Conceptual relations established by processes: the case of *cocción* (firing) in industrial ceramics

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Abstract: This paper presents an analysis of some of the conceptual relations that can be established by processes in the field of ceramic industry. First, the conceptual nature of industrial processes is analysed. Second, we define argumental and circumstantial relations in which one of the elements linked by the relation belongs to the conceptual class activity. Then, we present a case study of the concept "cocción" (*firing*) in the context of ceramic industry and finally, we put forward some concluding remarks about the relationships established by processes.

Key-words: processes, conceptual relationships, ontologies, ceramic industry

Résumé: Ce papier présente une analyse de certaines relations conceptuelles qui peuvent être établies par des processus dans le domaine de l'industrie céramique. D'abord on analyse la nature conceptuelle des processus. En deuxième lieu, nous présentons des relations argumentales et circonstancielles dans lesquels un des éléments uni par le lien pourrait correspondre à la classe conceptuelle activité. Ensuite, nous présentons un cas d'étude du concept « cocción » (*cuisson*) dans le contexte de l'industrie de la céramique et finalement nous avançons quelques conclusions sur les liens établis par les processus.

Mots-clés: Processus, Relations conceptuelles, Ontologies, Industrie céramique

1 Introduction

In this contribution we study the nature of the conceptual relationships established by concepts belonging to the class activity, in particular, by industrial processes. In order to do so, we set out from the catalogue of conceptual relationships developed in our previous research (Maroto, 2007; Alcina, 2009; Maroto & Alcina, 2009).

This research is part of the TXTCERAM[1] and ONTODIC[2] projects, which are being carried out by the TecnoLeTTra Team at the Universitat Jaume I in Castellón (Spain). The TXTCERAM project's main objective is to create an electronic corpus of specialized texts from the field of ceramics which can be used to test the efficiency of certain software tools in the design of an integrated computer-assisted system for elaborating and consulting terminologies. The aim of the ONTODIC project is to propose a systematic methodology for the elaboration of onomasiological terminological dictionaries using an ontology editor. As part of these projects we are currently developing a dictionary of ceramics terminology that allows the user to make queries based on the meaning and not only through the lemma.

In this context, the formal representation of conceptual relations plays a key role when we want to retrieve information about concepts. For example, we may want to retrieve all the floor tiles produced through a particular process (for example, extrusion). If we have formally represented the relationship between each type of floor tile and its production process through the conceptual relation product-process, then we will be able to retrieve this information. In Maroto & Alcina (2009) we applied our proposal for the formalization and retrieval of conceptual information about relationships established by finished ceramic goods. In this contribution we focus on the representation of conceptual relationships established by the process of firing. Processes are complex concepts, and therefore we consider it worthwhile analysing whether our proposal for the formal representation of finished ceramic goods is also suitable in the case of industrial processes.

First of all, activity is defined as one of the conceptual classes in the model put forward by Sager and Kageura (1994) and is related to the description of "dynamic concepts" proposed by Pilke (2001) and taken up by Nuopponen (2007).

Second, we briefly describe the catalogue of conceptual relationships developed in our previous research, with special emphasis on argumental and circumstantial relationships, in which at least one of the concepts involved is a process, and therefore belongs to the conceptual class activity.

Then we explain the methodology followed and the preliminary results obtained in our empirical study of the concept "cocción" (*firing*). For this empirical study we have used both corpus and manual analysis of specialized texts about ceramic industry. We will point at some difficulties that arise when we represent knowledge about the relationships established by processes.

Finally, our model for the implementation of "cocción" in *Protégé* is presented, and we discuss the results and provide some concluding remarks about the specificity of activities with a view to implementing them in an ontology editor.

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[1] "TXTCERAM. Extracción semiautomática y análisis conceptual formal de términos de la cerámica a partir de un corpus electrónico. Su eficacia y utilidad en la mediación lingüística". (TXTCERAM. Semiautomatic extraction an formal conceptual analysis of ceramics terms extracted from an electronic corpus. Efficiency and usefulness in linguistic mediation), funded by the Generalitat Valenciana (project code: GV05/260).

[2] "ONTODIC. Metodología y tecnologías para la elaboración de diccionarios onomasiológicos basados en ontologías. Recursos terminológicos para la e-traducción" (ONTODIC. Methods and technology for the elaboration of ontology-based onomasiological dictionaries. Terminological resources for e-translation), funded by the Spanish Ministry of Science and Technology (project code: TSI2006-01911).

2 The conceptual nature of activities

In this section we analyse the nature of the conceptual class activity as described by Sager & Kageura (1994), whose model was used in the elaboration of the catalogue of conceptual relationships developed and described in detail in Maroto (2007).

Then we consider the characteristics of the so-called "dynamic concepts" defined by Pilke (2001) and taken up again for the analysis of conceptual relations in processes by Nuopponen (2007).

The concepts linked through a relationship are assigned to a conceptual class. In their conceptual model, Sager and Kageura (1994) identify four types of concepts: entities, activities, properties and relationships. In the following paragraphs we present Sager and Kageura's definition of each type of concept, supplying examples from our empirical analysis of the field of industrial ceramics:

- **a) Entity**: A type of concept obtained by the abstraction of elements from experience and reflection whose existence is considered to be independent in space and time. Entities can be defined separately and are necessary to identify and classify the units of experience and knowledge. All ceramic products (*wall tiles, floor tiles*), raw materials (*clay, stoneware*), machinery and their components (*oil hydraulic press*, *single-deck roller kiln*), as well as the places where processes occur (*dryer*) and where products are used (*walls, floors*) would be examples in the field of industrial ceramics.

- **b) Activity**: A type of concept obtained by the abstraction of processes, operations or events performed by or with entities. Their structure is more complex than that of entities because they can only be carried out with the direct participation of the latter. Some of the activities identified in the field of ceramics are manufacturing processes (*dust pressing*, *firing*) and tile-laying processes (*tiling*, *thin-set tiling*).

- **c) Property:** A type of concept derived from the analysis of the components and characteristics of entities, activities and relationships. Properties are always considered to be associated to other concepts on a first level of abstraction, and they are only constituted as independent concepts on a second level. They allow for the identification of the differences between entities and activities, while they also reflect their features and characteristics. Some examples in our thematic area would be all the characteristics of ceramic products (*frost resistance, porosity, colour*).

- **d) Relationship**: A type of concept obtained from the abstraction of physical and temporal relationships or other types of ontological relationships among objects, and from the logical relationships among entities, relationships and activities. Relationships are the type of concepts that identify the links that exist or have been established between two or more entities, activities or properties, or any combination of the three. Some examples of relationship concepts identified in the field of ceramics are *phase* (indicates a sequential relationship) and *composition* (indicates a meronymic relationship).

According to this classification of conceptual classes, industrial processes such as firing belong to the conceptual class activity. This conceptual class is complex, as it

necessarily involves the direct participation of entities. That is why in ontological engineering they are sometimes described as secondary concepts.

Nuopponen (2007: 201) describes a typical process as "a whole consisting of a series of actions or operations, and having a start and a finish". Processes consist of a designed set of operations which are carried out in a particular order, using particular tools and which produce some change in the properties of entities (or even new entities) as an outcome. Processes are therefore "dynamic concepts" in the sense proposed by Pilke (2001: 239), who defines them as concepts that can be realized either as an action or an event belonging to a certain specialist field.

Based upon Pilke's work, Nuopponen (2007: 210) applies her typology of relations (Nuopponen, 2005) to the description of the Japanese tea ceremony, and identifies five broad types of relations (with their subtypes) which are particularly relevant when describing activities, actions or processes, which are grouped as follows:

- concept relations of contiguity, such as locative or temporal relations
- activity relations, such as agent, object or teleological relations
- origination relations, such as ingredient and resultative relations
- instrumental relations, such as tool relations
- transmission relations, such as source and target relations or sequential transmission relations.

Most of these had already been described in her exhaustive classification of conceptual relations (Nuopponen, 2005), and answer to the following basic questions:

- Who? (agent)
- What? (patient)
- With what? (instrument)
- How? (method)
- Why? (cause)
- Where? (place)
- From where? (place of origin)
- To where? (destination)
- Through what? (intermediary route)

In our analysis we will concentrate on what we have called argumental and circumstantial relationships (Maroto & Alcina, 2009: 246-247), whereas temporal and place relations have not been considered at this stage of the research. Therefore, we will try to answer the following questions: who?, what?, with what?, why? and how?, adapting them to our own catalogue of relationships.

3 Conceptual relationships considered in the analysis

The catalogue of conceptual relations used in this study was developed as part of our previous research (Maroto, 2007 and Maroto & Alcina, 2009). An exhaustive description of the catalogue exceeds the scope of this paper, but we will nevertheless devote this section to summarize what we understand by conceptual relation and the main groups that have been established, with special emphasis on argumental and circumstantial relations, in which processes are always involved, and therefore are likely to appear when we try to represent knowledge about processes such as "cocción" (*firing*).

We consider relationships as semantic links between two or more specialized concepts. This definition, put forward by Otman (1996), is expressed by means of the notation ***a*** **R** ***b***, where ***a*** and ***b*** are concepts linked by the relationship **R**.

In the notation ***a*** **R** ***b***, concepts ***a*** and ***b*** linked by **R** belong to one of the conceptual classes described above (entities, activities or properties), while **R** has certain properties (transitivity, symmetry, cardinality and the existence of an inverse relation) that have consequences in the formal representation of each relationship.

Each relationship has been designated in such a way that the name shows the role played by the concepts linked, that is, which element accounts for concept ***a*** (usually called *domain* of the relationship) in the notation, and which element is represented by concept ***b*** (usually called *range* of the relationship). This naming convention – already used by Sager (1990) to name complex relationships– reveals clearly the nature and directionality of the relationship, while making it possible to identify the conceptual classes to which the domain and range of a relationship belong, and allows to test whether it is suitable for the description of the relations established by processes (activities).

Five groups of conceptual relationships were established in the catalogue: logical relationships, meronymic relationships, sequential relationships, argumental and circumstantial relationships, and other relationships[3].

In this article we focus on argumental and circumstantial relationships. The reason why we have chosen this group of relationships is that one of the elements involved is always a process, and therefore belongs to the conceptual class activity. The association of argumental and circumstantial relationships is based on a proposal by Dancette and L'Homme (2004), which coincides with the relationships that Sager (1990) calls *complex relationships*. They can be defined as the paradigmatic conceptual relationships that are established between predicates and their arguments (argumental relationships), as well as those which indicate the circumstances in which a predicate occurs (circumstantial relationships). These relations give answer to some of the above-mentioned questions suggested by Nuopponen (2007).

The following argumental and circumstantial relationships are included in our catalogue: process–agent, process–product, process–patient, process–instrument, process–state, process–method, cause–effect and object–use. We will now define briefly each relationship, explicitly stating the conceptual classes that they link and the question that they answer.

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[3] For a more comprehensive description of each relationship, see Maroto (2007) and Maroto and Alcina (2009).

- Process–agent: Relationship established between a process and the entity or entities that carry out the process. These entities can be both animate and inanimate. The conceptual classes involved can be activities (processes) and entities (agent). This relationship answers the question *Who carries out the process?*
- Process–product: Relationship established between a process and the final product resulting from the process. The conceptual classes involved can be activities (processes) and entities (products). This relationship answers the question *What entity or entities result from the process?*
- Process–patient: Relationship established between a process and the entity on which the process is carried out. The conceptual classes involved are activities (processes) and entities (patient). This relationship answers the question *On what entity is the process carried out?*
- Process–instrument: Relationship established between a process and the instrument used to carry out the process. The conceptual classes involved can be activities (processes) and entities (instruments). This relationship answers the question *With what entity is the process carried out?*
- Process–state: Relationship established between a process and the final state of the patient of the process. The conceptual classes involved can be activities (processes) and properties (state). This relationship answers the question *What is the final outcome of the process?* or even *How does the process change the prior state of affairs?*
- Process–method: Relationship established between a process and the method used to carry it out. The conceptual classes involved are always activities. This relationship answers the question *How is the process carried out?*
- Cause–effect: Relationship established between a cause and the effect it produces. The cause and effect can be entities, activities or properties. This relationship answers the question *Why is the process carried out?* or *What is the intention or purpose of the process?*
- Object–use: Relationship established between an object and the use it is meant for. This relationship can be established between entities (object) and properties or activities (use). This relationship answers the question *What is the object (final outcome of the process) used for?*

As can be seen, in every relationship at least one of the concepts involved (either the domain or the range, or both) belongs to the conceptual class activity.

4 Empirical analysis: the case of "cocción"

Firing ("cocción" in Spanish) is the crucial stage in the production of ceramic products. It consists of a set of operations –carried out in different kilns− that cause

certain physical and chemical reactions that confer the final product special properties.
We have chosen this concept as a starting point for the analysis of the relationships established by processes because it is central in the ceramic industry.

Both a manual analysis of an introductory text about firing and the analysis of concordances of the term "cocción" in a corpus of specialized texts were combined in order to extract the concepts related to "cocción" by an argumental or circumstantial relation. We have undertaken these two analyses because, although a representative corpus yields a larger set of examples, the study of an introductory text allows the researcher to reach a better understanding of the whole process of firing, which will later enable to establish relationships in the corpus.

The introductory text chosen for the manual analysis is a chapter devoted to firing in a 2005 handbook about the technology of ceramic materials written originally in Spanish by an expert in the field (Morales Güeto, 2005).

For the analysis of concordances of the term "cocción" we have explored the TXTCERAM corpus, which is a monolingual specialized corpus in Spanish about ceramic industry made up by 34 specialized texts which contains 2,444,791 words. The term "cocción" appears 4,224 times in the corpus. We have looked at the first 300 concordances in order to get a representative idea of the concepts related to "cocción".

Concepts related to "cocción" by argumental and circumstantial relationships have been identified in context, deciding in each case the type of argumental or circumstantial relationship that links each concept to "cocción". Table 1 contains examples of each relationship extracted from the corpus. The first column shows the different argumental and circumstantial relationships, whereas the second shows the two concepts linked by the relationship (one of them being always "cocción" or a closely related concept).

Argumental and circumstantial relationship	***Concepts related (domain-range)***
Process-agent	Cocción-hornero (*firing-kiln operator*) Cocción-horno (*firing-kiln*)
Process-patient	Cocción-pasta cerámica (*firing-ceramic paste*) Cocción blanca-arcilla china (*white firing-Chinese-clay*)
Process-product	Primera cocción-bizcocho (*first firing-biscuit*) Tercera cocción-decoración (*third firing-decoration*)
Process-state	Cocción-estado vítreo (*firing-vitreous state*)
Cause-effect	Cocción-contracción (*firing-contraction*) Cocción-sinteración (*firing-sintering*)

Process-instrument	Cocción-horno (*firing-kiln*) Medición de la temperatura de cocción-pirómetro (*measure of firing temperatura-pyrometer*)
Process-method	Cocción- método del microscopio electrónico (*firing-electronic microscope method*) Cocción-gresificación (*firing-vitrification*)
Object-use	--

Table 1. Examples from the empirical analysis.

We have found examples of all but one of the relationships presented in the previous section. The reason why we have not found examples for the object-use relationship is that it refers to the link between a final product and the application it is meant for, and we have been looking at the process of making these final products. We believe that if we examined other activities such as the tile-lying processes, this relationship is likely to become more relevant and yield more examples.

The assignment of a particular argumental or circumstantial relationship has not always been free of difficulties. Some problematic issues we have encountered in the analysis are the following:

- Sometimes it is hard to differentiate the process-instrument and the process-agent relationships. Although it is generally admitted that the agent must be animate, in the case of the ceramic industry, most processes are carried out without any human or other animate intervention. We can distinguish between processes in which an animate agent operates an instrument (for example, if someone uses a hammer in order to carry out an action, the hammer would be an instrument and the person who operates it would be the agent), whereas the process of firing a ceramic piece could be said to be carried out entirely by the kiln, that could be considered the agent of the whole process, as there is hardly human intervention. There seems to be a difference depending on the degree of automatization of the process. This difficulty could be overcome by establishing a clear criterion that distinguishes between those processes in which there is human intervention, where the animate entity (normally a human being) would be the agent and the inanimate entity used would be considered an instrument, and those where the inanimate entity can be considered the agent of the whole process, because it plays a quasi-active role in the process.
- A second difficulty arises from the fact that the term “cocción” is polysemous. The analysis shows that this term is used to refer both to the whole firing cycle, and to the particular step of the cycle in which the final properties of the finished product are achieved through physical and chemical reactions. This difficulty could be overcome by considering both concepts separately and establishing two separate sets of related terms depending on the meaning.

- A third problem arises from the fact that our analysis is based only on contextual information, which is not always enough in order to clarify the nature of the relationship. For example, in view of the contexts in the corpus, one may think that the relationship between "horno" (*kiln*) and "cocción" (*firing*) could be either the following three:

- Process-place: the kiln is the physical space where the firing occurs. Ex.: "horno" (*kiln*) is defined as "Una estructura en la que un material o producto se cuece, calcina o se somete de alguna manera a temperaturas elevadas". (*A structure in which a material or product is fired, calcined or is subject somehow to high temperatures*).

- Process-instrument: the firing is carried out using a kiln. Ex.: "A pesar de la ingeniería que se le haya aplicado, el horno continúa siendo un instrumento fascinante y temperamental." (*No matter how much engineering has been applied, the kiln keeps being a fascinating and temperamental instrument*).

- Process-agent: As we mentioned above, the process of firing a ceramic piece could be said to be carried out entirely by the kiln, that could be considered the agent of the whole process, in which there is hardly human intervention.

This kind of ambiguity could be resolved with the help of an expert in the field who could actually decide which relationship is more suitable from an industrial point of view, or even, it may be convenient to establish more than one relationship between the same two concepts depending on the stage of the process or other factors.

- Sometimes it was also difficult to distinguish between object-use and the process-instrument relationships. What we consider an instrument is any artefact that helps in carrying out a process, whereas the kind of object involved in the object-use relationship is considered to be a finished product and not a means of carrying out the action.

- Finally, we have become aware of the relevance and complexity of the cause-effect relationship in any process. In analysing causes and effects we have noticed that, as Nuopponen (2005) had already pointed out, there is a difference between consequence causal relations and causal coordination of concepts. That is, we can distinguish between single causes and effects (for example humidity causes corrosion) and chains of causes and effects, where the effect of the first cause may be the cause of another effect (for example humidity causes corrosion and corrosion causes the appearance of wholes on the surface of a ceramic product). Another possibility to approach causal relationships could be considering what Barrière (2002: 98) calls "semantic relation refinement", which allows to subdivide causal relationships depending on the granularity of the analysis and therefore to establish a hierarchy of causal relationships.

5 Implementation of the concept "cocción" in the ontology editor *Protégé*

Once the concepts related to "cocción" through argumental and circumstantial relationships have been identified, this concept and the related concepts have been introduced in the conceptual database *Ontoceram,* created using the ontology editor *Protégé-frames* (Stanford Medical Informatics, 2009).

In this database, concepts are represented through the *Class* component of *Protégé*. The concept "cocción" is inserted in the concept hierarchy as a subordinate of PROCESO (*"process"*), which in turn depends from the top concept ACTIVIDAD ("activity"). The hierarchical structure enables to reflect the relationship between generic and specific concepts. For example, "monococción" (*single firing*) is a subtype of firing and therefore is situated depending from "cocción" in the hierarchy of concepts.

The concepts related to "cocción" are also represented through the *Class* component of *Protégé.* The link between "cocción" and its related concepts is represented through the *Slot* component, which allows for the assignment of attributes, thus making the relationships explicit in *Ontoceram.*

Terms are represented through the *Instance* component of the ontology editor, thus making it possible to retrieve the information through queries (Maroto & Alcina, 2009: 255-256).

In the screenshot shown in **Fig. 1** it can be seen how the concept *Cocción* and its related concepts appear in *Ontoceram*. This concept is subordinated to PROCESO (*process*) and has been assigned several relationship *slots* that link "cocción" to other concepts also included in the database. For example, "cocción" has been related to "contracción" (*contraction*) and "sinterazión" (*sintering*) through the slot "causa-efecto" (*cause-effect*).

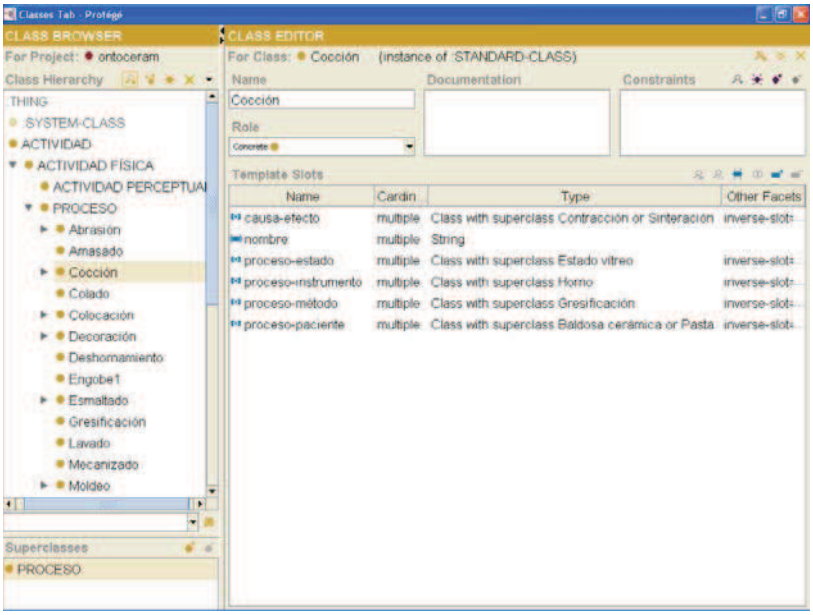

Fig. 1 – Implementation of the concept "cocción" (*firing*) in *Ontoceram.*

6 Conclusion

The analysis of the argumental and circumstantial relations established by the process of firing in the ceramic industry presented in the contribution has allowed us to test the validity of the catalogue of conceptual relationships established in our previous research for the representation of knowledge about activities.

Although the relationships initially proposed seem to be useful for this task, there are several aspects that need further refinement.

First, we need to better define the nature of the concepts linked by each relationship in order to avoid ambiguity. Experts in the field could help in order to determine the type of relationship that better suits the requirements of the specialized field when the analysis of specialized texts suggests that more than one relation is possible. We should also establish clear criteria in order to define the scope of each argumental and circumstantial relationship.

Second, the cause-effect relationship needs to be further refined in order to better represent the possibility of cause-effect chains.

Finally, the analysis of argumental and circumstantial relationships needs to be complemented with the study of other relevant relationships, such as generic-specific relationships (in order to reflect different kinds of firing processes) and meronymic relationships (in particular the stage-process relationship). Other relevant relationships that need further analysis are sequential relationships (both spatial and temporal) in order to fully represent processes.

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