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An Ontology Design Pattern of the Multidisciplinary and Complex Field of Climate Change

Ibrahima Diop[1] and Moussa Lo[2]

[1] **Laboratoire d'Analyse Numérique et d'Informatique (LANI),**

UMMISCO UGB – Team LIRIMA University Gaston Berger

Ibrahima.diop2010@gmail.com

[2] **Laboratoire d'Analyse Numérique et d'Informatique (LANI),**

UMMISCO UGB – Team LIRIMA University Gaston Berger

moussa.lo@ugb.edu.sn

Abstract

This article presents the manual and collaborative construction of an ontology design pattern (a generic ontology), named OntoCLUVA, of climate change (CC) field. This pattern is built for the needs of the construction of climate change ontologies. We used this pattern for a knowledge management system (KMS) of climate change. It will allow to each module of this KMS to build its own ontology of climate change domain for its tasks consisting in discovering and adapting the ontology components.

Keywords: *ontology design pattern, generic ontology, ontology construction, knowledge management system, OntoCLUVA, climate change.*

1. Introduction

Under the CLUVA project[1], one of the needs is to have a Knowledge Management System (KMS) composed of several modules (tasks) that require knowledge about climate change (CC) domain. In this context, we cannot build a single ontology of this domain, to all the tasks of the KMS's modules. But, based on the assumption [1] saying that: "an ontology can be generic for a set of tasks if it has a level of description detail allowing to represent the views of each task.", we propose to build a generic ontology of the climate change that is reusable in the ontologies design in this field. This is a problematic of the works on Ontology Design Patterns (ODP) [2], [3] and [4]. The idea of this ODP approach is to design a pattern and from this one, build ontologies, by discovering and adapting ontologies components that are specific to a task.
An ontology design pattern is a generic block that goes into the design of several ontologies or serves as a basis via an adaptation to the creation of several components, see Figure 1.
An ontology component is a basic block that goes in the design of an ontology and that can be very specific, see Figure 1.

[1] www.cluva.eu

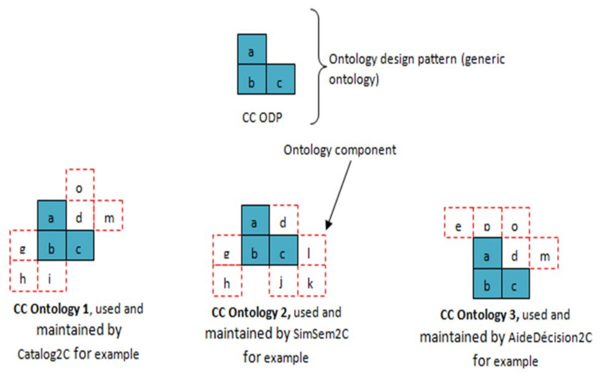

Fig. 1 Illustration of an ontology design pattern and ontologies components in a context of a knowledge management system of climate change.

This paper presents the context of the construction of an ontology design pattern, the climate change domain. We present the construction of this ontology design pattern in several phases. Then, we propose solutions for the construction of climate change domain ontologies using this pattern.

2. The climate change domain

2.1 A multidisciplinary and complex domain

The consequences of global warming justify the interest of politicians and scientists on the issue of climate change which is a multidisciplinary and complex field. That is to say, it is at the crossroads of several interrelated disciplines such as climate, planning, risk governance, etc. Therefore, it involves several experts: geographers, planners, hydrologists, climatologists, economists, sociologists, mathematicians, etc.

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The climate change area involves more human and institutional actors who have different specialties among others communicate and share their knowledge to better play their roles in this area. An ontology of this area is a great need for the integration of data and models, semantic search for resources, etc. This is to meet the needs of communication and sharing of knowledge of the actors in the governance of risks and catastrophes.

In the field of climate change, knowledge occupies a strategic place in the governance of risks and catastrophes, especially in systems such as the adaptation of populations and organizations, resilience or vulnerability reduction, etc. Some become increasingly complex systems with their simulations (by experts for a better understanding), which cannot leave aside the domain knowledge of climate change representable by an ontology of the domain, communications and behaviors of autonomous entities or agents (individuals, populations, organizations, etc.).

We did not find existing ontological resources to this area. What we found was rather a conceptual model of risks and catastrophes [5]. This conceptual model is not in the context of climate change, but in a general context of risks and catastrophes management. It does not address the risks and catastrophes due to climate change.

In addition to the intensity of work in the field of ontology engineering for knowledge representation and the real need of domain knowledge of climate change for the communication, the resource sharing and the simulation of complex systems, we found, he has not yet built an ontology for the CC area.

It is therefore important to build a design pattern ontologies (a generic ontology) making a good abstraction of this area of CC to facilitate the construction of ontologies in this complex and multidisciplinary area of CC.

In this article, after the construction of this pattern we develop possible uses of the pattern to go to specific ontologies tasks in this area.

2.2 A manual methodology for the construction of a generic ontology (ontology design pattern) of climate change.

The ontology building methodologies can be classified into three categories: reuse existing ontologies [6], [7], knowledge process [8], [9] and manual design [10], [11], [12].

For the construction of a generic ontology of the multidisciplinary and complex field of climate change, we have not used a methodology based on the reuse of existing ontologies. Because we did not find existing ontological resources (ontology design patterns, ontology component or ontology) for this domain.

We did not also choose a methodology based on processes that extract knowledge through texts and data, since we have lots of existing terminology resources in this field. But, thanks to a discussion in [13], we have realized that it is technically difficult for those processes to delimit the corpus and also to extract expertise and good practice from textual documents. This report is relevant in the case of a multidisciplinary and complex field such as the climate change field. It is difficult to extract all knowledge if we ignore the interdependence between corpora.

Why a manual methodology for the construction of a generic ontology of climate change?

Firstly, the field of CC is multidisciplinary and complex. So it has several interrelated corpora of texts: many concepts and relationships candidates for inclusion in the ontology. Since the need is to build an ontology, only little concepts and relationships (the most generic) among the large number of candidates have to be included in the ontology.

This raises the problem of making good abstraction, i.e., selecting concepts and relationships so that all modules of the KMS start the construction of its ontologies with this generic ontology (ontology design pattern).

Manual methods, favoring a more advanced understanding, lead to better abstraction than those of semi-automatic learning. Moreover, the cost in time and effort, in choosing a manual methodology, are reduced by the fact of building a generic ontology (limited number of concepts and relationships).

Thus, we propose a manual methodology. It has a life cycle based on the proposal of [14] which is a fusion of proposals life cycles [10] and [15]. In this proposal [14], the life cycle can be seen in three steps: the construction, the use and the maintenance.

The last part of this article discusses only the construction of this ontology design pattern and is done in several phases: specification phase, knowledge acquisition phase, sub domains conceptualization phase, integration of sub domains conceptualizations phase and phases of formalization and implementation.

3. Specification phase

The specification phase begins with the creation of a steering group for the construction of the ontology named organizer group. In this phase, the needs that motivate the ontology construction are described and the following are done: the division into sub domains, the identification of communication channels between the sub domains, the competencies questionnaire (skills questionnaire), the assignation experts in the sub domains and the communication channels.

3.1 Organizer group

The organizer group is responsible to organize and to control the construction of this generic ontology. Thus, it

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cuts the domain into sub domain, which carries out the questionnaire and from this one proposes an allocation of experts in the subfields.
This group is also in charge of knowledge acquisition from terminological resources and knowledge collections techniques. As a result of this knowledge acquisition, the organizer group produces a network of sub domains and an informal model for each sub domain to serve as a working basis and examples to the experts during the conceptualization of the sub domains.
This group participates in the conceptualization of each sub domain in order to compliance with the rules of conceptualization and integration consensus as defined later in this specification phase.
The members of this group consist of a very limited number of knowledge engineers and experts who have extensive experience that allows them to have an overview of the field.
The OntoCLUVA organizer group consists of two knowledge engineers and an expert of the climate change domain.

3.2 Needs description

The objectives or ambitions of the ontology are explained in this step needs description. The goal is to build a generic ontology for climate change domain reusable for getting specific ontologies that meet the needs of knowledge of modules of a KMS in this field, see figure 2. For this purpose, we use this ontology design pattern for the constructions of climate change ontologies allowing to dispose:

- a metric space for the semantic search in a catalog of climate change partners resources,
- a meta model for semantic simulator of complex systems of the climate change field,
- a shared vocabulary for the integration semantics multi agent systems for the domain of CC,
- a global vocabulary of architecture of data integration module of climate change.

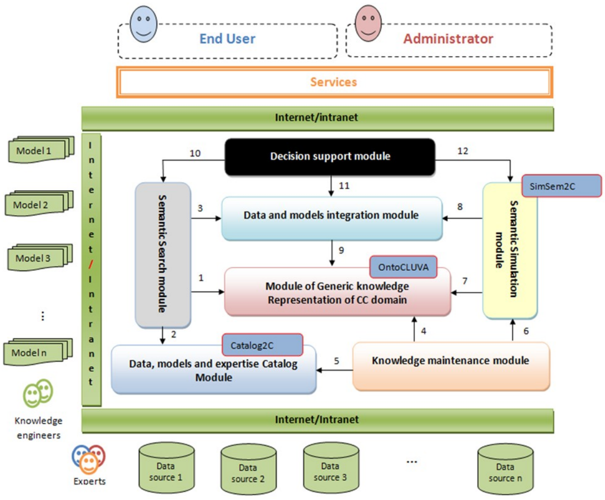

Fig. 2 General and functional architecture of a knowledge management system of climate change centered on the representation of generic knowledge of CC that is to say, the construction of an ontology design pattern of CC.

3.3 Sub domains division and communication channels identification of climate change field

For the sub domains division and communication channels identification steps, the organizer group does manuals treatments of general corpus and experts interviews. In the case of the OntoCLUVA construction, this group offered a division of the climate change (CC) field into four (4) sub domains or systems:

- *Climate change* system contains the concepts and relations related to climate, to hazard, to human action on the climate...;
- *Urban vulnerability* system contains the concepts and relations related to the urban system and its vulnerabilities…;
- *Risks and catastrophes* system contains the concepts and relations related to risks, catastrophes and damages…;
- *Governance* system contains concepts and relations related to the ruling body actors, to actors' roles or missions, and to their instruments...

After sub domains division, in considering the complexity of the climate change field, the organizer group proposes communication channels reflecting the relationship between sub domains noted: (1), (2), (3), (4) and (5) in the network (graph) of sub domains of Figure 3.

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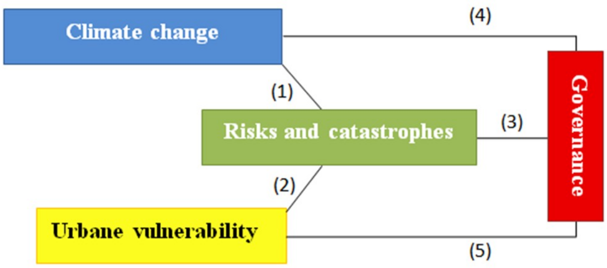

Fig. 3 Sub domains network of climate change

In this network, only the sub domains climate change and vulnerability do not maintain a direct communication. But they communicate indirectly through sub-domains risks and catastrophes and governance. Because according to the documentation work (informal document analysis of the general corpus), the interviews with experts and the brainstorming to validate this sub domains network, it appears that: climate change and vulnerability are two separated systems. But the coupling of this two sub systems gives the risks and catastrophes that lead to the need for governance. Governance is to manage risks and catastrophes. It is also to prevent the risks and catastrophes by understanding the causes of climate change to make decisions to reduce the phenomenon and by understanding the urban vulnerability in order to reduce that vulnerability.
This sub domain network is a beautiful synthesis of climate change field and is used for the realization of the competencies questionnaire (skills questionnaire) for the management of the multidisciplinary field in the construction of this ontology.

3.4 Skills questionnaire

The organizer group proposes a skills questionnaire (see Appendix1) to be filled by all the experts involved in the construction of OntoCLUVA ontology. This questionnaire results from the needs that motivate the creation of the ontology and the sub-domains network (Figure 3). It helps to know the profiles of our experts and to find out where we do not have enough skills in order to indentify the limits of the ontology building.
The questionnaire contains information about the expert (name, surname, laboratory steam...) who fills it. It also contains key concepts that the expert chooses to show his skills in CC. In this questionnaire the expert may indicate other information related to his grade or level, his thesis topic, the keywords associated with his thesis subject and a summary of his experiences in the conceptualization of the field of climate change.
After filling the questionnaire by an expert, the organizer group adds to it an identifier of the expert (E1, E2,..., En). These are identifiers that are handled in the next steps of the construction of the ontology.
This questionnaire is then very useful as it allows to allocate the experts.

3.5 Affectation of experts

With the information provided by this skills questionnaire, we determine the experts involved in the conceptualization of each sub domain, including channels experts.
A channel expert in two interrelated sub domains is an expert who has expertise in both sub domains and therefore has checked in his skills questionnaire concepts in both sub domains. He participated in the conceptualizations of the two interrelated sub domains and play important roles. He serves as a relay and informs to the experts of one sub domain about what is happening in the conceptualization of the other sub domain.
Helped by knowledge engineers, experts channels are our solution to manage conflicts, inconsistencies and verifications.
Figure 4, below, shows the shared spaces of conceptualizations that were created for the conceptualization of the sub domains obtained from the division of the domain into sub domain. Figure 4 also shows that the assignments of experts, based on information from the questionnaires tuck in sub domains and communication channels that are shared spaces.

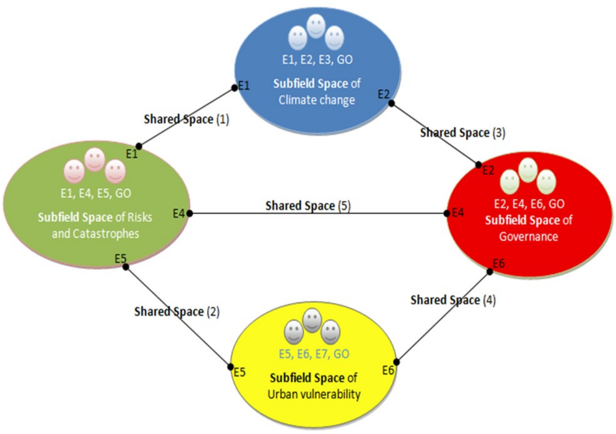

Fig. 4 Experts affectations in the sub domains and communications channels

In the figure 4, E4 is the identifier of the expert channel of channel three (3) between the sub domains "governance" and "risks and catastrophes."

3.6 Consensus of conceptualization and integration

The consensus enables experts to conceptualize and integrate conceptual models of sub domains. Note that the

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consensus, in our case, is not a whole process to build the ontology, as defined in [16]. But there is a set of rules used in the phases of conceptualization and integration to trace the boundaries of experts according to their expertise in the field.
In the case of OntoCLUVA, the consensus is derived from the network of sub domains by the organizer group and is subject to consents of experts. It is thus divided into five (5) rules; see table 1, of which the three (3) are for sub domain conceptualization and the remaining two (2) to integrate sub domains conceptualizations. The conceptualization of a sub domain and the integration of these sub domains are collaborative because the field of climate change is multidisciplinary and complex.

Table 1: consensus of sub domain conceptualization and sub domains integration

Rule 1:	The concepts of each subfield are proposed by experts in that same subfield.
Rule 2:	It is the channel expert who decides if a conflict concept belongs to one or the other sub domain of its channel.
Rule 3:	The semantic relations between concepts in the same subfield are proposed by experts in this subfield.
Rule 4:	In order to get relations between the concepts of two different subfields, it is necessary for these two subfields to share a communication channel. In the division into subfields of the Figure 3, these channels are denoted by (1), (2), (3), (4), and (5).
Rule 5:	The relations between the concepts of two different subfields, sharing a channel and proposed by the experts of one of the subfield, are validated by experts of the other one.

The specification phase ends with a meeting of the experts of the subfields, about information and validation, prepared by the organizer group. In this meeting, the organizer group presents at first the need motivating the construction of ontology OntoCLUVA and the acquisition of knowledge based on the general corpus and acquisition of knowledge techniques. Then, it presents the division into sub domain of the climate change, the allocation of experts in these sub domains, the informal models sub domains and the consensus conceptualization and the proposed integration during the various stages of the specification phase.
After giving the experts the necessary information, it is up to the sponsor brainstorming experts to validate the sub domains division, the experts' assignments in the sub domains below and the consensus of conceptualization and integration.
Thus, this meeting helps the organizer group to enrich its proposals with input from experts in the subfields. But also the meeting allows to impregnate experts before starting the conceptualization and, from the start, to make them collaborate in the dynamic of the construction of this OntoCLUVA ontology.

4. Knowledge acquisition phase

The knowledge acquisition for the construction of OntoCLUVA ontology is an ongoing process, which is called in all phases of the construction of the ontology. It is based on the terminological resources, the expertise of experts in the field of climate change and manual collection techniques, which are: informal analysis of documents, free interviews and brainstorming.
The terminological resources used in OntoCLUVA construction are organized in several corpora:

- The general corpus is formed by the group organizer to understand the generalities of the domain of climate change. This corpus is used to cut into sub domains and provides informal models of the sub domains.
- The corpora of sub domains are mainly used in the conceptualization of the sub domains. They are made by experts in the fields.

4.1 Knowledge acquisition in the specification phase

For the acquisition of knowledge in the specification phase, see area A in Figure 5, the organizer group uses the general corpus and the manual collection techniques.
The informal analysis of documents and the free interviews are manual collection techniques used in this phase that lead to the organizer group to do the sub domains division and to prepare meetings of experts offering the informal models of each sub domains (see the Appendixes 2, 3, 4 and 5).

4.2 Knowledge acquisition in the conceptualization phase

In the conceptualization phase, for each sub domain, experts are the central actors. In their tasks of conceptualizing of their sub domain, experts of a sub domain are in contact with the organizer group which offers them, during a meeting (brainstorming), the general corpus, the network sub domain and the informal model of their sub domain.
The experts in each field set up specific corpus in their subfield and also use the techniques of collection manuals of knowledge that are: informal analysis of documents (general corpus and specific corpus), free talks between experts and brainstorming (meeting between experts in a domain), see area B of Figure 5.

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4.3 Knowledge acquisition in the integration phase

To integrate conceptualizations of sub domains, actors are the group organizer and the canals experts. They have general corpus (through the group Organization), specifics corpora of sub-domains, conceptual models of sub domains (via channel experts who are also experts sub domains), consensus of conceptualization and integration and manual acquisition techniques to provide the final conceptual model of climate change field, see area C of Figure 5.

4.4 Knowledge acquisition in formalization and implementation phases

The resources of these phases of formalization and implementation are the organizer group, the needs motivating the construction of the ontology and the final conceptual model obtained after integrating conceptualizations of sub domains. To move from this final conceptual model to the ontology, the organizer group chooses a formalism and an implementation tool to meet the needs of the system of knowledge management.
Figure 5 shows the process of knowledge acquisition in the specification, conceptualization and integration phase.

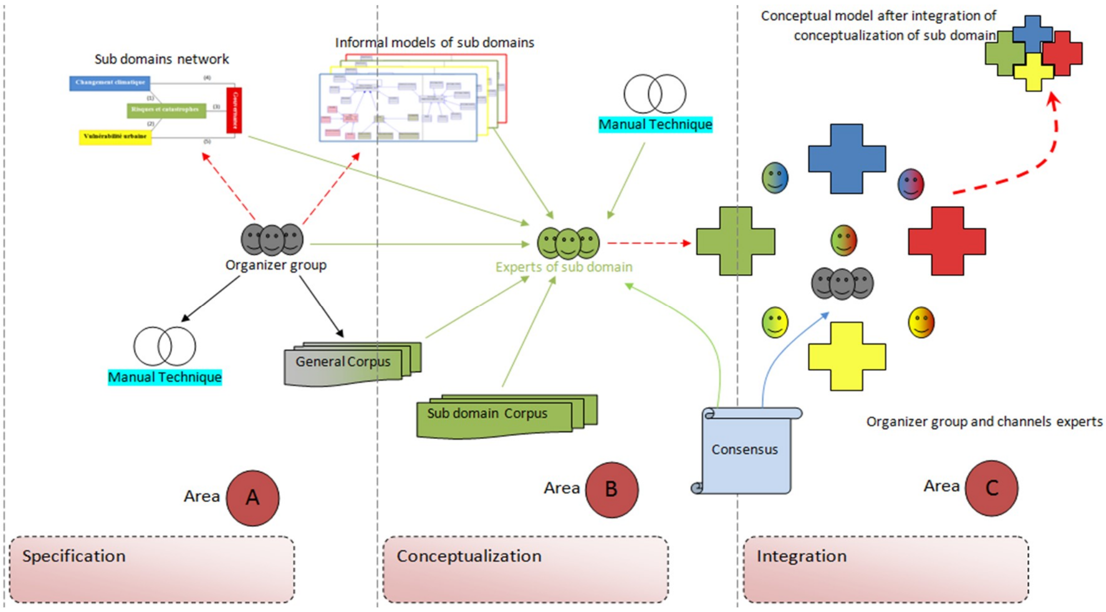

Fig. 5 Knowledge acquisition processes of specification, conceptualization and integration phases

Now, we have experts in every sub domain having their corpus of resources, a consensus of conceptualization and integration, an informal model for their sub domain obtained in the specification phase. In the next, we turn to the conceptualization of the sub domains.

5. The other phases

5.1 Conceptualization phase

The conceptualization of a sub domain begins with an information session where the organizer group presents the used general corpus, the used knowledge acquisitions techniques, the proposed sub domain network and the obtained informal conceptual models of sub domains by this group.

Then, follows a discussion between experts, brainstorming, based on their informal model proposed during the knowledge acquisition in the specification phase.
The experts do the necessary changes in their informal model and in addition to the general corpus they take into account the corpus of their sub domains and their expertise.
In their proposals, experts in a field have to respect the consensus of conceptualization and integration, and the remarks of the channels experts and the organizer group. An example of these remarks can be that a concept is already present in the conceptualization of another sub domain. This may involve putting this concept in a color chosen by the concerned expert channel, to show its presence in another sub domain.

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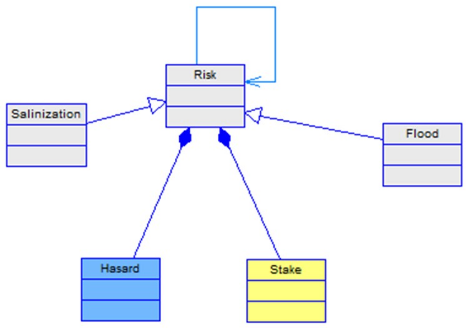

Fig. 6 Illustration of the conceptualization of a sub domain by its experts from their informal model

The purpose of a meeting of conceptualization of a sub domain is to propose a conceptual model accepted by experts in this field that respects the consensus integration.

5.2 Integration of sub domains conceptualizations Phase

The sub domains are conceptualized by taking into account the fact that they will be integrated later through the presence of the channel experts and the organizer group which participle in the conceptualizations of interrelated sub domains and the establishment of a consensus of conceptualization and integration.
Channels experts verify that the consensus is respected and validate the inter relationships of sub domains. These experts together with the organizer group align the conceptual models of sub domains in order to get the conceptual model of the generic ontology OntoCLUVA which will be validated by the following experts in all areas before being formalized and implemented.

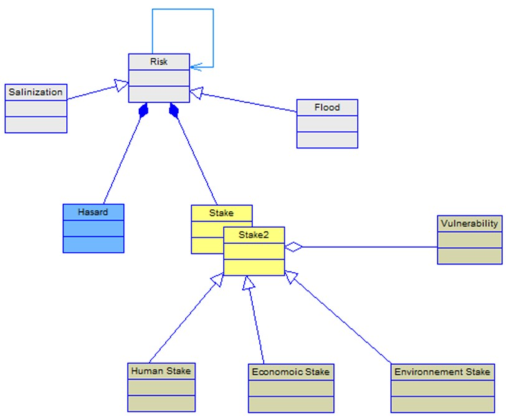

Fig. 7 Expert canal (2) appointed E5 merges the two concepts "Stake". It has put the concepts in yellow color in order to show that they are related.

5.3 Formalization and implementation phases

OWL[1], a language that provides a way to write web ontologies, is a W3C Recommendation since February 10, 2004. OWL takes advantage in the universality of XML syntax. Compared to RDF and RDFS, which provides the user the ability to describe classes and properties, OWL includes, in addition, comparison tools properties and classes: identity, equity, otherwise, cardinality, symmetry, transitivity , disjunction, etc. OWL provides greater machinery ability for interpretation than RDF and RDFS, thanks to a wider vocabulary and a real formal semantics. This motivated our choice OWL to formalize OntoCLUVA.
To implement OntoCLUVA, we use Protégé [17], which is an ontology editor distributed as open source. Protégé is a highly extensible editor capable of handling a wide variety of formats. It supports OWL, like many other formats.

6. Ontology building methodology for climate change

The manual methodologies of ontology construction, starting often from scratch, are very expensive in terms of human resources and time. These problems have driven the research towards semi-automatic learning methods: ontologies reuse and knowledge extraction processes from texts. The main purpose of these learning semi-automatic methods is to reduce the time and the efforts required in the development process of an ontology [18].
But the problem with these methodologies is that the techniques used are not yet able to meet the challenges of extracting knowledge from the texts in the field and reuse of ontologies built in contexts or tasks different. This is why, today, ontologies are build, although containing the concepts and relationships in the field, but without a good abstraction that is the justification for the relevance of the concepts and relationships of an ontology for the context use or for those tasks.
These problems of semi-automatic learning techniques become more difficult in the case of complex and multidisciplinary areas such as the area of climate change. Because in these areas, there are several disciplines involved thus more corpora to set up and according to its complexity, these corpora are interdependent. It is difficult to extract some knowledge if we leave aside the interdependence between the corpora. Similarly, if ontologies exist in these areas, to reflect the multidisciplinary and complexity, a methodology based on the reuse of ontologies request to have more advanced technology than we have today.

[1] http://www.w3.org/TR/owl-ref/

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Thus, the construction of an ontology of a multidisciplinary and complex field as the field of CC is still a problem to be solved if we want to take into account the context of use and the tasks of this ontology.

To build ontologies of multidisciplinary and complex domain, one should not watch these ontological engineering methodologies separately, but instead they should be seen as complementary [19].

With the patron OntoCLUVA of climate change, we propose to reduce the time and effort to build ontologies in the field of climate change. Thus, in the figure 8, we propose to use the NeOn methodology for ontology engineering [19] and OntoCLUVA for only from a expressed need of ontology of climate change build a specific ontology for this expressed need.

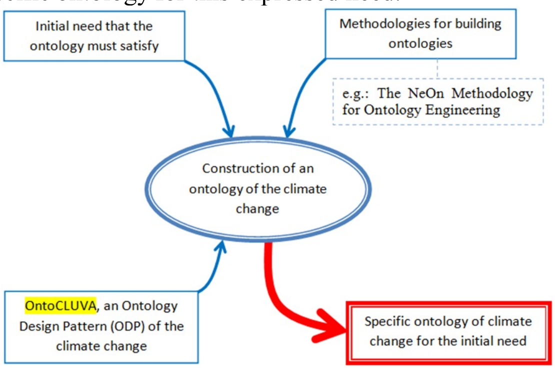

Fig. 8: illustration of the use of OntoCLUVA for the construction of climate change ontologies with, for example, the NeOn methodology [19] for ontology engineering

It is this vision that guided the construction of ontologies of the multidisciplinary and complex field of climate change for a KMS of this field. We started to make a good abstraction with manual methodology to obtain an ontology design pattern or a generic ontology. Then, we used this pattern for the constructions of other ontologies with semi-automatic learning methodologies based on discovery and adaptation of ontologies components (see figure 9).

For this, we currently use this patron OntoCLUVA as metric space in the semantic search for resources in a catalog, named Catalog2C of resources of partners of climate change field.

We have also used the patron OntoCLUVA as meta model of semantic simulation of complex systems in the field of climate change which is an application of a semantic architecture of SMA [20] that we have proposed.

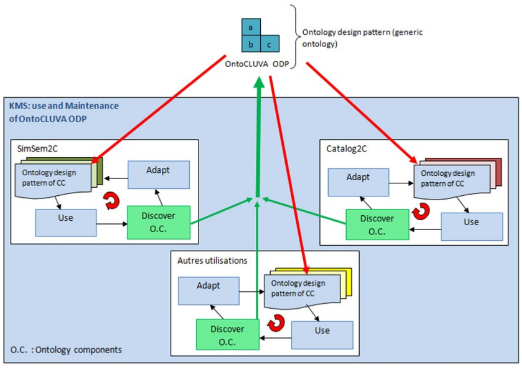

Fig. 9 the use of the ontology design pattern (generic ontology) of the field of climate change, called OntoCLUVA, in a knowledge management system.

This manual construction of an ontology design pattern (generic ontology) of climate change domain named OntoCLUVA and the maintenance of this ontology in their context of use based on semi automatic techniques are the first steps towards a collaborative methodology for the construction of generic ontology of multidisciplinary and complex areas.

It is also possible to maintain this ontology design pattern (generic ontology) itself with the assumption that if an ontology component is discovered by all applications (KMS modules) or that experts see the value of a ontology component founded even by a single application, then this component is an ODP. We agree with this idea in [21] saying: "*It is possible to combine and match these two visions of components and patterns: a component - operation or structure – become a design pattern if it displays a certain frequency and a certain interest showing that it is used and considered useful*".

7. Conclusion

In this work, we produced an ontology design pattern of the complex and multidisciplinary field of climate change. This pattern allows to build ontologies on climate change.

In this work, we have also proposed a methodology to build ontologies of climate change from this pattern.

We used this methodology to build ontologies of climate change for Catalog2C and SimSem2C applications or modules of knowledge management system of climate change that we offer.

To complete the requirement described in this knowledge management system with a semantic simulation other use of this ontology are underway in the architecture of the module data integration of climate change and the architecture of the module of decision support for the actors in the governance of climate risks.

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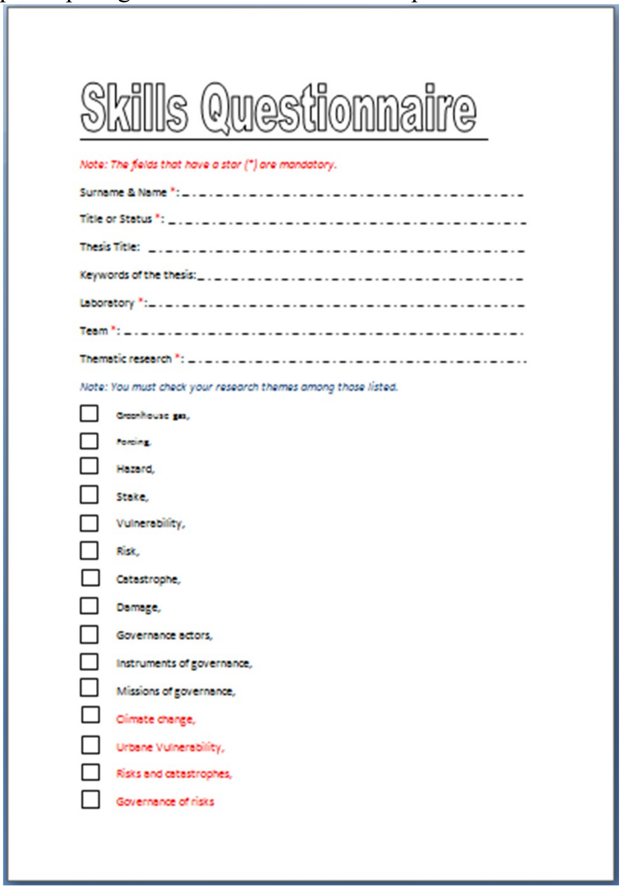
Appendix

Appendix 1, the skills questionnaire for the experts participating in the OntoCLUVA conceptualization



Skills Questionnaire

Note: The fields that have a star (*) are mandatory.

Surname & Name *: ____________________

Title or Status *: ____________________

Thesis Title: ____________________

Keywords of the thesis: ____________________

Laboratory *: ____________________

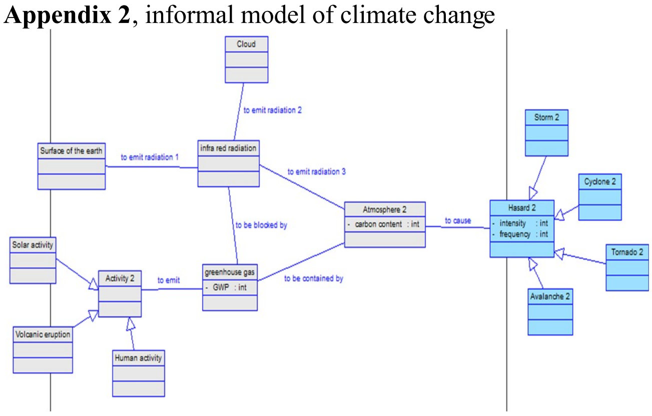
Team *: ____________________

Thematic research *: ____________________

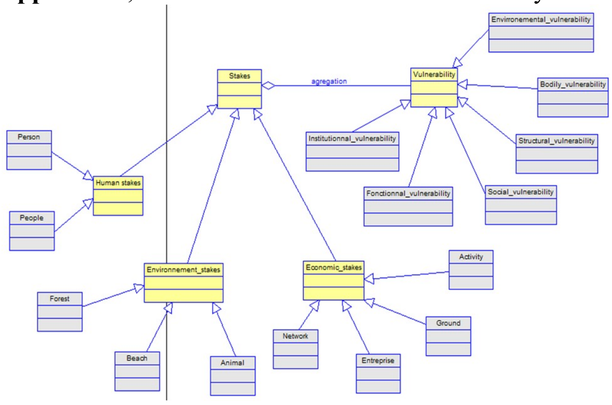
Note: You must check your research themes among those listed.

- ☐ Greenhouse gas,
- ☐ Forcing,
- ☐ Hazard,
- ☐ Stake,
- ☐ Vulnerability,
- ☐ Risk,
- ☐ Catastrophe,
- ☐ Damage,
- ☐ Governance actors,
- ☐ Instruments of governance,
- ☐ Missions of governance,
- ☐ Climate change,
- ☐ Urbane Vulnerability,
- ☐ Risks and catastrophes,
- ☐ Governance of risks

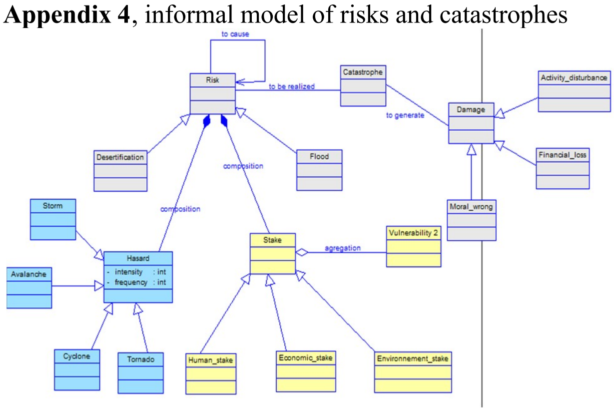
Appendix 2, informal model of climate change



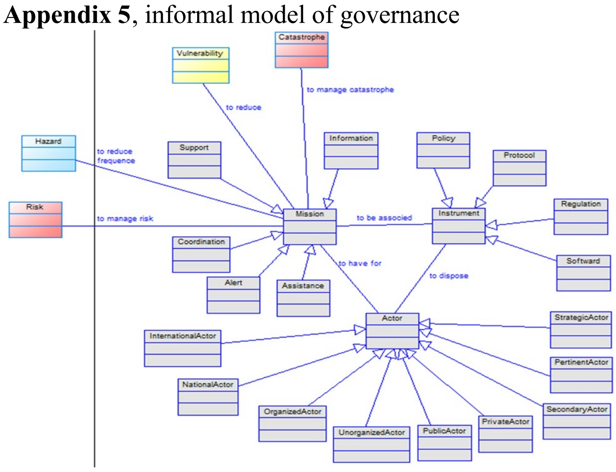
Appendix 3, informal model of urbane vulnerability



Appendix 4, informal model of risks and catastrophes



Appendix 5, informal model of governance



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