A TOOL FOR BUILDING ONTOLOGIES BASED ON ISM

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Abstract - A great help found for cases in which understanding a domain becomes mandatory is to use an Ontology. However, building one is not trivial because we have to achieve the desired objectives of standardization, uniformity, explanation, sharing, and reuse; an effort is necessary to capture, structure, describe and axiomatize them. This article uses ISM (Interpretative Structural Modeling) to capture ontologies in any knowledge domain. ISM can classify and hierarchize objects with low computational cost. Structuring ontologies efficiently can be helpful in hierarchization and disambiguation situations. The tool below can effectively capture and structure ontologies in a particular domain.

Keywords— ISM (Interpretative Structural Modeling), construction of Ontologies, Ontology.

I. INTRODUCTION

Understanding a knowledge domain has proven useful through ontology[1]. One of the main reasons for the recent emphasis on building ontologies is the possibility of sharing and reusing knowledge so that the investment made in acquiring it offers a return to society as a whole [2].

As the term has gained comprehensive interdisciplinary coverage, numerous attempts to define the concept of ontology have been made [3]. The distinction between using the term in philosophy and the computational area is striking. In order not to generate confusion, some theorists even suggest the adoption of different names. An ontology presents concepts and definitions and shows relations in a particular domain.

The ontology of a domain allows the ordering and disambiguation of terms and the correct exchange of information between systems and agents that share it. However, ontologies also have their disadvantages. Having a single domain ontology shared by several different applications, agents, and devices may not be viable since knowledge of a given domain strongly depends on a specific purpose [5]. Thus, the representation of knowledge to solve a problem is strongly affected by the nature of the problem and the strategies applied to solve the problem in question [6].

Currently, many areas study, create or seek applications using ontologies. Although there is no consensus on the precise definition of ontology, two terms are repeated in all the classic definitions found in several areas: concept and sharing [7 - 10].

These two terms, concept and sharing, are fundamental in constructing an ontology. Capturing concepts is a fundamental step for the elaboration of any ontology. Attention must be given to explaining the terms and their meanings to clarify what one wants to refer to. The second term, sharing, is the result of consensus between the different opinions of a given group on the concepts raised. A well-done and structured conceptualization will allow a posteriori a wider acceptance of the ontology and, consequently, its greater sharing [7] [11].

In the literature, there are a set of methodologies for building an ontology [12-20]. However, only some
methodologies have a tool for capturing and explaining concepts. In this sense, the Interpretive Structural Modeling (ISM) technique [30] can minimize problems in constructing an ontology, facilitating capturing of its concepts. The ISM technique allows participants to create an ontology to interact and achieve the desired conceptualization, establishing relationships between concepts and defining a dictionary of terms.

Therefore, this work presents an ISM tool to simplify the capture and conceptualization of an ontology. This new methodology aims at creating knowledge in a simple and fast way using ISM. As the main contributions of this work, we can mention the development of a simple and efficient tool for building an ontology using the ISM and the demonstration of the use of this tool in a domain as a use case.

This article is structured as follows: section II will present the efforts already made toward the creation of ontologies; section III will shed light on what interpretive structure modeling (ISM) is and how it operates in capturing ontologies; section IV presents our proposal for using the ISM to generate ontologies; section V presents an application of ISM in the creation of an ontology and, finally, in section VI the conclusions and proposals for the development of future work in this field.

II. RELATED WORKS

The literature on ontology creation has proliferated quite quickly, which makes any attempt to cite all methodologies in a single work unfeasible. Today, both serious works are available, which treat the subject as a new area of study called Ontology Engineering, and others face the subject with extreme superficiality.

Almeida & Bax [12] and, more recently, Subhashini & Akilandeswari [13] present literature reviews discussing various methodologies and tools for building ontologies and organizing them in tables. Although this study is comprehensive, the authors point out that many instruments still need to be included in the analysis, given the vast field on the subject.

It is worth it here to analyze some of the most representative contributions to the capture and creation of ontologies, which have become benchmarks. These aspects of ontologies considered most relevant for this work are discussed to verify if there is any tool or process for capturing concepts.

Gruninger and Fox [14] establish an approach to build the so-called “ontology engineering.” Its methodology was based on the authors’ experience in the TOVE Project (Toronto Virtual Enterprise). As for the concept capture process, in this methodology, the ontologies are created from scenarios that motivate their applications. These scenarios are typically problems or situations that are not adequately handled by an existing ontology or lack an ontology. According to the authors, any proposal for a new ontology must first describe the motivational scenario (or scenarios) and the set of intended solutions for the problems presented in this scenario. The key is knowing the context, so it is possible to understand better the motivation for building an ontology in terms of its application. This approach, however, does not describe any form of formalization for capturing concepts.

Uschold and King [15], in turn, provide a sequence of steps for building ontologies. His approach is less formalistic than Gruninger and Fox [14] if analyzed entirely but more structured regarding steps to follow. It is a method of building ontologies for enterprise projects in the business area. With this work methodology, Enterprise Ontology was created, a collection of concepts and definitions relevant to the field of companies and business developed by the Artificial Intelligence Applications Institute of the University of Edinburgh. As for capturing concepts, the authors suggest the following steps:

- Identification of the purpose of the ontology: in this step, it is necessary to clarify why the ontology is being built and its intended uses. At this point, defining and characterizing the ontology users is very useful.
- Data capture: identification of key concepts and relationships in the domain of interest; production of definitions for concepts and relationships in the form of clear and unambiguous texts; identification of terms to name the concepts and relationships; reaching an agreement that legitimizes the result of everything described above.

Despite defining the necessary steps, the authors do not suggest a tool or application facilitate the process.

Another methodology for creating ontologies is that of Bernaras [16], used in the KACTUS project. It aims to investigate the use of ontologies in complex technical systems. One of the applications created was for diagnosing faults in electrical networks. For the capture phase, during the development of an ontology, the focus is on the application specification.

CYC [17] [18] is a knowledge base that contains an ontology of approximately 100,000 axiomatized terms, all in formal language. This methodology is the most hermetic regarding the capture phase, and it suggests identifying and codifying the explicit and implicit knowledge existing in the knowledge sources. The methodology, however, does not explain how to accomplish this task.

Falbo [20] [21] proposes the following steps for creating an ontology: identification of purpose and specification of requirements; capturing the ontology and its formalization; integration with existing ontologies and ontology evaluation and documentation. The author describes the ontology capture stage as being:

- The most important part is the development of an ontology. The objective is to capture the conceptualization of the domain based on ontological competence. Relevant concepts and their relationships must be identified and organized. A graphical language should be used with a dictionary of terms to facilitate communication with domain experts". There is, however, no suggested method for carrying out this step.

The article by Noy & McGuinness [3], [19], [22] is a true guide, where the authors define six steps for building an ontology. Some of them even refer to the ontology capture
step. We can highlight the following steps: the domain that the ontology will cover; the purpose of the ontology; what kinds of questions the ontology should provide answers to; consider the reuse of existing ontologies and enumerate important terms in the ontology. Certainly, these steps help a lot to capture the concepts. In their work, there is a description of the stages. However, a methodology for capturing the concepts is not explicitly presented.

Another way to build ontologies is the methodology developed at the Artificial Intelligence Laboratory of the University of Madrid called Methontology [23]. Its author states that ontologies can be analyzed in a development process by life cycles and thus proposes a development process of successive prototypes, allowing for add, remove or change definitions until a state of maturity is reached. In a simplified way, five phases are used in this methodology: specification, conceptualization, formalization, implementation, and maintenance, just like in a software development process. Also, despite the explicit mention of a conceptualization phase, no form or tool for this phase is cited.

The On-to-Knowledge methodology, elaborated by Sure & Studer [24], was developed and applied in the project named OTKM. Its main objective was to allow the application of ontologies in information management on the worldwide web to improve knowledge management processes in large organizations. In this methodology, the process for developing an ontology is divided into five stages, of which we highlight the first three, which are related to capturing concepts, namely:

- Feasibility study: where to look for problems or opportunities for constructing an ontology. The focus of this activity should be management applications and knowledge, with broad involvement of people;
- "Kick-off" or the start of activities, where the activities developed are the capture of specification requirements and the analysis of knowledge sources;
- Refinement stage, where knowledge contained in the sources is extracted and translated into a formal language.

Once again, we have a generic description of the steps without indicating a way to capture the concepts.

SENSUS [25], in turn, was a methodology created to build a large base of concepts for the creation of translation systems (which the authors called "translation machines"). This methodology was developed at the ISI (Information Science Institute) by Eduard Hovy and Kevin Knight. The methodology for building SENSUS has the following proposed steps for capturing concepts: (i) several terms are selected as seeds for the ontology under construction; (ii) these terms are manually added to the existing ontology set; (iii) concepts that emerge during the addition of these terms are included in the new ontology; (iv) terms that are relevant to the particular domain and that have not yet been included in the ontology are added; (v) the last step is the analysis of related concepts. In step v, if a tree node contains several paths to it, it is considered relevant to include the entire subtree in the ontology that will be generated. This inclusion must be done manually and with great care. Higher hierarchical level concepts contain many relationships, but they should not be included in the generated ontology, which is why deciding on inclusion requires domain knowledge.

It is a process much more focused on the knowledge of the domain by the participating experts. Hardly accessible to the construction of simpler ontologies with practical application. The focus is, more ambitious, a translation machine.

The POEM methodology [26] is an evolutionary methodology, advocating completion of the ontology construction process from inception to implementation in several iterations and through incremental releases. Each of the iterations is made up of several phases. POEM is a complete methodology comprising several phases to carry out conceptualization, design, implementation, evaluation, and project management tasks. It incorporates software engineering standards and is designed for use with the Semantic Web. There is a description of several stages. In a way, it is based on the construction of a detailed project for constructing successive and incremental models of an ontology. Despite all the steps being well specified, just like the structure of a project, there is no description of any method to help capture the concepts.

Regarding the methods presented, it can be observed that:

- Most do not present details, and they describe major steps in a very generic way;
- All emphasize the importance of the capture stage;
- Not all require a presentation in formal language, but someplace formalization is fundamental;
- As for the strategy for identifying concepts, some adopt the approach from the most generic to the most specific, called “top-down”; others adopt the so-called “middle-out” approach, starting from middle concepts, closer to a consensual image. For example, the concept of a dog is the middle between animal (generic) and labrador (instance). The few who adopt the “bottom-up” approach want strong proximity to the application of ontology. Finally, some methods do not define any strategy.
- Most methods are specific for use in a particular domain of knowledge.
- Although some remember that the process must be collaborative, none emphasizes the implications arising from this need. That is, they do not discuss in detail ways of dealing with the difficulties of the interaction process that aims to capture the ontology;
- Almost all methodologies claim that the key to building ontologies is the focus on their domain and their use, but that, to enable the reuse of knowledge, ontologies should try to be, as much as possible, independent of the applications they will be based on.

Therefore, considering the methodologies described above for creating ontologies, it is clear that none of them presents an explicit method for capturing concepts. It must
be considered that the tool proposed in this article can help capture concepts, making it possible to apply it together with any of the methodologies presented, facilitating the process of explaining the knowledge domain.

III. ISM – Origins and Contributions

Interpretative Structural Modeling (ISM) was developed in the 70s, in the United States, by John N. Warfield. ISM emerged as a way to simplify the structuring of complex problems. In Brazil, it was developed and used mainly by Professor James C. Wright in the Future Studies Program at the Faculty of Economics and Administration at the University of São Paulo (FEA – USP).

ISM had its beginnings in 1971 at the Battelle Memorial Institute based in the city of Columbus, USA. Warfield and Hill created what they called Delta Charts, a new form of flowcharts that not only took into account the flow of activities but also their decisions, logical functions, hierarchies, and priorities [27]. The methodology developed from 1971 to 1974 was first described in issue number 4 of the series called Battelle Monograph under the title of Structuring Complex Systems [28] and later in other publications [29], [30]. The ISM technique focuses on the important elements of the core problem being explored, explicitly establishing the interrelationships between them. In the end, ISM produces a hierarchical graph of the elements that make up the problem while showing the relationships between them. These relationships are always represented by verbs, such as element A precedes element B; or element A has element B; or element A is connected to element B, as shown in Figure 1. It is like reducing the various discourses to a common denominator: ISM translates into graphic language, in an integrated way, the set of perceptions about the same problem. This graphic representation constitutes a structural model, which discriminates: the elements of the problem, the relationships between these elements, and the hierarchical levels of each one in the considered context.

IV. How ISM Works

The first step in using ISM is to establish the type of relationship between elements. For example, a significant element X1 defines a relationship with an element X2, mediated by a verb (for example: contributes to). For Xn elements, it is possible to create a square matrix Xn x Xn that describes the relationship between each pair of elements: when two elements are related, we have the value 1; otherwise, 0. For example, suppose we want to model that a "Political Crisis" contributes to the "Retraction of Investments." In that case, the description matrix below can be used where X1 represents "Retraction of Investments," and X2 represents "Political Crisis" and obtain the following description matrix:

\[
\begin{bmatrix}
X1 & X2 \\
1 & 2
\end{bmatrix}
\]

Next, we present an example adapted from Wright [32] that shows the process of applying the technique. We have a set of 4 relationships of the type "contributes" to:

1. Retraction of Investments "contributes" to Stagflation.
2. Political Crisis "contributes" to the Retraction of Investments.
3. Increased Costs "contributes" to the Retraction of Investments, Reduction of Consumption, and Stagflation.
4. Reducing Consumption "contributes" to Increased Costs.
These four relationships are among the five elements shown in Table 1 and can be represented using the digraph in Figure 2.

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$</td>
<td>Retraction of Investments</td>
</tr>
<tr>
<td>$X_2$</td>
<td>Political Crisis</td>
</tr>
<tr>
<td>$X_3$</td>
<td>Increase in Costs</td>
</tr>
<tr>
<td>$X_4$</td>
<td>Consumption Reduction</td>
</tr>
<tr>
<td>$X_5$</td>
<td>Stagflation</td>
</tr>
</tbody>
</table>

Table 1 – Description of Elements

From these four relationships between the five elements, we can assemble the following description matrix $D$:

$$X_n = \{X_1, X_2, X_3, X_4, X_5\}$$

Relation = “contributes to”

$$D = \begin{bmatrix}
0 & 0 & 0 & 0 & 1 \\
1 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 1 \\
0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0
\end{bmatrix}$$

Warfield and others [37–39] tackled the problem and realized to get a problem’s complete picture, it would be necessary to propagate the influence of the elements in each row of the matrix to show the paths of each element in relation to the problem, thus creating the Access Matrix ($M$). To do so, they resorted to successive Boolean potentiations to propagate the influence of each line of the Access Matrix to the other lines. It is done as follows:

$$M = (D + I)^n = (D + I)^{n+1}$$

Where:

$$M = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 \\
1 & 1 & 0 & 0 & 1 \\
1 & 1 & 1 & 0 & 1 \\
0 & 1 & 1 & 1 & 1 \\
0 & 0 & 0 & 0 & 1
\end{bmatrix}$$

When the matrix stabilizes, the next potentializations of matrix $M$ do not generate new values. The final result of the iterations is obtained, forming the basis for the next steps within the ISM technique.

The classic resolution process of the ISM technique consists of determining all the paths that will form the digraphs of the problem being studied (Fig.2). To do so; it is necessary to fill in values $D_{ij}=0$ or $D_{ij}=1$, the problem description matrix. It would be much work if this process were done on a question-and-answer basis. For this, ISM also uses responses that are inferred by the system. This ability to infer responses is valid because only transitive relations can be used in the process. It is also possible to infer responses from information that establishes the inexistence of relationships. It is noticed that the number of interactions grows a lot as new elements are added to the process, and the issue that limited the use of ISM in the 70s and 80s was the fact that it depended on large computers, mainly to process a large number of interactions, a currently minimized problem.

Once the stages where all the elements of the problem are inserted and the relationships between them are completed, the potentializations with the Matrix $M$ are made, we proceed to the hierarchization. Through it, it is possible to have a precise idea of how the elements are related and what position they occupy within the studied problem.

The definition of the hierarchical level occupied by the elements in the final structure is done in the ISM based on the relationships between these elements. For each element $X_n$ of the Access Matrix ($M$), the set of its successors ($SX$) and predecessors ($AX$) are analyzed. Elements at the first level of the structure are those that are related only to themselves. By eliminating the elements of that level and repeating the process, the elements of the second level are obtained, and so on. The set of successors ($SX$) of each element in the structure consists of all elements that can be reached from it. In Access Matrix $M$, the successors of a given element $X_i$ are all the elements whose column has the value “1” in the line corresponding to “i”:

$$SX_i = \{X_j \mid M_{ij} = 1\}$$

For example, the successors of element $X_4$ in the Access Matrix $M$ shown in the example studied is the set:

$$SX_4 = \{1, 3, 4, 5\}$$
The set of predecessors (AX) of a given structure element is all the elements through which this element can be reached. In the access matrix M, the ancestors of a given element Xj are all the elements whose row has the value 1 in the column corresponding to j. The ancestors of element X4 in Access Matrix M, for example, is the set of the following elements:

$$AX4 = \{ 3, 4\}$$

The intersection between sets (SX) of successors and (AX) of ancestors contains all elements common to both sets. Considering the Access Matrix M, a table can be constructed that shows all successor and predecessor elements and the intersection of their sets (Table 2).

### Table 2 – Predecessor/Successor Elements – Phase 1

<table>
<thead>
<tr>
<th>Element</th>
<th>Antecessors (AX)</th>
<th>Successors (SX)</th>
<th>Intersection (AX ∩ SX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1, 2, 3, 4</td>
<td>1, 5</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1, 2, 5</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3, 4</td>
<td>1, 3, 4, 5</td>
<td>3, 4</td>
</tr>
<tr>
<td>4</td>
<td>3, 4</td>
<td>1, 3, 4, 5</td>
<td>3, 4</td>
</tr>
<tr>
<td>5</td>
<td>1, 2, 3, 4, 5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Within the ISM methodology, the elements located at the first level of the structure are all those in which the set resulting from the intersection and the successors are the same. It is noticed in Table 2 that element X5 is at the top of the structure.

The second level is determined by eliminating all the elements that remain on the first level from the access matrix M, and a new result is constructed, as shown in Table 3.

### Table 3 - Elements Antecessors/Successors – Phase 2

<table>
<thead>
<tr>
<th>Element</th>
<th>Antecessors (AX)</th>
<th>Successors (SX)</th>
<th>Intersection (AX ∩ SX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1, 2, 3, 4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1, 2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3, 4</td>
<td>1, 3, 4</td>
<td>3, 4</td>
</tr>
<tr>
<td>4</td>
<td>3, 4</td>
<td>1, 2, 4</td>
<td>3, 4</td>
</tr>
</tbody>
</table>

Checking Table 3, it is clear that only element X1 is on the second level. On the third level, the process is repeated. All references to element X1 are eliminated, and a new output is generated (Table 4).

### Table 4 - Predecessor/Successor Elements – Phase 3

<table>
<thead>
<tr>
<th>Element</th>
<th>Antecessors (AX)</th>
<th>Successors (SX)</th>
<th>Intersection (AX ∩ SX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3, 4</td>
<td>3, 4</td>
<td>3, 4</td>
</tr>
<tr>
<td>4</td>
<td>3, 4</td>
<td>3, 4</td>
<td>3, 4</td>
</tr>
</tbody>
</table>

They are at the lowest level, X3, and X4, resulting in the hierarchical structure shown in Figure 2.

### Fig. 3 – Hierarchy of Elements

Once the levels of each element are established, it remains to establish the relationship between them to have the final result of the process. The interrelation of the elements and their hierarchization is sought, and, for this, the matrix M is reordered according to the level of each element, generating a new matrix called the Hierarchical Access Matrix (HM):

$$MH = X_5 \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ X_1 & 1 & 0 & 0 & 0 \\ X_3 & 1 & 0 & 1 & 1 \\ X_4 & 1 & 1 & 0 & 1 & 1 \end{bmatrix}$$

The MH contains information about all existing paths between the elements, so it is necessary to eliminate redundant paths. An example of a redundant path is the cycles identified in the HM by having the same successor and predecessor elements. In the example, X3 and X4 represent redundant cycles. Element X4 is removed, resulting in the following matrix:

$$M1 = \begin{bmatrix} X_5 & X_1 & X_2 & X_3 & X_4 \\ X_1 & 1 & 1 & 0 & 0 \\ X_2 & 1 & 1 & 1 & 0 \\ X_3 & 1 & 1 & 0 & 1 \end{bmatrix}$$

After these simplifications, the last step is taken, which is the addition of variable names, which results in the structure shown in Figure 4.
The graphical representation of Figure 4 is the final result of the application process of the ISM technique, where the problem is hierarchized and its related elements.

As highlighted by other authors [40–42], the ISM technique accelerates the decision-making process, improves the process, and makes no assumptions about the structure of a subject or domain except assuming its existence. It also makes no assumptions about the importance of elements or concepts expressed through analyzed elements. ISM's structural modeling lets the matter unfold and prompts the subsequent use of a more problem-focused method.

The characteristics of the ISM technique that make its adaptation suitable for the construction of ontologies are:

- Its objective is to facilitate the meeting of the different visions of a group of people (ontology creators) around a common objective;
- It works, basically, from the survey of relevant concepts and the establishment of relations between these concepts;
- It organizes discussions within a domain of knowledge, providing a routine of questions and answers that make clear the consensus obtained;
- Hierarchically structure the various elements raised by the group as relevant to the problem under discussion;
- It generates graphical representations, facilitating the visualization of the results within a certain context.

VI. A TOOL FOR ONTOLOGY CONSTRUCTION BASED ON ISM

This work proposes the development of a tool for ontology knowledge capture called OCT(ISM) – Ontology Capture Tool (Interpretive Structural Modeling), which uses ISM to capture knowledge required for a given domain.

The fundamental functionalities of the OCT (ISM) are:

- The representation of domain concepts and their relationships;
- The generation of a conceptual vocabulary of the domain.
- Hierarchization of concepts and their presentation in graphic form
- Facilities that guarantee access to non-specialists in ontologies;
- Possibility of integration with other ontology formalization tools

OCT (ISM) is divided into five fundamental blocks (Figure 5):

- Block 1 – Element Extraction: all concepts relating to a given domain are raised of knowledge. This functional block is responsible for storing the concepts generated by the group participating in the process of capturing the ontology of the domain in question.
- Block 2 – Definition of the type of Relation: This block is responsible for defining the type of relationship that will link the concepts. The group should be alerted that the choice of a “contains” type relationship implies an approach from the whole to the parts (top-down), while the choice of
a "is contained" type relationship implies an approach from the parts to the whole (bottom-up).

Block 3 – Establishment of relationships between concepts: This functional block is responsible for establishing the relationship determined in the previous block between two concepts: the association through the relationship between concept 1 and concept 2.

Block 4 – Visualization of Results: In this functional block, one can see the results of the application of the ISM on the relations arrangements carried out in the previous block. The tool displays a graphic window where the elements are arranged hierarchically, allowing the group to visualize and decide if the result corresponds to their understanding of the domain. If the group accepts the result, it goes on to block 5 to make its impression. However, suppose the group is not satisfied with the result. In that case, it can return to block 1 to insert more concepts or to block 3 in order to review or modify the existing relations between the concepts of the ontology. In this functional block, the part of the interface responsible for storing the definitions for each concept is also available, which is fundamental so that the dictionary of the captured ontology is generated at the end of the process.

I. CASE STUDY

We could observe the validity of this approach and the use of OCT(ISM) in capturing ontologies in a case study carried out in a company that produces steel frames (doors, windows, wainscoting, etc.). The domain of quality within the production environment was investigated. Detect the concepts shared by the production leaders (who are called in charge) about quality.

The participants in the capture process of this ontology can thus be characterized: as having a medium education level; at least five years of working for the company. About 40% of the leaders were hired in the labor market, and 60% were internally promoted. The ontology capture session had the seven production leaders from the productive areas, the human resources director, the marketing director, and the mediator of the process that put the relationships in the tool.

Respecting the proposed tool, we started with the concept survey phase. Thanks to the active participation of the group and receptivity, 34 concepts were raised in just under two hours of work, which are listed in Table 5.

Concepts and their definitions duly agreed upon, the phase of definition of the type of relationship was set, the choice was "contributes to," later it was set out to establish the relationships between concepts.

Here the first problem arose; the relationship adopted by the group ended up giving rise to situations type A contributes to B, and B contributes to A, which somehow confused the participants and did not allow the evolution of the process. As seen by the group and the mediator, the result was not representative.

After a break, the capture work was resumed with three fundamental actions:

- Search for focus, reminding the group that the "quality" sought was in the company's production domain, concepts related to "quality that the customer wants" or others not directly related to the organizational day-to-day were isolated in a consensual manner;
- Changing the type of relationship to "result of," as it is more restrictive than "contributes to;"
- Gradual insertion of elements, with visualization of the graphical relationship of the defined relationships, allows better participation and immediate adjustments.

Having taken these actions and within the time available, 25 concepts were selected, resulting in the capture of the ontology shown in Figure 5 and the dictionary of concepts in Table 5.

Fig.6 – Ontology Captured

At the group's request, it was decided to keep the 34 concepts in the dictionary of terms, and an asterisk precedes structured concepts.

<table>
<thead>
<tr>
<th>Table 5 – Dictionary of Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Finishing: is one of the items subject to quality control.</td>
</tr>
<tr>
<td>2. *Welding wire: component of the raw material used for welding.</td>
</tr>
<tr>
<td>3. *Attention (from the company): concerns the attention that supervisors receive from the company. It is realized in training, evaluations, vertical relationships, and the flow of information between the summit and the base.</td>
</tr>
<tr>
<td>4. *Absence of defects: is the perfect part, conforming to the standard.</td>
</tr>
<tr>
<td>5. *Evaluation: it is the mechanism to distinguish the best performances. Its result shows that, for the company, the labor components are not all the same. The assessment results reveal inappropriate behavior and highlight behavior worthy of distinction, which helps increase commitment.</td>
</tr>
<tr>
<td>6. *Attention (from the company): concerns the attention that supervisors receive from the company. It is realized in training, evaluations, vertical relationships, and the flow of information between the summit and the base.</td>
</tr>
<tr>
<td>7. *Commitment: the result of attention.</td>
</tr>
<tr>
<td>8. *Attention (from the company): concerns the attention that supervisors receive from the company. It is realized in training, evaluations, vertical relationships, and the flow of information between the summit and the base.</td>
</tr>
<tr>
<td>9. *Different segments: these are the segments that the company seeks to serve with its different product standards.</td>
</tr>
<tr>
<td>10. *In charge: are the team leaders. Their qualification depends on the same elements as the qualification of the workforce. They are responsible for organizing the sectors.</td>
</tr>
<tr>
<td>11. *Standard specifications: a series of specifications translating what the customer wants. Standards are specified based on market research, customer requirements on orders (sales), and customer complaints (after-sales).</td>
</tr>
<tr>
<td>12. *Aesthetics: the appearance of the product and constitutes one of the items subject to quality control.</td>
</tr>
<tr>
<td>13. *Tools: are machine components that wear out and need maintenance or replacement, so quality in goods production is maintained.</td>
</tr>
</tbody>
</table>
14. Functioning: depends on the size, profile, raw material, and labor.

15. Information: refers to the flow of information within the company. An efficient flow of information contributes to the pleasure of working and the product's quality.

16. Investment: company action for quality. It can be an investment in labor or an investment in machines/roads.

17. Cleaning: contributes to the proper functioning of the machines, as any dirt can affect it.

18. Skilled workforce: it is the workforce that enjoys working, commitment, training, evaluation, and internal satisfaction.

19. Machines: are equipment that, in order to produce with quality, need to be well maintained (clean), well operated by the workforce, and composed of tools in good condition.

20. Raw material: It is made up of welding wire etc.

21. Measurement: it is the measurement that must be obeyed to obtain the perfect piece (it is part of the standard).

22. Non-wrinkled: it is one of the quality control items. It depends on the organization of the sector, machines and tools, labor, and internal and external transport. The dent is a defect that can affect the aesthetics of the functioning and, therefore, impairs the quality.

23. Sector organization: it is carried out by supervisors and maintained by the workforce. It includes cleaning and information flow. Their suitability is ensured by training and assessment. Contributes to the pleasure of working and not kneading the products.

24. Patterns: the realization, in a prototype, of the specified patterns. It translates into a series of tolerance indices that are the basis for quality control and is differentiated by target audience segment. It is part of the standard: the weld (bump, etc.), the size, the aesthetics (appearance), the functioning, etc.

25. Perfect part (PRODUCT): is the part that conforms to the standard. It results from suitable machines, quality raw material, and an efficient flow of information.


27. Profile: it is a product component, the quality of which depends on compliance with the measurements and not being dented. It results from adequate raw materials, tools, and qualified labor.

28. Pleasure to work: is the result of good human relations, efficient flow of information between the company's sectors, receiving attention from the company (training and evaluation), adequate physical conditions for the performance of activities (organization of the sector and machines and suitable tools).

29. Deadline: is the delivery deadline stipulated in the customer's order. It depends on a perfect, finished product on time and efficient information flow.

30. Quality: means perfection, absence of defects. It is what the customer wants.

31. Internal satisfaction: it is the same as the pleasure of working.

32. Welding: this is one of the items subject to quality control. Make up the pattern. It results from skilled labor, quality raw material, and adequate machinery. It influences the look (product's aesthetics), as it can produce lumps.

33. Transport: the internal and external displacement of the parts. It can cause damage to parts, along with improper vehicles and packaging.

34. Training: type of company investment in labor. It is interpreted by those in charge as the company's attention to the workforce. Produces: commitment, awareness, qualification for production.

The case study participants presented essential requirements for the proposed activity: they were participatory and knew the domain. The result concerning the knowledge captured was satisfactory, as will be analyzed later. However, some problems were detected during the use of the tool and methodology, which are listed below:

1. Problem: The ratio was chosen in the first attempt to capture the concepts ("contributes to") was considered little enlightening or weak. In addition, sometimes the moderator asked, "what contributes to the element to be related," and sometimes the moderator asked, "what the element to relate contributes to," which generated a series of inversions of relationships.

Recommended Solution: Relate, by way of example, two or three elements in order to verify that the type of relationship is adequate. The question must be obvious to eliminate the probability of reversals. Using stronger relationships such as "result of" avoids this ambiguity.

2. Problem: The terms that designate the concepts raised are very generic, which ended up confusing. For example, the term "information" can be used in several ways.

Recommended Solution: Properly define the concepts represented by very generic terms or replace these terms with more specific ones.

3. Problem: The concepts raised show the lack of a more accurate definition of the domain, as quality from the employees' point of view was mixed with the quality that employees imagine the customer wants. For example: "what the customer wants" and "perfection."

Recommended Solution: Define the domain well and leave this definition in view of the group so that it restricts the survey of concepts. The domain's boundaries must be clear, and whenever there is doubt as to whether or not an element belongs to the domain, the domain definition must be used.

4. Problem: During the establishment of relationships, there was doubt as to the meaning of some terms, such as "information," "perfection," "attention," and "profile."

Recommended Solution: Develop the definition of the terms that designate the concepts before proceeding with the relations between them. The definition helps to clarify the type of relationship that the element has with the others, in addition to serving as a reference source to resolve later doubts about the meaning of each term in the context.

5. Problem: The survey of concepts did not suffer any type of restriction or subsequent "filter," which was evident in synonymous expressions, such as "perfection," "perfect piece," and "absence of defects."

Recommended Solution: Place mechanisms that allow "filtering" concepts to minimize the occurrence of very close concepts or synonymous terms.

6. Problem: Repeated reflexive relationships of the type "A contributes to B, and B contributes to A" impair the hierarchical structure, as it is not identified which of the concepts is a part and which is a whole.

Recommended Solution: Select relationship types that do not allow for reflexive relationships. For example, "is part of," "contains," "is a result of," etc. In this case, the type of relationship chosen, "contributes to," allowed the occurrence of several reflexive relationships, which undermined the hierarchy of concepts.

Despite the problems presented, the results were expressive. When analyzing the hierarchical structuring of the concepts produced by the ISM, as seen in figure 6, four relevant aspects can be noted:

The first is that at the highest level, where quality was explored, the concepts "perfection" and "absence of defects" show that they are synonymous terms and can be unified due to the relationships established.

The second is the appearance of an aspect of another domain, the customer domain, evidenced by the terms that translate what the group imagines that customers want and that would be translated into the "specifications of standards" (list of desires and demands of the consumer in relation to the company's products). This strand ended up
being isolated from the rest of the ontology, as it has no direct relationship with the concepts involved in the intended domain.

The third aspect is that the tool captured knowledge that was not evident to the group at the beginning of the process. The main example of this was the concept of "information," which was related to all other concepts related to product quality. Although the term generated some difficulties at the beginning of the discussions, as it was too generic, its meaning for the group was understood when everyone agreed that "the information needs to get where it is needed." At the next meeting, the term "information" could perhaps be replaced by "efficient communication" or "efficient flow of information." The appearance of this concept of information at the second level of the hierarchical structure denoted its importance for quality in the view of the participants. However, it was not obvious and was revealed by the tool.

The fourth aspect is that the "quality product" must present what the group defined as "aesthetics," that is, a product with a good appearance, the result of three great blocks of concepts: qualified labor, quality machines, and defined standards. The following stand out here: the workforce, which is related, from the group's point of view, to the concepts of evaluation, training, company attention, commitment, satisfaction, and pleasure in working; the machines, which are related to the tools that, in the case of the industry in question, are components of the machines; and the standard, which is related to the measure, the raw material, the adequate profile and organization of the sector.

The evaluation results obtained by applying the tool developed in this work can be evaluated for its ease of application and the result presented in the ontology capture. However, the resulting ontology cannot be evaluated for two reasons: it is not finished, there are still the later stages to capture, and it was not compared to other ontologies on the same domain that eventually exist.

The captured ontology is of such a particular domain (view of the quality of those in charge of a given company) that it would be difficult to quantify how much better or worse it is compared to other ontologies captured by other methods. However, it can be said that there is a result and that it is valid because, according to the testimony of the participants in the process, it contributed to the company. Subsequently, the ontology was used to illustrate the company's thinking and values on the subject of quality, forming part of its documentation and training manuals.

From the point of view of functionality, the easiest aspect to be evaluated, the tool proved adequate, as it behaved in the field just as it was tested on the bench. However, in the real situation, it was noticed the importance the mediator and the methodology for applying the tool. It was concluded that the methodology must undergo further refinement, and the mediator must undergo prior training to enable him to conduct this process. Such measures would make the application of the tool easier for non-experts.

VII. CONCLUSION

The construction of ontologies to represent knowledge is an old resource that originated in Philosophy. However, ontologies have gained multiple applications in various areas previously unheard of by philosophers. Today, ontologies are used as much in machines as in sociotechnical systems. Although the usefulness of ontologies is currently defended, a clear methodology and a facilitating tool for their construction have not been found. It is observed that specialists within technical laboratories have constructed ontologies. The "state of the art" in ontologies currently presents a degree of refinement and complexity that makes its application less and less accessible to non-specialists. It makes participatory capture difficult, precisely what theorists define as one of the main conditions to achieve a good representation of knowledge through ontologies.

The production of an ontology has two clear phases: capture and formalization. This work presented a proposal for using the ISM technique as a basis for the ontology capture method. Highlighting its characteristics of simplicity, ease of use, ease of hierarchizing and relating elements, ease of establishing definitions, and disambiguation of concepts.

The OCT (ISM) is adhering to the challenge. However, it is important to emphasize that this method does not include the steps of formalization and axiomatization. Even excluding these steps, this work is a whole in itself, as it provides a structure for the participants of an ontology generation process to interact and reach the desired conceptualization, establishing relationships between concepts and defining a dictionary of terms. This structure can either end a complete process since the capture of an ontology allows independent applications for subsequent formalization, or it can constitute a reference and a facilitating element for the next steps in constructing an ontology by other tools or methods.

This work demonstrates that the developed tool can significantly assist in capturing concepts for constructing a solid ontology in terms of concept relationship and consensus by the participants of a specific knowledge domain.

REFERENCES


