The Semantics of History. Interdisciplinary Categories and Methods for Digital Historical Research

Esther Travé Allepuz[1], Pablo del Fresno Bernal[2], Alfred Mauri Martí[3], Sonia Medina Gordo[1] *

[1] Universitat de Barcelona, Barcelona (Spain)
[2] Sistemes de Gestió de Patrimoni SCCL, Barcelona (Spain)
[3] Centre d'Estudis Martorellencs, Martorell (Spain)

Received 4 November 2020 | Accepted 21 December 2020 | Published 10 February 2021

unir
LA UNIVERSIDAD EN INTERNET

Abstract

This paper aims at introducing and discussing the data modelling and labelling methods for interdisciplinary and digital research in History developed and used by the authors. Our approach suggests the development of a conceptual framework for interdisciplinary research in history as a much-needed strategy to ensure that historians use all vestiges from the past regardless of their origin or support for the construction of historical discourse. By labelling Units of Topography and Actors in a wide range of historical sources and exploiting the obtained data, we use the Monastery of Sant Genís de Rocafort (Martorell, Spain) as a lab example of our method. This should lead researchers to the development of an integrated historical discourse maximizing the potential of interdisciplinary and fair research and minimizing the risks of bias.

Keywords

Unit of Topography, Actor, Integrated History, Ontology, Database, Records Management, Landscape Archaeology.

DOI: 10.9781/ijimai.2021.02.002

I. Introduction

HISTORICAL Science is a discipline devoted to the analysis and comprehension of the past for a better understanding of the present, and hence a potential forecasting of the future. Therefore, space and time are unavoidably the main scenarios of research in History, and the alternation between permanence and change is its main object of study. This analysis of the so-called historical time [1], in which different entities exist and events occur transforming the reality of the past into something new and different, leads historians to construct the past in a narrative form.

The fact that data related to time and change are present in any written, material or immaterial vestige of the past boosts –and even forces– interdisciplinary research in History. Despite this, traditional approaches have frequently focused on written vestiges preferably, while disregarding other sources of information such as archaeology, iconography, literature, and a wide range of social sciences and humanities, which have been often considered as complementary at their best. In doing so, the different vestiges of the past do not *integrate* within a single discourse, but originate parallel discourses that might incur into contradiction and potentially lead to endless academic debates.

The spatial and material turns in History [2]–[6] have challenged these old-fashioned approaches, and have led to a more accurate construction of the past. A new interdisciplinary research framework –in which the difference between SSH and STEM blur into a new paradigm of digital and FAIR science– challenges History, and requires an effort from different disciplines in order to explore common languages and codes for the construction of the past. In this process of science going digital, common and exchangeable units of information are required, despite the specificity of different areas of expertise. Within this domain, some experiences on NLP have been developed [7]–[8] and most of them are related to textual sources [9]–[10]. Despite this, the strengthening of concept-based and relation-based corpora for the development of NLP in digital humanities [11] focusing on the ontological approach to historical data suggests a challenging scenario for historians. Scholars dealing with historical science should face the need of rethinking methodologies and the way to use ICT in order to solve wider and more complex research questions and to take our investigation beyond the 20th Century historical issues. One of our objectives is to provide ontological reflections about data and data management in order to produce richer historical relates, as long as they integrate as many vestiges of the past as possible.

Our contribution aims at offering a methodological proposal and practical application our teamwork has developed within the last years, as an extended version of [12]. Arising from landscape archaeology and the study of the material vestiges of the medieval period, our research methodology deals with data labelling and records management, and nowadays it has overcome the archaeological domain to integrate all vestiges of the past regardless of their nature or origin to strengthen historical research in the digital domain. We will develop these issues within an updated state of the art in section II. In the following sections, we will describe the method according to the labelling categories we propose and the resulting data modelling. We will use a practical case of study –the medieval monastery of Sant Genís de Rocafort, Martorell, Spain– as an illustrative example.

* Corresponding author.
E-mail addresses: esther.trave@ub.edu (Esther Travé Allepuz), pdfsgp@gmail.com (Pablo del Fresno Bernal), bnn@heraclit.net (Alfred Mauri Martí), smedingo12@alumnes.ub.edu (Sonia Medina Gordo).

II. Landscape Archaeology and Integrated History

History has not been the most enthusiastic discipline to join the so-called Digital Humanities so far, and data managing strategies have been widely challenged in our domain [13]. Far from being overwhelmed by the unknowns of this digital turn, a few exceptions deal with different ways of representing historical information [14]–[15] and the building of a semantic definition for historical ontology [16]–[18]. Recent experiences focus on quantitative data analyses [19] and, predominantly, on written historical texts [20]–[21]; and some of them struggle to find the best ways to deal with bias [22] and uncertainty [23]. Despite this, a normalized user-friendly code to exploit vestiges of different nature and support is still missing and historical knowledge seems to be restricted to its written apparel.

Our team developed a first proposal to identify minimum units of information and label them as Units of Topography, Units of Stratigraphy and Actors, as will be defined below, in the framework of Landscape Archaeology. The initial goal was to integrate vestiges both from written or material sources in the archaeological analysis of medieval landscape and, therefore, to explore landscape as a historical construct from a holistic perspective. More than twenty years later, our research information system has gone far beyond landscape archaeology or the medieval period to become a solid proposal for historical research, understanding Historical Science as a FAIR [24] construction of the past. It follows the principles stated by far-reaching research projects in this field such as the International Research on Permanent Authentic Records in Electronic Systems (InterPARES) [25] (pp. 6–7) or Parthenos [26]. This FAIR-ness is achieved when ensuring the reliability and traceability of the research process, and when integrating as many sources of information as possible, even those that had been traditionally disregarded until recently as marginal or non-significant.

This is possible due to the development of ICT in the past decades. Recent advances allow for a significant speedup of data gathering and exploitation processes of much larger datasets, which opens a brand-new field for historical research in which new and more complex questions can be asked to past vestiges. Ensuring the existence of clear and unambiguous definitions of the ontology-mediated elements that identify units of information and their relations [27] is an underpinning issue to this regard. The following section deals with it.

III. Labelling Categories and Data Modelling

As defined by K. Thibodeau [28] (p. 7), an Entity is something that existed and an Event is something that happened or was done. Entities and Events have a relationship of involvement, as every event involves at least one entity that might be the participant in the event, its observer, the mechanism for the event to happen, or the object altered by the event itself. In terms of data-labelling, the categories Unit of Topography and Actor, as defined by A. Mauri [29] (p. 45), and their relations, provide the unique and univocal identifiers for historical facts regardless of their link to permanence (Entity) or change (Event), or the nature and support of the vestige. Units of Topography as we use them are, in fact, a wider conception of archaeological Units of Stratigraphy [30], which overcomes their materiality and turns them into a broader concept to identify any entity or action existing or occurring at a particular time, notwithstanding its presence or absence in the archaeological record.

The following definitions apply to each one of these categories:

- Unit of Topography (UT): It is the evidence of an action or situation that can be located in space and time, regardless of the specificity of the information source and its biotic, non-biotic or anthropic attributes. Each UT has a specific location and date. Location can be expressed as a UTM coordinate or as an administrative delimitation that might have changed through time.
- Unit of Stratigraphy (US): It is the material evidence of an action occurred in the past, representing an archaeological aspect of the cycle of time. They are of universal character and can be found on any archaeological site in the world [30] (p. 42). As a reflection of materiality, graphic and cartographic representations are essential attributes of these units.
- Actor: It is the individual or corporative, active or passive, protagonist of an action identified as a UT. If being an individual, its attributes are their name, gender, religion, citizenship, date of birth and death, etc. Different individual actors gathered for a given period of time with a particular purpose and under determinate conditions can act as corporative actors.

As the US category is contained in the definition of a UT and we might consider them as equals at some point, Table I summarizes their differences and ontological specificities.

As shown in Fig. 1, several types of relationships can be set between UT/US and Ac. A UT can include, link or delimitate another UT. Hence, Inclusion, Delimitation and Link are classes of the UT-UT relation. An Actor always plays an active or passive role within a UT, so Role is the only class of Ac-UT. Actors can relate to other actors through familial, political, social or economic Ac-Ac relationships. The materiality of US implies that the only possible relation between US is physical contact. When interpreting the archaeological register, we can group several US into activities and assemble these activities into groups of activities

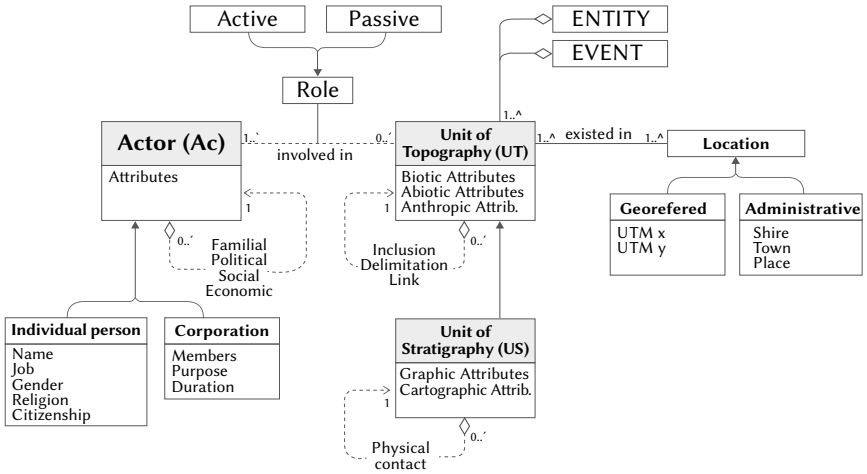


Fig. 1. UML diagram of ontological concepts –UT, US, Ac and their relations– for integrated historical research.

according to [31]. The relation and equivalence between UT, as shown in Table I, and US is then a matter of scale: UT can be equivalent to US in the archaeological record, or we can define UT during the data interpretation process. Anyhow, the UT scale is the one allowing for an interdisciplinary approach in History.

TABLE I. Units of Information (UT/US) Ontological Summary

Attribute		US	UT
Source of obtention		Material	Written, material, visual, sound…
Materiality		Essential	Non-essential
Informative dimensions	Spatial	Essential	Essential
	Descriptive	Essential	Essential
	Graphic	Essential	Non-essential
	Cartographic	Essential	Non-essential
	Temporal	Essential	Essential
Possible relations	US-US/UT-UT	Physical contact	Inclusion, delimitation, link
	Ac-US/Ac-UT	Non-possible*	Non-essential
	US-UT	US = UT US + US = UT	US = UT UT + UT = UT
Involvement in event		Essential (altered)	Non-essential

* The material register does not inform about Ac.

IV. A Case Study: Results at Sant Genís De Rocafort

A. Site and Materials

We have selected a Catalonian monument –the monastery of Sant Genís de Rocafort– located at the town of Martorell (Barcelona) in order to put into practice our labelling proposal and demonstrate the validity of our information system from an interdisciplinary perspective. The Lord of Castellvell and his wife founded the monastery of Sant Genís in 1042 as the ruling centre of a small Priory [32].

Since then, the monastery, located on the top of a hill, became an emblematic element of Martorell's landscape, and down on the foothill the ancient temple of Santa Margarida became the parish church of the Priory, which had a flourishing period in 11th – 13th Cent AD, even though the monastic community never included more than four or five monks. The monastery became dependent of larger monasteries within a Benedictine network, probably in the 13th Cent. Since then, the monastery of Sant Miquel de Cruïlles (Girona, Spain) [33] had the patronage over Sant Genís, while being itself dependent from the Piedmontese Saint Michael's Abbey (San Michele della Chiusa, Italy). In the late middle age, Sant Genís started its slow decadence until 1534, when it became a secular Priory owned by a Barcelonese merchant named Joan Bolet. He slightly refurbished the buildings of Sant Genís and Santa Margarida, and the Priory endured until the 19th Cent AD. After some years in private hands, the Priory became a public property of Martorell's Town Council in 1967.

Historical research at this site has benefited from the proposed system of management information. Architectural analysis of the building, restoration works, and archaeological fieldwork provide a new research perspective for the construction of an integrated historical discourse built from the written evidences kept in archival records and thoroughly analysed in the past [34].

B. Practical Examples of Data Labelling

Accordingly, we selected some written, graphic or material vestiges of Sant Genís' past and analysed them by identifying and labelling the US, UT and Ac informed within at different stages. Managing information throughout these lab examples in an integrated form provides a synthesis for the method's development. The following subsections deal with each type of selected sources, labelling them appropriately, and Table II and Table III summarize the information gathered so that it can be furtherly discussed.

TABLE II. Simplified Ac Dataset Gathered from Selected Examples.

Ac	Name	Attributes	Related UT/Ac
01	Bonus	Lord of Castellvell	Ac02, 03; UT01
02	Guilielmus		Ac01
03	Sicardis		Ac01; UT01
04	Clement VII	Pope	UT20, 21
05	Joan Bolet	Barcelonese merchant	Ac06; UT07, 22, 23
06	Simó Capellades	Priest, Prior	Ac05; UT23, 25

TABLE III. Simplified UT Dataset Gathered from Selected Examples

ut	Brief Description	Related UT/US/Ac	Attributes	Date
01	Donation	Ac01, 03	Event (property)	1042
02	Romanesque Church	UT07, 25, 26, 27, 28, 29, 30, 31*; **US5001 – 5024**	Building	12th Cent
03	County of Barcelona	UT07	Political entity	
04	Castellvell	Ac01; UT05, 06, 07	Town	
05	Martorell	UT04, 06, 07	Town	
06	Priory border	UT07, 08 – 18	Border	
07	Priory of Sant Genís	UT04, 05, 06, 22, 25	Religious entity	
08	Congostell	UT07	Place	
09	Mountain range	UT07, 10, 11	Mountain range	
10	Rosanes	UT07, 11	Place	
11	Rocafort	UT02, 07, 10, 25	Hill	
12	Montgoi	UT07	Hill	
13	Vena	UT07	Place	
14	Grau	UT07	Place	
15	Torrent	UT07	Place	
16	Lloreda	UT07	Place	
17	Torrent of Lloreda	UT07	Waterflow	
18	Anoia River	UT07	Waterflow	
19	Donation letter	Ac01, 03; UT01	Document	1042
20	Papal bull	Ac04, UT21	Document	1534
21	Concession	Ac04, UT20, 22	Event (gift)	1534
22	Patronage	Ac05, UT07, 22	Entity (property)	1534
23	Refurbishment	Ac05, UT02, 25, 31*; **US247, 248, 249, 5025, 5027, 5031, 5033, 5068 – 5070**	Building transformation	16th Cent
24	St Miquel de Cruïlles	UT25	Religious entity	
25	Monastery of St Genís	UT07, 24, 25, 31*; **US5026, 5030, 5032**	Religious entity	
26	Partial collapse of Romanesque building	UT02; **=US5034**	Destruction	1448
27	Apse walls	UT02, 26, 28		
28	Apse demolition	UT02, 27; **=US5086**	Destruction	1928
29	Abandonment	UT02, 07, 25; **US5019, 5023, 5077, 5080, 5083**	Enduring event	19th Cent
30	Restoration	UT02; **US5035 – 5039, 5079, 5082, 5085**	Building transformation	2014
31	Archaeological fieldwork	UT02, 25, 26, 28, 29; **US247, 248, 249**	Event (Research)	Since 2010

* Units of Stratigraphy (US) with the labelling format **000** are related to the Romanesque church or the monastery buildings and thus included in UT30.

1. Archival Sources or Written Primary Files

A copy of the donation document of 1042 kept at the Diocesan Archive of Barcelona [32] and published in [34] (p. 139-143) informs about the location and borders of the Priory. We can label texts and identify the units of information contained and their attributes by following this code: <**UT00**> <**Ac00**> <Att-UT00> <Att-Ac00> <Date-UT00>. We also label relations in accordance with concepts related: <Ac00-UT00> <Ac00-Ac00> <UT00-UT00>. A semicolon separates different UT, Ac, Attributes, or Relations identified through the same word or syntagmatic expression.

Sit omnibus notum quod ego <**Ac01** *Bonus*>, <Ac01-Ac02 *filius*> <**Ac02** *Guilielmi*>, <Att-Ac01 *dominus Castri Vetuli*>, *et* <Ac01-Ac03 *uxor mea*> <**Ac03** *Sicardis*> *pariter in unum in nomine Domini* <**UT01** *donatores*> *Domino Deo et sancto Genesio martiri Christi, cuius* <**UT02** *ecclesia*> *sita est in* <**UT03** *comitatu barchinonensi*>, <UT02-UT04; UT02-UT05 *intra terminos*> <**UT04** *Castri Vetuli*> <UT04-UT05 *de*> <**UT05** *Martorello*>. *[...]* <UT06-UT07 *Habent autem*> <**UT06***terminum*> <**UT07** *hec omnia*> *ab ortu solis in ipso* <**UT08** *Coangustello*>, *atque ascendendo in sumitate* <**UT09** *serre*> *pergit per sumitatem illius* <**UT09** *serre*>, *que est* <Att-UT09 *intra* <**UT10** *Rodanes*> <UT10-UT11 *et*> <**UT22** *Rocam fortem*>>, *usque in* <**UT12** *muntem Gaudii*>. *Et inde pergit usque ad* <**UT13** *Bennam*>, *secundum quod hiemali tempore sive pluviali decurrunt aque ab oriente contra septentrionem. A meridie in ipsa Bennam, atque pergit inde usque ad ipsum* <**UT14** *Gradum*>, *et descendit in ipsum* <**UT15** *torrentem*> *qui discurrit. Ab occidio in ipsa* <**UT16** *Laureta*>, *et inde pergit per ipsam* <**UT17** *rieram de Laureta*> *usque in medium* <**UT18** *flumen Annole*>. *A circio similiter in medium* <**UT18** *flumen Anolle*> *et inde pergit per medium ipsius fluminis usque in ipsum* <**UT08** *Coangustellum*>. *[...]* <Date-UT01; Date-UT19 *Facta* <**UT19** *carta donationis*> *huius sex idus aprilis anno undecino regni Henrici Regis*>. [26], [29] (p. 140)

Fig. 2. Aerial view of Sant Genís de Rocafort after fieldwork carried out in 2020 (a), and photographic vestiges from the beginning of the 20th Century (b-c) [35]–[36]. Interpreted relations between US and UT are recorded in Table III.

2. Photographic Vestiges and Architectural Analysis

Architectural analysis from an archaeological perspective aims at identifying the building phases and further transformations in architectural heritage. Photographic vestiges usually allow for the identification of constructive elements that have disappeared nowadays. We identified and labelled US in Fig. 2 accordingly:

3. Archaeological Fieldwork

Because archaeology is a destructive process, building a precise and detailed archaeological record following a clearly stated protocol has been the commitment of archaeological science for a very long time. US have been the main unit of information since 1980 [30].

In Fig. 3, we selected just three US for labelling as a lab example amongst the entire archaeological record at this site. The stratigraphic method for archaeological excavation and register is widely accepted among scholars in this domain and our UT/Ac labelling strategy is built in accordance to the archaeological method, as stated above, due to the authors' archaeological background. Therefore, we could not avoid selecting archaeological examples for building an integrated historical narrative, as the archaeological record is concomitant with our proposal for information management, even though the excavation results in Sant Genís are much wider than shown in this paper.

4. Bibliographic Reflections

In all scientific production and in any form of Past Construction in particular, the so-called state-of-the-art –or past reflections, in Thibodeau's terms [28]– are valuable sources of information that must be considered in terms of data labelling and management. The same labelling method proposed for archival sources or written primary files works for secondary information as well.

In Fig. 4 we show an example of data labelling within an excerpt from a published piece of research about the Priory of Sant Genís [34]. That is the summary and study of a rich documentary assemblage informing about the priory from archival sources, and providing the historical framework and state-of-the-art before the archaeological excavation started.

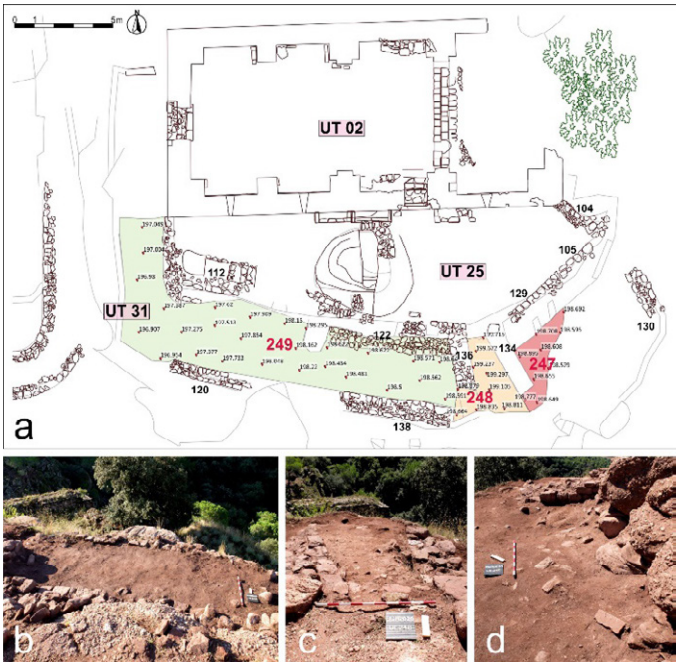


Fig. 3. Cartographic (a) and photographic representations of US 249, 248 and 247 (b-d). As per architectural analysis, US-UT relations are recorded in Table III.

Fig. 4. Labelling example of a short excerpt from the bibliographic reference of a previously published study [34].

UT/Ac data labelling is operational both on original texts when possible –even if annotated by hand, as in the example on Fig. 4– and also on transcriptions and translations. In section I above, we labelled on the transcribed Latin version of the Priory's foundation and below, the translation to the excerpt in Fig. 4 is labelled in the English language. Actors labelled in both examples are summarized in Table II.

In <Date-UT20 *1534, April 24th*>, <Att-Ac04 *Pope* > <**Ac04** *Clement VII*> *announced in his* <**UT20** *papal bull*> *to* <**Ac05** *Joan Bolet*> *his approval of the initiative to restore the buildings of the Priory and to increase its rents. He also* <**UT21** *allowed*> *Bolet to exercise his* <**UT22** *patronage*> <UT22-UT07 *upon the*> <**UT07** *Priory*>, <Att-UT22 *assuming all financial responsibility as an owner*>. *The sole* <Att-UT22 *exception to this absolute control was to use the Priory for non-religious purposes*>, *as stated in the* <**UT19** *donation text of 1042*>, *which was strictly forbidden. Receiving this papal bull was an achievement for* <**Ac05** *Joan Bolet*>, <Ac05-UT23 *who had begun*> *the* <**UT23** *arrangement of refurbishing work*> *at the* <**UT07** *Priory*> *buildings some time earlier, with the collaboration of neighbouring clerks and bishop's encouragement. The Benedictine abbot of* <**UT24** *Sant Miquel de Cruïlles*> *was tolerant with Bolet's plans, and the* <Att-Ac00 <Ac06-UT25 *prior of*> <**UT25** *Sant Genís*>> <**Ac06** *Simó Capellades*> *was an enthusiastic and indispensable* <Ac06-UT23 *collaborator*> <Ac06-UT05 *of the*> <Att-Ac05 *Barcelonese merchant*> *as well.* [34] (p. 79)

5. Landscape Analysis and Cartographic Sources

The proposal introduced in this paper offers a useful tool for landscape archaeology as well, and we can label cartographic sources similarly. We must bear in mind that the concept of Unit of Topography –in accordance with the definition proposed– implies a location and date as main attributes for further exploitation. UT/US gathered from selected examples and included in Table III have a precise location expressed as UTM coordinates that have been used to produce and label the maps shown in Fig. 5.

To that extent, Geographic Information Systems (GIS) have a great potential for data processing and exploitation, and they provide a useful tool for the landscape approach to historical knowledge. Providing topographic and chronologic attributes for past entities and events is a conceptual requirement for a spatial turn [37] in History, but also for a general scientific procedure of Past Construction under normalized terms and categories.

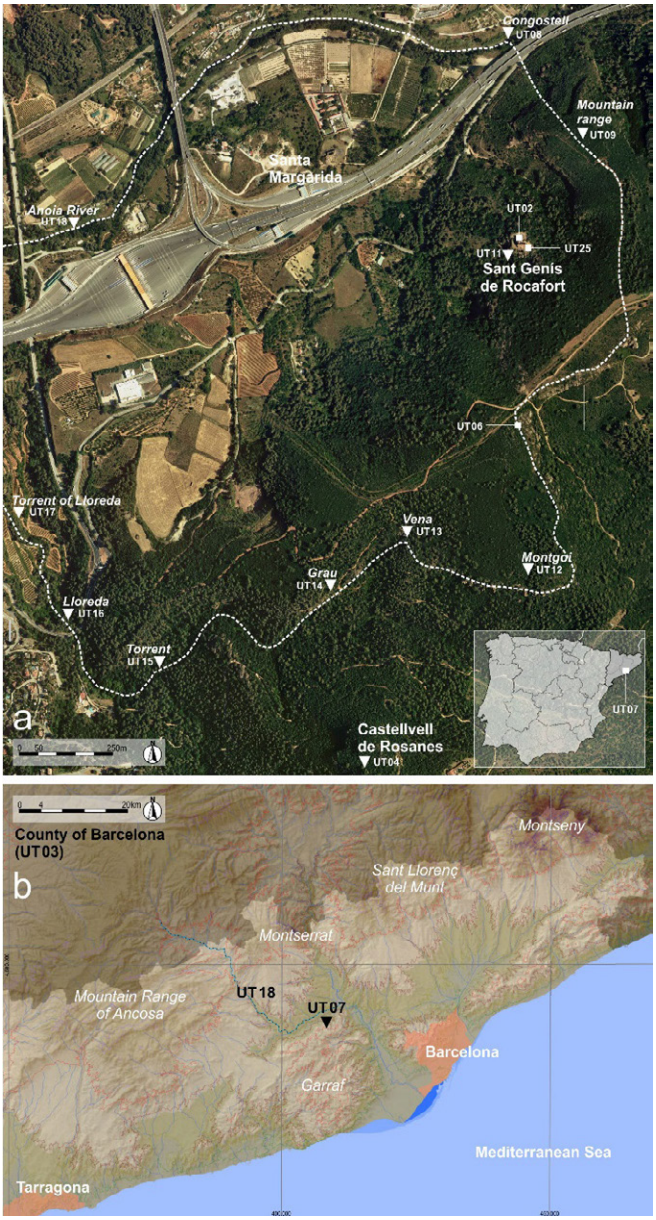


Fig. 5. Aerial view [38] of the Priory of Sant Genís with UT labelling according to the toponymy mentioned in the foundation document (a). Below, UT identification on a general map [29] of the Medieval County of Barcelona (b).

C. Data Exploitation

Cartographic representations and data exploitation by means of GIS technology are both a way to process data and a final representation which may be used for publication and dissemination. Anyway, our proposal –originally thought from the domain of landscape archaeology– goes beyond spatial representations and can focus on temporal sequences or relational data interpretation as well.

Although we summarized data gathered from our lab example in a couple of simple tables, these form part of an ontology-mediated database in which UT, Ac and the relations between them are collected in separate tables. The diagram shown in Fig. 6 represents the main components of a database storing the crucial units of information, their attributes and relations. When keeping this structure, databases can adapt to the needs of a particular research project and show variable interfaces and self-search exploitations, but they will always be interchangeable and potentially interconnected, as far as they share a common data modelling [39]–[40], as shown in Fig. 6.

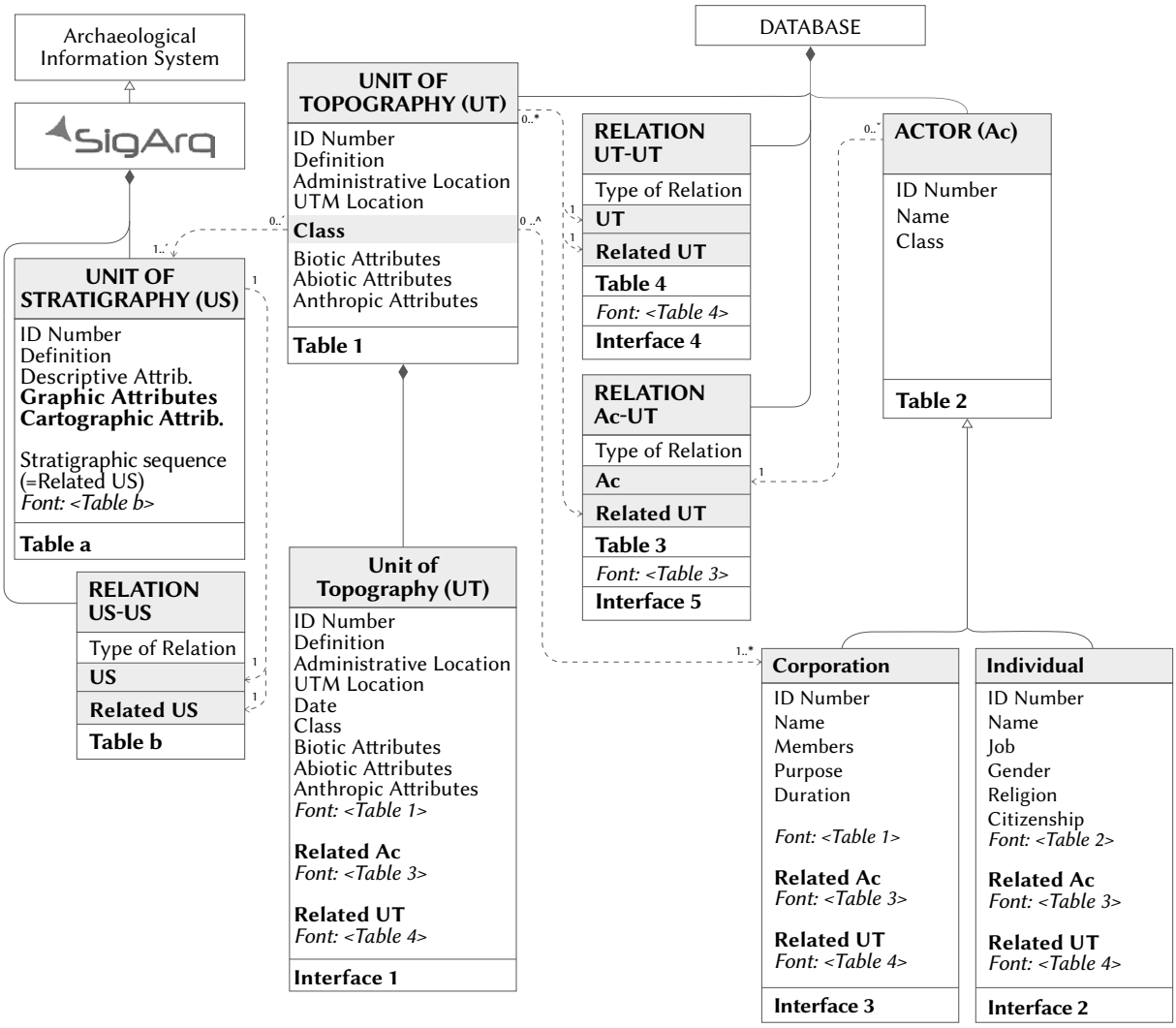


Fig. 6. UML diagram of generic database components.

Fig. 7 represents some interfaces of the current applications used nowadays by our team. One of these is a GIS-based information system created for archaeological purposes [41]–[42]. All of them share the same categories –UT/US/Ac– and hence they allow interdisciplinary research beyond the particular expertise of anyone of us.

When gathering and storing data in the form of tidy-structured tables with variables in columns and observations in rows [43], and according to identified US, UT and Ac regardless of the nature or support of the vestige, multiple representations are possible. Flux diagrams and matrices can visually establish the temporal sequence of activities and their permanence or transformation. Fig. 8 shows an extract of a historical Harris-like [30] matrix created for the Priory of Sant Genís the Rocafort including the Ac, UT exemplified throughout this paper. The archaeological US Harris-matrix routinely developed in archaeology is also included.

This is an example of data exploitation and representation as an interdisciplinary historical matrix, including the archaeological results within the historical discourse arising from written evidence and explaining the Priory's past in a richer construction. Notice how the material vestiges of the buildings' refurbishment in the 16th Century were positively identified within the archaeological register combined with the architectural analysis. In such a representation, Actors mentioned in written vestiges can be assigned to phases and located visually within the corresponding period.

V. Discussion: Towards an Integrated History

The most striking point of using Unit of Topography and Actor as ontological concepts of Historical semantics is that they allow for a truly interdisciplinary research. Unfortunately, today historical science understood as a whole still lacks a common code for data integration within its discourse. The methodological particularities of each method make sense as far as they follow specific goals and socially determined functions. This should not be a problem for creating an integrated construction of the past, as far as they share a common system for information management and exchange, which –unfortunately– has not happened yet [44] (p. 41-42).

In a context of FAIR research, the aim to create an integrated historical discourse is a challenge that historians should face with a sense of urgency. Nevertheless, interdisciplinarity in history does not mean –or should not mean– juxtaposing different past constructions arising from each discipline (history, archaeology, literature, iconography, archival science, linguistics, law, and SSH in general), but creating an interdisciplinary narrative joining the efforts of many different scholars. Sharing a common system for information management and exchange allows us to monitor the research process from the beginning and to locate information precisely, which makes it findable and accessible to colleagues from diverse expertise domains. This is the best way to deal with bias and uncertainty.

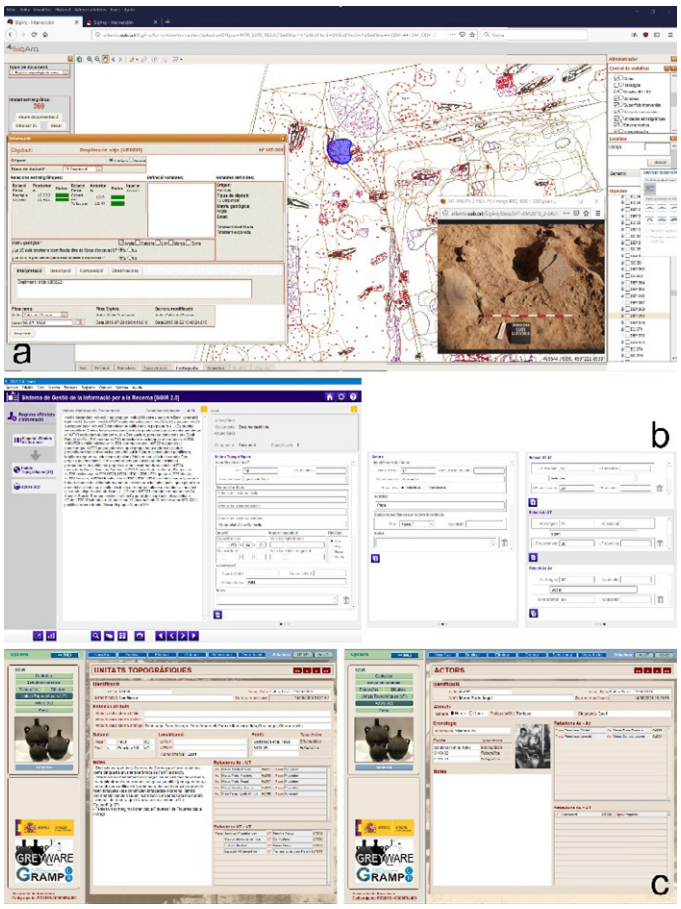


Fig. 7. Examples of record management tools developed by our team. Interface of SigArq software (a); SGIR 2.0 database screen view with forms for UT (left), Ac (centre) and Relation –UT-UT, Ac-UT and AC-AC– (right) (b), and Greyware database interfaces for UT (bottom left) and Ac (bottom right), showing in both cases relations between them as an automatized search from relation tables (c).

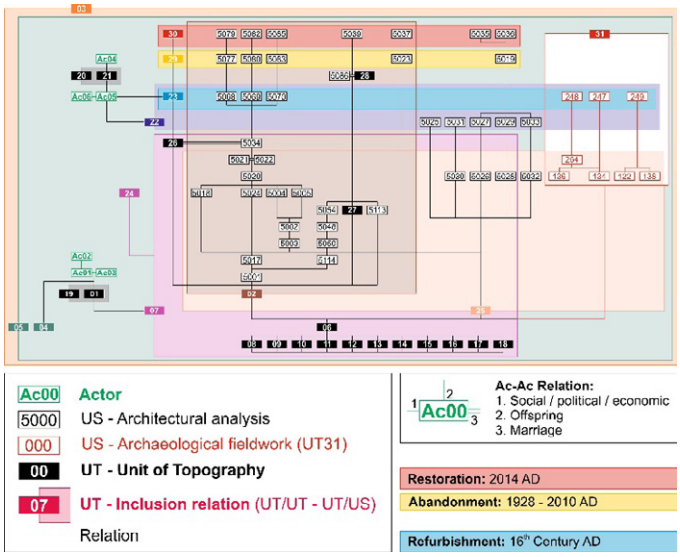


Fig. 8. Excerpt of the Historical matrix created for the archaeological site of Sant Genís de Rocafort. Only UT, Ac and US mentioned throughout this paper as a lab example for the method proposed and summarized in Table II and Table III are included.

Our proposal suggests widening the scope of the archaeological method as a response to this challenge. As defined in [30] (p. 42), the concept of US includes any kind of action leaving a material imprint and identified within spatiotemporal coordinates, no matter if it is positive –adding materials– or negative –removing them. Therefore, during the archaeological fieldwork we register positive US when stratigraphic accumulation of materials occurs and we identify negative US in holes, broken structures or eroded layers.

This concept has proved to be wide enough to be adopted by other archaeology-related disciplines such as architectural analyses of buildings and material heritage studies [45] (p. 79). Since materiality –and, therefore, its cartographic and graphic informative dimension– is the main feature of US, could we define a similar concept equivalent to this unit of information but delinked from its material component? Yes, we could. Units of topography provide this univocal identification of entities and events in the past, with spatiotemporal coordinates and relations between them. Archaeology does not inform about actors, but many other sources of historical information do. Therefore, the proposal of UT/Ac gathering is an adequate compromise solution in order to develop an ontology for past construction in which entities and events are identified through non-ambiguous parameters.

Successful data labelling strategies (TEI) are limited to written sources and hence increasingly used in literature and language studies [46]. They might be successfully applied to the written examples we provided, but they fail in labelling iconographic or photographic vestiges. Textual encoding and labelling tools have a great potential for written vestiges from the past, but historical science needs an additional category for data labelling regardless of the origin or support of the vestige. Our labelling proposal implies looking for UT and Ac in too many different shapes and supports –even if textual sources are the most abundant. This actually implies more interpretative knowledge on the historians' part, as it is not possible to detect these data units through mere automatic data labelling applications yet.

Furthermore, UT/Ac identification allows for multiple readings of past vestiges, which can be as exhaustive as required in a particular research project. Data gathered in the examples provided throughout this paper have been enough to demonstrate the validity of the method. We have attempted to find a balance between a theoretical demonstration and a practical case of study, but the historical sources informing about the Priory of Sant Genís de Rocafort are much wider and the historical matrix arising from them is far more complex. This also shows how the historian can read, analyse and interpret past vestiges to a desired level, according to their interest or domain of expertise, and how future experts dealing with the same vestiges can then generate new knowledge *building upon* previous reflections, but not *disregarding* them.

In recent years, data modelling and database construction in the terms described in this paper have allowed us to develop integrated approaches [29], [47] and software [42] overcoming the traditional inconveniences arising from the fragmentation of sources of information. Interactive multimedia and artificial intelligence have a great potential to automatize research processes and have proved to be novel and useful in the domain of SSH. Research projects in the field of History, Archaeology or Archival Science can benefit significantly from shared and transdisciplinary approaches to the past when using a common code. We consider the dialectics between US/UT and Ac as useful categories for data modelling, according to the semantics of Entity and Event as major ontological concepts in historical science [28], [48].

VI. Conclusion

Historical science is a wide discipline that has to consider all the sources of information available, which implies several other disciplines taking part in this process. Archaeology, linguistics, literature, and many others provide valuable data to contribute significantly to the

construction of the past. Historians should not add some of these data to a main discourse arising only from written sources but integrate all this information within interdisciplinary processes of data gathering and exploitation.

The NLP community has presented several attempts to process historical knowledge, according to two underpinning –one theoretical and one practical/methodological– ideas: the definition of event and data extraction through text labelling. In doing so initiatives share the common limitation of not having a precise and shared definition of event amongst the academy, and the data extraction procedure being limited to written sources. Furthermore, no attempt has been made to find a domain-specific definition of event combining the historical perspective and ongoing research in the NLP field.

Hybrid intelligence would be, to our perception, a challenging field to explore the possibilities of historical knowledge to become digital and interdisciplinary, and to develop appropriate UT/Ac recognition patterns. NLP systems might be focussed on finding and tagging event-meaningful concepts in written sources, even including archaeological excavation documents and text-supported records, but the heterogeneity of supports and formats for historical vestiges are much wider than these.

The concept of Unit of Stratigraphy, broadly used in archaeology, provides a useful characterization of actions in the past according to their materiality. Widening this idea, the categories Unit of Topography and Actor, as described throughout this paper, provide single and univocal semantic concepts to identify entities and events. Building databases according to these categories is a valuable strategy that integrates knowledge both from SSH and STEM to the historical domain, and made information systems interoperable, ensuring the traceability of the entire research process. While there is a range of opportunities of automatizing processes in terms of text labelling by tagging Units of Topography and Actors, there is still a need for trained and experienced historians who decide the level at which data have to be recorded. Anyway, there is a considerable potential in terms of data exploitation and visualization, in which ICT in general should definitely contribute.

Acknowledgments

This study is part of the current research tasks carried out by the Medieval and Postmedieval Archaeology Research Group GRAMP.-UB (2017-SGR-833-GRC) at the University of Barcelona, to which the authors belong, and it is included in our Landscape Archaeology research line. Theoretical development, conceptualization, and applied methods are part of funded research projects developed by the Centre d'Estudis Martorellencs (CLT009/18/00036 – DGPC/exp. 35) and the University of Barcelona (GREYWARE PID2019-103896RJ-I00). The authors wish to thank Ms Noemí Travé for language edition and review.

References

[1] J. Arostegui. *La investigación histórica: teoría y método (Historical research: Theory and method)*, Barcelona, Spain: Crítica, 1995.

[2] A. Torre. "Un «tournant spatial» en histoire? Paysages, regards, ressources (A spatial turn in history ? Landscapes, visions, resources)", *Annales. Histoire, Sciences Sociales*, vol. 2008, no. 5, pp. 1127-1144, 2018, [On-line] Available: https://www.cairn-int.info/article-E_ANNA_635_1127--a-spatial-turn-in-history.htm

[3] R. White. *What is Spatial History? Spatial History Lab: Working Paper*, Standford, USA: Standford University, 2010, [On-line] Available: https://web.stanford.edu/group/spatialhistory/cgi-bin/site/pub.php?id=29

[4] D. Cosgrove. "Landscape and Landschaft. Lecture delivered at the «Spatial Turn in History» Symposium", *German Historical Institute Bulletin*, vol. 35 no. Fall, pp. 57-71, 2004. [On-line] Available: https://is.cuni.cz/studium/predmety/index.php?do=download&did=130419&kod=JMB067

[5] F. Trentmann. "Materiality in the Future of History: Things, Practices and Politics", *Journal of British Studies*, vol. 48, pp. 283-307, 2009, doi: 10.1086/596123.

[6] D. Hicks. "The material-cultural turn: event and effect" in *The Oxford Handbook of Material Culture Studies*, Hicks, D.; Beaudry, M. C. Eds. Oxford, UK: Oxford University Pres, 2010, pp. 25-98. doi: 10.1093/oxfordhb/9780199218714.013.0002.

[7] E. Hinrichs, M. Hinrichs, S. Kübler, T. Trippel. "Language technology for digital humanities: introduction to the special issue", *Languaje Resources & Evaluation*, vol. 53, pp. 559-563, 2019.

[8] D.W. Oard. "A Whirlwind Tour of Automated Language Processing for the Humanities and Social Sciences" in *Working Together or Apart: Promoting Digital Scholarship*, Washington DC, USA: Council on Library and Information Resources, 2009.

[9] J. Kuhn. "Computational text analysis within the Humanities: How to combine working practices from the contributing fields", *Language Resources & Evaluation*, vol. 53, pp. 565-602, 2019.

[10] M. Piotrowski. *Natural Language Processing for Historical Texts. Synthesis Lectures on Human Language Technologies*, San Rafael, California, USA: Morgan & Claypool Publishers, 2012. [On-line] Available: https://doi.org/10.2200/S00436ED1V01Y201207HLT017

[11] P. Ruiz. *Concept-based and relation-based corpus navigation: applications of natural language processing in digital humanities. Linguistics.* PhD Dissertation. Paris, France: PSL Research University, 2017. [On-line] Available: https://tel.archives-ouvertes.fr/tel-01575167v2

[12] E. Travé, P. Del Fresno, A. Mauri, S. Medina. "The Semantics of historical knowledge. Labelling Strategies for Interdisciplinary and Digital Research in History", in *HI4NLP 2020 Hybrid Intelligence for Natural Language Processing Tasks 2020. Proceedings of the Workshop on Hybrid Intelligence for Natural Language Processing Tasks (HI4NLP 2020)co-located with 24th European Conference on Artificial Intelligence (ECAI 2020) Santiago de Compostela, Spain, August 29, 2020*, P. Gamallo, M. García, P. Martín-Rodilla, M. Pereira-Fariña, Eds. Santiago de Compostela, Spain: CEUR, 2020, pp. 17-21, [On-line] Available: http://ceur-ws.org/Vol-2693/paper2.pdf

[13] J. Delve, R. G. Healey. "Is there a role for data warehousing technology in historical research?" in *Humanities, Computers and Cultural Heritage. Proceedings of the XVI International Conference of the Association of Arts and Sciences*, Royal Netherlands Academy of Arts and Sciences Ed. Amsterdam, Netherlands: KNAW, 2005, pp. 106-111. [On-line] Available: https://dans.knaw.nl/nl/over/organisatie-beleid/publicaties/DANShumanitiescomputersandculturalheritageUK.pdf

[14] A. Ivanovs, A. Varfolomeyev. "Editing an exploratory analysis of medieval documents by means of XML technologies" in *Humanities, Computers and Cultural Heritage*, Netherlands: KNAW, 2005, pp. 155-160.

[15] F. de Jong, H. Rode, D. Hiemstra. "Temporal language models for the disclosure of historical text", in *Humanities, Computers and Cultural Heritage*, Netherlands: KNAW, 2005, pp. 161-168.

[16] S. Eriksson, H. Skånes. "Addressing semantics and historical data heterogeneities in cross-temporal landscape analysis", *Agriculture, Ecosystems and Environment*, vol. 139, pp. 516-521, 2010, doi: 10.1016/j.agee.2010.09.011.

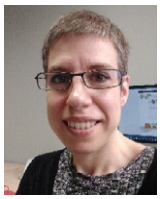
[17] G. Nagypál. "History ontology building: The technical view", in *Humanities, Computers and Cultural Heritage,* Netherlands: KNAW, 2005, pp. 207-214.

[18] B. Tomaszewski. "Local Model Semantics, Categories, and External Representation: Towards a Model for Geo-historical Context", in *Modeling and Using Context. 6th International and Interdisciplinary Conference, CONTEXT 2007, Roskilde, Denmark, August 20-24, 2007, Proceedings. Lecture Notes in Artificial Intelligence*, vol. 4635, B. Kokinov, D. C. Richardson, Th. R. Roth-Berghofer, L. Vieu, Eds. Berlin / Heidelberg, Germany: Springer, 2007, pp. [On-line] Available: http://context-07.ruc.dk/Context2007DocCons.pdf

[19] H. Berger. 'Microhistory and quantitative data analysis', In *Humanities, Computers and Cultural Heritage,* Netherlands: KNAW, 2005, pp. 39-42.

[20] A. Antonacopoulos, D. Karatzas. "Semantics-Based Content Extraction in Typewritten Historical Documents", in *Proceedings of the 8th International Conference on Document Analysis and Recognition (ICDAR2005)*, IEEE Computer Society Ed. Washington DC, United States: IEEE Digital

Library, 2005, pp. 48-53, doi: 10.1109/ICDAR.2005.215.
[21] M. Heller, G. Vogeler. "Modern information retrieval technology for historical documents", in *Humanities, Computers and Cultural Heritage*, Netherlands: KNAW, 2005, pp. 143-148.
[22] C. Coffin. "The voices of History: Theorising the interpersonal semantics of historical discourses", *Text*, vol. 22, no. 4, pp. 503-508, 2002, doi: 10.1515/text.2002.020.
[23] G. Nagypál, B. Motik. "A Fuzzy Model for Representing Uncertain, Subjective, and Vague Temporal Knowledge in Ontologies", in *On The Move to Meaningful Internet Systems 2003: CoopIS, DOA, and ODBASE. OTM 2003. Lecture Notes in Computer Science*, vol. 2888, R. Meersman, Z. Tari, D. C. Schmidt, Eds. Berlin / Heidelberg, Germany: Springer, 2003, pp. 906-923, doi: 10.1007/978-3-540-39964-3_57.
[24] M. D. Wilkinson et al. "The FAIR Guiding Principles for scientific data management and stewardship", *Scientific Data*, vol. **3**, paper 160018, 2016, doi: 10.1038/sdata.2016.18
[25] G. Gänser, G. Michetti. *InterPARES Trust Project. Ontology of Functional Activities for Archival Systems*; TR05-Final Report-20180526, 2018. [On-line] Available: https://interparestrust.org
[26] Parthenos. *Guidelines to FAIRify Data Management and Make Data Reusable.* [On-line] Available: https://zenodo.org/record/2668479
[27] A. Mosca. "Ontology-mediated Data Integration and Access in Research and Innovation Policy", in *Proceedings of the Joint Ontology Workshops 2017 (JOWO 2017), Episode 3: The Tyrolean Autumn of Ontology, Bozen-Bolzano, Italy, 21–23 September 2017,* S. Borgo, O. Kutz, F. Loebe, F. Neuhaus, Eds. Bozen-Bolzano, Italy: CEUR, 2017, [On-line] Available: http://ceur-ws.org/Vol-2050/invited4-Mosca.pdf
[28] K. Thibodeau, "The Construction of the Past: Towards a Theory for Knowing the Past", *Information*, vol. 10, paper 332, 2019, doi: 10.3390/info10110332.
[29] A. Mauri. *La configuració del paisatge medieval: el comtat de Barcelona fins al segle XI (The formation of medieval landscape: The county of Barcelona until the 11th Cent). PhD Dissertation.* Barcelona, Spain: Universitat de Barcelona, 2006. [On-line] Available: https://www.tesisenred.net/handle/10803/2065
[30] E. C. Harris. *Principles of archaeological stratigraphy (Second edition)*, San Diego, USA: Academic Press, 1989, [On-line] Available: https://www.sciencedirect.com/book/9780123266514/principles-of-archaeological-stratigraphy
[31] A. Carandini. *Historias en la Tierra: Manual de Excavación Arqueológica (Stories from the earth. Excavation Handbook)*, Barcelona, Spain: Crítica, 1997.
[32] *Foundation Act of the Priory of Sant Genís de Rocafort.* Barcelonese Diocesan Archive, Vol. *Dotaliarum*, no. 5, pp. 31-32.
[33] E. Mallorquí, *El monestir de Sant Miquel de Cruïlles a l'edat mitjana. Estudi i edició dels documents. 1035-1300 (The monastery of Sant Miquel de Cruïlles in the middle age. Study and edition of documents. 1035-1300)*, Girona, Spain: Ajuntament de la Bisbal d'Empordà, 2000.
[34] J. Baucells. *El Priorat de Sant Genís de Rocafort (Martorell) (The Priory of Sant Genís de Rocafort)*, Centre d'Estudis Martorellencs. Ed. Martorell, Spain: CEM, 2007.
[35] J. Salvany. *Sant Genís de Rocafort.* Biblioteca de Catalunya Ed. Barcelona, Spain: BC, 1915.
[36] J. Salvany. *Sant Genís de Rocafort.* Biblioteca de Catalunya Ed. Barcelona, Spain: BC, 1912.
[37] I. Hodder, C. Orton. *Spatial Analysis in Archaeology*, Cambridge, UK: Cambridge University Press, 1976.
[38] *Sant Genís de Rocafort. Ortophoto.* Provided by Institut Cartogràfic i Geològic de Catalunya. Barcelona. [On-line] Available: http://www.icc.cat/vissir3/
[39] C. González-Pérez. "A Conceptual Modelling Language for the Humanities and Social Sciences", in *Sixth International Conference on Research Challenges in Information Science (RCIS)*, IEEE Computer Society Ed. Washington DC, United States: IEEE Digital Library, 2012, doi: 10.1109/RCIS.2012.6240430.
[40] E. Travé, P. Del Fresno, A. Mauri. "Ontology-mediated Historical Data Modelling: Theoretical and Practical Tools for an Integrated Construction of the Past", in *Digital Humanities Special Issue.* C. González-Perez Ed. *Information*, vol. 11, paper 182, doi:10.3390/info11040182.
[41] P. Del Fresno. *Sistema de Información Arqueológica: propuesta de normalización, desarrollo conceptual e informático. (Archaeological Information System: Normalization proposal, conceptual and computing development) PhD Dissertation.* Vitoria, Spain: University of the Basque Country, 2016. [On-line] Available: https://www.academia.edu/23836202/
[42] *SigArq. Sistema de Información Geoespacial Arqueológico.* [On-line] Available: http://www.sigarq.es/home/
[43] H. Wickham, 'Tidy Data', *Journal of Statistical Software*, vol. 59, no.10, pp. 1-10, 2004, doi: 10.18637/jss.v059.i10.
[44] A. Mauri, E. Travé, P. Del Fresno. '"An integrated implementation of written and material sources – conceptual challenge and technological resources", in *Archaeology. New Approaches in Theory and Techniques*, I. Ollich Ed. Rijeka, Croatia: InTech, 2012, pp. 41-64, doi:10.5772/38934.
[45] P. Del Fresno, A. Mauri, E. Travé. "Documentació d'intervencions de restauració en jaciments arqueològics i patrimoni edificat: cap a la construcció d'un Sistema d'informació (Recording restoration tasks in archaeological sites and building heritage: towards the construction of an information system)". *Documentar en la conservació-restauració. Mètodes i noves technologies*, Conservadors Restauradors Associats de Catalunya. Barcelona: Spain, CRAC, 2020, in press.
[46] C. M. Sperberg-McQueen, L. Burnard. *TEI P5: Guidelines for Electronic Text Encoding and Interchange TEI.* Text Encoding Initiative Consortium, 2019. [On-line] Available: https://tei-c.org/release/doc/tei-p5-doc/en/Guidelines.pdf
[47] E. Travé. "Los hornos medievales y la cerámica negra" in *Actas del IXI Congreso de la Asociación de Ceramología. Obra negra y alfarería de cocina*, Asociación de Ceramología Ed., Quart, Spain: Ajuntament de Quart, 2017, pp. 123-147. [On-line] Available: http://www.ceramologia.org/gestion/archivos/1084.Est.pdf
[48] R. Sprugnoli, S. Tonelli. "One, no one and one hundred thousand events: Defining and processing events in an inter-disciplinary perspective", *Natural language engineering*, vol. 23, no. 4, pp. 485-503, 2016, doi: 10.1017/S1351324916000292.



Esther Travé Allepuz

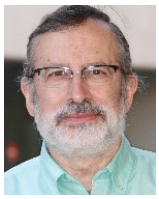
Esther Travé holds a Degree in History (Universitat de Barcelona, Spain, 2005) and a PhD in Medieval History at the same university (2009). She is a medieval archaeologist and her research field is the production and distribution of greyware pottery in medieval and postmedieval ages. She was trained in Ceramic Petrography at the University of Sheffield (2008) and in XRF and XRD techniques at the Institute of Archaeology, University College London (UCL) (2012-2014). She lectures at the University of Barcelona since 2015, and she currently is leading researcher of the archaeological project developed at the Sites of Santa Margarida and Sant Genís de Rocafort (Martorell). Her most recent research has been devoted to data analysis and the development of interdisciplinary approaches applied, in particular, to the historical and archaeological study of pottery.

Pablo del Fresno Bernal

Pablo Del Fresno obtained his Degree in History at the University of the Basque Country (Spain, 2000). He holds an MSc in Geographic Information Technologies (Universitat Autònoma de Barcelona, Spain, 2008) and a PhD in History (University of the Basque Country, 2016). He works as a professional archaeologist at Sistemes de Gestió de Patrimoni SCCL. Based upon the theoretical reflection of his PhD dissertation, he is the development coordinator of the Archaeological Information System SigArq, within a long collaborative framework in which the Geographic Information and Remote Sensing Lab (LIGIT) at the UAB takes part. He participates in several archaeological projects in which the SigArq system is involved. Amongst these, Santa Catalina (Mansilla de la Sierra, La Rioja), the Convent de Penyafort (Santa Margarida i els Monjos, Barcelona), and the Archaeological Research Project of Santa Margarida and Sant Genís de Rocafort (Martorell, Barcelona), are the more relevant.

Sonia Medina Gordo

Sonia Medina is a PhD candidate working under Esther Travé's supervision at the University of Barcelona. Her PhD project aims at developing digital strategies for data management and exploitation and applying them to the historical analysis of the formation of the Castilian Feudal System at the Upper Arlanza Basin (Burgos, Spain). She holds a Degree in History (Universitat de Barcelona, Spain, 2018) and a MA in Advanced History Studies (Universidad de Salamanca, Spain, 2019). Approaching the medieval period according to an interdisciplinary method integrating results from historical science and archaeology led her to join this research team. She contributes to the data modelling and database development, the way of dealing with uncertainty and bias in historical discourses being one of her main interests.



Alfred Mauri Martí

Alfred Mauri has a long career in Archival Science and Archaeology since he obtained his Degree in Prehistory, Ancient History and Archaeology (Universitat de Barcelona, Spain, 1983). From 1981 to 2002 he worked in Martorell (Spain), as an archivist in charge of the Town Council Archive, while he was the leading researcher at the Archaeological Site of Santa Margarida, located in the same town. He performed his PhD Dissertation in the field of Landscape Archaeology and developed the concept of Unit of Topography. After obtaining his PhD (Universitat de Barcelona, Spain, 2006) he has been Lecturer and Degree coordinator at the High School of Archival Science and Records Management of the Universitat Autònoma de Barcelona. He has been director of this same centre for three years (2016 – 2018). His main research lines are landscape archaeology and archeaology of architecture, the integrated and georeferenced historical data management, and Big Data analysis and exploitation.

Editor's Note

Artificial Intelligence (AI) has become nowadays one of the main relevant technologies that is driven us to a new revolution, a change in society, just as well as other human inventions, such as navigation, steam machines, or electricity did in our past. There are several ways in which AI might be developed, and the European Union has chosen a path, a way to transit through this revolution, in which Artificial Intelligence will be a tool at the service of Humanity. That was precisely the motto of the 2020 European Conference on Artificial Intelligence ("Paving the way towards Human-Centric AI"), of which these special issue is a selection of the best papers selected by the organizers of some of the Workshops in ECAI 2020.

These workshops constitute a diverse list of different subjects that are relevant to AI at present, some that envision the future, and finally also multidisciplinary topics in an increasingly transversal discipline. This selection aims at proposing, discussing and finding ways to confront the many challenges that lie ahead and for which solutions need to be found. Designing the correct strategy is crucial to be able embrace a future in which AI ensures empowering people, making true the conference motto.

The selected papers belong to the following Workshops: Hybrid Intelligence for Natural Language Processing Tasks (HI4NLP); Applied Deep Generative Networks (ADGN); Declarative Problem Solving (DPSW); Advancing towards the Sustainable Development Goals: AI for a fair, just and equitable world (AI4EQ); Evaluating Progress in AI (epAI); Singular Problems for Health Care (SP4HC); Intelligent Information Processing and Natural Language Generation (IntelLanG); and Data Fusion for Artificial Intelligence (DAFUSAI).

With the workshop "Advancing Towards the Sustainable Development Goals (SDGs): Artificial Intelligence for a Fair, Just and Equitable World (AI4Eq)" we aimed to illustrate the R&D path that would confer a decisive role to AI in achieving the UN Agenda 2030. Eradicating poverty is a central objective of the SDGs so the emphasis is on AI benefits for low and middle income countries, and the growing pockets of underdevelopment in high income countries.

There is a growing interest in the role that AI can play in achieving SDGs on the part of international organisations, such as UN Global Pulse [1], UNHCR [2], the UNICEF Global Innovation Centre [3], the World Wide Web Foundation [4], the International Telecommunications Union [5], and even the World Economic Forum [6]. In order for AI to catalyse the necessary transformation promoted by the 2030 Agenda, a research agenda that is practice-oriented and that goes beyond cataloging AI risks and potentialities is required, in part as a counter-weight to the heavily-plugged corporate sector view on AI ethics, which is often little more than "ethicswash" for a program in which the effect of AI/S development and deployment will most likely be to increase inequality [7] [8]. The three papers selected from the submissions to AI4Eq for this special issue describe research on SDG-oriented AI applications, as well as AI tools conceived to support the development of AI respectful of, and even actively committed to, fundamental human rights, focusing particularly on protecting and empowering the most vulnerable and marginalized.

The paper "Achieving fair inference using error-prone outcomes" focusses on a field that is attracting increasing interest: the assessment of fairness criteria in supervised learning. The authors demonstrate that existing methods to assess and calibrate fairness criteria do not extend to the true target variables of interest, when error-prone proxy targets are used. They propose a framework that combines fair machine-learning methods, such as those found in the fairness literature, and measurement models found in the statistical literature; and illustrate their approach in a healthcare decision problem showing how a latent variable model to account for measurement error removes the unfairness detected previously.

The paper "Attesting Digital Discrimination Using Norms" also addresses the problem of digital discrimination arising from bias in machine-learning algorithms. In this case, the authors point to the need to provide non-expert users of machine-learning algorithms with simple tools to determine if a machine-learning system is potentially discriminatory, and to make explicit under which assumptions the systems are discrimination free. The authors suggest using "norms" as an abstraction to represent different situations that may lead to digital discrimination. In particular, they formalise non-discrimination norms in the context of machine-learning systems and propose a digital-discrimination attesting algorithm to check whether the systems violate these norms, illustrating its performance in three case studies where, in particular, gender and racial biases are identified.

"No App is an Island: Collective Action and Sustainable Development Goal-Sensitive Design" deals with the challenges of engineering ever more complex socio-technical systems to address "wicked" societal problems, with respect to satisfying qualitative human values and to assessing their impact on global challenges. The authors present a set of sets of design principles and an associated meta-platform, which focusses the design of socio-technical systems on the potential interaction of human and artificial intelligence with respect to three aspects: firstly, decision support regarding the codification of deep social knowledge; secondly, visualisation of community contribution to successful collective action; and thirdly, systemic improvement with respect to the SDGs through impact assessment and measurement. This SDG-sensitive design methodology is illustrated through the design of two collective action apps, one for encouraging plastic re-use and reducing plastic waste, and the other for addressing redistribution of surplus food.

The Workshop on Hybrid Intelligence for Natural Language Processing Tasks (HI4NLP) has provided a forum to discuss exciting research on hybrid technologies for NLP. In particular, our interest lies in those methodologies and architectures which combine and integrate symbolic information into statistical methods, including neural networks, thus allowing for building more transparent and interpretable models.

The paper "Assessing Lexical-Semantic Regularities in Portuguese Word Embeddings" introduces TALES, a new dataset with lexical-semantic word analogies. The authors use this resource to perform a detailed analysis of various word embeddings for Portuguese, including static representations such as GloVe [9] and word2vec [10], and current contextualized models (e.g., BERT [11]). Interestingly, this paper also discusses how distributional models can be used to enlarge lexical-semantic knowledge bases, which can be beneficial to various natural language processing tasks.

On "The Semantics of History. Interdisciplinary Categories and Methods for Digital Historical Research", Travé et al. present a conceptual framework for interdisciplinary research in History, focusing on data modeling and labeling methods. In particular, they propose identifying minimum units of information (units of topography, units of stratigraphy, and actors) and their relations, for which methodological aspects are described. A detailed case study on landscape archaeology shows the usefulness of the proposed framework, which takes advantage of knowledge obtained from several sources.

DOI: 10.9781/ijimai.2021.02.014

ECAI 2020 also hosted the first edition of the Declarative Problem Solving Workshop (DPSW), gathering researchers from different AI disciplines with a common interest in solving computational problems via their explicit representation in some declarative language. This covers, for instance, the solution of combinatorial problems, optimization, numerical constraints, planning, scheduling, temporal constraints, etc, or combinations of these categories provided that their specification is made in terms of some declarative formal language. The workshop spanned two days, August 29th and 30th, and included the presentations corresponding to thirteen accepted regular papers. The average audience was around 25 participants, reaching a maximum of 40 during the invited talk by Vladimir Lifschitz, that closed the event. Although the papers covered different disciplines like constraints, planning, natural language or pattern mining, perhaps the most frequent topic was the problem solving paradigm of Answer Set Programming (ASP). Two contributions obtained the workshop best paper award in a tie, and were extended into full journal papers included in this volume. The first best paper, "Smoke Test Planning using Answer Set Programming" by Tobias Philipp, Valentin Roland and Lukas Schweizer, presented a declarative method for optimizing the automated generation of smoke tests for hardware devices, that is, quick tests of main functionalities that may spot a large error in the early stages of hardware design. The second best paper, "An Application of Declarative Languages in Distributed Architectures: ASP and DALI microservices", by Stefania Costantini, Giovanni de Gasperis and Lorenzo de Lauretis, introduced an innovative combination of the microservices architecture with a modular variant of ASP, showing potential applications of declarative problem solving to Multi-Agent Systems, Internet of Things (IoT) or Cloud Computing.

The workshop on Intelligent Information Processing and Natural Language Generation (IntelLang) aimed to identify challenges and explore current results that arise from the interaction of Intelligent Information Processing techniques and research in Natural Language Generation (NLG), both at the level of models and applications. The use of intelligent data and information processing techniques can help in many relevant aspects of the NLG problem, for example in the contribution of formalisms for knowledge modeling and management, or in the development of models for the evaluation of the quality of the proposals, among many others. The workshop provided a forum for discussion of these new research directions and attracted a broad spectrum of contributions, emphasising either or both of the workshop's main themes - NLG and Information Processing. Our hope is that these contributions will serve to enhance the sharing of ideas among the two communities.

The paper "Improving Asynchronous Interview Interaction with Follow-up Question Generation" proposes a follow-up question generation model (followQG) capable of generating relevant and diverse follow-up questions based on the previously asked questions, and its answers. This model is integrated in a 3D virtual interviewing system, Maya, with capability of follow-up question generation, taking advantage of the implicit knowledge from deep pre-trained language models to generate rich and varied natural language follow-up questions. Empirical results suggest that followQG generates questions that humans rate as high quality, achieving 77% relevance, and a comparison with strong baselines of neural network and rule-based systems shows that it produces better quality questions.

The paper "Neural Scoring of Logical Inferences from Data using Feedback" proposes a neural network model that generates personalised lifestyle insights based on a model of their significance, and feedback from the user. These insights are derived from wearable sensors in smartwatches or sleep trackers, and their generation should adapt automatically to the preferences and goals of the user. Simulated analysis of the presented model shows its ability to assign high scores to a) insights with statistically significant behaviour patterns and b) topics related to simple or complex user preferences at any given time. The authors believe that the proposed neural networks model could be adapted for any application that needs user feedback to score logical inferences from data.

The first workshop on Evaluating Progress in Artificial Intelligence (EPAI) took place on September 4th and comprised 13 presentations and one invited talk from Professor Barry O'Sullivan, President of the European AI Association. There were over 30 attendants and a reasonably good number of (very active) attendees. EPAI 2020 served not only as a meeting point for people from different backgrounds and goals, but also to identify the most challenging/urgent needs for AI evaluation [12]. In this regard, it is very well-known that AI capabilities are growing at an unprecedented rate. Countless AI approaches and applications are being developed and can be expected over the long term. In hindsight, one would say that progress certainly has taken place just looking at the range of tasks that AI are able to solve autonomously today (according to the benchmarks, challenges, and competitions [13]) and were not solvable a few years ago, from machine translation to medical image analysis or self-driving vehicles [14]. Moreover, progress in AI is widely believed to have substantial social and economic benefits, and possibly to create unprecedented challenges. In order to properly prepare policy initiatives for the arrival of such technologies, accurate forecasts and timelines are necessary to enable timely action among policymakers and other stakeholders. However, there is still much uncertainty over how to assess and monitor the state, development, uptake, and impact of AI as a whole, including its future evolution, progress and benchmarking capabilities. While measuring the performance of state-of-the-art AI systems on narrow tasks is useful and fairly easy to do, where the assessment really becomes difficult, though, is in trying to map these narrow-task performances onto more general AI and how it can have an impact on society in terms of benefits, risks, interactions, values, ethics, oversight into these systems, etc.

EPAI papers covered different formalisations, methodologies and testbenches for the evaluation of AI systems with the final goal of measuring the field's rates of development, progress, and impact. Two contributions obtained, respectively, the workshop best paper award and runner-up award, and have been extended into full journal papers included in this volume. The best paper, "Artificial Canaries: Early Warning Signs for Anticipatory and Democratic Governance of AI" by Carla Zoe Cremer and Jess Whittlestone, propose a method for identifying early warning signs of transformative progress in AI, and discuss how these can support the anticipatory and democratic governance of AI. Their method combines expert elicitation and collaborative causal graphs to identify key mile-stones and identify the relationships between them.

The runner-up award paper, "Efficient and Robust Model Benchmarks with Item Response Theory and Adaptive Testing", by Hao Song and Peter Flach, investigate adaptive approaches to achieve better efficiency in model benchmarking. In this regard, they propose and analyse methods that allow machine learning practitioners to pick only a few representative datasets to quantify the quality of a technique, from which to extrapolate the performance on other datasets. To this end, they adapt existing approaches from psychometrics, Item Response Theory and Adaptive Testing specifically, by implementing certain modifications following the requirements of machine learning experiments, and present experimental results to validate the approach.

The workshop "Singular Problems for Healthcare (SP4HC)" was devoted to advances in Artificial Intelligence applied to Healthcare and Well-Being, with an active interest in frontier-of-knowledge Machine Learning subjects, sometimes named as singular Machine Learning problems. In particular, imbalanced classification, ordinal classification

or multi-label classification, which are pervasive in important practical problems in healthcare, have consequently generated a tremendous interest. From the scientific point of view, the workshop intended to serve as a basis for proposing and discussing advances in the artificial intelligence arena, with a range of applications. Some contributions have dealt with common challenges in healthcare applications, as imbalanced classes and feature selection using simple interpretable classifiers like logistic models and decision trees. Others used feature extraction from images and artificial neural networks approaches. Natural language processing, reinforcement learning and model-based reinforcement techniques, recommender systems or echo state networks, which are an alternative to standard recurrent neural networks, have also been examined. Finally, several temporal modelling approaches to manage the concept drift phenomenon have been applied for identification and classification tasks. From the medical perspective, the papers of this workshop had coped with different medical topics like melanoma skin cancer detection, wellness application for providing personalized health activities, Type 1 diabetes blood glucose control for insulin dose decisions, and antimicrobial multidrug resistance in Intensive Care Units (ICUs) for their characterization and prediction.

The paper selected as best of this workshop, "Antimicrobial Resistance Prediction in Intensive Care Unit for Pseudomonas Aeruginosa using Temporal Data-Driven Models" proposes new paradigms to address the problem of the increasing bacterial resistance to antibiotics, a particularly serious problem in hospital's ICUs because of the vulnerability of these patients. Knowing in advance whether a concrete bacterium is resistant or susceptible to an antibiotic is a crux step for clinicians to determine an effective antibiotic treatment. This article focuses on cultures of the Pseudomonas Aeruginosa bacterium because is one of the most frequent, dangerous and difficult to treat in the ICU. Several temporal data-driven models are proposed and analysed to predict the resistance or susceptibility to a specific antibiotic family previously to obtain the result of the antimicrobial susceptibility test and only using historical data registered in the electronic health system. The approach provides reasonably accurate results for some antimicrobial families, and could be used by clinicians as an early-warning system to support the election of the antibiotic therapy. This early prediction can save valuable time to start the adequate treatment for an ICU patient.

The Workshop on Data Fusion for Artificial Intelligence (DAFUSAI) was dedicated to discuss this crucial problem from both theoretical and applied point of views. Classiffication, image processing, decision-making, big data or deep learning require collecting data and fusing them in appropriate ways in order to solve specific problems. For this reason, a huge effort is devoted to the developments and analysis of data fusion methods [15]. Aggregation functions are one of the most widely used methods in this sense. They are defined as monotone functions with appropriate boundary conditions and include, among others, most of the means or functions such as the product, the minimum or the maximum. However, in recent years it has been shown that the concept of aggregation function can be too restrictive, as it does not cover some examples which can provide good results in particular applications, as it is the case of the mode. Furthermore, some data fusion functions more general than aggregations,- the so called pre-aggregation functions [16]-, have been proposed to deal with problems ranging from classiffication [17] to the computational brain [18], with very promising results.

From the papers presented at the DAFUSAI Workshop, we have selected the paper by Sicui Zhang et al., entitled "Towards Multi-perspective Conformance Checking with Fuzzy Sets". The paper points out the problem faced by the organizations concerning the necessity to employ data-driven techniques to audit their business processes and ensure they comply with laws and internal/external regulations, which can be inefficient and subject to frauds or abuses. An increasingly popular approach to automatically assess the compliance of the executions of organization processes is represented by alignment-based conformance checking. These techniques present several advantages, e.g., by comparing real process executions with the models, they can show possible discrepancies. However, there are also some drawbacks, e.g., as they perform a crisp evaluation of process compliance, a behavior process is classiffied as either compliant or d-viant (even if such deviation is not severe). In this paper, the authors discuss about these problems, proposing a novel conformance checking approach aimed at representing actors' tolerance with respect to process deviations, taking it into account when assessing the severity of the deviations. Additionally, as a proof of concept, the authors performed a set of synthetic experiments to assess the approach. The obtained results clearly show the advantages of considering a more flexible evaluation of process deviations, and the impact on the quality and the interpretation of the obtained diagnostics.

With this special issue, we have attempted to describe progress in various areas of Artificial Intelligence by outlining some of the most interesting papers presented in several selected workshops of the European Conference in AI in 2020. These papers reveal a mature discipline, stating novel aspects, and opening questions and problems that require equally novel approaches. We hope that its reading can inspire new directions and solutions that can lead us to both theoretical and practical developments, helping us to advance to a future in which humans undoubtedly will be at the center of the technology.

Acknowledgements

We would like to thank the other co-organizers of the workshops involved, as well as the reviewers, for their invaluable contribution to the selection and quality of the articles included in this special issue.

Amparo Alonso-Betanzos[1], Pedro Cabalar[2], Gracaliz P. Dimuro[10,11], Marcos Garcia[3], José Hernández-Orallo[4], Raquel Hervás[5], Ángeles Manjarés[6], Fernando Martínez-Plumed[7,4], Inmaculada Mora-Jiménez[8], Miquel Sànchez-Marré[9]

[1] Research Center on Information and Communication Technologies (CITIC). Universidad da Coruña (Spain)

[2] Universidade da Coruña (Spain)

[3] Research Center in Intelligent Technologies (CiTIUS). Universidade de Santiago de Compostela, Galicia (Spain)

[4] Valencian Research Institute for Artificial Intelligence (VRAIN). Universitat Politècnica de València (Spain)

[5] Facultad de Informática, Instituto de Tecnología del Conocimiento

Universidad Complutense de Madrid (Spain)

[6] Dept. Inteligencia Artificial ETSI, UNED (Spain)

[7] European Commission Joint Research Centre, Seville (Spain)

[8] Department of Signal Theory and Communications, Telematics and Computing Systems. Universidad Rey Juan Carlos, Madrid (Spain)

[9] Intelligent Data Science and Artificial Intelligence Research Centre (IDEAI-UPC) Dept. of Computer Science, Universitat Politècnica de Catalunya, Barcelona (Spain)

[10] Centro de Ciências Computacionais (C3) Universidade Federal do Rio Grande (Brazil)

[11] Departamento de Estadística, Informática y Matemáticas Universidad Pública de Navarra, Pamplona (Spain)

References

[1] UN Global Pulse, "Big data for development: Challenges and opportunities," 2012. [Online].

[2] UN, "Human Rights Based Approach to development," 2003. [Online].

[3] UNICEF Global Innovation Centre, "Generation AI," 2003. [Online].

[4] World Wide Web Foundation, "Artificial Intelligence: The Road Ahead in Low and Middle-Income Countries," World Wide Web Foundation, 2017. [Online].

[5] International Telecommunications Union, "AI for good global summit 2018," International Telecommunication Union, Geneva, 2018. [Online].

[6] World Economic Forum, "Harnessing artificial intelligence for the earth," 2018. [Online].

[7] R. Ochigame, "The invention of "Ethical AI"," 2019. [Online].

[8] Y. Benkler, "Don't let industry write the rules for AI," *Nature*, vol. 569, no. 7754, pp. 161–162, 2019.

[9] J. Pennington, R. Socher, C. D. Manning, "Glove: Global vectors for word representation," in *Empirical Methods in Natural Language Processing (EMNLP)*, 2014, pp. 1532–1543.

[10] T. Mikolov, K. Chen, G. Corrado, J. Dean, "Efficient estimation of word representations in vector space," in *Workshop Proceedings of the International Conference on Learning Representations (ICLR) 2013*, 2013. arXiv preprint arXiv:1301.3781.

[11] J. Devlin, M.-W. Chang, K. Lee, K. Toutanova, "BERT: Pre-training of deep bidirectional transformers for language understanding," in *Proceedings of the 2019 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long and Short Papers)*, Minneapolis, Minnesota, June 2019, pp. 4171–4186, Association for Computational Linguistics.

[12] F. Martínez-Plumed, J. Hernández-Orallo, E. Gómez, "Tracking AI: The capability is (not) near," *Frontiers in Artificial Intelligence and Applications*, vol. 320: ECAI 2020, pp. 2915–2916, 2020.

[13] J. Hernández-Orallo, M. Baroni, J. Bieger, N. Chmait, D. L. Dowe, K. Hofmann, F. Martínez-Plumed, C. Strannegård, K. R. Thórisson, "A new AI evaluation cosmos: Ready to play the game?," *AI Magazine*, vol. 38, no. 3, pp. 66–69, 2017.

[14] F. Martínez-Plumed, E. Gómez, J. Hernández-Orallo, "Futures of artificial intelligence through technology readiness levels," *Telematics and Informatics*, vol. 58, p. 101525, 2021.

[15] G. Pereira Dimuro, J. Fernández, B. in Bedregal, R. Mesiar, J. Antonio Sanz, G. Lucca, H. Bustince, "The state-of-art of the generalizations of the Choquet integral: From aggregation and pre-aggregation to ordered directionally monotone functions," *Information Fusion*, vol. 57, pp. 27 – 43, 2020, doi: https://doi.org/10.1016/j.inffus.2019.10.005.

[16] G. Lucca, J. Sanz, G. Pereira Dimuro, B. Bedregal, R. Mesiar, A. Kolesárová, H. Bustince Sola, "Pre-aggregation functions: construction and an application," *IEEE Transactions on Fuzzy Systems*, vol. 24, pp. 260–272, April 2016, doi: 10.1109/TFUZZ.2015.2453020.

[17] M. Elkano, M. Galar, J. A. Sanz, P. F. Schiavo, S. Pereira, G. caliz Pereira Dimuro, E. N. Borges, H. Bustince, "Consensus via penalty functions for decision making in ensembles in fuzzy rule-based classification systems," *Applied Soft Computing*, vol. 67, pp. 728 –740, 2018, doi: https://doi.org/10.1016/j.asoc.2017.05.050.

[18] L. Ko, Y. Lu, H. Bustince, Y. Chang, Y. Chang, J. Ferandez, Y. Wang, J. A. Sanz, G. Pereira Dimuro, C. Lin, "Multimodal fuzzy fusion for enhancing the motor-imagery-based brain computer interface," *IEEE Computational Intelligence Magazine*, vol. 14, no. 1, pp. 96–106, 2019, doi: 10.1109/MCI.2018.2881647.