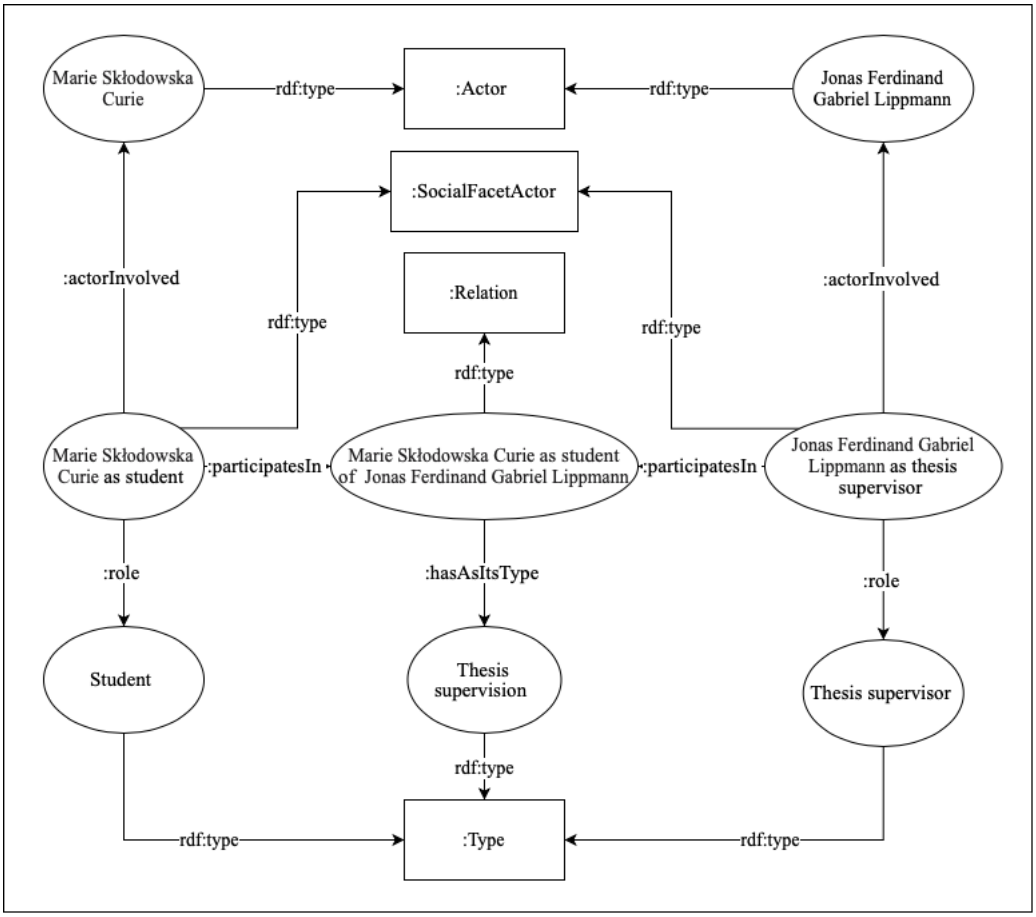

Figure 10. Diagram of the multi-directional expressive approach

As mentioned above, whilst the actors' roles are often reciprocal (e.g. friend-friend), it is not always the case (e.g. parent-child or mentor-mentee), and it is not necessarily possible to infer one actor's role from the other actor's role. For example, it is not possible to infer from the fact that Marie Skłodowska Curie studied under Jonas Ferdinand Gabriel Lippmann that he was her thesis supervisor, as he could have been her professor in a formal course just as well. It is precisely for this reason that it is important to specify each party's role independently: this way, the ontological pattern impartially formalizes the social relationship and does not give precedence to one actor over another (principle of structural parity).

Expressive approaches, whether uni- or multi-directional, share two notable disadvantages. The first disadvantage is the proliferation of triples needed to represent a single relationship which presents implementation challenges because of the technological resources it requires. Complex queries, using an expressive structure, will *de facto* yield precise results, but generic queries tend to be more complex because of the need to combine a set of very specific queries under a common result. One way to tackle this issue is to offer users pre-written SPARQL queries or build interfaces facilitating the construction of queries, along with a detailed and accessible specification of the model as well as of the list of controlled vocabulary terms used as different instances of `crm:E55_Type` throughout the model. This has the advantage of offering an easier *querying* process to practitioners who can rely on their knowledge or reputable controlled vocabularies to orient themselves, whilst still making it possible for them to make complex queries on more precise *recorded* information about *actual* relationships. This extensive use of `crm:E55_Type` also reduces the need for in-house expertise by mobilizing skills practitioners already master (i.e. use of controlled vocabularies).

The second disadvantage is that this proliferation of triples, though it supports more comprehensive and detailed records of actors' interactions, also increases the risk of introducing factual errors through an automated logic that leaves little room for nuance. The choice of such methodologies therefore entails the development of validation protocols and the expertise they require. Hence, expressive methodologies, despite rationalization of patterns, involve a twofold challenge: the need for a technological infrastructure that is sufficiently powerful and resilient to implement them effectively, and the development of the required expertise. Collaboration between institutions and sharing of resources, especially amongst smaller institutions, might thus be a solution to minimize the technological and human challenges of such methodologies.

Despite these challenges, multi-directional expressive methodologies result in patterns that enable a

recording of information that is much closer to the real, *actual* relationships actors enact in the world than minimalist and uni-directional patterns. As such, even though they still limit querying to what is recorded (an inevitability, really), they simplify the recording of information on the part of practitioners by using categorizing skills they already have (either in terms of hierarchically ordering classes or strategically using controlled vocabularies). For the same reasons, they facilitate aggregation (through the use of ordered structures such as said class hierarchies or controlled vocabularies) and, in turn, *searching* (by streamlining queries and facilitating the publication of editable frequently used queries). For these reasons, the use of multi-directional expressive methodologies seems to be the most likely to answer the current and future needs of heritage practitioners.

2.3. Dual approach

It is also possible to combine the minimalist and uni-directional expressive approaches to formalize each relation using both property and class instances in order to distinctly embody relationships and link them to actors. This allows the user to leverage the approach that best suits their needs (general or specific queries) and resources (limited or extensive reasoning capability). This is the path chosen in Agent Relationship Ontology (AgRelOn), which uses (1) a class to represent, with an instance, the relationship between two agents, and (2) direct properties between the two actors to impart directionality to the relation (without indicating any roles). These two methods are linked by another property, `agrelon:correspondsTo` [40,41].

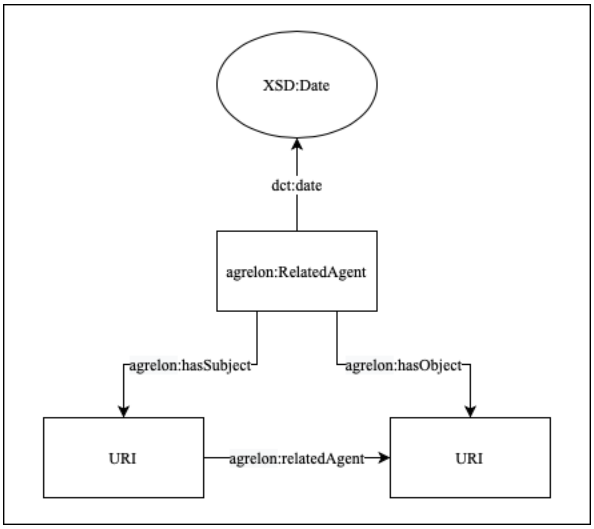

Figure 11. Diagram of the relationship pattern in AgRelOn

The main advantage of a dual approach such as that proposed by AgRelOn is that it affords the user latitude to implement a property-based methodology or a class-based methodology, or even a combination of the two, depending on their needs. However, this has the drawback of requiring the creation of new classes and properties when new categories of relationships are introduced, which entails the disadvantages of the expressive approach without the simplicity and agility of the minimalist approach, in addition to imposing the structural uni-directionality of the minimalist approach. Besides, this latitude in the way content is implemented can substantially hinder a user's understanding of the available data if they are unfamiliar with the cataloguer's input rules, and the corpus may be analyzed without all the available data being considered.

3. Proposal of the Canadian Heritage Information Network

As stated above, the multidirectional expressive methodologies appear to best meet the above-mentioned criteria of rationalization of ontological patterns, structural parity and logical consistency. It is thus essential to leverage them for heritage purposes, within CIDOC CRM, in order to address the heritage community's specific needs.

In this context, structural parity of ontological patterns is the cornerstone of a process of documenting social interactions that goes beyond manifest, explicitly documented interactions between actors. Good modellization based on this approach offers an opportunity to look at the latent or under documented interactions between actors and uncover them through effective data aggregation. Even though at the moment most recorded interactions are between two instances of actors, with uni-directional patterns accounting for the perspective of a predominant actor whilst bi-directional patterns include the standpoints of two, multi-directional patterns are also possible (though less frequently recorded as such). The latter can be useful in the case of relationships that involve more than two actors in a non-reciprocal manner. These would include, for example, a couple buying a house who could be considered to have a relationship with the seller: in such a case, three actors could be linked to a single federating relationship entity (two in the role of buyer, and one in the role of seller).

This would be useful for situations that involve more than two actors in a non-reciprocal manner.

Because *recorded* information currently pertains, by and far, to relationships between two actors (with multiple actors often being federated under a group name rather than multi-directionally connected), this will be the focus of this article. Yet, *actual* relationships are more complex and if at the moment the two buyers might be assumed to be a couple, or federated under a "X duo" grouping, it would be ideal to be in a position to be more precise since this is, once again, a type of information that cannot be inferred (e.g. the two buyers might be husband and wife, but they could also be brother and sister). As such, structural parity in a pattern necessitates the accommodation of multi-directional information regardless of the number of actors involved. In this respect, parity-based modelling requires that two specific aspects of actor interactions be considered: (1) the directionality of the interaction, which must at least be bi-directional, but should allow for multi-directionality, and (2) the possibility to record as much information about the perspective of an actor on the relationship as about that of their counterpart (an ontological symmetry that, along with multi-directionality, supports structural parity).

Because CIDOC CRM primarily addresses object-oriented heritage documentation needs, it does not have classes that deal specifically with social interactions, which are typically considered activities that happen to be enacted by actors. They are functionally useful in the context of relationship patterns because they offer a way for interactions to be situated in time and tied to actors through the use of the `crm:PC14_carried_out_by`, which is the only CIDOC CRM class that enables the specification of the role of an actor.

Hence, relational activities—namely `crm:E7_Activity` instances—are used as the federating instance around which relationship information is articulated. Treating an actor's sociability as a set of qualified relational activities—whereas an instance of `crm:E55_Type` is applied to an instance of `crm:E7_Activity` in order to indicate its nature—has the advantage of minimizing the creation of new classes. This ensures that ontological patterns are consistent with CIDOC CRM, interoperable, and usable by third parties in addition to reducing the resources required to maintain those ontological patterns (rationalization principle) by relying on controlled vocabularies to organize information (a method practitioners are familiar with).

Such a pattern makes it possible to indicate the roles of Marie Skłodowska Curie and Jonas Ferdinand Gabriel Lippmann using only CIDOC CRM entities:

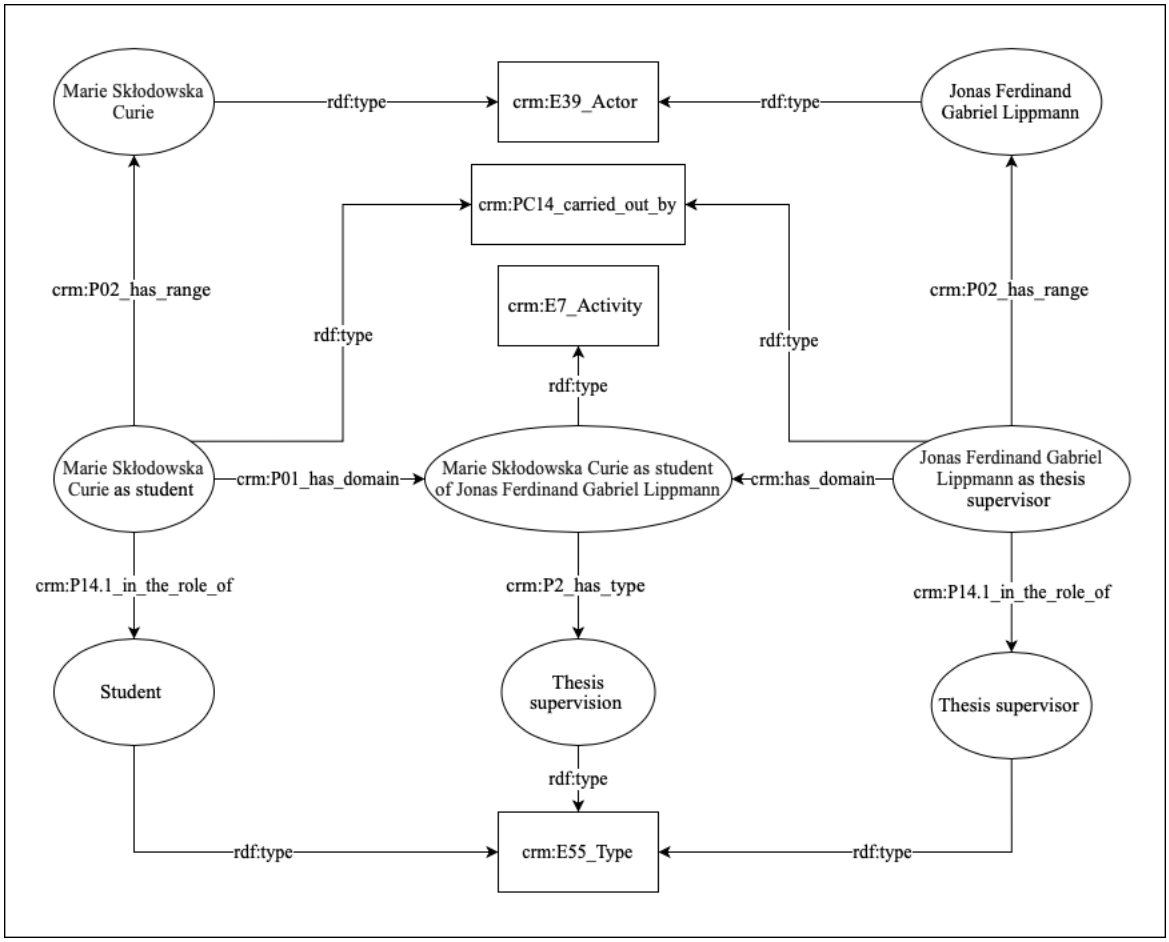

Figure 12. Diagram of the relationship pattern proposed by the Canadian Heritage Information Network

This approach works for connections between actors, but is problematic when it comes to connections that go beyond interactions amongst individuals to encompass non-manifest social relationships. For example, a person might have an impact on others despite having no definite intention to do so, or be influenced by agents that are not actors (such as stylistic movements). Problematically though, CIDOC CRM precisely confines activities to *intentional* enactions whilst such cases presuppose a conception of actors' agency that goes *beyond that of intentionality*. Still, a larger view of agency appears consistent with the above-mentioned recent developments in social sciences, is more reflective of *actual* relationships as they are embodied in the world, and is closer to the way data is *documented* by heritage professionals and *queried* by them. The eventual development of a special ontological pattern to answer those needs would thus be welcomed, although it is not possible in the current of CIDOC CRM.

The other main consequence of using a federating `crm:E7_Activity` is the relative mutation of this class, which is fundamentally a one-time event but is functionally used as if it were an evolving phenomenon (a phase). This approach is advocated by several CIDOC CRM users, including Linked Art and FRBRoo. Since this enables the substantial enhancement of the description of social interactions with additional information, and it is consistent with current practice in the semantic community, its use appears appropriate despite these drawbacks.

Using attributes (`crm:E55_Type`) associated with a relational activity (`crm:E7_Activity`), various aspects of a relationship can then be specified using controlled lexicons and vocabularies, starting with the relationship's nature (kinship, friendship, influence, etc.) and the time interval during which a relationship between the parties existed. This is preferable to the creation of new classes because interoperability and consistency rely, in large part, on multiple stakeholders knowing of and using these classes as well as the creating organization advertising and maintaining them (which can be demanding in terms of resources). This also enables organizations to mobilize the expertise they already have in vocabulary management rather than building capacity entirely. It is thus preferable to use entities already defined by CIDOC CRM.

In the specific case of this pattern, accounting for the standpoint of both actors entails, as mentioned above, the recognition of each actor's role in the relationship, which is best done using property-classes, namely `crm:PC14_carried_out_by`. Such property-classes have been developed by the CRM SIG with the intended purpose of documenting how an activity has been carried out by appending statements to a `crm:P14_carried_out_by` property. One of the targeted uses of property-classes is specifically the very one proposed here: specifying the role an instance of `crm:E39_Actor` endorses in the context of a `crm:E7_Activity` by using a controlled vocabulary term (in a `crm:E55_Type`) linked to the `crm:PC14_carried_out_by` class instance through a `crm:P14.1_in_the_role_of`. `crm:P01_has_domain` and `crm:P02_has_range` properties are used respectively to link `crm:E7_Activity` and `crm:E39_Actor` classes to `crm:PC14_carried_out_by`.

The use of this class is sometimes contested because it formalizes elements that have no concrete embodiment in the world. However, this practice seems justified inasmuch as it is recommended by the CRM SIG which supports how it enables structural parity by recording the social facets assumed by the actors in the context of the documented activities, in accordance with the postulates of CIDOC CRM.

Of course, from the standpoint of available data, the actor being documented will continue to have precedence over its counterpart.[18] It nonetheless appears essential not to make this predominance structural since documented data might become more egalitarian as a result of increased documentation efforts, or as additional reasoning functionalities (such as inference or linguistic analysis) may uncover relationships that are not currently apparent. Better documentation capacity could thus lead to the eventual implementation of multi-directional relationships and having a pattern that accommodates such data with structural parity in mind (by documenting the standpoint of each actor as well as their role) would then be of importance to the heritage community.

This seems especially relevant since a relationship can result from a series of minor activities represented as a single meta-activity and relationships are considered to encompass various social interactions, which can be documented across multiple records. This plurality of relational instances used in a consistent and interoperable manner thus contains a potential for precision that increases exponentially in an aggregation context where the documentary primacy of one actor or another varies depending on which record is examined. For this reason, it is preferable to use existing classes (`crm:E7_Activity`, `crm:PC14_carried_out_by`, etc.), which ensures consistency not only within an organization's model but also with CIDOC CRM and the way it is generally used (internal and external logical consistency).

Consistent use of relational instances can also support the development of (semi-)automated analysis tools for evaluating and documenting additional attributes of a relationship [35]. With the possibility to further document these elements (directionality, attributes and, eventually, event plurality), interactions between actors can be articulated in accordance with the above-mentioned principles of ontological pattern rationalization, structural parity and logical consistency, whilst maximizing a model's expressiveness and interoperability. The approach proposed above thus

[18] In fact, at present, only bi-directional relationships are implemented in CHIN's own model.

seems to be the most adept at meeting heritage needs in conformity with CIDOC CRM.

Nonetheless, interactions could be treated as events (`crm:E5_Event`) rather than activities (`crm:E7_Activity`). This would make it possible to designate actors as participants in the relationship event, which would also make it possible to document unintentional social interactions. The reason this approach is currently set aside is that it would require the creation of a new class (`crm:PC11_had_participant`) and of a new property (`crm:P11.1_in_the_role_of`) to indicate each participant's role. As it has previously been established, the creation of classes and properties should be discouraged in favour of the use of high-level and generalized CIDOC CRM classes commonly used by the community and categorized by types. Still, these issues could be addressed by creating new high-level classes documenting events and roles from a sociological perspective. This is the objective of a new CIDOC CRM extension called CRMsoc that is currently under development [42]. Its efforts focus on the conceptualization of the social aspects of human lives, including the relationships between actors. New entities could thus be created to answer the needs expressed in this paper. For example, a new class could be developed to represent actors in particular roles, thus replacing the reified property `crm:PC14_carried_out_by`. Similarly a new relationship event class could be developed, thus solving the issues posed by the use of the `crm:E7_Activity class`.

4. Conclusion

Although the analysis of social interactions is an essential component of historical research, the majority of heritage institutions do not document information about social relationships in structured fields in their databases. When they do so, it is often a simple inventory of existing interactions without additional documentation or description, and semanticization remains minimal. The process of ontological modelling and subsequent enhanced semanticization of social interactions could not only facilitate searches of heritage corpora but also identify lacuna and latent information, leading to a better documentation of relationships.

Different models conceptualize social interactions according to the respective needs of the fields that produce them. In the heritage context, a number of principles (ontological rationalization, structural parity, logical consistency) and constraints (limited human and technological resources, use of existing CIDOC CRM classes and properties wherever possible) guide the choice of an approach based on the representation of multi-directional social relationships as classes associated with roles that characterize the interactions between individuals (multi-directional expressive approach).

This has the main benefit of providing a representation of relationships based solely on the classes and properties of CIDOC CRM, the ontology most commonly used by heritage institutions (unlike the minimalist approach); it also provides a high degree of expressiveness (unlike a uni-directional expressive approach). However, this is based on a functional use of the `crm:E7_Activity` class as a phase rather than a one-time event (which is how this class is fundamentally defined). Moreover, the definition of `crm:E7_Activity` postulates intentionality on the part of the actor, which is not always present in the case of social relationships (this is particularly true of family relationships, which may be found without the knowledge of the parties involved).

At present, there does not appear to be an ontological model perfectly capable of effectively representing social interactions on a structural parity basis, even though this is an essential element for the fair and accurate documentation of interactions between actors. On the one hand, it is essential to ensure structural parity in order to meet the representation needs of the various communities documented by museums. On the other hand, the actors have multiple relational profiles (of authority, temporal, familial, associative), which consequently require representations specifically dedicated to the modelling of social interactions by the semantic heritage community. The establishment of a working group to deal with this issue (CRMsoc) demonstrates the need for further reflection in this area. Although it is possible to address most modelling needs using CIDOC CRM in its current form, as proposed in this paper, it seems preferable to recognize the design-related importance of actors' participation, whether intentional or not, in social interactions by creating new classes and properties in an official extension or by rewriting the application notes of existing entities.

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