Chapter 1 – Introduction (planning)

[Flow: Communication Process->Vocabularies->Controlled Vocabularies->Goals of CV->Ontology->Ontology problems->Ontology learning->Pattern Extraction/Knowledge discovery->Approach to enrich an ontology based in data mining techniques.]

1P - Communication process/Languages/Vocabularies

2P - Controlled vocabularies, what are they?

3P - What problems CVs address?

* words with similar meaning and different spelling (Synonym),
* words with the same spelling and different meaning (Homograph)
* Standardization of the vocabulary of a community, one term represent only one concept

4P - Ontology as a form of CV, what is an ontology?

Why use an ontology?

5P - Problems of ontologies.

Static

Require previous agreement on the vocabulary

Require high maintenance

6P - (Automatic maintenance) Ontology learning, to help on maintenance of an ontology

What processes/techniques exist?

7P - Pattern Extraction and Data Mining Techniques to help on ontology learning and knowledge discovery

8P - What will I propose? Approach to discover knowledge in unstructured documents.

Section 1.1 – Challenges

* Lack of existence of a pure approach to quantify relations discovered from unstructured information in documents, without help of an ontology.

Ontology learning is a problem because there are no pure automatic mechanisms. (Explain ontology learning??)

* What can be done to measure a relation and find its meaning?
* This document presents an approach to help discover relations in unstructured information in documents, knowing that there are no real methods to help measure a relation between two or more concepts.

Research question:

How to quantify semantic relations between concepts in a domain ontology, using external sources of non-structured information.

Hypothesis:

Semantic relations between concepts from a domain ontology, can be quantified by applying data mining techniques for pattern extraction into non-structured sources of information.

* Having a set of documents with unstructured information, how could meaning be discovered, in the way of relations between its concepts?
* How to discover the domain of a set of words?

Section 1.2 – Expected outcomes

Present the way that I will propose solutions to research questions.

* How to address the problems?
* What techniques to use?
* Why are these techniques used to solve the problems, and not others?
* Develop a system, proof of concept, to present the results to domain experts.

Section 1.3 – Context of work

* Falar onde foi desenvolvido o trabalho
* A sua ligação com os projetos europeus (e-Cognos e CoSPaces)
* Enquadramento da tese de doutoramento do Ruben e a minha contribuição para a mesma.

Section 1.4 – Document Structure

Chapter 2 – Controlled Vocabularies

* (What are they? What do they represent?)
* What forms of representation of information exist?
* Ontologies (Definition, Construction, relations, concepts)

What is an ontology? What is it utility? How to construct one? Languages to represent it.

* E-cognos (European project for the creation of an ontology in B&C domain)
* Ontology learning
* Relations (meaning)
* Concepts
* Application domain. (Practical cases in building and construction domain)

Chapter 3 – Pattern Extraction from unstructured information sources

* Data mining / Knowledge Discovery. (What is DM/KD? Techniques used today?)
* Association Rules (Definition, Rules)
  + Algorithms to discover [ECLAT, APRIORI, FP-GROWTH]
  + Weaknesses/Strengths between them
  + Why FP-Growth?
* Application domain. (Practical cases where association rules are used)

Chapter 4 – Concept Model

- Explain conceptual model/solution

- Describe an application example

From unstructured information to knowledge representation and ontology structure

- Dimensions included in the model???

- Enrichment process

FP-Growth how to build and FP-Tree

Association rule evaluation

- DER / MVC / UML Diagrams

Chapter 5 – Model Design and Development (Proof of concept)

- Method proposal to address the question.

- What were the technologies used for the solution.

Technologies used,

- Implementation description.

(Present the server / front end solution)

- Include use cases (Relations discovered, new concepts discovered, etc.)

(Discover a relation between two concepts, update a relation between two concepts, and discover new concepts)

- Front end

Brief explanation of the functionality of the front end. Explain in a form of manual??

Chapter 6 – Assessment

* Present list of relations discovered and discuss them
* Present new concepts discovered

Chapter 7 – Conclusion and Future directions

- Evaluate if the goals reached success.

- Evaluate the achievement of the hypothesis

- Present the paper

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# Introduction

With the exponential growth of available information in digital format nowadays, rises the necessity to discover ways to organize it, in order to be easily accessible. For an information search to succeed, meaning that the results provided by the search mechanism are exactly the ones being searched for, this search has to include the same terms of each document. This suggests that a simple search by term for the information could not be enough, as the set of terms, or vocabulary available in information being searched could be different from the vocabulary being used. Therefore, it is of great importance to discover approaches for the representation of ideas (concepts), and not just the representation of vocabs, with the purpose of access the information intended.

Nowadays, computers systems can represent sets of terms or words (also referred to as vocabularies). However, vocabularies themselves, do not represent ideas or concepts, they just represent words. In order represent concepts and ideas, one approach can be considered. This approach is the use of mechanisms to represent more than pure words, to represent concepts. These mechanisms are referred as Controlled Vocabularies (CV). CVs are defined subsets of terms from a natural language, like English, used to represent concepts, with some sort of organization. CVs represent the concepts by assigning to each, one or more words, or phrases that translates its meaning.

Natural languages are very rich in their vocabulary properties. They can have different meanings represented by the same word (Homograph words), in several contexts. Also, there are words that can be pronounced in the same way, however have different spelling and meaning (Homophone words). Homograph and Homophone words can lead to ambiguity and confusion when using the terms by people. CVs address the problems of Homograph and Homophone words solving them by assigning each term to just one concept, narrowing down the possibility of one term represent more than one meaning. The goal of the former step is to remove the ambiguity existent in the words of a language and to provide the necessary consistency to the use of these words, in the domain where a CV is applied.

An Ontology is a type of CV that addresses problems like the consistent representation or word ambiguity in information. Specifically, Gruber provides a definition for ontology as “*(...) a formal specification of a shared conceptualization of a domain of interest.*” (Gruber, 1993) In other words, an ontology represents a formal agreement, where formal implies that it has to be machine readable, and agreement implies an arrangement by the community members using it like inside a company, for the representation of concepts by terms with similar meaning related to a domain. An Ontology is used when there is the need to share or exchange information amongst community members where the understanding of the meaning of the concepts in a domain needs to be recognized by all peers. Ontologies can be represented as a hierarchically structured set of concepts. These concepts describe a specific domain of knowledge.

Although ontologies provide structures for concept representation, they present some challenges. One of these challenges is that an Ontology is a static structure, meaning that over time, its contents do not get updated without human help, hence they can become obsolete. Also in order to update an Ontology, as they are complex structures, the maintenance necessary still requires much resources to do it, and this can increase its costs. As referred above, the Ontology is a shared structured, and its concepts need to be recognized by all. This recognition process requires time to do it and could bring more delay and raise the costs of an Ontology.

One of the areas that deal with the creation and maintenance of an ontology, is Ontology Learning (OL) which studies the mechanisms and processes to transform heavy tasks like creation and maintenance of Ontologies, into a semi (with human help) or complete automatic process (without human help). Although semi-automatic processes for its creation or maintenance, these processes still require human support, for instance of an ontology expert, to simple tasks like to add new concepts discovered to the ontology.

One of the motors that drive OL itself is the recognition of patterns in the data that could originate knowledge to further evaluation. A pattern, specifically in semantics, can be seen as a predictable occurrence that repeats itself along some text data. Furthermore, Knowledge “is a familiarity, awareness or understanding of someone or something, such as facts, information, descriptions or skills, which is acquired through experience or education by perceiving, discovering or learning.” (Wikipedia, 2015) For instance, this could be learned from some information not yet known or unpredictable in the domain. Therefore, OL provides techniques to discover knowledge.

For a system be able to recognize patterns and further extract knowledge from data and information, several processes can be used. Data Mining (also referred in literature as Knowledge Discovery in Databases or KDD) is one of them, and is a process to analyse and discover patterns and knowledge in data. Data mining allows experts to find knowledge in new data or data they already have. Additionally, with data mining techniques, decision makers can use the new knowledge that otherwise could be unknown or unavailable, to make better decisions.

The main objective of the work developed in this dissertation is to present an approach that could help and ease the process of ontology creation and maintenance. Specifically, the proposed approach adopts a mechanism suitable for the use of data mining techniques for pattern discovery and extraction, and knowledge discovery from unstructured sources of information. From a document corpus, the techniques will be applied to discover knowledge. Additionally, is also proposed an approach to help maintain and update CVs, namely domain ontologies, with the previous discovered knowledge. Furthermore, a proof of concept to represent this approach, referred as DOKS (Dynamic Ontology learning with Knowledge sources from unstructured text System), is also part of the results produced.

## Challenges

One of the biggest challenges in information systems when constructing a CV is to find both meaning and relations among concepts and ideas. Similarly, other challenge is to discover knowledge in sources of information that could be later used, for instance, to update a CV. This dissertation propose an approach to solve these challenges based in the following research question:

**How to formally discover and quantify semantic relations between concepts in a domain ontology, using external sources of non-structured information?**

That question raises the hypothesis which leads the development of this work, as follows:

**Semantic relations between concepts from a domain ontology, can be quantified by applying data mining techniques for pattern extraction and knowledge discovery into unstructured sources of information.**

## Expected Outcomes

With this work, the author expects to achieve the following goals.

Starting with a document corpus with non-structured data as content, the first goal will be to discover patterns in such data. This will be made applying an algorithm, namely FP-Growth (FP-G). FP-G is an algorithm that discovers frequent patterns in sets of data.

The second goal will be, from a set of structured information, with frequent patterns, represented by concepts, already discovered and extracted, that one can discover relations (or associations) between the concepts. Association Rules (AR) is the technique that will be used to execute this task.

The third goal is to discover new concepts from the set of non-structured data, to update a domain ontology. This will take advantage of FP-G and AR techniques also, in two steps. Step one will be the discovery of frequent words in text data. Step two will be the match of this words with the concepts from a domain ontology and the discovery of the ones that are not present in the same ontology.

The fourth goal is the discovery of knowledge in the set of discovered patterns that could be useful to help the OL process. Such a goal is made by taking advantage of a set of metrics used in the AR algorithm. This will provide the possible context and domain of a concept.

The fifth and last proposed goal is to develop a proof of concept, a software system, based in the previous challenges in order to show the results in an understandable form. Additionally, is to turn this process of OL into a pure automatic OL process. Starting from a document corpus received to the knowledge discovered from OL.

Moreover, another goal is to write a scientific document with the development of the present work that could be approved by the academic community.

## Section – Context of work

The context of the present work arises from the Innovative Collaborative Work Environments for Individuals and Teams in Design and Engineering project (CoSPaces). CoSPaces was an European Research project aiming to provide digital solutions in a collaborative workspace between individuals, teams and enterprises. The project expected to achieve the former by improving collaboration methods, like human communication and knowledge sharing support, taking advantage and improving existing IT systems.

This dissertation takes advantage of the application background based in the Building & Construction sector.

Also, the present work described in this dissertation contributed to a PhD Thesis, namely “*Semantic enrichment of knowledge sources supported by domain ontologies*”, whose main goal was to “*introduce a novel conceptual framework to support the creation of knowledge representations based on enriched Semantic Vectors, using the classical vector space model approach extended with ontological support*” (Costa, 2014). The contribution for this thesis was the proposal of an ontology learning method based in knowledge discovery techniques.

EU research project E-Cognos was an inspiration in CV domain. Specifically, it provided the insight and methodology needed to build a domain ontology. Also, provided the ground for the structure representation of the semantics in an ontology applied in the B&C sector.

Finally, some resources from SEKS (Figueiras, 2012), namely the ontology manipulation libraries were adopted in this work.

## Section – Document Structure

Following this brief introduction in Chapter 1 with the presentation of the problem, the goals that the author of the present document expects to achieve and the contextualization of the work, this dissertation will be guided by the following structure.

In Chapter 2, the domain of study is Controlled Vocabularies. Ontology will be the selected CV discussed. It will be explained in more detail what is an Ontology, how to build one. The existent formalisms to represent them and where are they used.

Chapter 3 will explain what is data mining and knowledge discovery, and present techniques to discover patterns from non-structured data. One of them, Association Rules will be explained in more detail. FP-Growth, and the concurrent algorithms to discover patterns will be compared, and explained why the former was chosen.

In the next chapter the explanation for the solution proposed, can be observed. Thus, Chapter 4 will present the concept model, an application example describing how to reach from non-structured information to knowledge representation and ontology learning. This chapter also includes the methodology behind FP-Growth and the evaluation of an Association Rule.

With Chapter 5, one can expect to read about the development of a proof of concept. The design and development of a model, with the proposal method to address the question. This will be described with the technologies used, following a description of the implementation and use cases. The framework developed will also be presented in this chapter.

Chapter 6 will be the assessment of the solution proposal, and Chapter 7 will present some conclusions from the author, and some possible future directions in this area.

Chapter 2 – Controlled Vocabularies

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# Controlled Vocabularies

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