Instituto Politécnico de Coimbra
Instituto Superior de Contabilidade
e Administração de Coimbra

Alexandra Isabel de Sousa Matos

Product information management for complex modular security systems

Coimbra, julho de 2021

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Trabalho de projeto submetido ao Instituto Superior de Contabilidade e Administração de Coimbra para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Controlo de Gestão, realizado sob a orientação do Professor Doutor Fernando Paulo dos Santos Rodrigues Belfo e supervisão de Andrea Göhler.

Coimbra, julho de 2021

TERMO DE RESPONSABILIDADE

Declaro ser a autora deste trabalho de projeto, que constitui um trabalho original e inédito, que nunca foi submetido a outra Instituição de ensino superior para obtenção de um grau académico ou outra habilitação. Atesto ainda que todas as citações estão devidamente identificadas e que tenho consciência de que o plágio constitui uma grave falta de ética, que poderá resultar na anulação do presente trabalho de projeto.

PENSAMENTO

"There is no such thing as failure.

When you win, you win. When you lose, you learn."

(Richie, 2021)

DEDICATÓRIA

Dedico este trabalho de projeto à minha família, que sempre me apoiou nas minhas decisões, sendo um pilar central na minha vida e na conclusão dos meus estudos académicos.

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RESUMO

Um sistema PIM gere toda a informação que possibilita a comercialização dos produtos através de diferentes canais. A sua importância durante o ciclo de vida de um produto aumentou devido à sofisticação técnica dos produtos, a gerir internamente e a publicar externamente. Sistemas, tais como o ERP e o CCMS, deverão integrar-se com um sistema PIM, o qual deve funcionar como a "espinha dorsal" da informação de produto.

O presente projeto tem como objetivo principal a criação de uma solução para gerir a informação de produto para sistemas modulares complexos. A proposta de solução inclui a criação de uma ontologia para parte dos inúmeros sistemas disponíveis no catálogo de produtos de uma das maiores organizações multinacionais do setor de engenharia e tecnologia a nível mundial. O processo de criação da solução proposta baseou-se na metodologia de investigação pesquisa-ação e foi dividido em cinco fases. Na fase de diagnóstico descreveu-se e analisou-se a atual situação dos sistemas ERP e CCMS que gerem o catálogo online dos sistemas de produtos comercializados. Levantaram-se ainda as taxonomias de produto atuais e elaborou-se a proposta. Na fase de planeamento da ação descreveram-se a equipa de trabalho, a abordagem inspirada na metodologia *Agile* usada para desenvolver a solução, as reuniões de planeamento, os parceiros de trabalho, as ferramentas a usar e a sua justificação. Na fase de tomada de ação foi descrito o processo de criação da solução ontológica e o resultado final, incluindo a construção das novas taxonomias e a sua validação pelos especialistas. Propuseram-se exemplos e representações gráficas usando a ferramenta *Protégé*. Na fase de avaliação, a solução ontológica foi testada, tendo-se validado que os requisitos necessários foram satisfeitos pela estrutura. Na fase de especificação de aprendizagem propuseram-se os próximos passos para a implementação e gestão futura do modelo ontológico.

Com esta solução, a organização poderá gerir mais eficientemente a informação de produto e a estrutura de dados. Ela possui versatilidade para gerir produtos individuais ou sistemas modulares complexos e melhorar a sua comunicação com o cliente. Além disso, a ontologia tem ainda um enorme potencial se combinada com técnicas de IA. Algumas limitações do projeto e propostas de trabalhos futuros foram ainda apresentadas.

Palavras-chave: Product Information Management, PIM, data architecture, e-commerce, ontology, action research

ABSTRACT

A PIM system manages all the information that makes it possible to sell products through different channels. Its importance during the product life cycle has increased due to the technical sophistication of the products to be managed internally and published externally. Systems such as ERP and CCMS should be integrated with a PIM system that should function as the "backbone" of product information.

The main objective of this project is to create a solution to manage product information for complex modular systems. The solution proposal includes the creation of an ontology for part of the numerous systems available in the product catalog of one of the largest multinational organizations in the engineering and technology sector. The process of creating the proposed solution was based on the action-research methodology and has been divided into five phases. In the Diagnosing phase, the current situation of the ERP and the CCMS systems that manage the online catalog of marketed product systems was described and analyzed. In addition to that, the current product taxonomies were raised and the proposal was made. In the Action planning phase, the team, the approach inspired by the Agile methodology used to develop the solution, the planning meetings, the work partners, the used tools and its justification were described. In the Action taking phase, the process of creating the ontological solution and the final result were described, including the construction of new taxonomies and their validation by experts. Examples and graphical representations using *Protégé* were proposed. In the Evaluating phase, the ontological solution was tested, having confirmed that the necessary requirements were accomplished by the structure. In the Specifying learning phase, the next steps for the implementation and future management of the ontological model were proposed.

With this solution, the organization will be able to manage product information and data structure more efficiently. It has the versatility to manage individual products or complex modular systems and improve the communication with the customer. Furthermore, the ontology has great potential if combined with AI practices. Some limitations of the project and proposals for future work were presented as well.

Keywords: Product Information Management, PIM, data architecture, e-commerce, ontology, action research

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List of abbreviations and acronyms

AI .... Artificial Intelligence

B2B .... Business-to-business

B2C .... Business-to-consumer

CCMS ...... Component Content Management System

CG .... Conceptual Graphs

CTN .... Commercial Type Number

DARPA .... Defense Advanced Research Projects Agency

DL .... Description Logics

DPCC .... Digital Product Content Chain

EOL .... End Of Life

ERD .... Entity-Relationship Diagram

ERM .... Entity Relationship Model

ERP .... Enterprise Resource Planning

FOL .... First Order Logic

IBM .... International Business Machines Corporation

IoT .... Internet of Things

IS/IT .... Information Systems/Information Technology

KR&R ...... Knowledge representation and reasoning

MAM .... Media Asset Management

MRP .... Material Requirements Planning

MRPII ...... Manufacturing Resource Planning

OMT......... Object-Modeling Technique

OOA......... Object-oriented Analysis

OOD......... Object-oriented Design

OOSE .... Object-oriented Design Methodology

OWL .... Ontology Web Language

PIM .... Product Information Management

QG1.......... Quality Gate 1

R&D......... Research & Development

RDF.......... Resource Description Framework

UIN .... Unique Identifier Number

UML......... Unified Modeling Language

W3C......... World Wide Web Consortium

XML......... Extensible Markup Language

1 INTRODUCTION

1.1 Theoretical framework

"Data is the new oil."

The quote goes back to 2006, made by the Mathematician Clive Humby (Palmer, 2006). Today, data is seen as one of the most valuable resources in the world. However, data can only be considered valuable if it is organized, structured, subject to a good and consistent management basis and, preferably, machine-readable, being able to adapt to the most modern technologies of the 21st century, such as Internet of Things (IoT).

The impact of digitalization (also known as digital transformation) is unquestionable when it comes to current and future society and businesses. Many authors compare digital transformation to the industrial revolution (Degryse, 2016; Jänicke & Jacob, 2013; Schwab, 2015; Tihinen et al., 2016).

The digital transformation at the center of the Industrial Revolution, also known as Industry 4.0 (Bloem et al., 2014; Prisecaru, 2016).

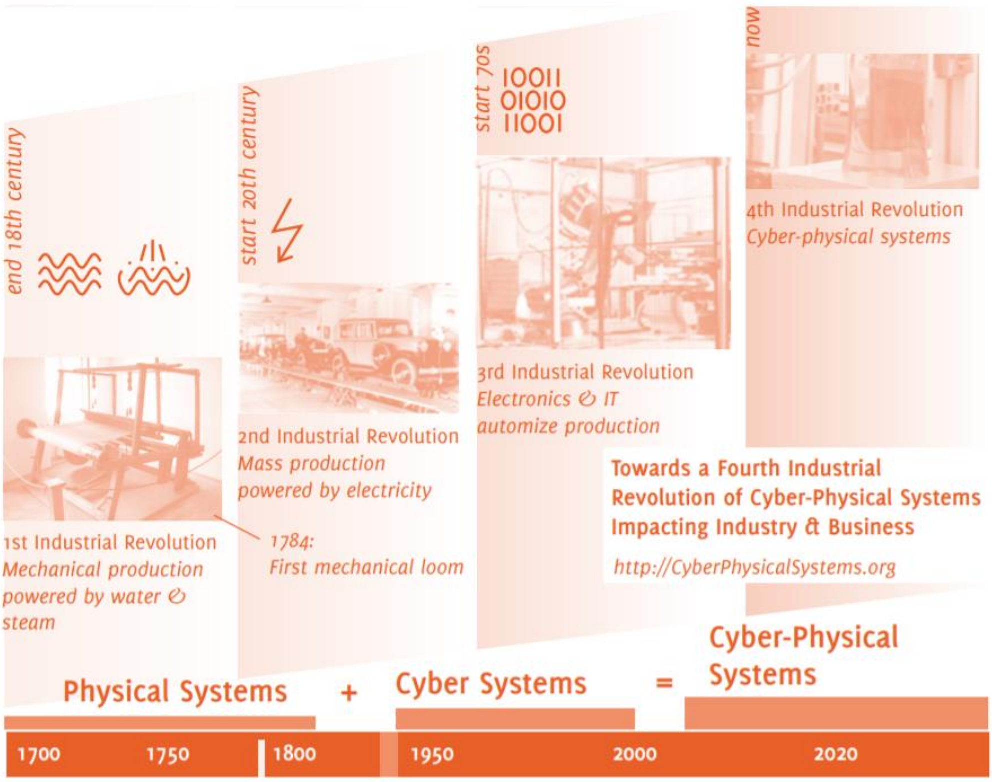


Figure 1 - The evolution of industry until the 4th industrial revolution.
Source: Bloem et al. (2014)

In addition to that, at this time, more than ever, with the current pandemic situation due to the SARS-CoV-2 coronavirus, people have inherently been increasingly dependent on e-commerce and online marketing, due to all the social restrictions imposed by governments from all over the world. This makes it necessary for an organization's data architecture to be based on a strong, consistent, theoretical- and practically logical basis, which facilitates not only the experience of the end-customer, but also the management that must be carried out by the respective data managers. In order to build or improve such data architecture technology and business must be aligned, willing and receptive to change. Once both parties are committed to the transition, data architecture may bring great benefits to the company and its way of working. For instance, the business adaptability may improve significantly through IT; a closer collaboration between IT and business, including a higher focus on deliverables and business requirements; workers understand the importance of their work and the company's success; less complexity and less failed IT systems (Tupper, 2011).

Following the topics of e-commerce, data architecture, and data management, this project will address the topic of product information management (PIM). These topics will be applied to a multinational company (Bosch Security Systems) that has a vast product catalog, which is complex, since the products can be purchased individually or in kits that, complementing each other, can form complete systems.

In addition to the challenge of providing complex systems in an intuitive way to the customers, the information that is behind the current Bosch Security Systems product catalog is poorly automated. Consequently, data management is not consistent and ends up making the user’s experience frustrating, be it for the individual who has to manage the information in the background (worker), or the individual who is interested in purchasing the company’s products. Furthermore, the overall company’s approach to e-commerce is lagging, if we look at other examples of vast product catalogs or marketplaces such as Amazon - a smart, automated e-commerce website, easy for employees to manage and easy for consumers to use.

The complex modularity of Bosch’s systems is considered to be one of the biggest challenges within the current movement of change. In this context, a complex modular security system represents the degree to which a system's component or even a smaller system within another bigger system may be separated and recombined, offering flexibility and variety in use. In summary, the customer is able to customize and adapt a system according to his necessity.

1.2 Problem approach

The main objective of this project is to find a digital solution that provides a significant improvement in the representation of the complex modular security systems that are offered by the organization in question and its effective and efficient management.

In this sense, the solution should facilitate the management of product information / data and its links in the long run. In this way, all departments should have a common central information source, which will provide information that is easier to interpret, more consistent, reliable, and machine-readable. The data model should serve as a basis for several systems used internally, facilitating potential interfaces between systems, and improving internal communication, between different departments overall.

Another important objective is to improve the end customer experience. The solution should also be reflected in the organization's online catalog, making it easier for the end consumer to choose different products and combine them for different application areas. In this way, it is expected that the user experience will significantly improve, resulting in less use of customer support services and potentially increasing orders.

In short, this project aims to help managing complex modular systems at a leading international technology and service company.

1.3 Research methodology summary

The methodology used in this project will be explained further on. In the first phase, it will consider a review of the literature on topics related to the exhaustive research carried out on “data and digitization”, concepts such as PIM, ontology, semantic web, ERP, CCMS, UML, ERD. After reviewing and analyzing the literature, a contextualization is made about the company in which the project will be applied. The action research method will be followed, to support the creation of the solution that intends to answer the defined objectives. The solution will be created with an appropriate tool (Protégé) to put the concept into practice in the context under study. Finally, to conclude, the obtained result will be analyzed and interpreted.

1.4 Document structure

The project is divided into 5 chapters.

After this first chapter, chapter 2 will present the literature review that was carried out in which the trends of digitalization in today's organizations and their importance were addressed. Also in this chapter, a study of the literature on PIM (Product Information Management), KR&R (Knowledge representation and reasoning), ontologies, semantic web, ERP (Enterprise Resource Planning), CCMS (Content Management System), UML (Unified Modeling Language), Data modeling and ERM (Entity-Relationship Model) is presented.

Chapter 3 introduces the work methodology used to carry out the study in practice. Also in that chapter, the organization and its use case are contextualized, in which the whole process and the respective research results are applied in practice. Concluding this chapter, a description of the solution proposal elaboration process that will answer the research question of the present project follows.

In chapter 4, results are presented and an analysis and discussion of those is made. Since this project is based on the action research methodology which has five different phases, chapter 4 is divided into five different subchapters accordingly. Chapter 4.1 is the diagnosis phase - a description and analysis of the as-is situation of the organization is made, namely, regarding the information systems used, the online catalogue, the current product taxonomies and, finally, the solution proposal is made. Chapter 4.2 is the action planning phase - the team is presented and the approach inspired in the Agile work methodology used to carry out the proposed solution is described. Furthermore, the planning meetings, the working partners, the tools to be used and their justification are described. Chapter 4.3 is the action-taking phase - the whole process of creating the ontological solution and its final result is described, including concrete examples and graphical representations of the solution in the tool itself (Protégé Ontology Editor, developed by Stanford University). Chapter 4.4 is the evaluation phase, where the ontological solution is tested in order to assess whether the structure fulfils the necessary requirements. And finally, Chapter 4.5 is the learning specification phase, in which the next steps for the implementation and future management of the ontological model are proposed.

2 LITERATURE REVIEW

For the elaboration of this master's project, it is essential to carry out an in-depth investigation and analysis of some of the key terms and concepts addressed throughout this written work. The following sub-chapters provide a description that is supported academically and scientifically by part of the bibliography considered relevant to clarify the key terms.

2.1 Digitalization and data

The impact of digitalization (also known as digital transformation) is unquestionable when it comes to society and businesses of today and of the future. Many authors compare digital transformation to the industrial revolution (Degryse, 2016; Jänicke & Jacob, 2013; Schwab, 2015; Tihinen et al., 2016).

The digital transformation at the center of the Industrial Revolution, also known as Industry 4.0 (Bloem et al., 2014; Prisecaru, 2016).

The term "digitalization" may be defined as:

- "Digital transformation, also known as digitalization, refers to a business model driven by the changes associated with the application of digital technology in all aspects of human society" (Stolterman & Croon Fors, 2004).
- "[…] the ability to turn existing products or services into digital variants, and thus offer advantages over tangible product" (Mahraz et al., 2019).
- "[…] changes in ways of working, roles, and business offering caused by adoption of digital technologies in an organization, or in the operation environment of the organization" (Greeven et al., 2017).

This refers to changes at several levels, including the following (Greeven et al., 2017):

- Process level: implementation of new digital tools, streamlining processes, and less manual steps.
- Organization level: providing new service formats.
- Business domain level: altering roles and value chains within the business environment.
- Society level: creating different and new social structures, incl. the type of work, new ways of decision making.

Disregarding and not to invest in digitalization can bring big disadvantages to companies, potentially leading to their irrelevance and loss in the future. Digitalization can impact a company's entire operation environment and internal functioning. Digitalization can also bring new business opportunities and change the roles of operators in a value chain. Thus, the impact of digitalization, and the goals of digitalization for an organization, can be identified from three different perspectives (Parviainen et al., 2017):

1. Internal efficiency, i.e., better way of working through digital methods and readjusting internal processes.
2. External opportunities, i.e., new business opportunities (services, customers etc.).
3. Disruptive change, in which digitalization generates complete changes in business roles.

In practice, there can be several challenges to digital transformation. A digital transformation project implies the involvement of digital resources to support the business model transformations that affect organizations, mainly operational processes, resources and internal and external users (Greeven et al., 2017).

However, many companies struggle in the transition into the new ways of working, many times due to previous generations' knowledge management systems. Many organizations do not change mindsets and processes or build a culture that can foster the change. Lack of an overall digitalization strategy and competing priorities are the most typical obstacles for digitalization, together with security concerns and insufficient technical skills.

When talking about digitalization, inherently, one must also mention data, as data fuels digital transformation. A key foundation and enabler for digital transformation must be data. Companies that do not keep up and are not continuously reinventing their business with data at the core will end up losing the race while their market is disrupted (Ibbitson, 2020).

With data fueling so many transformative approaches, whether it be artificial intelligence, machine learning or deep learning, or supporting deeper insight, the ability to deliver an agile platform to underpin the data workloads is key (Pettey, 2019).

The current available computational capacity, allied to machine learning techniques and algorithms (machine learning), allow processing huge amounts of information available in varied data sets from different areas. Machine learning has been increasingly used in the most diverse domains, whether in the public sector or in the fiscal (Seiça et al., 2019), education (C. Pimenta et al., 2018) and medicine areas (Brandão et al., 2021) or, in the private sector, as in marketing (Cui et al., 2006), in the media and entertainment industry (Sereday & Cui, 2017), in the events industry (Loureiro et al., 2014), in the tourism (P. Pimenta et al., 2009) and in many other areas, contributing to the creation of new knowledge and helping organizations to define strategies that allow them to increase their performance.

Data management technologies are becoming more powerful and start to require less costs, increasing product traceability. In all areas, this should be seen as an opportunity to improve and innovate (McKean, 2001).

The importance of most Information Systems/Information Technology (IS/IT) skills is continually increasing over time; data management, project management and other business skills, Web applications, services, and protocols, and wireless communications and applications are expected to be the most important five skills in the future (Lee & Mirchandani, 2010).

Another important concern among IS/IT managers is business and information technology alignment (Belfo, 2010, 2013; Belfo, 2018; Belfo & Sousa, 2013; Luftman & Derksen, 2014), which usually referred as the "measure of how much the mission, objectives and plans of IT support and are supported by the mission, objectives and business plans" (Reich & Benbasat, 1996). This alignment is one of the most important areas of IT governance, and included in some of the most important frameworks, like the Control Objectives for Information and related Technology (COBIT) (ITGI, 2007), the Information and Technology Infrastructure Library (ITIL) (Taylor, 2007) or The Open Group Architecture Framework (TOGAF) (The Open Group, 2009).

2.2 Product Information Management

Poor data quality, especially outdated or wrong product information, has a negative impact on demand and supply chain performance (Shooter et al., 2004).

The management of information has become one of the biggest challenges of supply network management. This is due to the increasing product customization and more and more complex supply networks. Product customization leads to bigger quantities and more specificities of product-related information. The current mainstream solutions (e.g. integrating product information databases) are not suitable for complex, short-term supply networks (Kärkkäinen et al., 2003).

The importance of solid Product Information Management (PIM) during the whole lifetime of the product has increased due to the technical sophistication of products as well as stricter governmental regulations for lifecycle management. It has been shown to be challenging to maintain the information up to date for the relevant supply chain members during the products' lifecycle. "Product centric information management" in which information regarding a product is retrieved over information networks when needed, using unique product identifiers as references is one solution type complying with the information decoupling point principle (Främling et al., 2006).

A PIM system allows a seamless integration of all the information produced throughout all phases of a product's life cycle. It is available to everyone in an organization at every managerial and technical level, along with key suppliers and customers (Sudarsan et al., 2005).

PIM comprises the process that includes managing all the information necessary to enable the sale and commercialization of products through different output channels, such as e-commerce sites, printed catalogs, markets such as Google Store and Amazon, sales channels. social media and electronic data platforms for business partners.

PIM solutions are most important to business-to-business (B2B) and business-to-consumer (B2C) organizations that commercialize products over various sales platforms. The use of PIM is generally influenced by a company's (UnchainedCommerce, 2020):

- wide range of products with a complex data set
- product characteristics that are subject to constant change
- big number of output channels
- excess of data sources and formats with a complex IT infrastructure that is non-uniform
- e-commerce

PIM systems manage customer-facing product data. This data is needed to support different geographic areas, data in multiple languages, and managing and modifying product information in a centralized catalog. It is a centralized solution and media-independent data management, allowing efficient data collection, enriching output and data management (UnchainedCommerce, 2020).

PIM and ERP integration

Organizations have lots of products, and once those products are made available online, a big amount of data has to be taken into account. A PIM system allows organizations to manage the product data and the way that the information is displayed within large and complex catalogs. A PIM can receive product information from multiple vendors or suppliers, and publish that data in e-commerce websites, print catalogs, and online marketplaces. Distributors may already have a system for doing this, thanks to the product file in their existing enterprise resource planning (ERP) system. Many distributors and wholesalers use ERP systems to manage most of all their data, including their customer file, ship-to file, vendor file, and product file. Nonetheless that is not the same as a PIM. ERP usually is not able to handle the complexity that is inherent to the big and complex catalogs composed of products from various vendors. Trying to use an ERP to maintain and publish consistent product information into an ecommerce site or catalog, involves many man hours which cost a company a lot of money. An ERP also can't manage product data quality like a PIM. PIM enables guaranteed data consistency and terminology across output channels.

The thing that makes the online world you attractive is that it offers an almost infinite space for information and product pages. Unfortunately, customers do not have infinite time to look through multiple product pages to find what they're looking for. Well succeeded ecommerce websites use a smart and intuitive product categorization for an improved and easier navigation, and this leads to more purchases.

PIM enables organizations to define the important attributes of their products, and this represents a big improvement in simplification of complex catalogs and elimination of duplicated product pages and search results that confuse customers.

Helping website tools generate sales

PIM plugs directly into component content management systems (CCMS), site search engines and commerce modules. When you actively edit and manage product data, images, video, brochures, and product categorization with the PIM, each of these systems works more intelligently, helping customers find and purchase products easier and quickly.

With the increasement of competition between B2B ecommerce, the businesses that focus their strategy on a PIM at the core, have a higher rate of success now and in the future.

Companies operating without a PIM in place struggle to compete against more mature ecommerce operations that provide better data governance, distribution, and accessibility by their partners, suppliers, agencies and online marketplaces (PIMVendors, 2020).

“A Product Information Management (PIM) solution provides a single place to collect, manage, and enrich your product information, create a product catalog, and distribute it to sales and eCommerce channels” (Akeneo, 2020).

One of the advantages of a PIM system is that it does not just integrate descriptive data of the product (e.g., name, characteristics, price). A toll like this can include marketing information, such as detailed features, enriched descriptions, SEO tags, and more. It may also include user information, like ratings, recommendations and comments and also multimedia information related to the product (e.g., product photos, manuals, certification information, videos, or technical documentation etc.) (Minderest, 2020).

In a general, a PIM becomes a master system, allowing the creation and management of products in a dynamic manner and with a lot and very complete information, to provide a consistent product vision. “For an ecommerce, efficiency and flexibility are competitive advantages, and with a PIM, manual errors are reduced and it is possible to react quickly to any changes in the market” (Minderest, 2020).

2.3 Knowledge representation and reasoning

In the present era of knowledge economy, the differentiation of companies has switched from visible assets (e.g., equipment, capital, labor) to invisible knowledge. There are two different ways in which knowledge can be distinguished: explicit knowledge and tacit knowledge. Tacit knowledge includes empirical knowledge that is difficult to document, and it is generally hidden in the form of personal mental models. The inability to transfer tacit knowledge to organizational knowledge would cause it to disappear after workers leave their jobs, and consequently lose important intellectual assets for companies. Companies trying to create higher knowledge value are highly concerned with how to transfer personal empirical knowledge inside of an enterprise into an organizational explicit knowledge by using an organized method to manage and effectively share this valuable empirical knowledge (Y. J. Chen, 2010; Nonaka, 1994).

Knowledge representation and reasoning (KR^2 or KR&R) is considered part of the area of artificial intelligence (AI). It is concerned with representing information about the world in a way that a computer system can use it, in a machine-readable manner, in order to solve complex tasks. It includes psychology findings about how humans solve problems and represent knowledge with the goal of designing formalisms that will simplify complex systems in their design and build. KR&R also includes findings from logic, which automate diverse types of reasoning (e.g., application of rules or relations of sets and subsets) (Levesque, 1986; Nonaka, 1994).

Examples of knowledge representation formalisms are (Levesque, 1986):

- semantic nets
- system architecture
- frames
- rules
- ontologies

Examples of automated reasoning engines are (Levesque, 1986):

- inference engines
- theorem provers
- classifiers

Representation of knowledge simply has to do with writing down, in some language or communicative medium, descriptions or pictures that correspond in some way to the world or a state of the world. Artificial intelligence (AI) is concerned with writing down descriptions of the world in which an intelligent machine might be embedded in such a way that the machine can come to new findings about its world through the manipulation of these symbolic representations (Levesque, 1986).

2.3.1 Ontologies

The concept of ontology originated in Ancient Greece, having occupied the minds of Plato, Aristotle and Parmenides (Wang, 2008). Ontology (from the Greek *ontos* "being" and *logoi*, "science of being") is the part of the metaphysics that deals with the nature, reality and existence of beings (Merriam-Webster, 2020).

“Ontology, as a branch of philosophy, is the science of "what is", of the kinds and structures of objects, properties, events, processes, and relations in every area of reality. Ontology seeks to provide a definitive and exhaustive classification of entities in all spheres of being” (Smith, 2012).

The classification should be (Smith & Welty, 2001):

- **Definitive**, providing an answer to the questions:
    - What classes of entities are needed for a complete description and explanation of all the goings-on in the universe?
    - What classes of entities are needed to give an account of what makes true all truths?
- **Exhaustive**: all types of entities should be included in the classification, including the types of relationships by which entities are tied together to form larger wholes.

The term "ontology" has gained currency in recent years in the field of computer and information science (Smith & Welty, 2001).

"Artificial intelligent researchers have initially borrowed the word "ontology" from Philosophy, then the word spread in many scientific domain and ontologies are now used in several developments" (Roussey et al., 2011).

According to Smith & Welty (2001), the "new ontology" is a consequence from what he calls "the Tower of Babel problem". This means, different groups of data- and knowledge base system designers have their own idiosyncratic terms and concepts, i.e., their own language, with which they build frameworks for information representation.

Different databases may use identical labels but with different meanings, but the same meaning may also be expressed through different terms. Diverse groups of people are involved in sharing and translating diverse information, the problems standing in the way of putting this information together in a single system increase significantly. There have to be found new ways to resolve the inherent incompatibilities between terminology and concepts (Smith & Welty, 2001).

Incompatibilities as such, are usually resolved case-by-case, but over time, however, it is being recognized that a common ontology might provide significant benefits and advantages over case-by-case resolutions. An ontology is, in the information science context, a dictionary of terms formulated in a canonical syntax and with commonly accepted definitions, designed to produce a taxonomical framework aimed at knowledge representation that can be shared commonly by different IT system communities. In addition to that, "(…) an ontology is a formal theory within which not only definitions but also a supporting framework of axioms is included" (Smith, 2003).

The possible benefits of ontology considered for the purposes of information management are full of great expectations. Each group of people responsible for the data (e.g., data analysts) must perform the task of making its terms and concepts compatible with those of other such groups only once, and thus, creating a single canonical backbone language. Equivalence algorithms and canonical representation are used in order to ensure the uniform representation and help to design data representation in cloud data interchange services among various information systems (Andreica et al., 2017). If all databases were calibrated in terms of just one common ontology (a single consistent, stable, and highly expressive set of category labels), thousands of person-years of effort that have been invested in creating separate database resources would be compensated, thanks to the creation of a single integrated knowledge base, comprehending all knowledge within a single system.

“The top-level ontology would then be designed to serve as common neutral backbone language, which would be supplemented by the work of ontologists working in more specialized domains” (Smith, 2012).

Types of ontologies

Ontologies can be of various different types and, depending on their context, they can designate different computer science objects. For instance, an ontology can be (Lassila & McGuinness, 2001):

- a thesaurus in the field of information retrieval or
- a model represented in OWL in the field of linked-data or
- an XML schema in the context of databases

It is important to know the content, the use and the goal of the different forms of ontologies. Literature presents various classifications of ontologies (Borgo, 2007; Lassila & McGuinness, 2001). This work focuses on two classifications (Roussey et al., 2011):

1. Expressivity and formality of the used languages (natural language, formal language, etc.)

2. Scope of the objects described by the ontology.

Depending on an ontology's expressivity (also known as knowledge representation language), the ontology can be composed of different components, such as concepts, properties, instances, axioms, etc.

Being one of the main components of an ontology, concepts can be defined in different and complementary ways. A concept can be defined by (Roussey et al., 2011):

- Textual definition. Example: the concept "person" is defined by the sentence "an individual human being".
- A set of properties. Example: the concept "person" has the property "birth date" and address. A property can be reused for several concepts.
- Logical definition composed of several formulae. Example: the concept "person" is defined by the formula "LivingEntity ∩ MovingEntity" (Roussey et al., 2011).
- A set of instances. Example: Michael Jackson is an instance of the concept "person".

Concepts, instances, and properties are supported by one or more symbols, and all the ontology components are connected through relations which only link concepts together.

There can be four types of ontologies that can be classified from less formal languages to more formal languages (Roussey et al., 2011).

1. Information ontologies

Information ontologies are diagrams used to clarify and organize ideas in the development of a project.

Characteristics ((Roussey et al., 2011):

- Easy to modify.
- Easily scalable.
- Human-readable (not machine-readable).
- Normally used during the conception phase of an information system development project.
- Focus on concepts, instances, and their relationships.
- The goal is to provide an overview of a project to express the status of the same project.
- Properties are not always well defined.
- Normally described by visual languages, for easy human understanding.
- Language or tool: Mind map

2. Linguistic/terminological ontologies

Linguistic/terminological ontologies can be, for instance: glossaries, dictionaries, controlled vocabularies, thesauri, lexical databases, etc.

Characteristics (Roussey et al., 2011):

- Focus on terms and their relationships.
- Terms are ambiguous.
- The goal is to present and define the used vocabulary.
- The result of a terminology agreement between a users' community (vocabulary normalization).
- Distinction between concepts and their instances are not taken in account.
- Language: Simple Knowledge Organization System (SKOS); Resource Description Framework (RDF)

3. Software ontologies

Software ontologies are a conceptual schema whose main focus is normally on data storage and data manipulation.

Characteristics (Roussey et al., 2011):

- Used for software development activities, with the goal of guaranteeing data consistency.
- Focus on concepts, properties, relations between concepts and their constraints.
- Normally defined with conceptual modeling languages used in software and database engineering.
- Language or tool: Unified Modeling Language (UML), Entity-Relationship Diagram (ERD), Object Model Language (OML)

4. Formal ontologies

Formal ontologies are a clear semantics for the language used to define the concept, clear motivations for the adopted distinctions between concepts as well as strict rules about how to define concepts and relationships.

Characteristics (Roussey et al., 2011):

- Uses formal logic (first order logic or description logic).
- The meaning of a concept is guaranteed by formal semantics (knowledge bases).
- The logical definition of a concept is composed of one or more logical formulae (axioms). A logical formula (or axiom)
- is a combination of concepts and semantic relations.

- A KB contains more expressive components than a conceptual schema.
- Purpose: retrieval, storage of data and reasoning.
- Compared to software ontology, data are not associated to method to make some calculation; data are stored in property only to be retrieved.
- Does not focus on a textual definition, but on axioms. Terms are used as a symbol.
- Language: Can be described by different formal languages (e.g., Description Logics (DL), Conceptual Graphs (CG), First Order Logic (FOL), Web Ontology Language (OWL)). OWL is the standard recommended by W3C.
- Tool: Protégé

OWL

OWL is designed for the purpose of being used by applications that must process content of information instead of only presenting information to humans. OWL simplifies and improves machine interpretability of Web content than the one supported by XML, RDF, and RDF Schema (RDF-S) (W3C, 2012).

The RDF-S provides additional vocabulary with a formal semantics. “The OWL is intended to provide a language that can be used to describe concepts and relations between them that are inherent in Web documents and applications” (Roussey et al., 2011). The OWL language is used to:

1. formalize a domain by defining concepts called classes and properties of those classes,
2. define instances called individuals and assert properties about them,
3. reason about these classes and individuals to the degree permitted by the formal semantics of the OWL language (Roussey et al., 2011).

The conceptualization activity is composed of several tasks. One of them is the construction of the concept taxonomy (Grandon, 2002).

Examples of well-built ontologies are, for instance, the Google Knowledge Graph, Amazon and Wikipedia’s WIKIDATA element.

2.4 Enterprise Resource Planning

Enterprise Resource Planning (ERP) is an information system that connects all the data and processes of a company in one single system. This interconnection can be seen from a functional perspective (finance, accounting, human resources, manufacturing, marketing, sales, purchasing, etc.) and from a systemic perspective (transaction processing system, management information systems, decision support systems etc.) (Acervo Lima, 2020).

ERP is a software which has been developed to establish a communication/connection several departments of a company, making it possible to automate and store all business information (Linx, 2020).

ERP is the backbone of electronic business, a transaction architecture that links all the functions of a company, for example, sales order processing, inventory control and management, production and distribution planning and finance. Figure 2 depicts the basic structure of na ERP system.

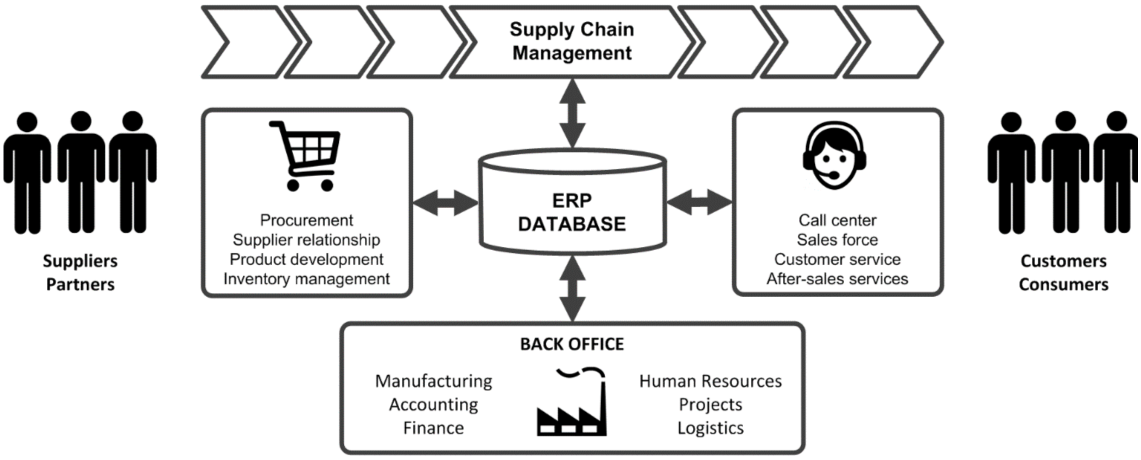


Figure 2 - Basic structure of an ERP system.
Source: Estébanez, Trigo, & Belfo (2016)

The first ERP systems were originated in the United States during World War II, from the necessity and high demand for management of army material resources.

At a later stage, manufacturing companies used ERP system with the purpose of managing and streamlining their inventory planning the use of resources in accordance with the demand for their products.

The name ERP was originated from the terms material requirements planning (MRP) and manufacturing resource planning (MRPII) (Chung & Synder, 1999; Holland et al., 1999; Yusuf & Little, 1998).

When it comes to purpose and functionalities, ERP systems have undergone an evident evolution over time:

- **MRP** - Developed to calculate more efficiently the materials needed.

- **MRPII** - Included new functionalities, such as, sales planning, capacity management and scheduling. MRPII was considered the next essential step in manufacturing planning. Profitability and customer satisfaction were considered important goals that applied to the entire enterprise and extending beyond manufacturing, and encompassing finance, human resources, and sales and distribution (Klaus et al., 2000).
- **ERP** - Developed in the late 20th century, before the new globalized trade organization, as a system that supported business management with a holistic approach to promote operational efficiency and support critical aspects of management. The currently known ERP systems have been created as applications with integrated business systems. Known for breaking barriers between functional departments and reducing double-work effort, the ERP system represented a big contribution to be more flexible and responsive business processes. Most ERP systems are only used in internal processes, integrating Finance & Accounting, Human Resources, Order Management (Sales) and Manufacturing (Estebanez et al., 2016). There is usually not much collaboration with outsourcing suppliers and customers.
- **ERPII** - Developed in the beginning of the 21st century, where innovative requirements for extended enterprises were incorporated. New modules and functionalities like customer relationship management (CRM), supply chain management (SCM), product lifecycle management (PLM) or employee lifecycle management (ELM) became part of ERPs, eliminating redundant information, increasing integration between the system and external actors and enhancing collaboration in all the supply chain. ERP II concept was based not only on the business coordination, but also on the industry orientation, expanding roles and functions of the system required by an industry sector or a specific industry (Møller, 2005; Xu, 2011).
- **ERPIII** - Recognizes knowledge as an important asset. The integration of the knowledge management (KM) function into ERP systems were encouraged and the term ERP III emerged (Møller, 2005).

There are many advantages when it comes to ERP system, but the main advantages that such a system is known for are: online access to data, the capability to share data and share knowledge within an organization, increase consistency between business strategy and operational decisions that contribute to businesses' competitiveness (Chuang & Shaw, 2005; Gupta & Kohli, 2006).

The availability of specific modules for each of the different functional areas of the company, avoiding duplicate tasks and improvement of real-time communication between different areas of a business.

Between the main disadvantages of ERP systems is the difficulty in its implementation (Quattrone & Hopper, 2006), as these systems tend to be more complex systems that have a big impact in an organization and require a large amount of resource capacity (Ward et al., 2005).

Another negative factor can be the non-acceptance of company members in the implementation of such a system (Wall Friederike, 2003). An ERP system requires a quite high investment and level of training of human resources in order to be able to use the system efficiently (Romeo J., 2002).

Other issues affecting ERP implementation have been discussed in several articles and cases, such as business processes reengineering, ERP-legacy integration, data management, implementation cost and schedule, ROI concerns, top management commitment, effective and strong project management, and project members' qualifications (Estebanez et al., 2016).

In some cases, ERP systems can even cripple or bring down businesses (Chuang & Shaw, 2005).

2.5 Content Management System

A component content management system (CCMS) is a software application used to manage digital content, data or information of a website project, or internet/intranet application. Content management refers to creating, editing, archiving, publishing, collaborating on, reporting, distributing website content, data and information (Bernard, 2016).

Nichani (2001) defines content management system as being a software tool that serves as a data repository that may contain authoring, sequencing, and content aggregation tools, with the goal of simplifying the creation and management of online content (Nichani, 2001).

The main purpose of a Content Management System (relating to web) is to provide the capability for multiple users with different permission levels to manage a website or a section of the content (Bernard, 2016).

Content management systems were originally created and used in the newspaper industry. In the nineties, content management systems have been adapted to manage large volumes of content that were aimed to be used in robust websites, incorporating a workflow process and allowing the management of information based on search and retrieval criteria (Irlbeck, Sonja; Mowat, 2007).

Today, content management systems can support multiple users in a collaborative environment, allowing the management of product data and authoring of technical documentation (e.g., installation manuals, quick installation guides, software manuals, datasheets, etc.) for digital content, as well as the management of part of a website.

In a CCMS, collaborative authoring for websites may include, text, graphics and photos, video, maps, and program code that display content and interact with the user. A CCMS allows the creation and modification of multilingual modular documentation in technical documentation and other editing contexts.

One of the great advantages of a CMS is that it supports reuses of content, i.e., content that has been created once, can be reused many times.

The use of a CCMS allows people to edit, even though they do not have an in-depth knowledge of HTML, however, still maintaining a good standard of page design and compilation. A CCMS fully manages all the complex site contents, starting from the contents collection from external sources, database management, going down to storage process and final publication (Dal Porto & Marchitelli, 2006).

Publication is a central aspect of a CCMS: it is based on the initial creation of templates, i.e. models that define the texts layout, getting the content from the database (Dal Porto & Marchitelli, 2006).

Features can vary between different CCMS', but the main functions are often considered to be indexing, search and retrieval, format management, revision control and publishing (Amsler & Curchville, 2021; Babeley, 2016):

- “Intuitive indexing, search and retrieval features index all data for easy access through search functions and allow users to search by attributes such as publication dates, keywords, or author.
- Format management facilitates turn scanned paper documents and legacy electronic documents into HTML or PDF documents.
- Revision features allow content to be updated and edited after initial publication. Revision control also tracks any changes made to files by individuals.
- Publishing functionality allows individuals to use a template, or a set of templates approved by the organization, as well as wizards and other tools to create or modify content” (Amsler & Curchville, 2021).

While a CCMS itself is not a source of knowledge, it can be a very valuable enabler in knowledge-capture processes (Robertson, 2003). The CCMS stores and manages the content, but does not analyze, organize, or distil content into knowledge (Irlbeck, Sonja; Mowat, 2007).

2.6 Unified Modeling Language

There are 4 types of computer languages (Völter, 2010):

1. Embedded (e.g., Java, CC++) - contains a certain set of instructions through which a programmer tells a computer how to do a certain task.
2. Query (e.g., SQL, XQuery) - through which we enquire some sort database, or through which we ask for a specific piece of information.
3. Data (e.g., XML, HTML, JSON) - used for data migration. They carry data in a specific structure, from one machine to another machine.
4. Modeling (e.g., XSD, UML, OWL) - used to say something about the data.

UML falls within the modeling languages.

In the late twentieth century, the Object Management Group (OMG) released the Unified Modeling Language (UML) (Booch et al., 2000).

Unified Modeling Language (UML) has emerged as the software industry’s dominant modeling language. It is the modeling language standard for specifying, visualizing, constructing, and documenting the components of software systems (Siau & Cao, 2001).

UML has been submitted to OMG as a proposal for a standard notation of object-oriented analysis and design techniques (Breu et al., 1997).

One of the purposes of UML was to provide the software development community with a consistent and common design language that could be used to develop and build computer applications. By using UML, IT professionals could read and disseminate system structure and design plans (Bell, 2003).

The Unified Modeling Language (UML) is a language for specifying, visualizing, constructing, and documenting the artifacts of software systems, as well as for business modeling and other non-software systems. The UML represents a collection of the best engineering practices that have proven successful in the modeling of large and complex systems (Booch et al., 2000).

UML is a common and unifying language that enables IT professionals to model computer applications. The primary authors were Jim Rumbaugh, Ivar Jacobson, and Grady Booch, who originally had their own competing methods (OMT, OOSE, and Booch). Eventually, they joined forces and brought about an open standard. One reason UML has become a standard modeling language is that it is programming-language independent. Also, the UML notation set is a language and not a methodology. This is important, because a language, as opposed to a methodology, can easily fit into any company's way of conducting business without requiring change. Since UML is not a methodology, it does not require any formal work products (i.e., "artifacts" in IBM Rational Unified Process® lingo). Yet it does provide several types of diagrams that, when used within a given methodology, increase the ease of understanding an application under development. The diagrams offer a good basic knowledge to the language and the principles behind its use. The most useful, standard UML diagrams are: use case diagram, class diagram, sequence diagram, state chart diagram, activity diagram, component diagram, and deployment diagram (Bell, 2003).

These diagrams provide multiple perspectives of the system under analysis or development. The underlying model integrates these perspectives so that a self-consistent system can be analyzed and built. These diagrams, along with supporting documentation, are the primary artifacts that a modeler sees, although the UML and supporting tools will provide for a number of derivative views (Booch et al., 2000).

Currently, UML focuses only on notation. Method and process issues are outlined but not dealt with in detail. However, it is stated that the process is to be use-case driven, architecture centric, iterative and incremental. Like other software engineering methods, UML provides a set of intuitive, graphical and textual description techniques that are supposed to be easily understandable for both system developers and expert users working in the application domain (Breu et al., 1997).

The Unified Modeling Language (UML) is a family of design notations that is rapidly becoming a de facto standard software design language. UML provides a variety of useful capabilities to the software designer, including multiple, interrelated design views, a semiformal semantics expressed as a UML meta model, and an associated language for expressing formal logic constraints on design elements (Medvidovic et al., 2002).

The Unified Modeling Language UML is a language for specifying, visualizing, and documenting object-oriented systems. UML combines the concepts of OOA/OOD, OMT and OOSE and is intended as a standard in the domain of object-oriented analysis and design (Breu et al., 1997).

2.7 Data modeling

In computer science, data modeling refers to the procedures required for the formal mapping of objects, which are relevant in a defined context using their attributes and relationships. The main objective is to clearly define and specify the objects that are to be managed in an information system, their attributes required for the information purposes and the relationships between the information objects. This will provide an overview of the data view of the information system (Ferstl et al., 2006).

The result are data models that, through several modeling stages, ultimately lead to operational databases.

Data models generally have a much longer lifespan than functions and processes and thus software. Data is stable, but functions are not. Data modeling can also be carried out outside of application development projects to represent certain facts. For example, it can be used to record data or other circumstances of a certain company division, a department, a business process (up to the entire company) and document them with their relationships.

One of the most critical stages when developing a computerized information system is the design of the data structures and the documentation of that design in a set of data models (Ferstl et al., 2006).

An information system can be thought of consisting of a database (containing stored data) together with programs that capture, store, manipulate, and retrieve data. These programs are designed to implement a process model (or functional specification), specifying the business processes that the system is going to perform. In the same way, the database is specified by a data model, describing what sort of data will be held and how it will be organized (Ferstl et al., 2006).

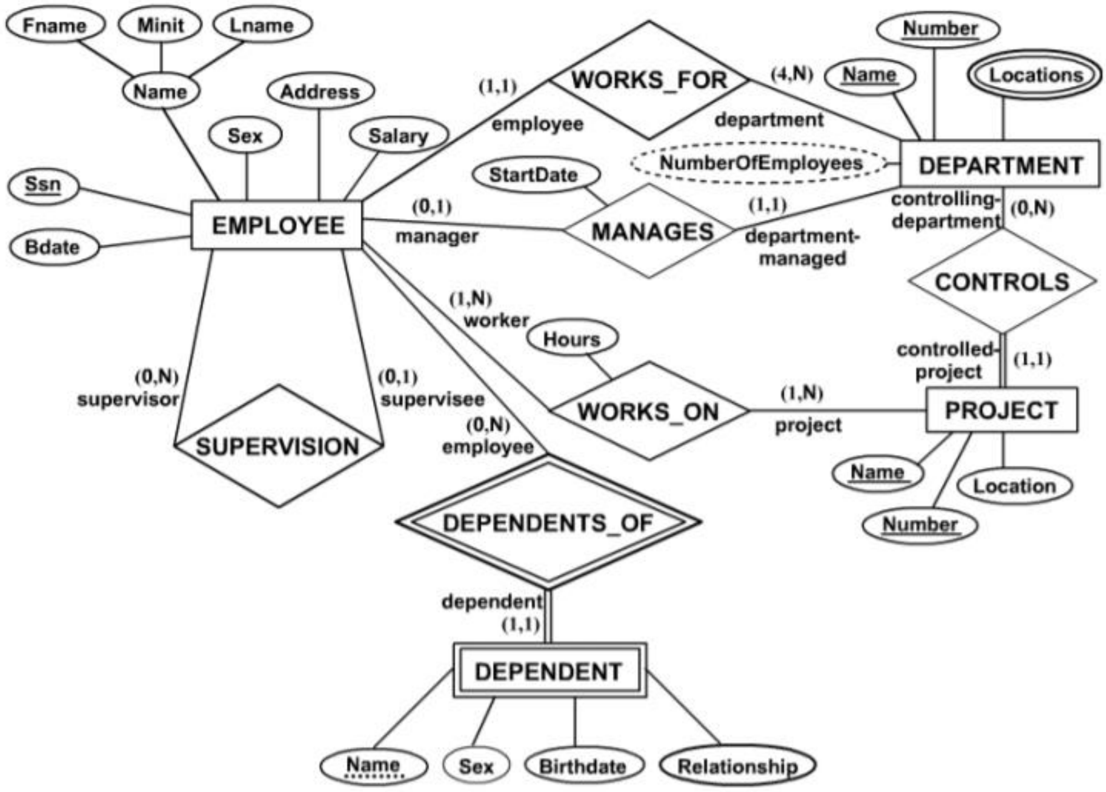


Figure 3 - An example of an Entity-Relationship diagram of a company database.
Source: (Soler et al., 2010)

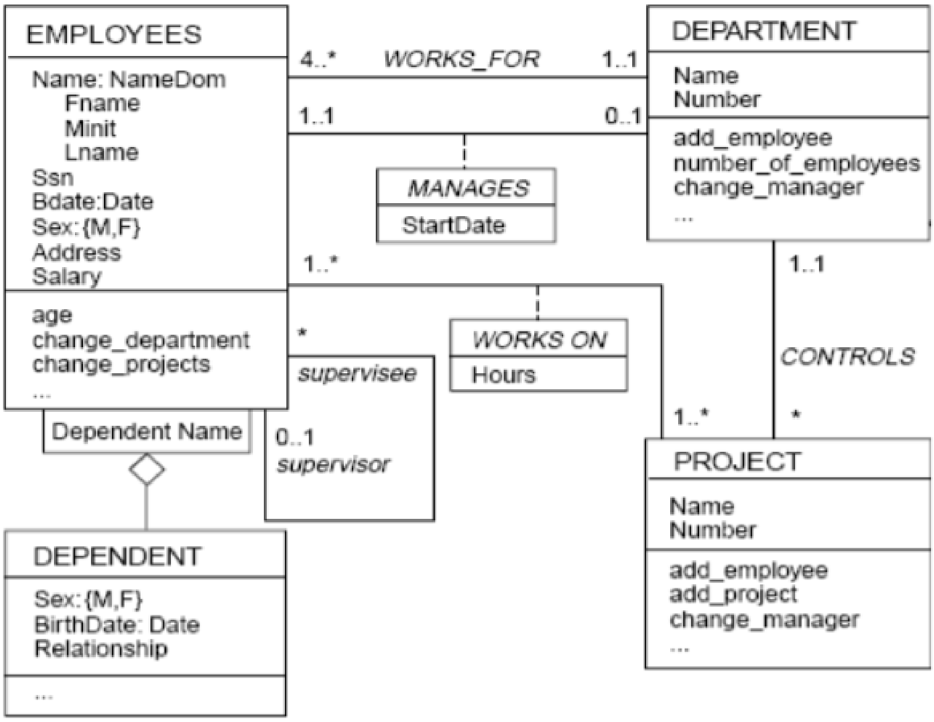


Figure 4 - An example of an UML class diagram of a company database.
Source: (Soler et al., 2010)

Data modeling is an essential task in developing a database. Any methodology for developing information systems that require stored data will therefore include a data-modeling phase (Simsion & Graham, 2005).

A data model used to be a simple abstraction of the table and column structure of a database that showed how the tables related to each other. Today this would be called a physical data model. Later, the logical data model was introduced, which would be defined as "fully normalized". However, this type of data model still was related to the contents of a single database. Another type of data model is the conceptual data model. Typically, this model includes no or few attributes and might be about the things the data represents, rather than about the data contained in it.

Initially these were all data models associated with a single application. Then cross-integration of data between applications started to appear. Enterprise data models started to appear, packages, enterprise architecture, etc. (West, 2011).

A data model defines the structure and intended meaning of data. It should also be noted that a data model is restrictive rather than permissive.

Data modeling has no widely-accepted, dominant notation, but two well-known notations are UML (Unified Modeling Languages) and IDEFIX (Blaha, 2010).

2.8 Entity-relationship model

An entity-relationship model is a data model to describe the data or information aspects of a business domain or its process requirements in an abstract way that ultimately can be implemented into a database, such as a relational database. The main components of the Entity-Relationship Models (ERM) are the entities (things, objects) their relationships and storage in databases (P. Chen, 2002).

ERM was developed by Peter Chen and published in an article, in 1976.

An ERM is a systematic way to describe and define a business process. The process is modeled as components (entities) that are linked to each other by relationships that express the dependencies and requirements between them, such as: a building can be divided into zero or more apartments, but an apartment can be in only one building. Entities can have several properties (attributes) that characterize them. Diagrams created to graph these entities, attributes and relationships are called entity-relationship diagrams.

A ERM model is usually implemented as a database. In the case of a relational database, which stores data in tables, the tables themselves represent the entities. Some data fields in these tables point to indexes in other tables. Such pointers represent relationships (Chen, 1976).

Description of the model components

Some examples of possible content when referring to entities are name, short name, definition, example(s), further explanations, estimated quantities, new or already available. Relationships can have short name, entity types involved, relationship statement 1 ("MA leads project"), relationship statement 2 (in the opposite direction), cardinality, possibly other conditions for the relationship ("only for private individuals").

When speaking of attributes there can be content such as name, short name, definition, example, further explanations, information format (e.g. number, 2 decimal places), value range (from 1 to 99), identifying for entity (yes / no / partially) (Elmasri & Navathe, 2008).

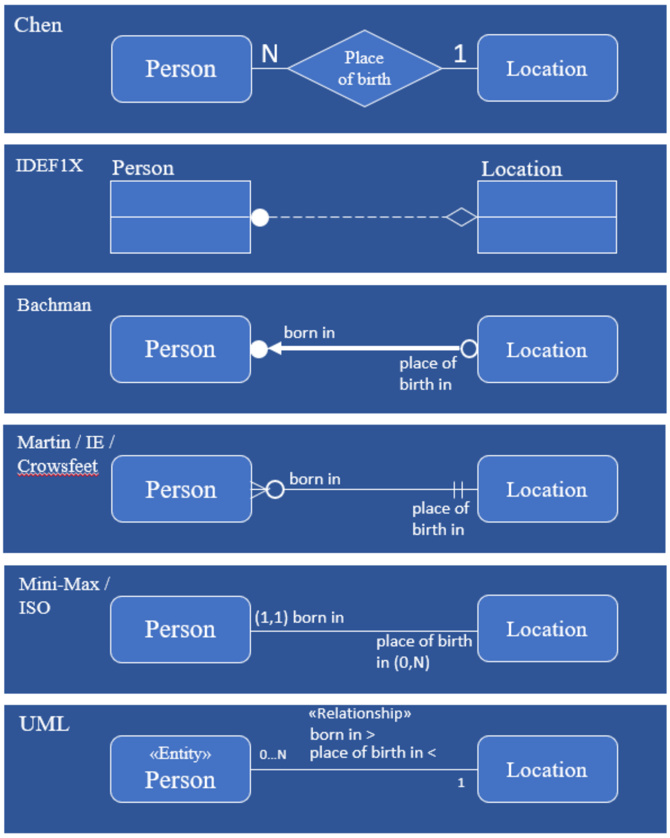


Figure 5 - ERD in different notations; Source: (Baumhauer, 2019)

Figure 5 depicts some of the given examples.

3 METHODOLOGY

This chapter describes the participatory action research methodology that has been adopted at this project.

3.1 Action research method

Action research is part of a type of research methods approaches. It is one of the most popular methods that are used in the information systems area.

According to Baskerville (1999), there are various forms of action research approaches (see Table 1). The various forms of action research have four common characteristics (Peters & Robinson, 1984):

1. Action- and change-oriented
2. Focus on the problem
3. The process involves systematic and iterative stages
4. Collaboration among participants

Action research is characterized as being a technical approach that uses intervention experiments that focus and act on problems or questions that have been recognized by the practitioners within a specific context.

Participatory action research is marked by the involvement of the practitioners as subjects and co-researchers. Argyris and Schön (1991) state that "causal inferences about the behavior of human beings are more likely to be valid and enactable when the human beings in question participate in building and testing them". Action research also emphasizes on the spontaneous, tacit theories-in-use that participants bring to practice and research (Baskerville, 1999).

Table 1 - IS Action Research forms and characteristics.
Source: Baskerville, 1999

Forms of IS action research	Characteristics of IS action research
• Canonical • IS prototyping • Soft systems methodology • ETHICS • Multiview • Action science • Participant observation • Action learning • Clinical field work • Process consultation	• Process model o Iterative o Reflective o Linear • Structure o Rigorous o Fluid • Typical involvement o Collaborative o Facilitative o Expert • Primary goals o Organizational development o System design o Scientific knowledge o Training

The action research method has gained popularity in scholarly investigations of information systems toward the end of the 90s.

In the context of organizations that interact and feed their information systems daily with information and data, action researchers believe that an organization and its information systems landscape must be recognized as a whole entity and can only be understood as such. Assuming an organization and its information technology as being separate components will not bring useful knowledge about the whole organization in the long run (Baskerville, 1999).

Change-orientation and interpretation are fundamental words in the action research approach, as questioning the status-quo is key and complex processes are best studied by introducing changes and analyzing their effects.

The action researcher intervenes actively in the research setting and is thus part of the study as one of the study subjects. Interpretation ability is fundamental. The action researcher must gather the information, observe it and perceive the meaning of it (Kant, 1908).

The “world perception” (the structure of world perception as modified by evaluation and ideals) of the researcher and the other subjects must be always considered (Checkland, 1981).

In the action research method, it is important to note that each social setting is different and unique when it comes to the set of interacting human subjects. Action research operationalizes and incorporates the subjects into their research as important collaborators. This type of research always involves a team that includes one or more researchers and subjects as co-participants in the change experiences. Action researchers must adopt qualitative data as a medium to the empirics. Idiographic descriptions of the “meaningfulness of actions” often adhere to the cognitive structure of the subjects, thus using the terminology of the subjects (Checkland, 1981).

According to Hult and Lennung (1980), Information System (IS) action research has four major characteristics (Hult & Lennung, 1980):

1. Understanding the immediate social situation, highlighting the complex nature of the social setting in the IS domain;

2. Assisting practical problem solving and expanding scientific knowledge. Thus, two important characteristics: highly interpretative assumptions made about observations and the intervention of the researcher in the problem setting;

3. I is performed within a team and enhances the competencies of the respective actors;

4. Primarily applicable for the understanding of change processes in social systems.

Susman and Evered (1978) define the action research approach as being a five-phase cyclical process. The present master’s degree project follows the same five phase process which will be described in more detail further in this chapter. As a short summary, the five steps are (Susman & Evered, 1978):

1. Diagnosing
2. Action planning
3. Action taking
4. Evaluating
5. Specifying learning

Briefly, in the action research approach, the roles of the researcher are aligned into more synergistic and collaborative ways of working. The responsibility of theorizing lays not only on the researcher but is shared with the other team members.

Members of the organization that is subject to study are actively engaged in the quest for information and ideas to guide their future actions (Greenwood et al., 1993).

In the working group, team members share their practical theory into the action research process; the action researcher brings his knowledge of action research and general IS theory. Consequently, the control over the social gets realigned.

The setting is free to self-reorganize rather than be artificially determined by the external researchers. In this way, participatory action research is based on assumptions that reality is situated, and social systems are self-referencing. Participatory action research is believed to be founded on more recent organizational philosophy (Baskerville, 1999).

3.2 Robert Bosch GmbH

3.2.1 The Bosch Group

The Bosch Group is a leading international technology and service company with around 400,000 employees worldwide (as of December 31, 2019). It generated sales of 77.7 billion euros in the 2019 financial year. The activities are divided into the four business sectors Mobility Solutions, Industrial Technology (Bosch Rexroth), Consumer Goods (power tools, household appliances) and Energy and Building Technology (thermotechnology, security systems). As a leading provider on the Internet of Things (IoT), Bosch offers innovative solutions for Smart Home, Industry 4.0 and Connected Mobility. Bosch pursues the vision of sustainable, safe and exciting mobility. With its expertise in sensor technology, software, and services as well as its own IoT cloud, the company is able to offer its customers networked and cross-domain solutions from a single source. The Bosch Group's strategic goal is to provide solutions and products for connected life that either have artificial intelligence (AI) or are developed or manufactured with its help. Bosch improves quality of life for people around the world with innovative and inspiring products and services. Bosch offers "technology for life". The Bosch Group comprises Robert Bosch GmbH and its around 440 subsidiaries and regional companies in 60 countries. Including trade and service partners, Bosch's global manufacturing, development and sales network extends to almost every country in the world. The company's innovative strength forms the basis for future growth. Bosch employs around 72,600 people in research and development at 126 locations worldwide. The company employs around 30,000 software developers (*Bosch Media Service*, 2021).

The company was founded in 1886 as a "workshop for precision mechanics and electrical engineering" by Robert Bosch (1861–1942) in Stuttgart, Germany. The corporate structure of Robert Bosch GmbH ensures the entrepreneurial independence of the Bosch Group. It enables the company to plan for the long term and to invest in significant advance payments for the future. 92 percent of the capital shares in Robert Bosch GmbH are held by the non-profit Robert Bosch Stiftung GmbH. The majority of voting rights are held by Robert Bosch Industrietreuhand KG; it exercises the entrepreneurial shareholder function. The remaining shares are held by the Bosch family and Robert Bosch GmbH (Hehle, 2019).

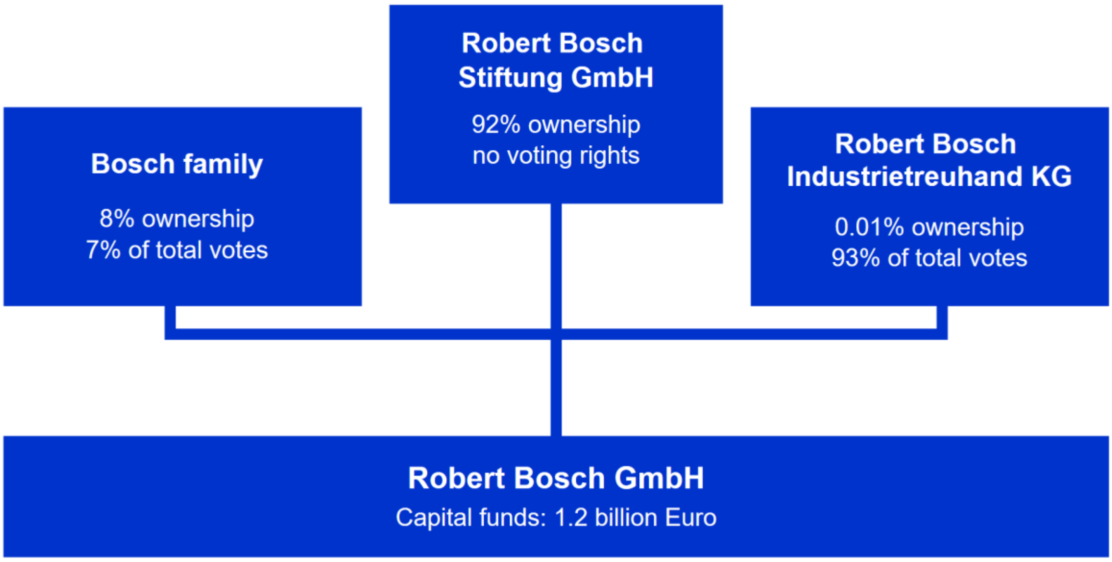


Figure 6 - Diagram of Robert Bosch GmbH

3.2.2 Bosch Building Technologies

The Building Technologies division has two business areas: the global product business for security and communication solutions and the regional business of system integration, which offers solutions and tailored services for building security, energy efficiency and building automation in selected countries. Both units focus on commercial buildings and infrastructure projects (Hehle, 2019).

The Bosch division Building Technologies is a leading global supplier of security, safety, and communications products and systems. In selected countries, Bosch offers solutions and services for building security, energy efficiency and building automation. About 9,000 associates generated sales of roughly 2.0 billion euros in 2018. Protecting lives, buildings and assets is the major aim. The product portfolio includes video surveillance, intrusion detection, fire detection and voice evacuation systems as well as access control and building management systems. Professional audio and conference systems for communication of voice, sound and music complete the range. Building Technologies develops and manufactures in its own plants in Europe, Americas and Asia (Hehle, 2019).

The headquarters of the Bosch Building Technologies division is in Grasbrunn, near Munich, Germany. The board of management consists of Tanja Rückert (President), Andreas Bartz (Executive Vice President Finance & Administration) and Thomas Quante (Executive Vice President Energy and Building Solutions).

3.2.3 The researcher within the organization

In the organization Robert Bosch GmbH, the researcher, Alexandra Matos, joined the Building Technologies division, namely Security Systems, in February 2018. In this division, the researcher, fulfills the role of technical communicator, in the Research & Development (R&D) department. As a technical communicator, it is up to the researcher the development of technical documentation for safety and security products, using consistent terminology and state of the art methods and approaches (e.g., Simplified Technical English). In this context, the researcher is responsible for the development of documentation for products in access control systems, namely software products. the researcher assists the team in developing global technical writing processes, standards, and tools. Alexandra is also responsible for data and terminology management, organizing and managing the translation process, organizing, and managing reviews, including proofreading, and preparing for multichannel publishing, as print production, software releases, web, or apps.

The researcher's 1st languages are Portuguese and German, but she is fluent in English as well.

In addition to role as a technical communicator, the researcher is responsible for the development and management of information models of the department responsible for the PIM project.

In performing both functions, the researcher is inherently in contact with the most diverse teams (e.g., product management, project management, customer support, engineering, management, logistics, …) located all around the globe.

3.3 Problem statement

This master's project work applies to the Bosch Group's Building Technologies division.

In the era of the fourth industrial revolution (also known as industry 4.0), automation, digitalization, data exchange, the internet of things (IoT) and artificial intelligence (AI), are only a few of the big topics that emerged with it.

Decisive for the fast spread of the term industry 4.0 was the recommendation for implementation of the German Government, which carried the term in its title and was picked up willingly by the Federal Ministry of Education and Research. It has become an eponym for a future project in the context of high-tech strategy 2020 (Lasi et al., 2014). Bosch Building Technologies, namely the area of Security Systems, joined this project and has set goals for the year 2020 in the scope of digitalization.

The relevance of industry 4.0 for business and information systems engineering is big. The integration of information systems and their modeling and design play a central role (Lasi et al., 2014).

As a leading IoT company, at Bosch, digitization of data and information play major roles, and the company aspires to become the benchmark when it comes to these subjects.

In order to keep a respectable brand image, deliver good quality products and services, and achieve excellence, it is necessary to build a strong foundation for this transition into the world of automation and digitalization of data. In the specific case of this project, digital transformation applies to marketing and sales, where the basis for IoT is being created to make Bosch Building Technologies a more software- and service-oriented company.

Bosch is concerned with the continuous improvement of its products and services, and always strives to adapt to the changing times and the needs of the world and its consumers. Online product catalogs play a vital role in stepping up into a modern digital marketing strategy. The ability to manage an online product catalog, effectively and efficiently, is essential for a business to succeed in today’s highly competitive market. The Bosch Security Systems (part of the Bosch Building Technologies division) online product catalog is necessarily one area that is in need for improvement in order to keep up with the rapidly changing digital world and its demanding consumers. The way information and data and modular security systems are managed, the way they ate presented and communicated to the customer through the online catalog are a few of the main concerns in the current days.

Bosch aims to offer an intuitive and an easy-to-use, state-of-the-art online product catalog, while bringing all the benefits of a user-friendly platform that facilitates not only the purchase of single products and complex modular systems, but also the management and maintenance of the content and the complete online product catalog itself.

In the scope of digitalization of data and its management, and with the necessity for improvement of the Bosch Security Systems online product catalog, the organization has started a movement of change. Two major projects are currently running in the organization: (1) the Product Information Management (PIM) project and (2) the New Web Architecture (NWA) project.

The PIM project focuses on the creation of "machine-readable data" and the management of product related information.

The NWA project aims to provide a new online catalog architecture and design, distribute product data efficiently within Bosch, reuse product data on new products and provide new services and functionalities online.

As a global supplier of security, safety, and communications products and systems, the Bosch Security Systems product portfolio includes many types of complex modular systems, such as video surveillance, intrusion detection, fire detection and voice evacuation systems, access control and building management systems, as well as professional audio and conference systems for communication of voice, sound, and music. (Hehle, 2019)

The complex modularity in the many systems that are included in the product portfolio represents the degree to which a system's component or even a smaller system within another bigger system may be separated and recombined, offering flexibility and variety in use. In summary, the customer is able to customize and adapt a system according to its necessity.

The complex modularity of Bosch's systems is considered to be one of the biggest challenges within the current movement of change, and it affects both the PIM project and the NWA project, as well as the customer's digital experience with the Brand.

The unresolved topic consists in finding a new improved way to manage and represent Bosch Security Systems' complex modular security systems so that the customer can have the information he needs in a clear and easy-to-use manner, in "two-clicks" whenever he needs it.

Thus, the main objective of the proposed project is to find a way to better represent complex modular security systems in the online catalog of Bosch Security Systems, as well as to define a method to manage these specific types of systems.

Therefore, the main research question that is posed in this project is as follows: How to manage product information for complex modular security systems?

Finding the answer to this question will allow a better management of product data in the long term and consequently have a big and positive impact in the company's financial savings.

This project aims to develop and seek an answer to the topic of product information management for complex modular security systems, which falls within the scope of management information systems.

3.4 Proposed phases

The phases applied in the course of this project work are based on the most prevalent description of the action research methodology (Susman & Evered, 1978). The phases (Figure 7) mentioned in Susman's & Evered (1978) description are:

1. diagnosing
2. action planning
3. action taking
4. evaluating
5. specifying learning

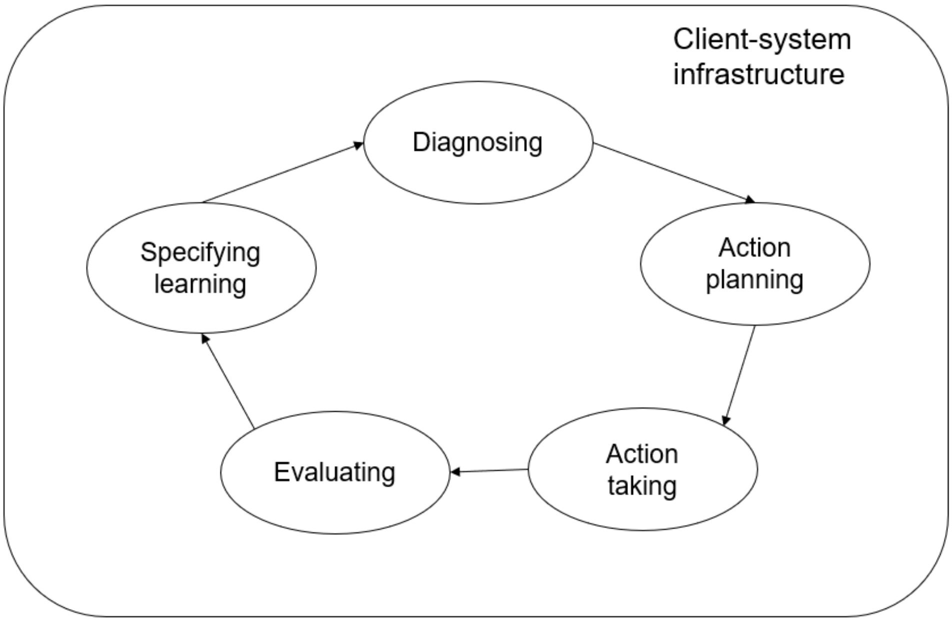


Figure 7 - The action research cycle

In the client-system infrastructure, the specification and agreement that establish the research environment are defined. The client-system infrastructure expresses the expectation that the actions will eventually provide and prove to be beneficial to the organization. The requirements and boundaries of the research domain are defined, as well as the responsibilities of the client and the researcher. A key aspect of the infrastructure is the collaborative nature of the undertaking. The research scientist works closely with practitioners who are located within the client-system. These individuals provide the subject system knowledge and insight necessary to understand the anomalies being studied (Baskerville, 1999).

The diagnosing phase is responsible for identifying the main problems that are the behind the causes of the organization's desire for change. Diagnosing involves self-interpretation of the complex organizational problem, not through reduction and simplification, but rather in a holistic fashion (Baskerville, 1999).

The client-system infrastructure and the diagnosing phase are defined in detail in the previous chapters 2.15 to 2.17 of the present project paper.

4 RESULTS AND DISCUSSION

4.1 Phase 1 - Diagnosing

Bosch Security Systems uses a customized version of the software system SCHEMA ST4 as its Content Management System (CCMS).

The CCMS manages digital content, allowing the creation and modification of multilingual modular documentation in technical documentation and other editing contexts.

It supports multiple users in a collaborative environment, allowing the management of product data and technical documentation, as well as the management of part of the online product catalog's content. Usually the technical documentation includes text, graphics and photos, and the content is Bosch Security Systems' online product catalog (or part of it) and all the technical documentation related to Bosch Security Systems' products.

In 2013, based on customer feedback, Bosch received a request: to offer the functionality of an online product selection tool within the Bosch online product catalog. The functionality would offer a state-of-the-art user experience, with the possibility to easily search and find products through a filtering functionality that allowed the user to find the exact product he needs or is looking for.

At that time, the product information that existed in the CCMS did not always match the product information that was on the company's Enterprise Resource Planning (ERP) system, SAP. The task of the ERP system is to specify a product in terms of its status, turnover, production and logistics – it is the backbone of every big company. On the other hand, the CCMS describes the functions and the use of a product, visually and textually.

Figure 8 - Representation of connection failures between the ERP system and the CCMS

The reason for this mismatch of information between the two systems existed due to the fact that the CCMS users had to enter all the product data and other important information (e.g., SAP number, Commercial Type Number, technical specifications, etc.) manually, in free-text form. Important master data, such as the order numbers, had to be manually re-entered during the product creation in the CCMS, which lead to frequent errors in the output. Not to mention that the tasks of introducing and managing the product data in the

CCMS was extremely time-consuming. There was no real-time reflection of the ERP system's content.

Since the average CCMS SCHEMA ST4 user had little or no knowledge about the ERP system, finding the necessary information was complex and was usually not checked for correctness by the CCMS user.

This aspect caused inconsistencies, lack of certainty and confidence towards the content and all data contained in the CCMS, and consequently in the Bosch Security Systems online product catalog, since data is reflected from the CCMS to the online product catalog. There was no way to be 100% sure that the information in the CCMS was correct and synchronized with the ERP system.

4.1.1 Connection between the CCMS and the ERP system

Since the lack of consistency and the insufficient exchange of data between the two systems could cause consequences which could result in large losses and disadvantages to the organization (both in the short and long term), the reliability and completeness of connection between the two systems – the CCMS and the ERP - was essential. Thus, Bosch made this essential connection between the ERP system and the CCMS possible (

Figure 9).

Now, when creating a product in the CCMS, important master data is no longer manually entered by the CCMS user. New or changed ERP master data is automatically imported into the CCMS every day. When new material master records exist in the imports from the ERP system, these are automatically created as taxonomy nodes. The new taxonomy nodes automatically create a link to a new product node and a new data node, and all these nodes are stored in a specific structure.

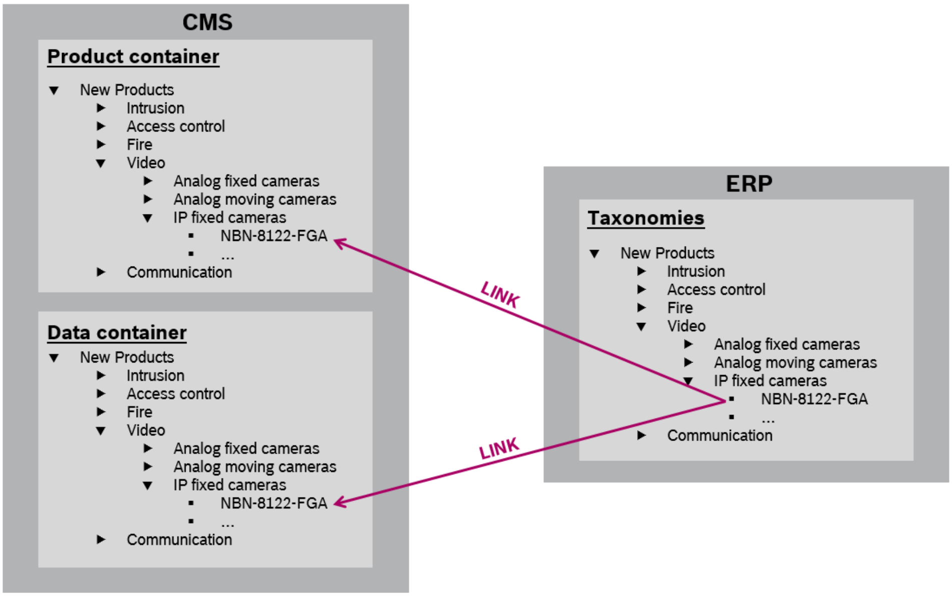


Figure 9 - The ERP system's taxonomy reflected in the CCMS

The following fields are required for the creation of a product in the ERP system:

- Unique Identifier Number (UIN)

  Order number with 10 digits, which clearly identifies the product and its place of manufacture.

- Commercial Type Number (CTN)

  Order number, which identifies the product. In contrast to the UIN, one CTN can have several UIN associated to it. In such cases, the product is the same but manufactured in different locations or as a new version with the same functions but changed list of parts.

- Product family name

  Name of the series or system to which the individual products belong. Used in the CCMS as a name for product families.

- Short Description

  Short description of the product (CTN + Product name) allowing fast identification of the product

- Product Hierarchy

Set categories of various levels to sort each product according to its functionality. The following hierarchy levels are required for the ERP system connection:

- Product Class

  First level of the Product Hierarchy which indicates the product segment, e.g., "Video System", "Fire system", "Access control system", "Communication system", "Intrusion alarm system".

- Product Main Class

  This is a second level of the Product Hierarchy.

- Sales Status

  The sales status defines whether a product is available on a particular market or not. The following statuses are relevant:

  S0 = Initial status; Basic data are filled, but the first Quality Gate (QG1) is pending; Documentation is to be created in the CCMS.

  S2 = The product is not yet available but could be announced already; gets status long after QG1

  S3 = The product is available on the market

  S9 = The product is announced as End Of Life (EOL). Applicable to all countries

  SB = Sales only on stock; Every product always gets this status before it goes into status S5; Applicable to all countries

  S5 = The product is EOL (End Of Life), i.e. completely out phased and no longer available

- Material Status

  The material status defines whether a product is available on a particular plant or not.

  S0 = Initial status; Basic data are filled, but QG1 is pending; Documentation is to be created.

  S2 = The product is not available yet; Receives the status long after QG1

  S3 = The product is available on the market.

S9 = The product is announced as EOL. Applicable to all countries.

YYEOSAL = End date when the product will be EOL for all countries at the latest. After that it should no longer be available on any country website.

SB = Sales only on stock; every product always gets this status before it goes into status S5; Applicable to all countries

S5 = The product is EOL

- Material group

  The material group provides information on whether it is a product or a kit.

- Material Type

  The material type provides information on whether it is a product or a component.

- Successor Material

  This field contains the material number of the successor product, which will replace the current product.

- End of Sales Date

  This field contains the date from which the product will no longer be sold worldwide. This date is set in the out-phasing process as soon as the field Material Status is set to S9.

As soon as a new product on the ERP system gets the status S0, it is ready for further processing and to be exported into the CCMS. The unique identifier in the ERP system is the UIN. To avoid duplicate information, the unique identifier in the CCMS is the Commercial Type Number.

Products with multiple UIN and the same CTN

Products with multiple UIN and the same CTN can have different material statuses and sales statuses.

If several UIN belong to 1 CTN, they get combined into one data record. To do this, it is necessary to confirm that the fields Commercial Type Number, Product name, short description, product hierarchy, material group and Material Type have been maintained identically. If there is a deviation in the fields, then it will be exported to the XML file, but listed in a log file. The error must first be cleaned up in the ERP system.

Changes to master data that do not affect the UIN on the ERP system

For an already existing product on the ERP system, all changes to master data that do not affect the UIN on the ERP system, overwrite the previous value and are exported. XML is used for the exchange between both systems. The changed XML file is picked up over a defined folder (file share) on a daily basis.

Timestamp

The batch to change product data runs daily as an XML file from the ERP system into a defined export folder. The file name contains a timestamp in the last place to quickly identify the last regular export and prevent overwriting. This XML file contains only the records of changed or new records. There is a log file in the same folder destined to register possible errors that may occur.

During the import in the CCMS, the modified XML file gets recognized in the file name through the time stamp. If there are more than 1 XML files in the pickup folder, then the CCMS starts by importing the oldest XML.

Unique product hierarchy number

Each product has a unique product hierarchy number. The product hierarchy number of each product can be split into the two levels. Depending on which level you are, different properties are displayed.

If a new CTN is created using the ERP system import, then a new product is automatically created in the specific folder for this taxonomy node. Below the folder, a folder structure is formed from the product hierarchy number. The user does not have writing permissions in this folder, but he can simply move the new product to its corresponding folder structure.

The structure of the text folder results from the product hierarchy number of the ERP system's master data. The hierarchy's name that can be split into two levels as subcategories that are then reflected in the title of the text folder of each level. Product families cannot be created in the area where the new products are stored.

In order to make it easier for the user to search for the master data of the respective product, in addition to the taxonomy link, the essential ERP master data of the taxonomy tree is displayed on the product. The data values cannot be duplicated.

If any changes are made to an already existing product that is uniquely identified by the ERP system's material number, all changes except the material number are overwritten in the already existing taxonomy node. This means that status, name, material group etc. will be updated according to the changes that have been made. If the CTN and / or the material description change, then the title of the product and the title of the linked data node are also overwritten.

The product hierarchies change regularly at the end of the year. The following changes must be considered during an import:

- One hierarchy number of an existing product is changed, and the name remains the same. As a result, all existing products of the old category receive the new level number.
- One hierarchy number of a product category is divided into two new hierarchy numbers. As a result, the two new categories are created, and the existing products are re-sorted accordingly, and the old category is deleted.
- Designation 1 of existing hierarchy number is changed. As a result, the taxonomy node of the category is renamed.

4.1.2 Using the CCMS as a PIM system

As the digitalization and automation of business processes grow, data management becomes more challenging.

To simplify the management and maintenance of products and product information, many solutions are now available in the market. They increase quality, efficiency and create many new opportunities.

A component content management system (CCMS) enables the creation, modification and management of digital content, mostly texts, images and other media.

Companies use a content management system to manage their website, which may also include information about products. However, the information managed in a CCMS is often poorly structured. For instance, for product information, there are two options: short or long product descriptions. All features can be collected in one field instead of one entry per feature to achieve filtering capabilities. For complicated products that require explanation, or if there is many products, successors, modular systems and historical products, it can become a real problem to post product information in a way that suits potential customers.

In the Bosch Security System's case, there is also the fact that the technical specifications are manually written, in free-text form, by many different technical writers from all around the world. This means that, for many years, product information has been written freely, without a defined standard, in many different ways by many different people. The lack of standardization and automation leads to inconsistent product information (e.g., having the same information written in 10 different ways).

If a CCMS system has weakness in managing product information, a Product Information Management (PIM) system may be a real help in describing products not only in terms of quality, but also in more detail and in all necessary languages. A PIM system can ensure that product information and images are always up-to-date and consistent in terms of what has been defined as standard.

Although it was clear that the organization was lacking product information management, Bosch did not switch to a PIM system, even after receiving the online product selection tool request.

The market regarding PIM systems started to grow since 2010 and the cost of such a system was significantly high. A new software and its integration in an already existing IT infrastructure would cost the organization a lot of time, capacity and money. The product data in the already existing CCMS was not identifiable because it did not have an ID number and, for that reason, it would not be possible to migrate the product information into a PIM system.

The PIM system would need to have the same data model as the ERP system and the CCMS.

As the existing CCMS already had the functionality of taxonomy through the connection that was established with the ERP system, the decision has been made to use the CCMS as a PIM system.

In its raw, unmodified standard form, the CCMS *SCHEMA ST4* (Quanos, 2021) is an established and reliable tool for creating technical documentation (e.g., installation manuals, data sheets, software manuals, quick installation guides, etc.). The system is among the best tools available in the market when it comes to technical documentation (SourceForge, 2021).

However, at Bosch Security Systems, the tool has been so customized and personalized that it is now fulfilling functions not only as a Component Content Management System (CCMS), but also as Product Information Management (PIM) system and Media Asset Management (MAM) system. Therefore, within the organization, the CCMS is known for the German saying "Eierlegende Wollmilchsau" - an "egg-laying wool milk pig" (see Figure 10). The saying illustrates an imaginary farm animal that combines the advantages of different animal species, namely chicken (laying eggs), sheep (delivering wool), cow (giving milk) and pork (meat).

However, this extreme customization that allows the system's multifunctionality and versatility, in an effort to satisfy the company's needs, brings consequences with it.

Due to the fact that it has been customized to fulfill many additional functions and not only the ones that it has originally been created for, the CCMS is now showing signs of system overload and cannot be used with the desired potential. In addition to the slow functioning, it is impairing the proper functioning of the features for which it was originally created for.

Hence, it is worth emphasizing that the CCMS is not a PIM system:

- No flexible import of product data
- No flexible collection and export in different formats (eCatalogue, Classification)
- No existing MAM integration to handle product images, documents and videos
- No web-based user interface
- No web service for product data
- Not designed as product information
- No integration in Bosch the data management system (DMS) IT-landscape
- No possibility for other systems (website, shop, apps, IoT) to request product info per web service
- No backend system providing product data for eCommerce and other DMS frontend systems

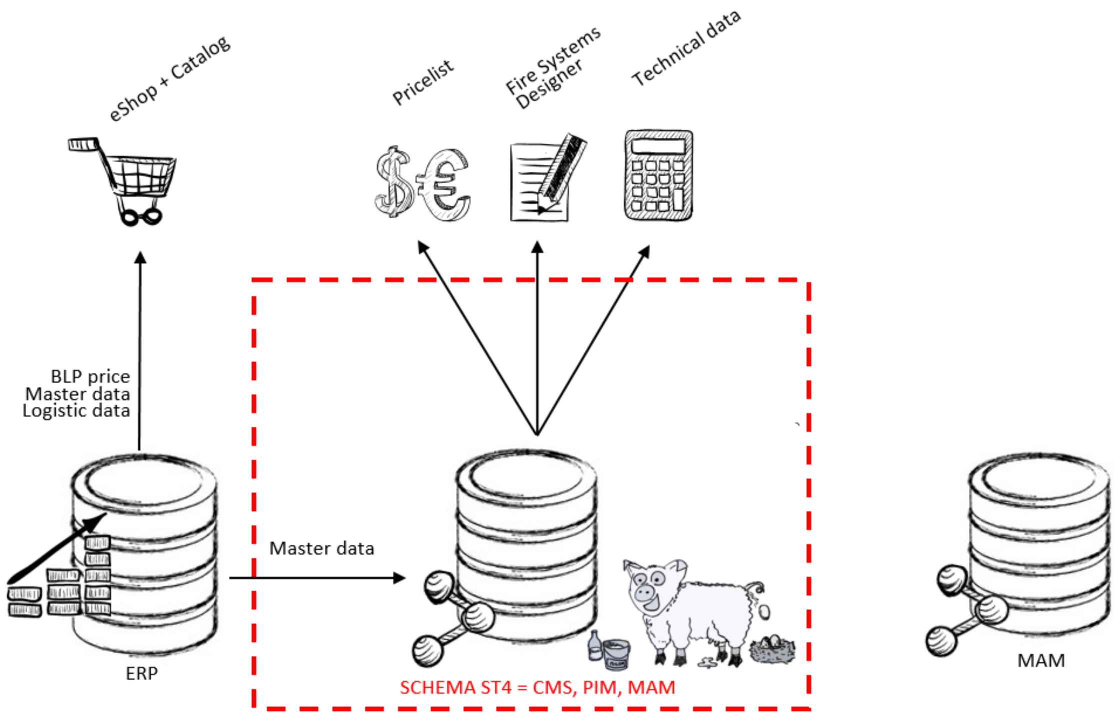


Figure 10 - Graphical representation of the usage of the CCMS

4.1.3 The current product structures

At this moment, in the CCMS, in the area where it is possible to see and manage the structure of the products represented in the online catalog, it is observed that a simple taxonomy does not allow a real perception of what the product portfolio is and its potential. Bosch Security Systems, as the name implies, provides security systems, i.e., complex modular systems such as video surveillance, intrusion detection, fire detection and voice evacuation systems, access control and building management systems, as well as professional audio and conference systems for communication of voice, sound, and music.

The complex modularity in the many systems that are included in the product portfolio represents the degree to which a system's component or even a smaller system within another bigger system may be separated and recombined, offering flexibility and variety in use. In summary, the customer is able to customize and adapt a system according to its necessity.

However, in the CCMS, it is only possible to establish simple taxonomic “is-a” relationships. The high-level structure is composed of:

- Video
- Intrusion Alarm

- Conference
- Public Address and Voice Alarm
- Fire Alarm
- Software Products
- Access Control

In the CCMS, below the high-level it is possible to link:

- Product family
- Product
- Accessory

In addition to this and, in theory, there are also “Systems” and “Kits”, but these relationships cannot be established in the CCMS, in practice.

A **product family** is a collection of product variants and accessories (optional). A product family consists of product variants having a basic set of similar function. Product families have no UIN and cannot be purchased (see graphical example in Figure 11).

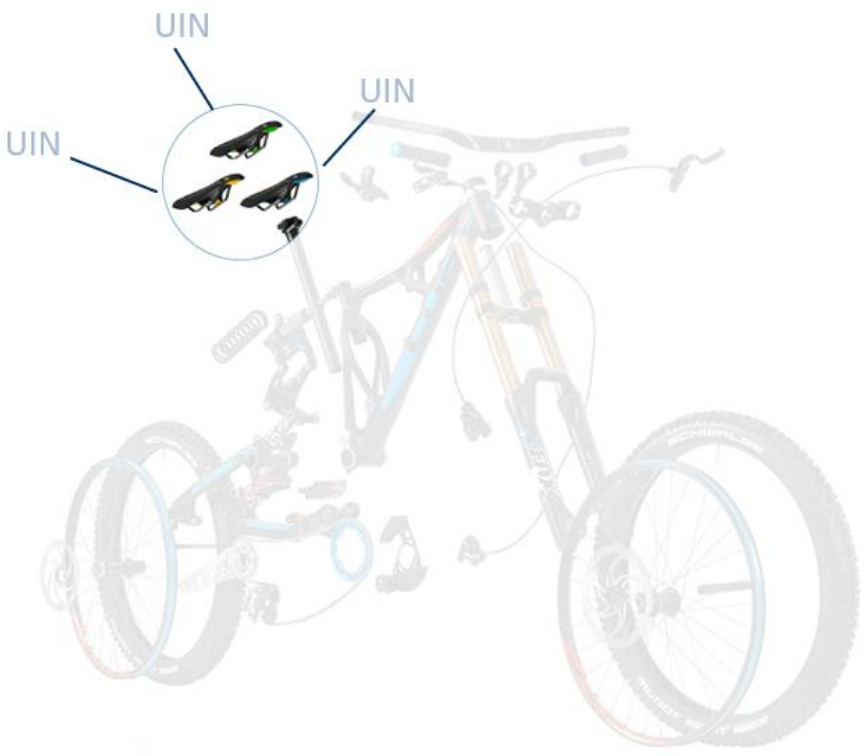


Figure 11 - Graphical representation of a product family (example: bicycle); Source: Bosch PIM training

A **product** is a stand-alone product and accessories (optional) for ordering. A product has a CTN and a UIN. A product could be reused below a system (see graphical example in Figure 12).

Figure 12 - Graphical representation of a product (example: bicycle); Source: Bosch PIM training

Accessories are optional and stand-alone products for ordering. An accessory has a CTN and a UIN. (1) The original node of an accessory always must be set up as a product in separate categories. (2) All accessories must be reused as Hardware, Service or Software accessory below one or several Product families, Products or Systems (see graphical example in Figure 13).

Figure 13 - Graphical representation of accessories (example: bicycle); Source: Bosch PIM training

Product family, product and accessory are the elements that can be found in the CCMS, but these elements do not cover the entire Bosch Security Systems product portfolio and the theoretical and practical concept. At Bosch Security Systems, it is not only possible to order a product family, product or accessory, but it is also possible to order kits and, most importantly for this project, systems.

A **kit** is a single stand-alone product for ordering. A kit has a CTN and UIN. Kits mostly represent a ready-to-order system. Products and accessories of a kit are already summarized in the ERP system below one order number. A kit consists of products having no basic set of similar functions, but all products together define one operating system (see graphical example in Figure 14).

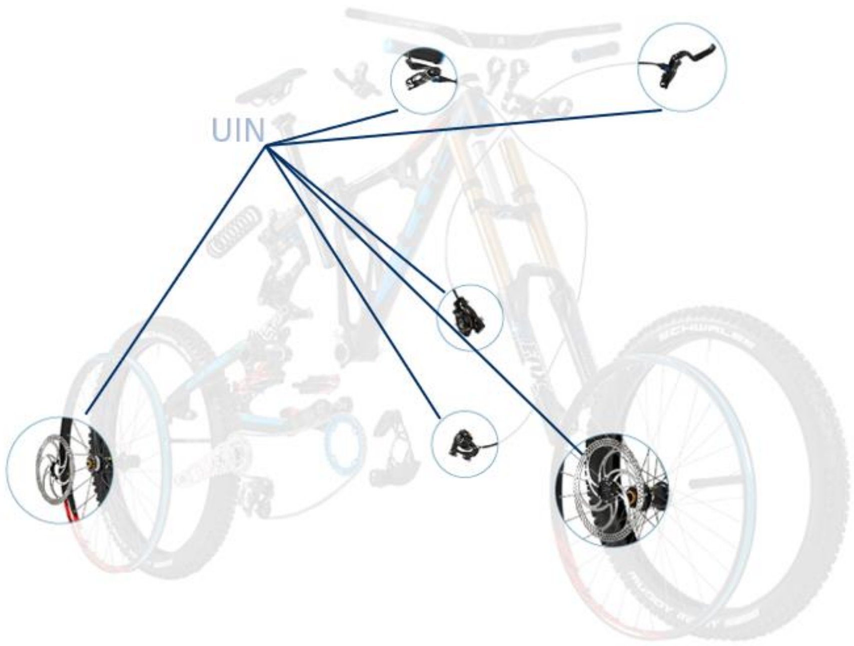


Figure 14 - Graphical representation of a kit (example: bicycle); Source: Bosch PIM training

A **system** is a collection of products and accessories (optional) for ordering. A system consists of products having no basic set of similar functions, but all products together define one operating system. All products for ordering must be reused below a Product family node. Systems have no part number and cannot be purchased (see graphical example in Figure 15).

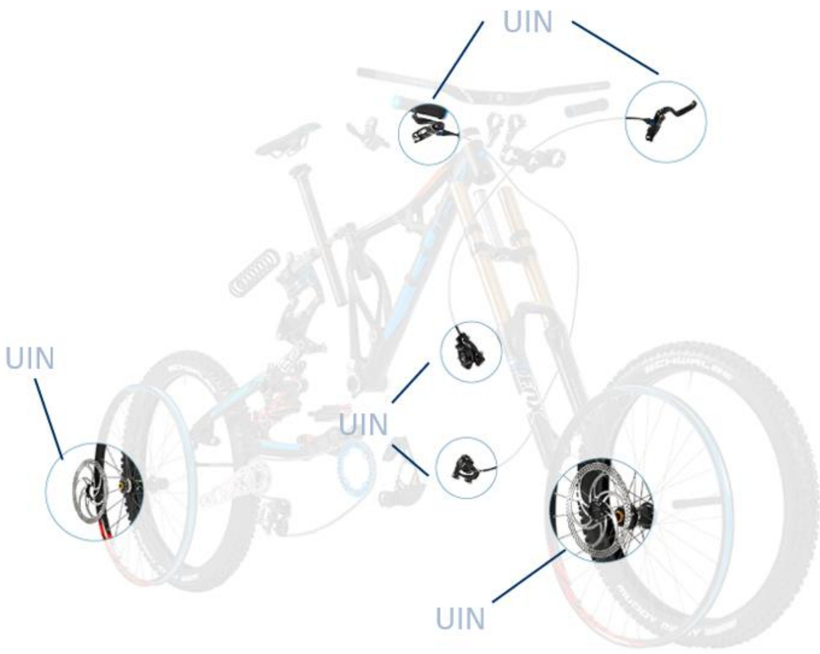


Figure 15 - Graphical representation of a system (example: bicycle); Source: Bosch PIM training

For kits and systems, the problem arises that there is no correct way of representing them in the CCMS. For the purpose of this project, focus is going to be put in systems.

At the moment, systems are being set up as product families in the CCMS and are also reflected as such in the online product catalog. Neither is it possible to deduce, from the current product taxonomy, that Bosch offers modular systems that can be “tailored” according to the customer’s needs. There is no way to distinguish between a product family and a system, unless you are a Bosch employee, an expert, or someone who is completely familiar with the Bosch product portfolio and the entire concept. A customer is also not able to deduce what he needs to order additionally, in order to complete the entire system, since both product families and systems have the same way of being represented.

It is possible to see all products and systems in a “messy” manner, but not possible to deduce that, for example, a PRAESIDIO system (which is a name for a Public Address system) supports on or two different amplifiers and an LCD call-station from the product taxonomy (Figure 16).

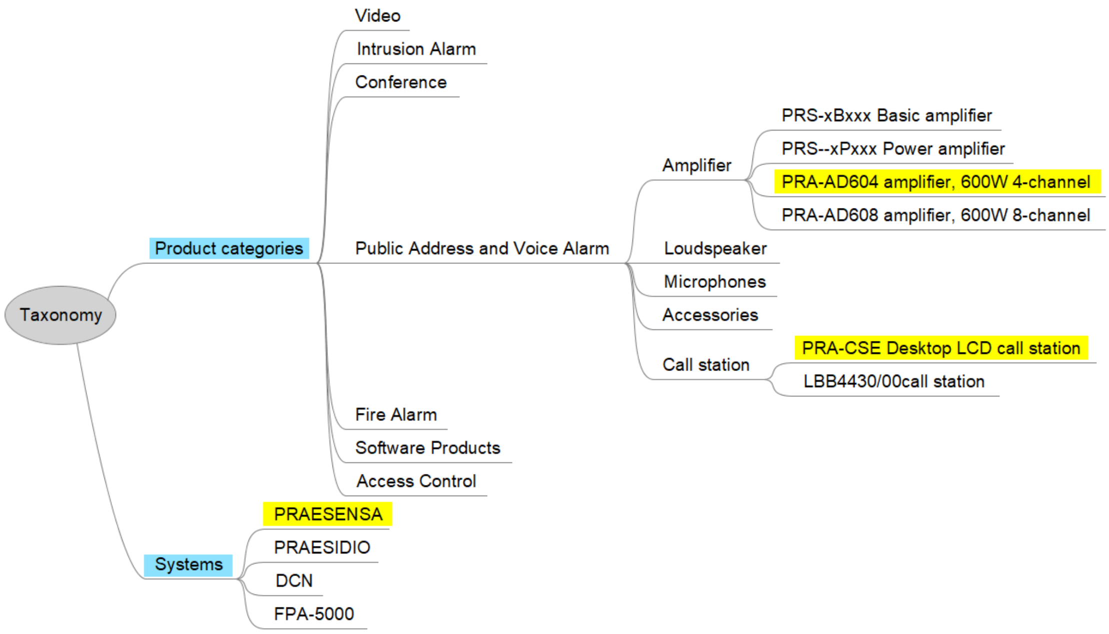


Figure 16 - Representation of the product taxonomy (current situation). Example of the PRAESENSA system. Tool used: FreeMind MindMap

In order to make it clear to every user which products are compatible with which systems, it would have to enable to establish a relationship or connection between a system and product families or single products of the product categories entity. It would also have to be possible to establish more than one relationship for one single entity. This is where the current taxonomy loses power and does not fulfill the current needs. Figure 17 depicts a draft example of the relationship that the team wants to achieve.

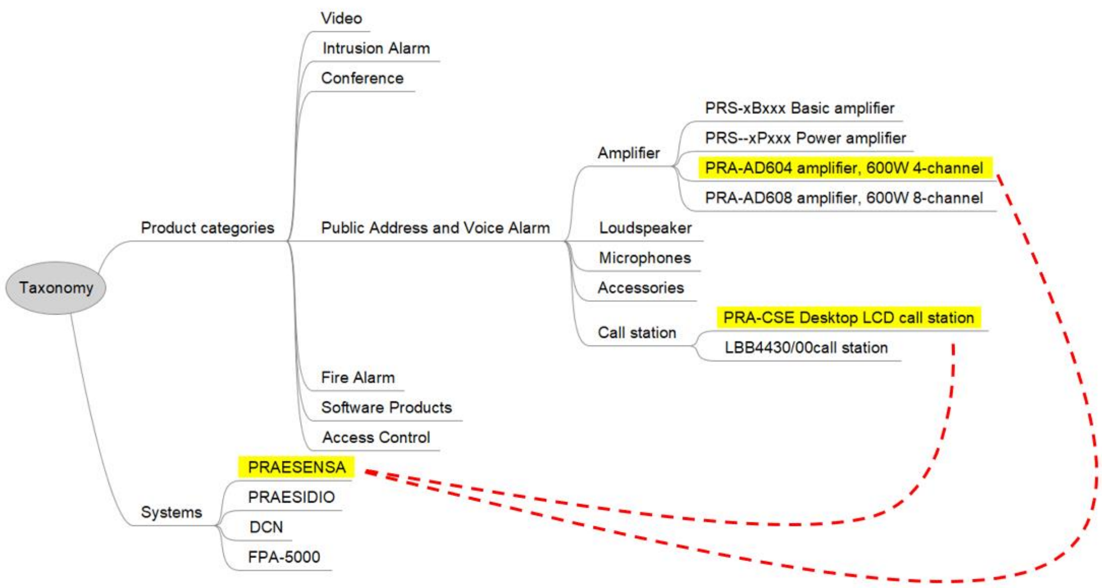


Figure 17 - Representation of the product taxonomy (desired situation). Example of the PRAESENSA system. Tool used: FreeMind MindMap

4.1.4 Improvement proposal

Given the desired situation, as shown in the example presented at Figure 17, it is possible to see that in order to satisfy the need to create an "infinite taxonomy", i.e., to establish several different relationships between different and / or the same taxonomic elements that are found in different taxonomies and taxonomic levels, it is necessary to create a network and not just a hierarchy, or, in this case, a taxonomic tree.

In a first phase of this project work, a meeting was held with four colleagues who proved to be extremely important during the course of this project, for their experience in the organization and its processes, for the information they provided and for the cooperation and participation throughout the project: (1) Digital Marketing Manager and supervisor of this project (10 years of experience at Bosch BT), (2) Team leader of Digital Product Content Chain (9 years of experience at Bosch BT), (3) Strategic Marketing Manager - BIM coordinator (26 years of experience at Bosch BT), (4) Senior Process Manager - Digital Marketing and Sales (6 years of experience at Bosch BT). These individuals provide valuable subject system knowledge and insight necessary to understand the anomalies being studied. In this first meeting, the problem described in the previous chapters of this project work was presented and the requirements for the potential solution were listed:

- Create a way to represent complex modular systems
- Have a way to manage the respective data
- Machine readability
- Support metadata

Bearing in mind the requirements mentioned above, it is relevant to recap:

> In its simplest form, a taxonomy is a list of words that are related to each other (a classification of data). It represents a collection of topics with an "is-a" relationship. In the context of information systems, taxonomies are machine readable and support metadata. When a taxonomy is complete, an information base is defined (Inmon, 2015).

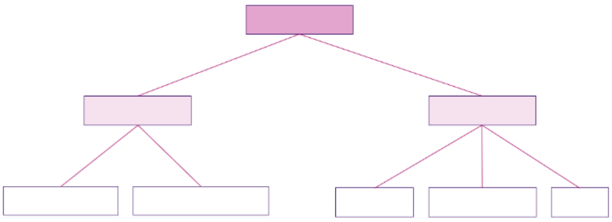


Figure 18 - Graphical representation of a taxonomy with a tree-like hierarchy

The use of a simple taxonomic structure will not allow to solve the whole problem in question, as it does not allow the establishment of the most complex and necessary relationships between entities of the different taxonomies. Figure 18 depicts a graphical example of a taxonomical structure.

In this sense, it is worth briefly recapitulating the concept of ontology. In its simplest form, an ontology is a group of related taxonomies (a specification of data). Ontologies establish relationships among taxonomies. Classes are hierarchically arranged in a taxonomy of subclass-superclass, slots with descriptions defining value constraints, and values for these slots. A knowledge base is defined when the ontology is complete, and when individual instances of these elements (classes and slots) are defined and any restrictions added or refined. Ontologies express a much richer collection of objects and relationships, such as “has-a”, “use-a” and "is-accessory-of". They are machine readable and support metadata. Ontologies enable the sharing of information between disparate systems within the same domain. They are used in many disciplines, but are most commonly associated with Artificial Intelligence (AI) (Inmon, 2015). Figure 19 depicts an example of a graphical representation of an ontology.

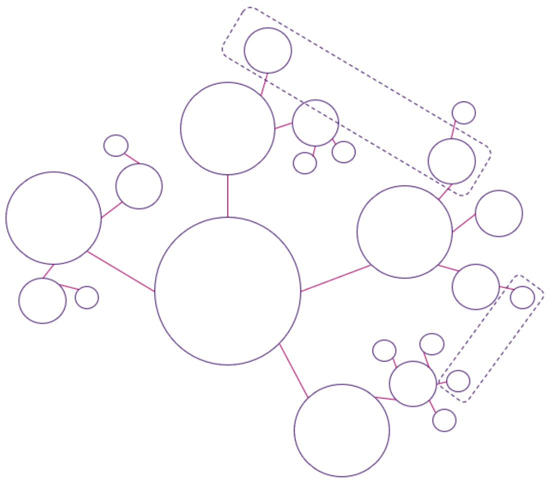


Figure 19 - A simple example of a graphical representation of an ontology

Taking into account the requirements described above and knowing that it will be necessary to create a network structure, based on the information collected in the chapter referring to the literature review, the present project work proposes the creation of an ontology for the purpose of meeting the requirements of this organization.

4.2 Phase 2 – Action planning

In the planning phase, the researcher and the practitioners start the collaboration. This phase specifies the plan and the actions for the development of the potential solution. The discovery of the planned actions is guided by the theoretical framework that has been specified in the previous chapters. This indicates both some desired future state for the organization, and the changes that would achieve such a state. The plan establishes the target for change and the approach to change.

As mentioned in chapter 2.17, the practitioners that took part in this research are:

- Practitioner 1 - Digital Marketing Manager and supervisor of this project (10 years of experience at Bosch BT)
- Practitioner 2 - Team leader of Digital Product Content Chain (9 years of experience at Bosch BT)
- Practitioner 3 - Strategic Marketing Manager - BIM coordinator (26 years of experience at Bosch BT)
- Practitioner 4 - Senior Process Manager - Digital Marketing and Sales (6 years of experience at Bosch BT).

Since all the practitioners involved in the present project have the German language as their first language, it was defined that the project work should be written in the English language so that it was readable and perceptible by all members involved in the project, as well as for the academic advisor (Prof. Dr. Fernando Paulo Belfo) and the evaluating higher education institution (ISCAC - Coimbra Business School).

Meetings between the practitioners and the researcher have been held in either the German or the English language.

The action plan has been defined by the researcher (Alexandra Matos) and the supervisor of this project (Practitioner 1). For the purpose of the planning of this project, the researcher and Practitioner 1 defined sprint meetings. Sprint meetings are the foundation of the Scrum methodology. In Scrum, sprints are regular work cycles, known as iterations or sprints (Beedle et al., 2001; Schwaber, 1997). For the purpose of this project, sprint meetings are where all communication takes place, and the researcher reports his findings and work to the supervisor. Within each sprint, different small work-packages have been defined. The sprint meetings took place, approximately, twice a month.

- Sprint 1 - Investigation (examination and discover)
- Sprint 2 - Clarification of concepts (literature review)
- Sprint 3 - Problem statement and influencing factors
- Sprint 4 – Solution proposal
- Sprint 5 - Results and conclusions

In a first phase, there were 3 meeting sessions with Practitioner 2 lasting two hours each. Practitioner 2 is the project leader of Product Information Management, as well as team leader of the Digital Product Content Chain department. In these meeting sessions, the entire current situation of the processes and systems involved was explained in detail, as described in chapter 4.1.1 to 4.1.3. After these sessions, whenever necessary, practitioner 2 was available to clarify any doubts or questions that might arise.

A detailed analysis and observation of the current situation has been made, including all the knowledge provided by the practitioners, taking into account the requirements described in chapter 4.1.4, and knowing that it will be necessary to create a network structure based on the information collected in the chapter referring to the literature review. The present project work proposed the creation of an ontology for the purpose of answering the research problem presented in this paper.

To create an ontology, it was previously necessary clarify the concept of ontology and to carry out an in-depth research on the technique to be used. After a vast literature search about the practice used to create ontologies and potential work tools to be used, for this project it was decided to use Protégé, a free, open-source ontology editor and framework for building intelligent systems.

Protégé was developed by the Stanford University with supporting papers developed by researchers of the same learning institution, namely Noy & McGuinness (2001) from the Stanford Knowledge Systems Laboratory. Protégé is an ontology editor recommended by W3C (World Wide Web Consortium) and by most knowledge base developers and researchers (W3C, 2015).

Protégé's plug-in architecture can be adapted to build both simple and complex ontology-based applications. Developers can integrate the output of Protégé with rule systems or other problem solvers to construct a wide range of intelligent systems. Protégé fully supports the latest OWL 2 Web Ontology Language and RDF specifications from the World Wide Web Consortium. The tool is based on Java, it is extensible, and provides a plug-and-play environment that makes it a flexible base for rapid prototyping and application development. It is possible to create and edit one or more ontologies in a single workspace via a completely customizable user interface. Visualization tools allow for interactive navigation of ontology relationships. Advanced explanation support aids in tracking down inconsistencies. Refactor operations available including ontology merging, moving axioms between ontologies, rename of multiple entities, and more (Protégé, 2020).

In summary, there are some of the main features and benefits of the Protégé ontology editor (Protégé, 2020):

- W3C standards compliant
- Customizable user interface
- Visualization support
- Ontology refactoring support
- Direct interface to reasoners
- Highly pluggable architecture

With the support and recommendation of the Digital Product Information and Packaging Director, the researcher had the opportunity to meet with a subject matter specialist, a research engineer, based at the Bosch Center for Artificial Intelligence (Renningen, Germany). The research engineer specifically conducts a team of researchers that is dedicated to the topic of semantic data management. The goal of this meeting was to share the details and possibilities of the present project and communicate useful information.

The research engineer shared good practices, the team's way of working, internal research information and tools that are used within the team to create semantic nets and ontologies. In addition to that, the research engineer communicated his advice for the present project, and confirmed that an ontology with be a good possible solution for the presented problem and confirmed that the Protégé ontology editor is an adequate tool to be used for this purpose, since his team uses it as well. At the end of the meeting, the research engineer, shared that, at that moment, there is still a lack of people, researchers and professionals that are dedicated to the study and development of semantic nets and ontologies, and added that there is a high demand for professionals and researchers dedicated to the subject internally and externally to Bosch.

After an exhaustive literature review and research on the topic of ontologies, the researcher proceeded to summarize and share the theoretical information that had been gathered with the different practitioners of this action research to disseminate the knowledge, "teach" the theory and logic behind ontologies, as well as describe how it could work for the specific project. These knowledge sharing meetings have been divided into four different sessions where the researcher explained relevant concepts and respective methodologies related to ontology, taxonomy, OWL, semantic nets. The sessions were supported by basic graphical examples, and questions and doubts were answered and clarified. The most occurring question was about what the differences between ontologies and taxonomies. Practitioner 4 showed particular interest and requested further sessions to get a more in-depth information on the technical and methodological part of ontologies.

Within the scope of the Digital Product Content Chain (DPCC) project, it was found that one of the major internal problems is the so-called "Tower of Babel" problem (Iliadis, 2019). The Bosch Building Technologies business sector is large and has many internal stakeholders and different departments all around the world. During the dissemination of the mission of the DPCC project among the different departments, the team members realized that one of the major obstacles that stood in the way of the dissemination and gaining support from other departments was, without a doubt, the existence of different notions of basic internal terms. For example, the term "product" was understood in different ways for different people and different departments, as it had never been truly formally defined. This situation applied to countless other terms and even processes. People in the same place speaking different languages and, in the end, no one understanding each other is the core of Tower of Babel problem.

It was then that for this reason, within the scope of the DPCC project, a consultancy company dedicated to the definition and improvement of processes was hired. Part of the work of this company was the elaboration of an information model, with the help of the consultant and expert for modeling and business architecture. The methodology used was developed by the consultant and expert and proved to be very similar to what is an ontology, when it was a variant of an Enterprise Relationship Diagram (ERD).

Stakeholders from different departments were brought together in the same meeting / workshop. There, different concepts were discussed based on real internal situations, and, once reaching a common agreement, concrete definitions were drawn up, network schemes were constructed, which included definitions for each entity / concept and different relationships between concepts. The information models were developed in a tool called Oracle Data Modeler.

After observing the methodology that would be applied in the present project work and having participated in the knowledge sharing sessions of the researcher, Practitioner 2 and leader of the DPCC project, invited the researcher (Alexandra Matos) to participate in the workshops with the consulting company and the different participants from the different Bosch Building Technologies' departments. Practitioner 2 invited the researcher to participate in an exclusive training, taught by the consulting firm's expert, with the objective of becoming responsible for the maintenance and long-term management of the information models built in the German language, becoming part of the internal Focus Team dedicated to Information Modeling.

4.3 Phase 3 – Action taking

The action taking phase concerned the implementation of the planned action. The researcher and practitioners collaborate in the active intervention into the organization, causing certain changes to be made. Intervention tactics can be adopted, such as recruiting intelligent laypersons as change catalysts and pacemakers (Baskerville, 1999).

To build a good ontology, it is necessary to have well-established and logical taxonomies as a basis. For the creation of the proposed ontology this project focused on the product segment "Access Control Systems" as an example application.

After trying to apply the current product taxonomy to start the creation of the ontology, the researcher realized that the taxonomy that is currently in use in the Bosch Security Systems online product catalog (Bosch, 2021) does not allow the creation of an efficient and adequate ontology for the purpose of this work.

Just by looking into the second level of the product taxonomy, it is possible to see that software and hardware products are displayed together at the same level (e.g., Access

Modular Controller and Access Management System) as there is already a specified class for Software products on level one. If we look even further into the taxonomy, the third level of Access Modular Controller consists of a mixture of different hardware products (Access Modular Controller, Extension Boards, Enclosures, Power supply units and mounting racks), product families and single products. In the third level, when selecting AMC2 - Access Modular Controller, we are presented with the main product page. At the main product page, if we choose to select "Variants", then only the product variants should be displayed, but in reality, we get to see variants as well as accessories which are rather Accessories that can be part of an Access Control System.

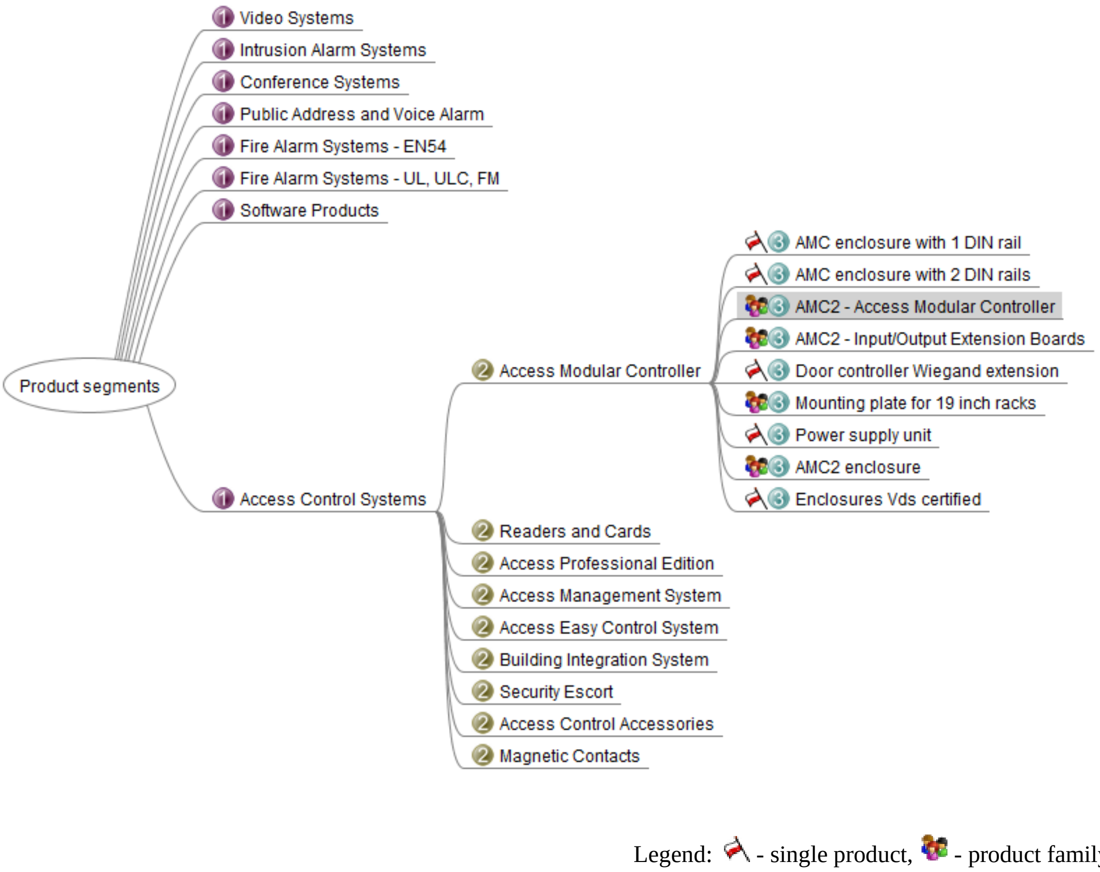


Figure 20 - MindMap for representing the Access Control System's product taxonomy; AMC2 – Access Modular Controller; Tool: FreeMind MindMap;

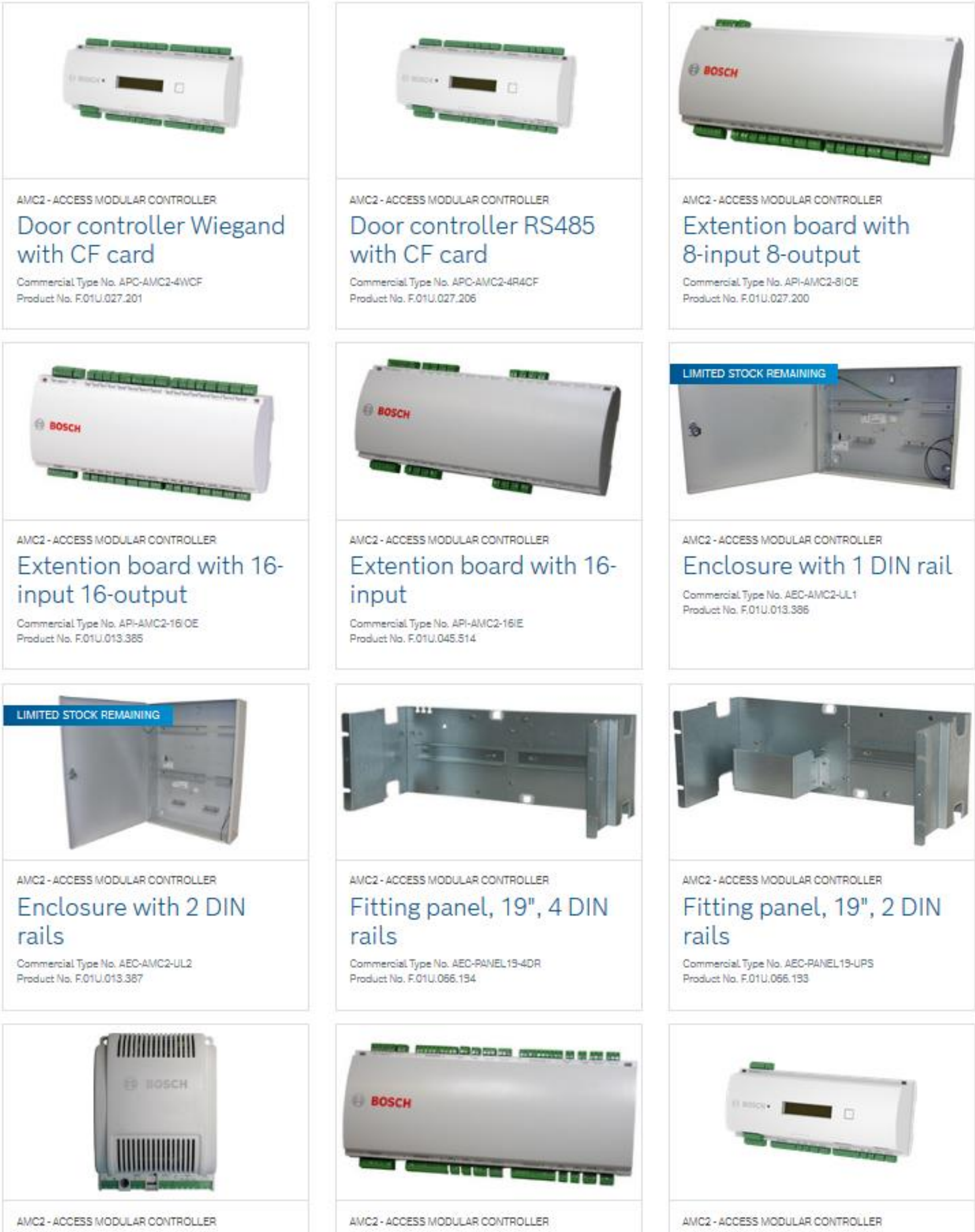
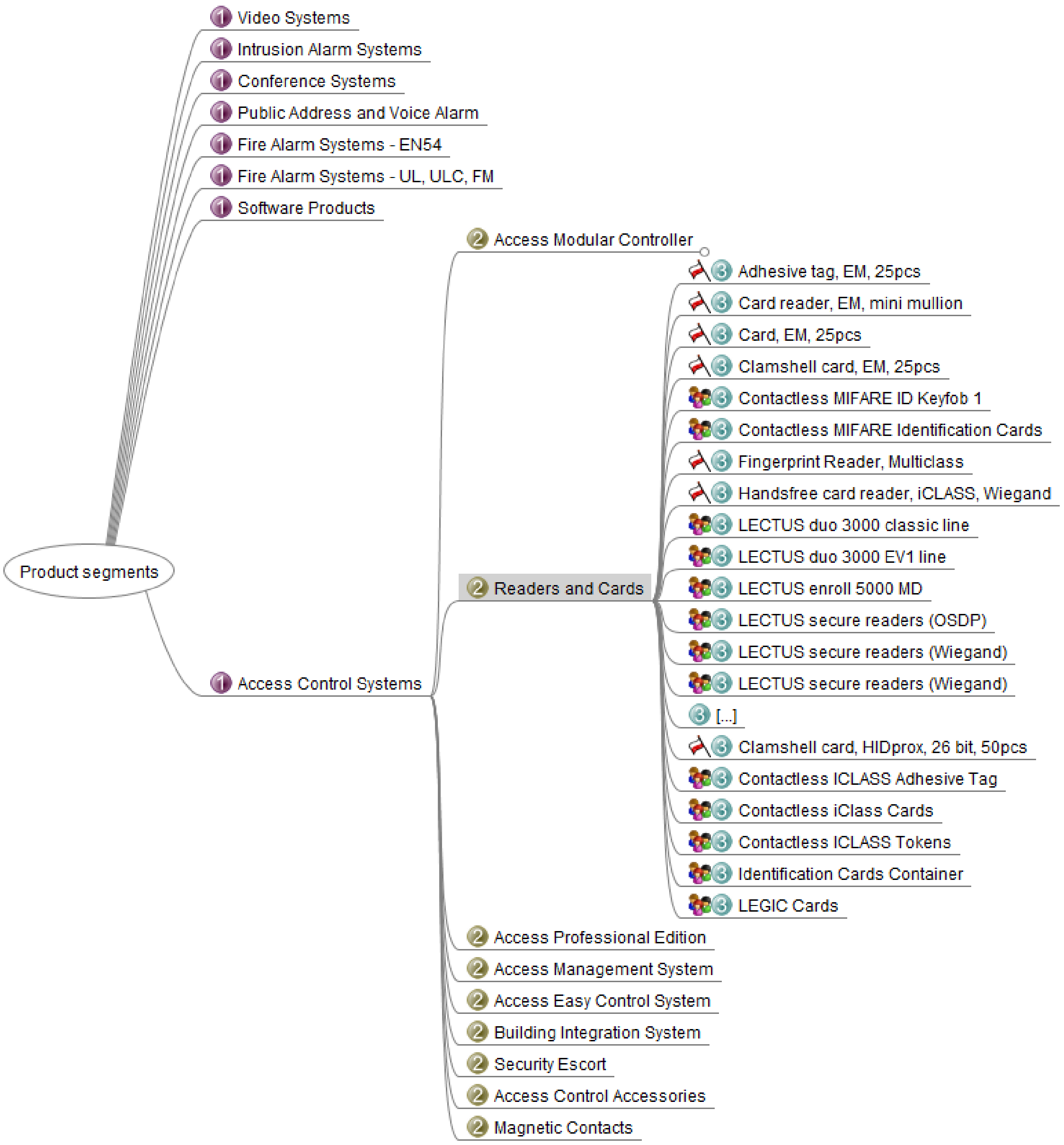


Figure 21 - Screenshot of the "Variants" section, under the product family " AMC2-Access Modular Controller; Source: Bosch Security Systems online catalog

Another example of inadequate taxonomy is the second level entity that is called “Readers and Cards”, where it gets especially confusing.



Legend: - single product, - product family

Figure 22 - MindMap for representing the Access Control System's product taxonomy; Readers and Cards; Tool: FreeMind MindMap;

In the third level, under the "Readers and Cards" entity, access control readers, cards, tags, tokens, and card accessories are displayed. This means that the name of the second level entity is not adequate because two different entities are being mixed, and in reality, there is even more to it than just cards and readers, but a vast amount of credential types and accessories.

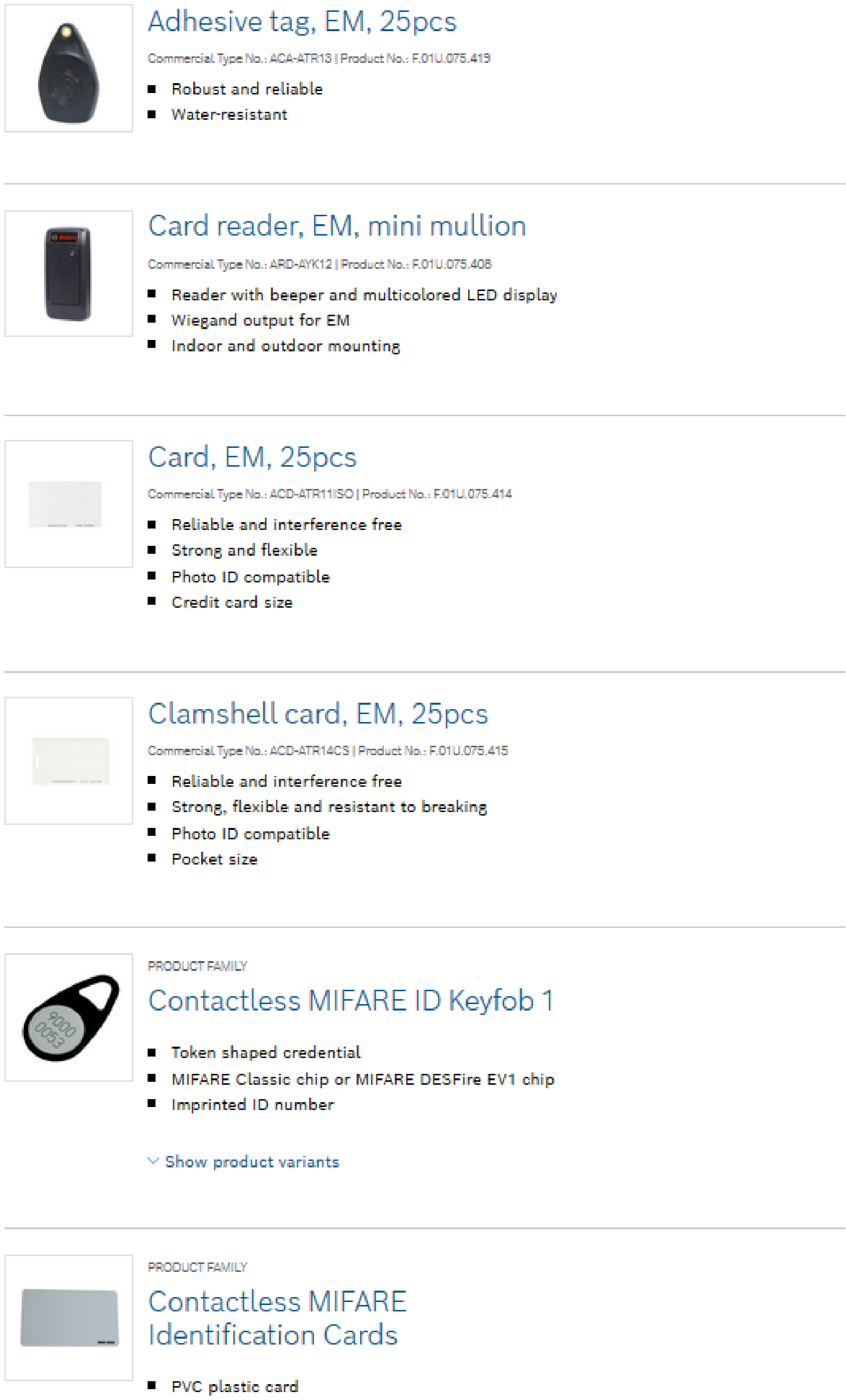


Figure 23 - Screenshot of part of the online product catalog view when selecting "Readers and cards"

Another issue that the user is confronted with is the fact that the names given to second-level entities are marketing names (e.g., “Access Management System” is a software product) instead of displaying a more generic name that tells the user which kind product he will be looking at (e.g., software or hardware product). An internal stakeholder, such as a product manager, a project manager or a technical writer are aware of what the marketing name is part of since they are involved in the rollout of a project, but the external stakeholder, such as a customer, cannot perceive what the marketing name means. From the customer's eyes perspective, an "Access Management System" could be assumed to be a software product, but also an entire access control system which includes software and hardware products.

Creating a new product taxonomy

According to the requirements, for the elaboration of a new product taxonomy, four main aspects were considered:

1. The new structure must be logical and user friendly
2. Allow easy navigation within the taxonomy
3. Use of simple, generic, and common market terminology
4. Any individual must be able to find a specific product, be it a specialist or a layman

Therefore, an online analysis has been conducted: Online catalogs of other competing companies of the same product segment (security systems, access control segment) have been compared. The product taxonomies on their web pages and online shops have been analyzed. Some of the main companies subject to study were *HID*, *Honeywell*, and *Senseon*.

After conducting a general comparison between the various product taxonomies of these companies, it was possible to conclude that there is no consistent terminology or structure. However, the terminology used is, in part, simpler and more generic, making the task of locating a specific product easier for the user. In addition, the first level of product classes is more granular and detailed, helping the user to have a complete overview of the products, right from the first interaction he has with the product catalog. This does not happen in the current online catalog of Bosch Security Systems.

With a focus on the terminology of products to be used in the new taxonomy, an online search was then carried out to decide which terms to use. The decision was made considering definitions that have been clarified online, search results for potential terms and the information collected in the previous phase (analysis of other companies approaches).

After creating a potential new product taxonomy, some persons have been invited to test it. These testers were the following:

- Tester A

  Education: High school

  Profession: Wind turbine maintenance technician

  Employer: Other

- Tester C

  Education: BA in Economics

  Profession: Logistics manager

  Employer: Other

- Tester D

  Education: BA in computer engineering

  Profession: Programmer

  Employer: Other

- Tester E

  Education: BA in Nursing

  Profession: Nurse

  Employer: Other

- Tester F

  Training: Electrical engineering

  Profession: Product manager

  Employer: Bosch

- Tester G

  Education: Law Degree

  Profession: Lawyer

  Employer: Other

Each tester was asked to find a specific product within the new product taxonomy. It was important that among the participants there were laypeople for the segment in question.

If lay participants were able to find the product easily, this would prove that the taxonomy is easy for any user to navigate in.

The tests were about the usability of the solution and consisted of checking how user-friendly the solution was. It was tested whether the users could easily find the product and use the taxonomy without getting stuck at any point. The usability tests evaluated if and how easily the few invited people could accomplish the defined purposes of the solution successfully, i.e., without any help from the researcher.

As the tests were carried out and close attention had been paid to the way testers instinctively navigated through the new structure, the product taxonomy has been fine-tuned.

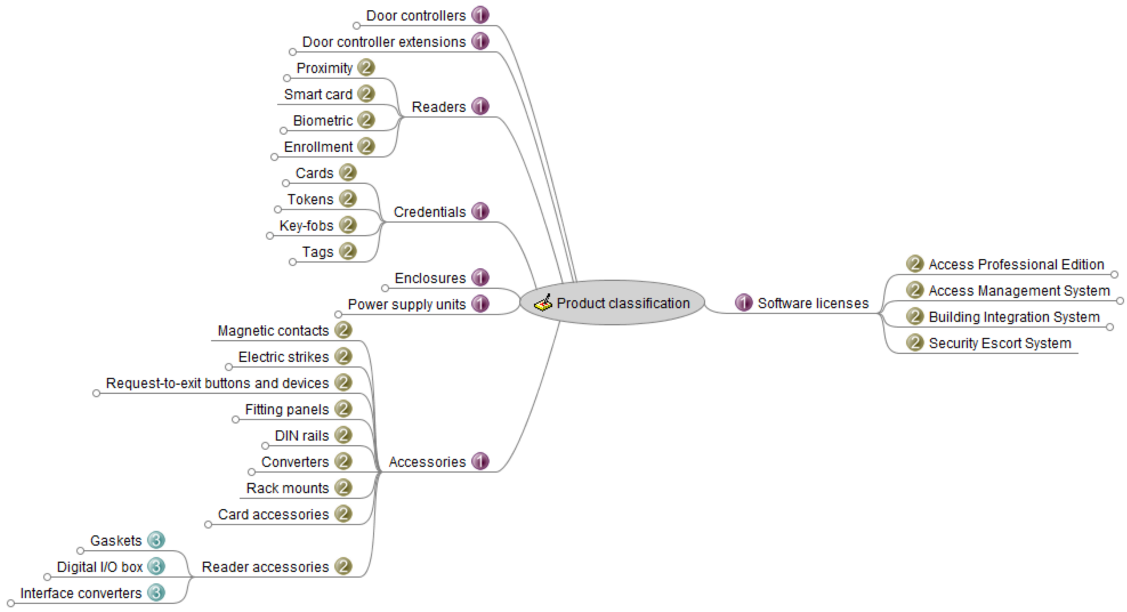


Figure 24 - Mind map of the final version of the new product taxonomy for the product classification perspective in the Access Control Systems product segment

The new taxonomy (Figure 24) has then been presented to the practitioners of the action research of this project, who proceeded to validate it.

At a later stage, Practitioner 2 requested more information on the methodology used, with the aim of carrying out several internal workshop sessions where a new product classification taxonomy would be created for each and all different product segments (fire alarm systems, communication systems, intrusion alarm systems and video systems), with the collaboration and input of different internal stakeholders of the respective product segments.

The workshop sessions, have been carried out by four members of the DPCC department, including Practitioner 2. In addition to the DPCC department members, Practitioner 1 and the researcher also participated. The entire team (incl. Practitioner 1 and the researcher) proceeded to create 4 additional taxonomies as different user perspectives that would be used for the online product selector/filtering tool. In total, five different taxonomies have been created:

(1) Product range – marketing names for a range of products and modular systems
(2) Product classification – generic product class names
(3) Properties – properties of products
(4) Application – the application use cases for products
(5) Resources – resources available for download for products

The goal is to implement these taxonomies as selectors in the online product catalog. The expected effect is that the search results are filtered and narrowed down as the user select specific entities from the different taxonomies, according to its needs.

The researcher was responsible for the moderation and creation of the first proposals for the product segment Access Control Systems. The additional participants of the workshop were specialists, namely the product managers, engineers of the product segment. In the workshop, the researcher presented the first proposals and asked for the participants opinion for discussion and fine-tuning of the taxonomies. Once a common agreement was reached, the taxonomies were adjusted, and the final versions were generated. Figure 25 presents the Product range taxonomy for the Access Control Systems product segment.

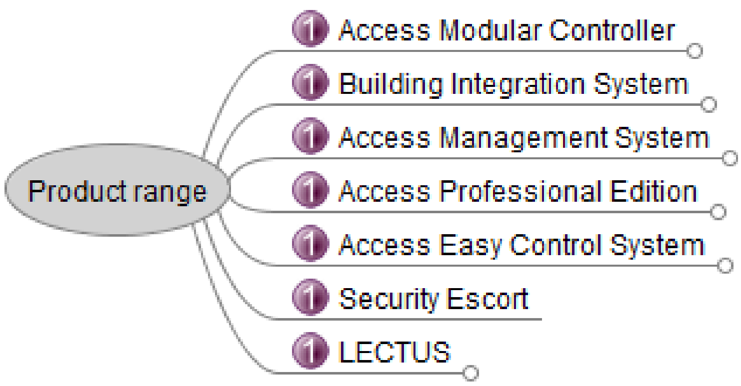


Figure 25 - Product range taxonomy for the Access Control Systems product segment

Tool: FreeMind MindMap

Figure 26 depicts the product classification taxonomy for the Access Control Systems product segment.

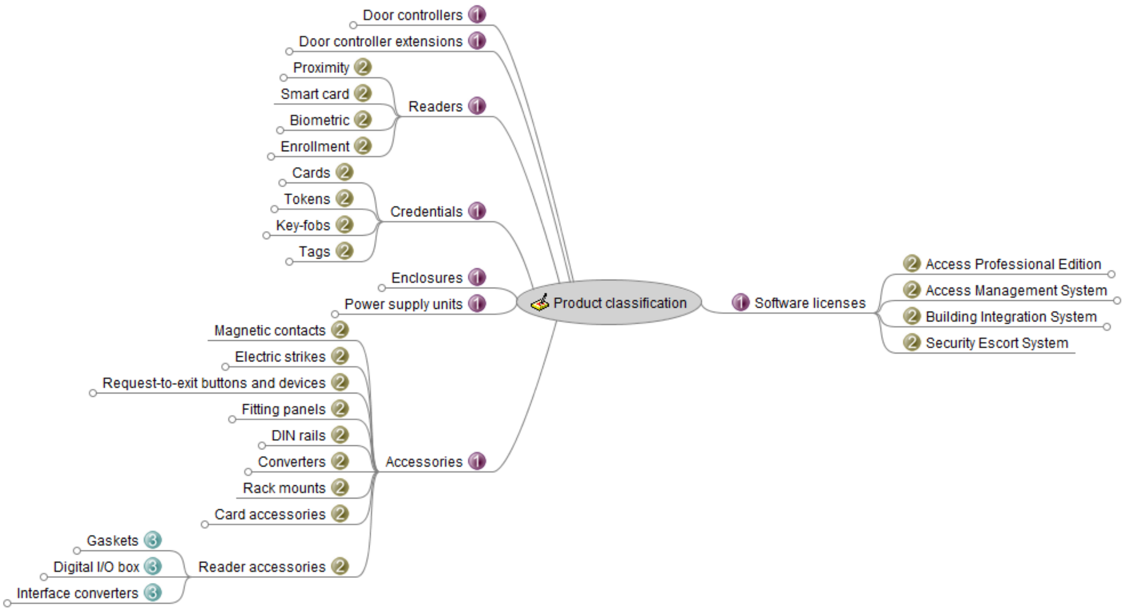


Figure 26 - Product classification taxonomy for the Access Control Systems product segment

Tool FreeMind MindMap

Figure 27 depicts the properties taxonomy for the Access Control Systems product segment.

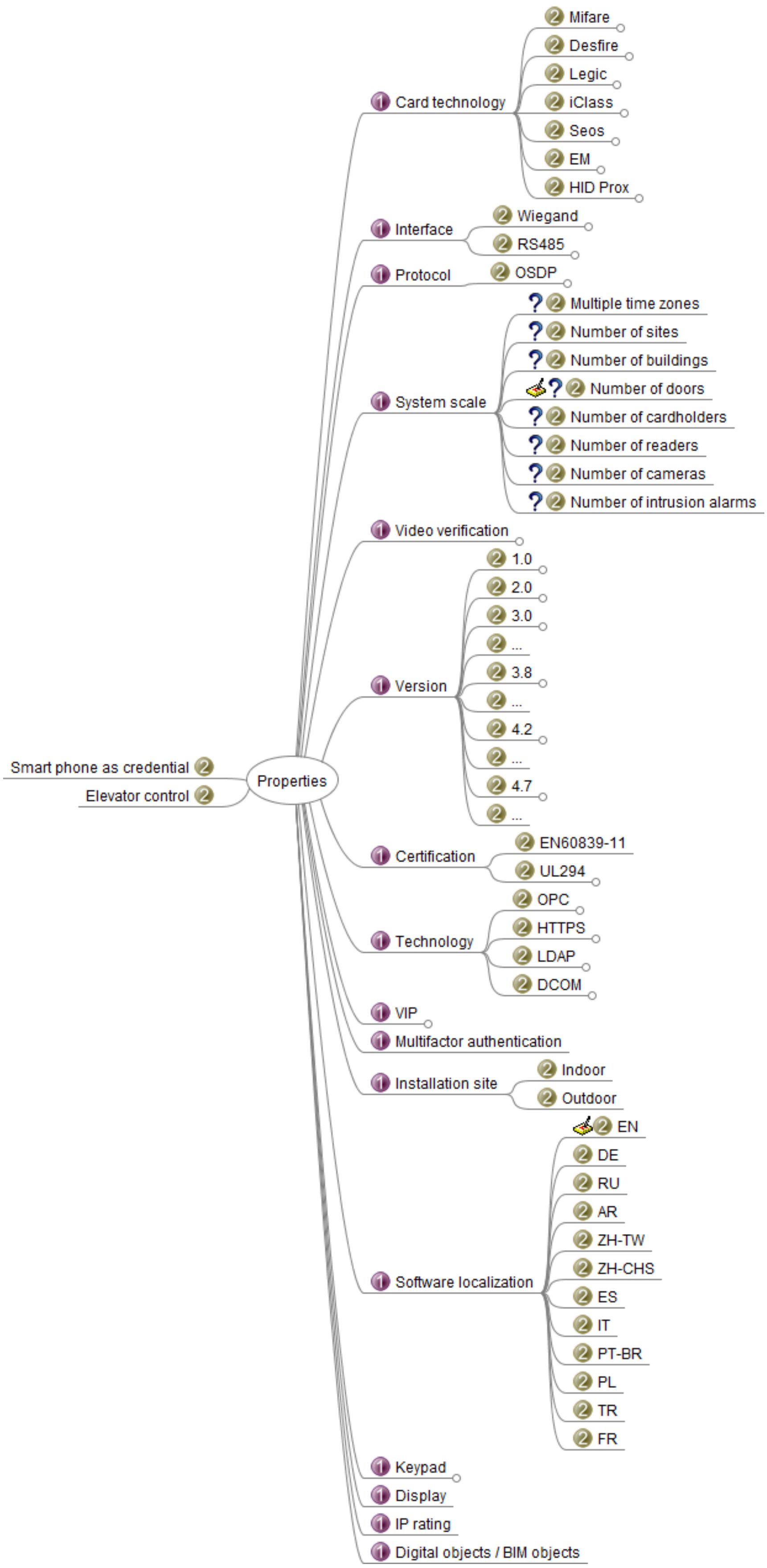


Figure 27 - Properties taxonomy for the Access Control Systems product segment

Tool FreeMind MindMap

Figure 28 depicts the application taxonomy for the Access Control Systems product segment.

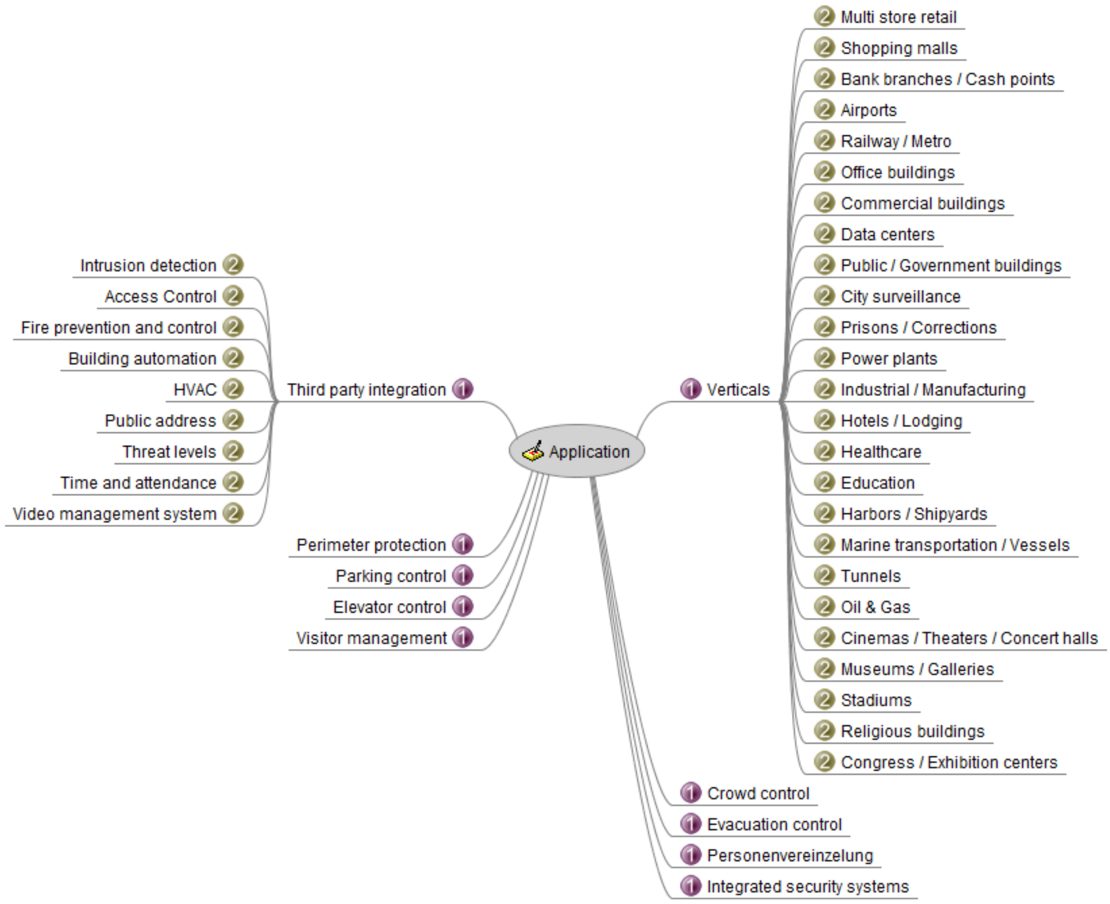


Figure 28 - Application taxonomy for the Access Control Systems product segment

Tool FreeMind MindMap

Figure 29 depicts the Resources taxonomy for the Access Control Systems product segment.

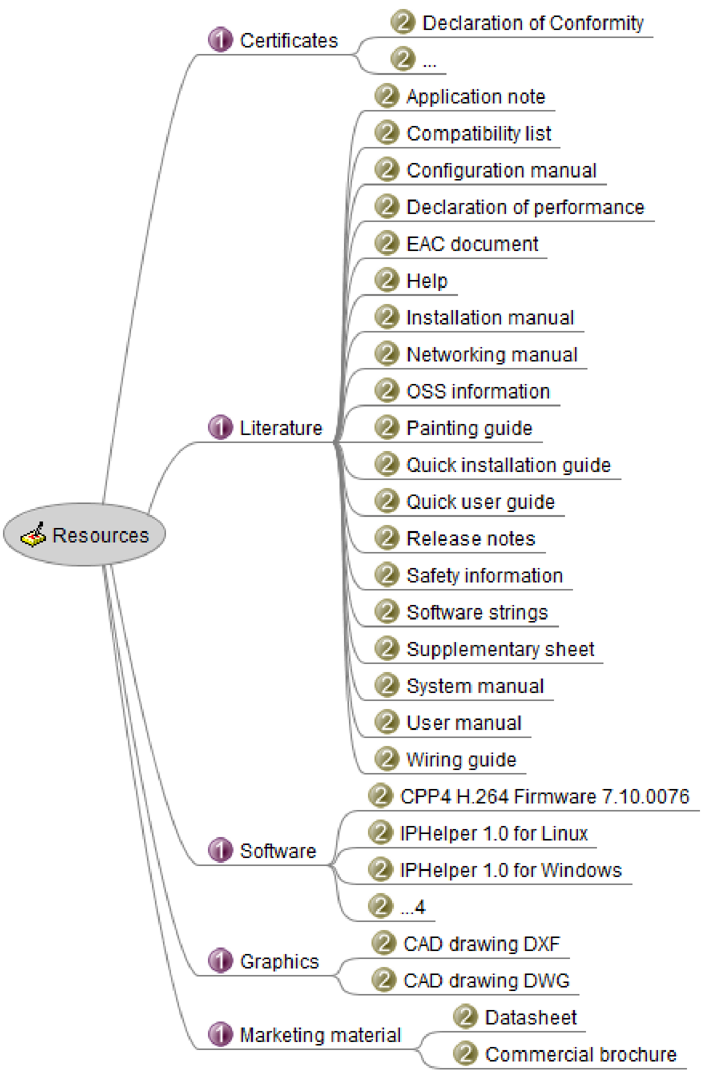


Figure 29 - Resources taxonomy for the Access Control Systems product segment

Tool FreeMind MindMap

Ontology

To create the ontology on the Protégé ontology editor, it was necessary to download the tool from the official website (*Protégé*, 2021) directly to your desktop, although the same website offers “WebProtégé” which allows you to edit and create ontologies from the web. From own experience and feedback from specialists, the researcher learned that the web version does not support all functionalities which will be needed for the purpose of this project.

After downloading the tool, it was possible to start its creation. Figure 30 is the view that the user gets by default:

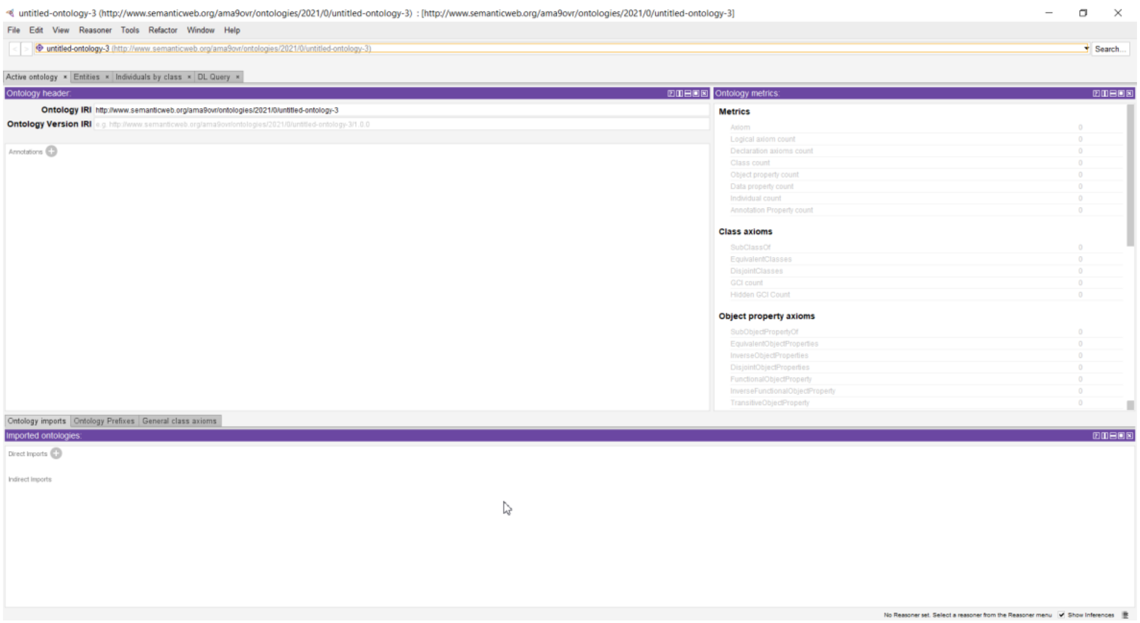


Figure 30 - Protégé ontology editor (default view after starting the tool)

Following the supporting documentation, the researcher started by selecting the "Classes" tab, in order to define the classes. Since the "Classes" tab was not available once the tool was started, the researcher added the classes tab by herself (see Figure 31).

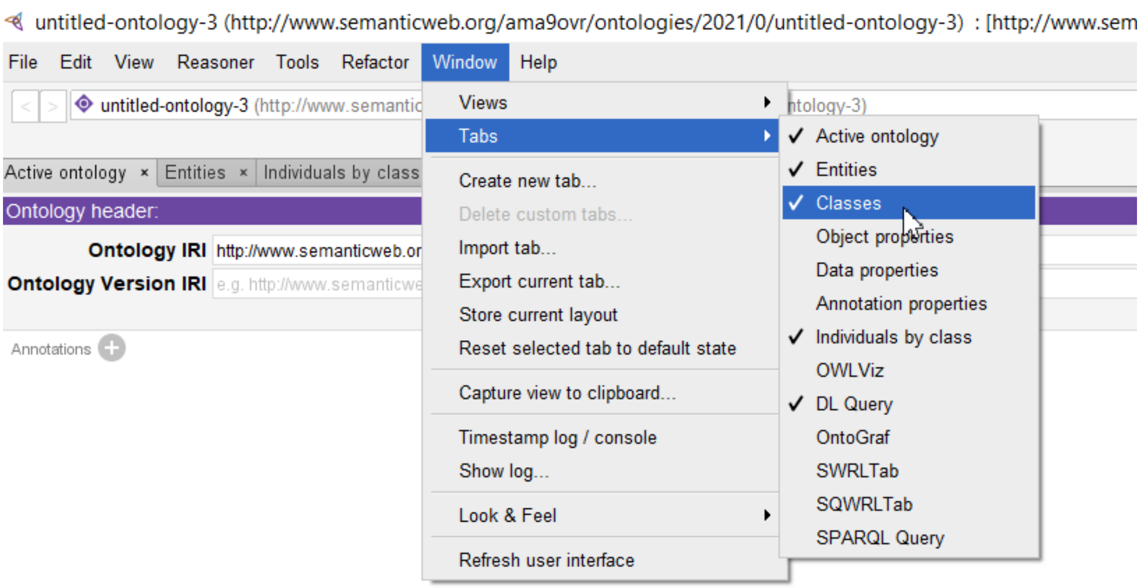


Figure 31 – How to add "Classes" tab at Protégé ontology editor

The classes that were used are the ones that have previously been created on *FreeMind*, with all four perspectives: Product range (systems), Classification, Application, Properties and Resources. On *Protégé*, it was possible to create each class and their respective subclasses, manually, one by one, but since the researcher already created all the classes on the *FreeMind* MindMap tool, she copied the classes from the tool and pasted them into *Notepad++*, and then copied the class hierarchy and imported it directly into *Protégé* as a tab indented text (see procedure in Figure 32, Figure 33 and Figure 34).

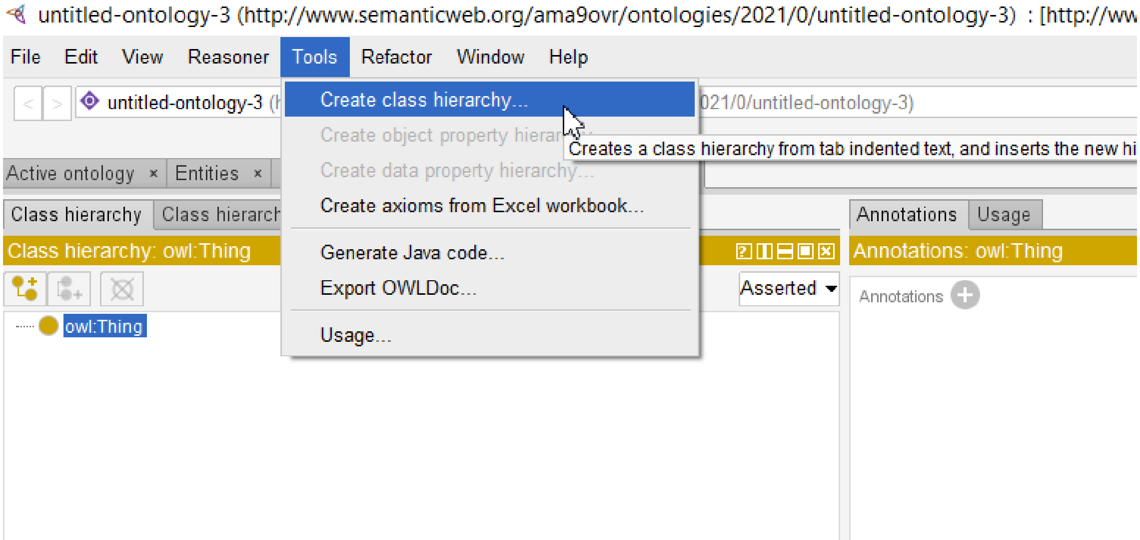


Figure 32 - Importing class hierarchy into Protégé as a tab indented text (part 1)

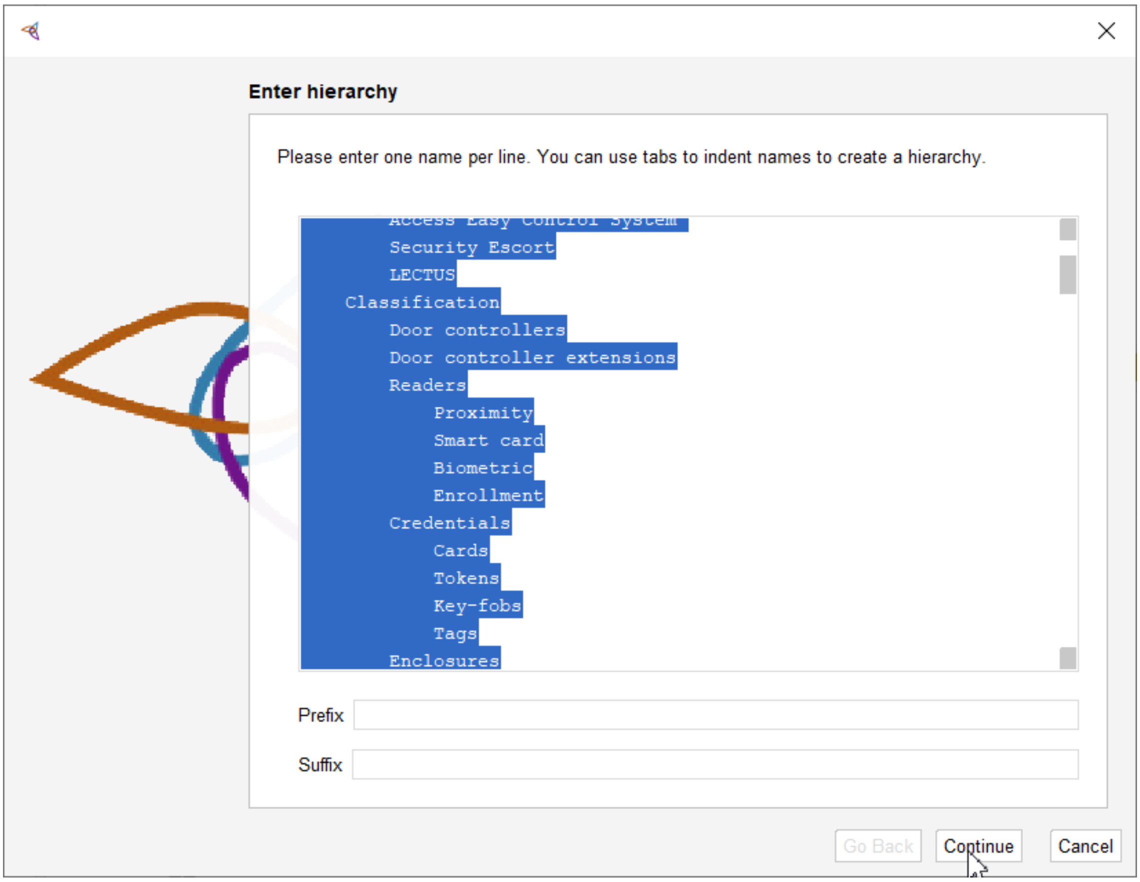


Figure 33 - Importing class hierarchy into Protégé as a tab indented text (part 2)

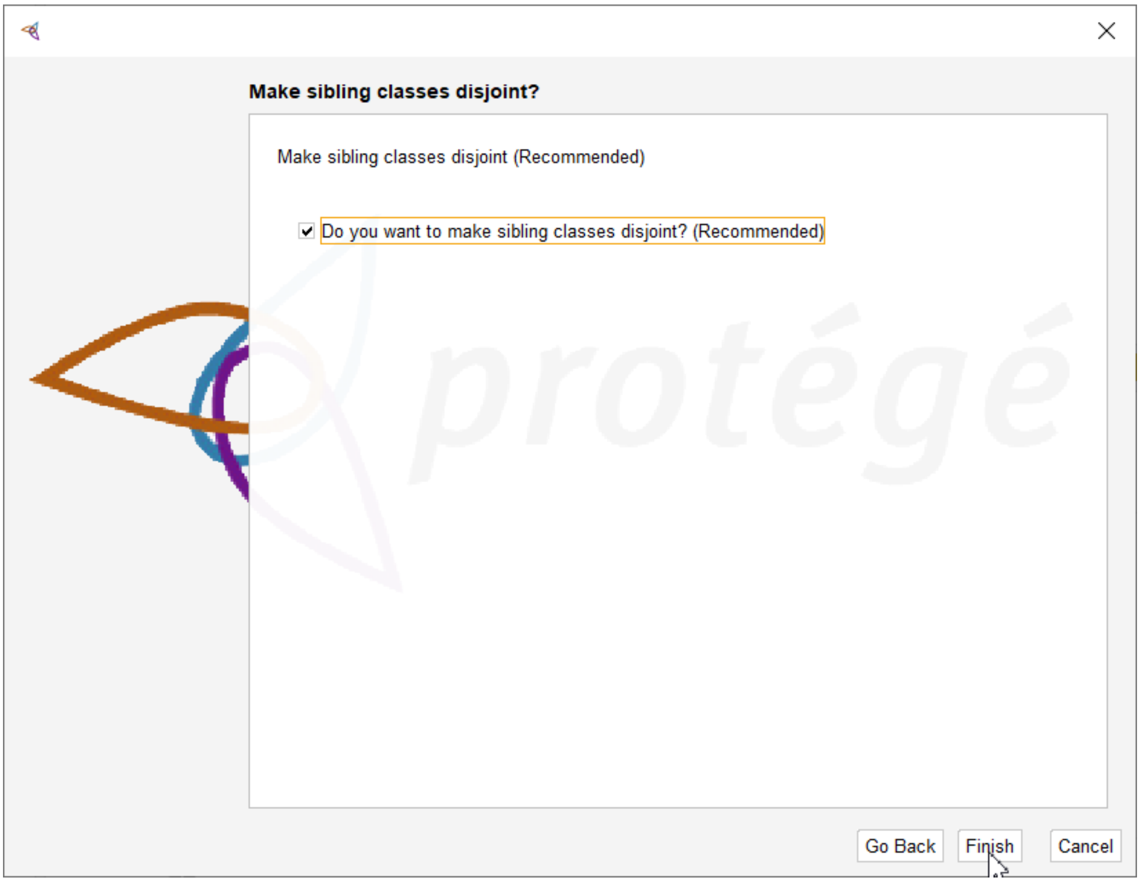


Figure 34 - Importing class hierarchy into Protégé as a tab indented text (part 3)

On Figure 34, the researcher kept the check box “Do you want to make sibling classes disjoint?” as selected by default, even though there might be cases, in the long-term future, in which she may have to adjust this statement manually. For clarification, two (sibling) classes in an ontology are disjoint if they cannot share an instance, regardless of how the classes are interpreted.

After importing the classes, the researcher created the “Object properties”. Since she did not have the object properties in a separate file, she created them manually on *Protégé*. To do so, it was necessary to select the “Object properties” tab on the *Protégé* ontology editor (see screenshots Figure 35) and add them manually, one by one.

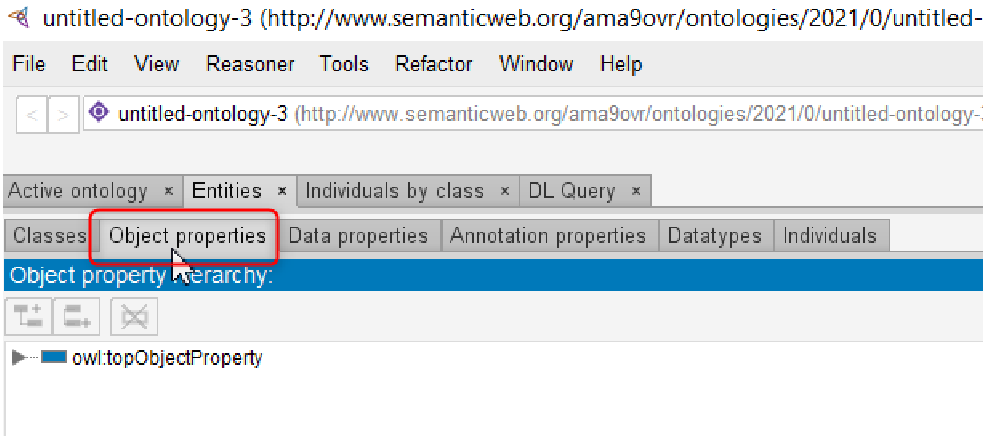


Figure 35 – "Object properties" tab on Protégé

At this point, it was important to remember the main research question, "How to manage product information for complex modular security systems?", and the main challenge/goal within this question.

To make it clear to all users which products are compatible with which systems, i.e., be able to establish a relationship or connection between a system and product families or single products and/or accessories and be able to establish more than one relationship for a single entity/class.

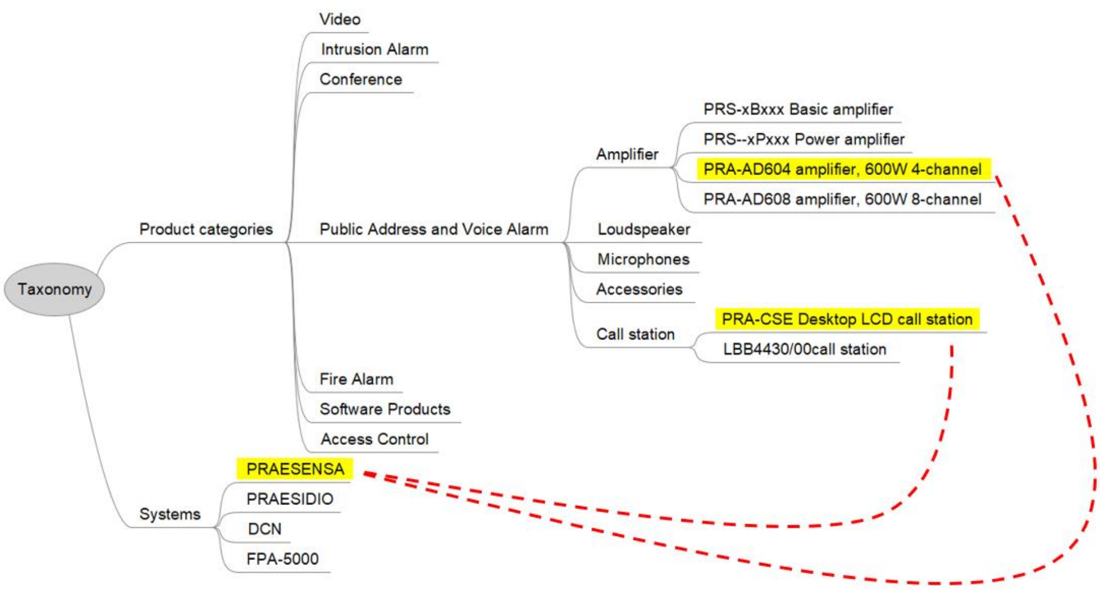


Figure 36 - Representation of the product taxonomy (desired situation). Example of the PRAESENSA system

Tool used: FreeMind MindMap

Figure 36 represents the PRAESENSA system case. In the present project, the researcher was focused on the Access Modular Controller 2 system, to solve the exact same issue as shown in Figure 36.

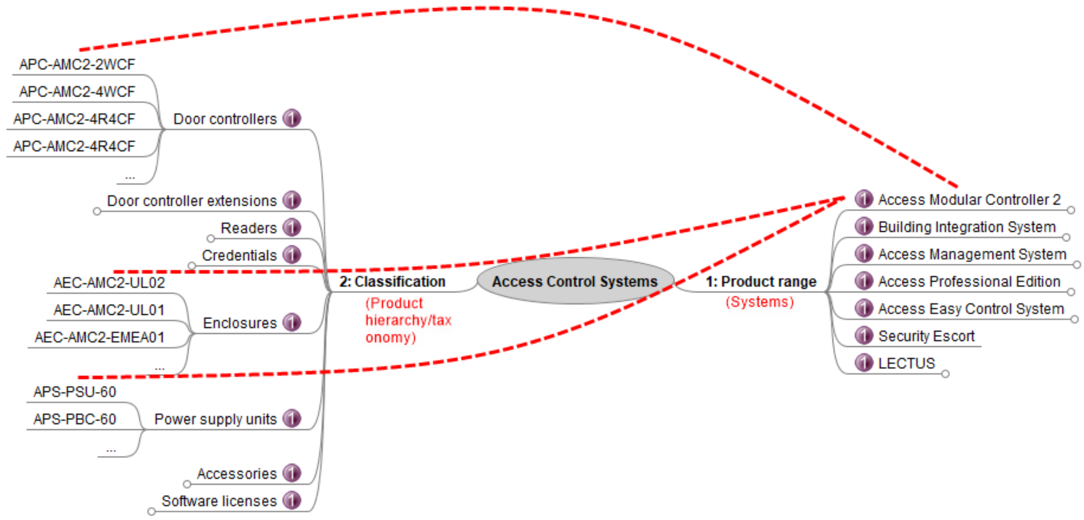


Figure 37 - "Access Modular Controller 2" use case on FreeMind (ideal situation)

At the "Access Modular Controller 2" example (Figure 37), the goal is to allocate the products APC-AMC2-2WCF, APC-AMC2-4WCF, APC-AMC2-4R4CF to the class "Door controllers", in the "Classification" perspective, as well as to the "Access Modular Controller 2" system, in the "Product range" perspective. In addition to this, the products AEC-AMC2-UL02, AEC-AMC2-UL01 (enclosures) and APS-PSU-60, APS-PBC-60 (power supply units) were allocated as accessories of the "Door_controllers" in the "Classification" perspective, as well as accessories of the system "Access Modular Controller 2" system, in the "Product range" perspective.

Following the previous problem/solution statements, the researcher proceeded with defining the "Object properties" (See Figure 38):

- hasAccessory
- hasProductFamily
- isAccessoryOf
- isCompatibleWith
- isProductFamilyOf

- isVariantOf

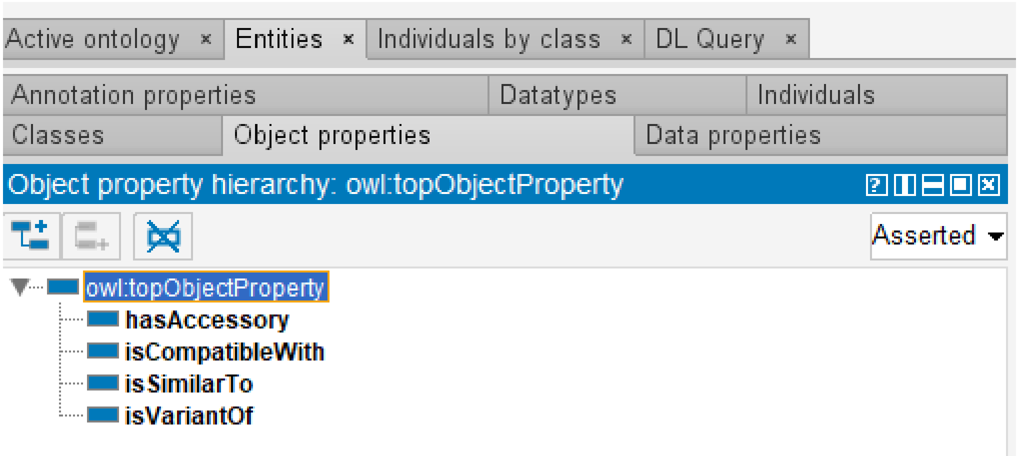


Figure 38 - "Object properties" tab on the Protégé ontology editor

These object properties defined the relationships between the different instances of the products. The researcher have specified a definition for each object property, in order to avoid any ambiguities (see Figure 39, Figure 40, Figure 41 and Figure 42).

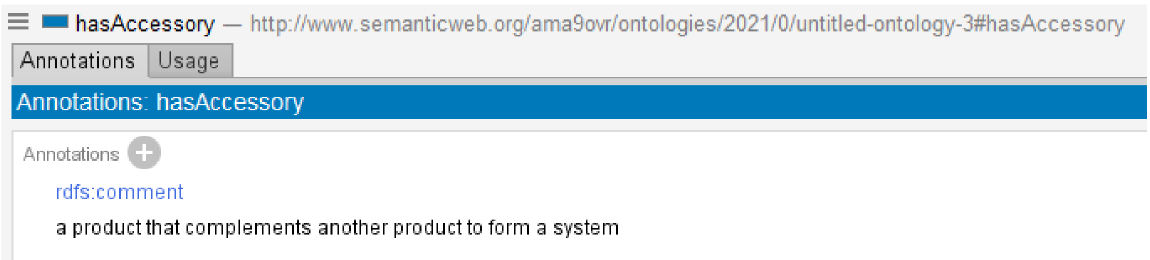


Figure 39 - Definition of object property "hasAccessory"

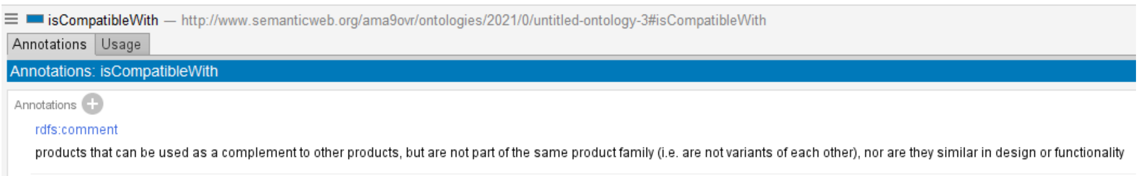


Figure 40 - Definition of object property "isCompatibleWith"

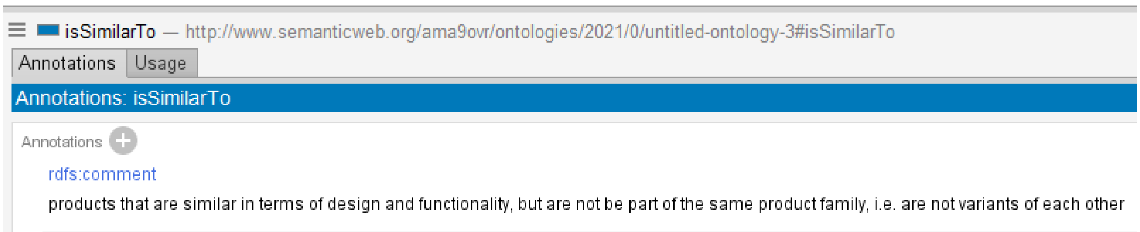


Figure 41- Definition of object property "isSimilarTo"

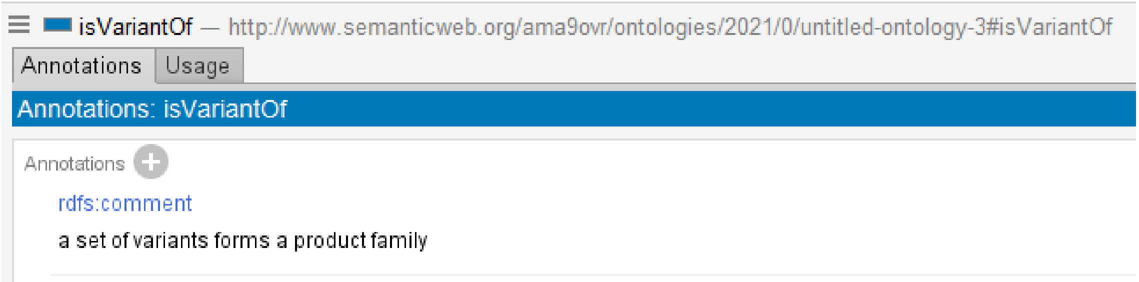


Figure 42 - Definition of object property "isVariantOf"

Afterwards, the researcher defined instances (CTN numbers) for some of the classes. She added the three door controllers (CTN numbers) and allocated them to the class “Door_controllers”: APC-AMC2-2WCF, APC-AMC2-4WCF, APC-AMC2-4R4CF, as well as to the “Access Modular Controller 2” system.

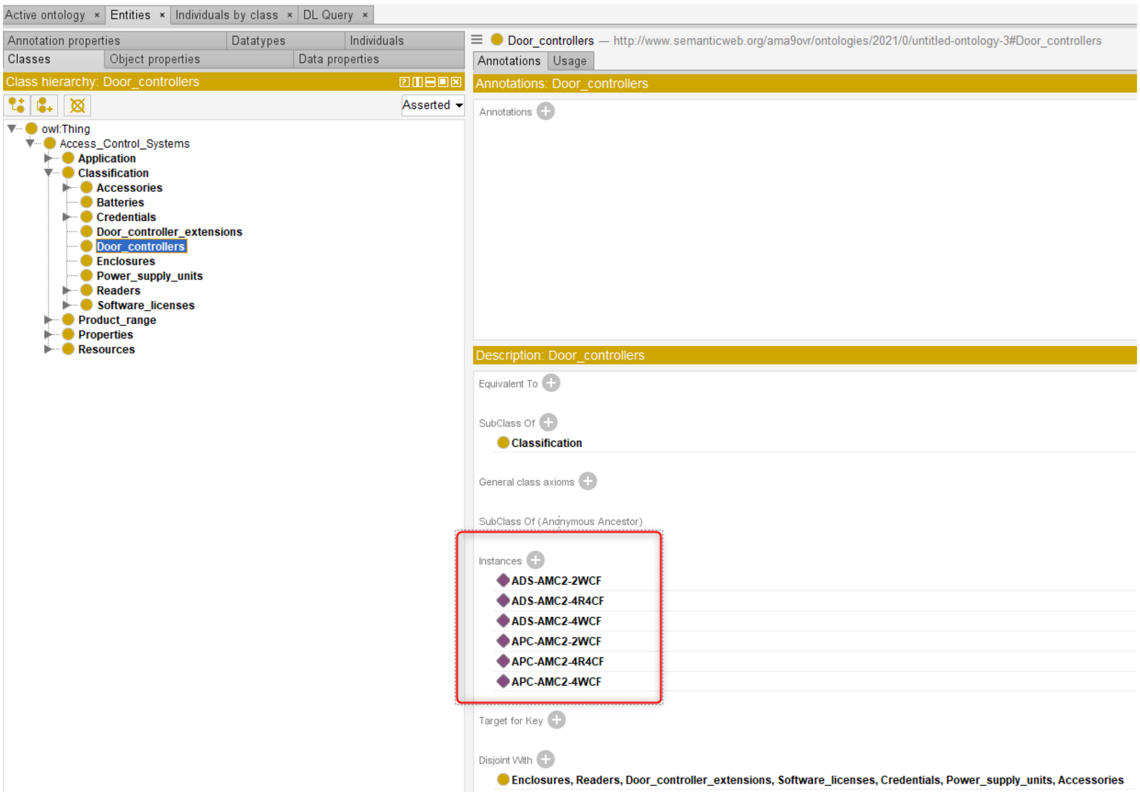


Figure 43 - "Classes" tab with CTN numbers as instances of class "Door_controlers" in Protégé

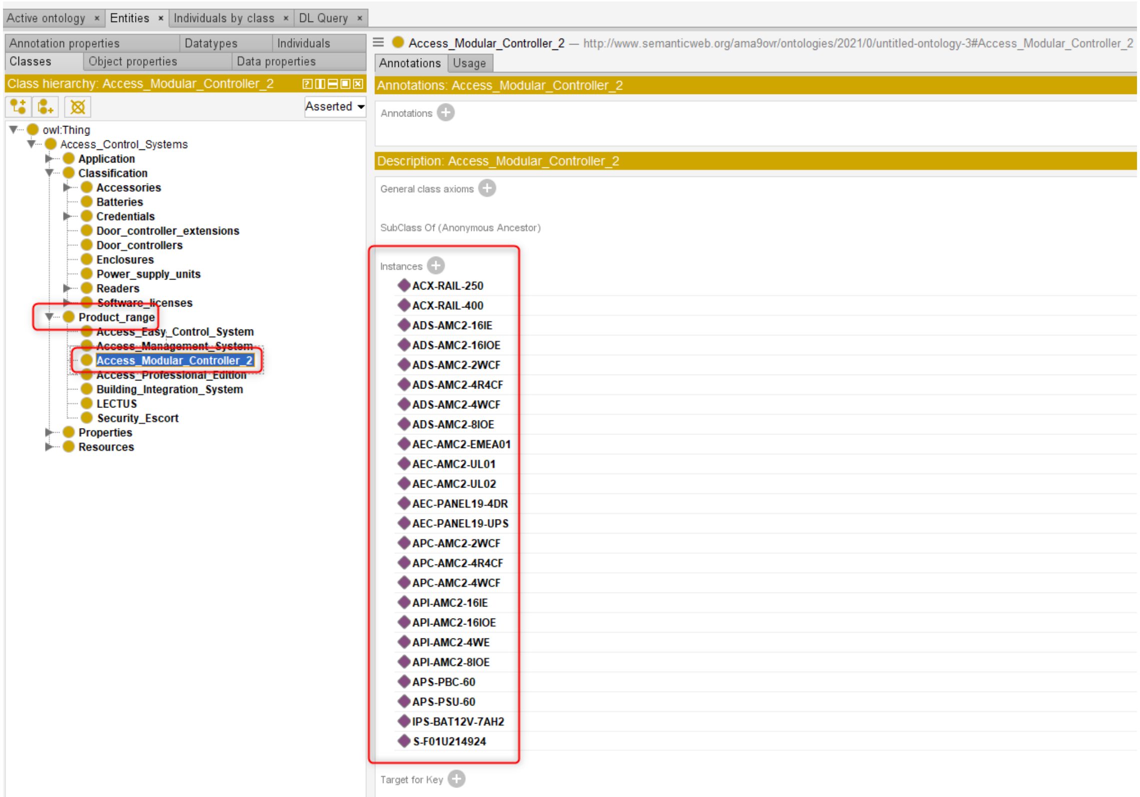


Figure 44 - "Classes" tab with CTN numbers as instances of class "Access_Modular_Controller_2" in Protégé

The same has been done to all the other product mentioned previously, respectively, AEC-AMC2-UL02, AEC-AMC2-UL01 (enclosures) and APS-PSU-60, APS-PBC-60 (power supply units). This means that, at this point, the CTNs are allocated to their "Product range", as well as to their position in the "Classification" range.

After this step, the researcher proceeded to start creating the "Property assertions" (see screenshot in Figure 45).

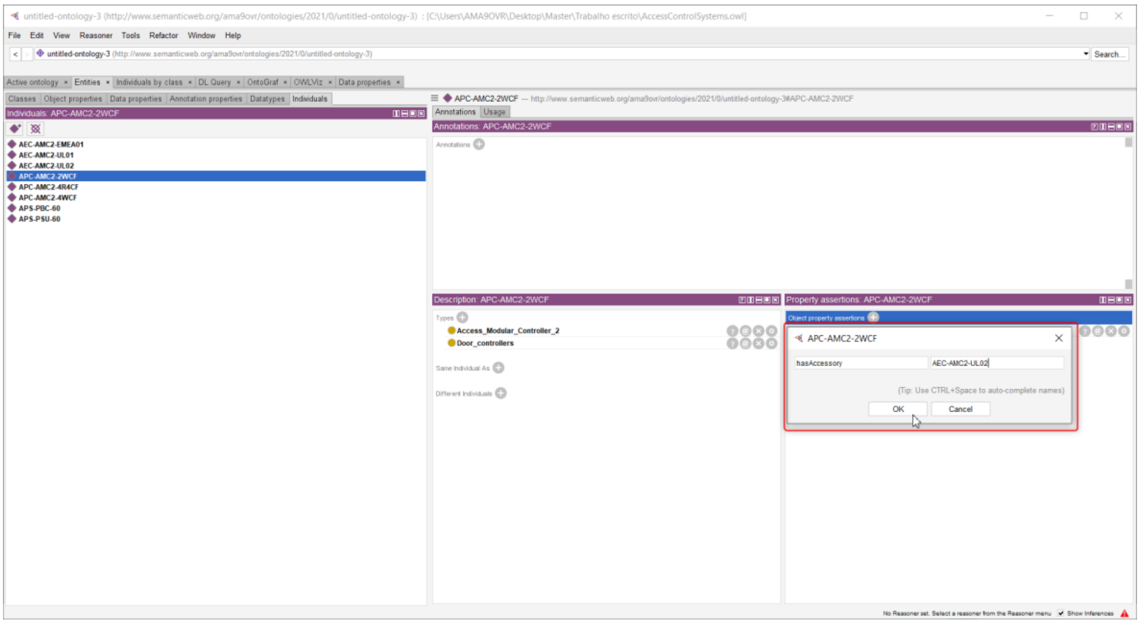


Figure 45 - Adding property assertion to instance APC-AMC2-2WCF: hasAccessory (slot) + AEC-AMC2-UL02 (value)

The property assertion shown in Figure 41 shows that the instance APC-AMC2-2WCF has an accessory that is product AEC-AMC-UL02. The researcher added a few more property assertions (see screenshot below) that are listed in the property assertions viewlet (Figure 46).

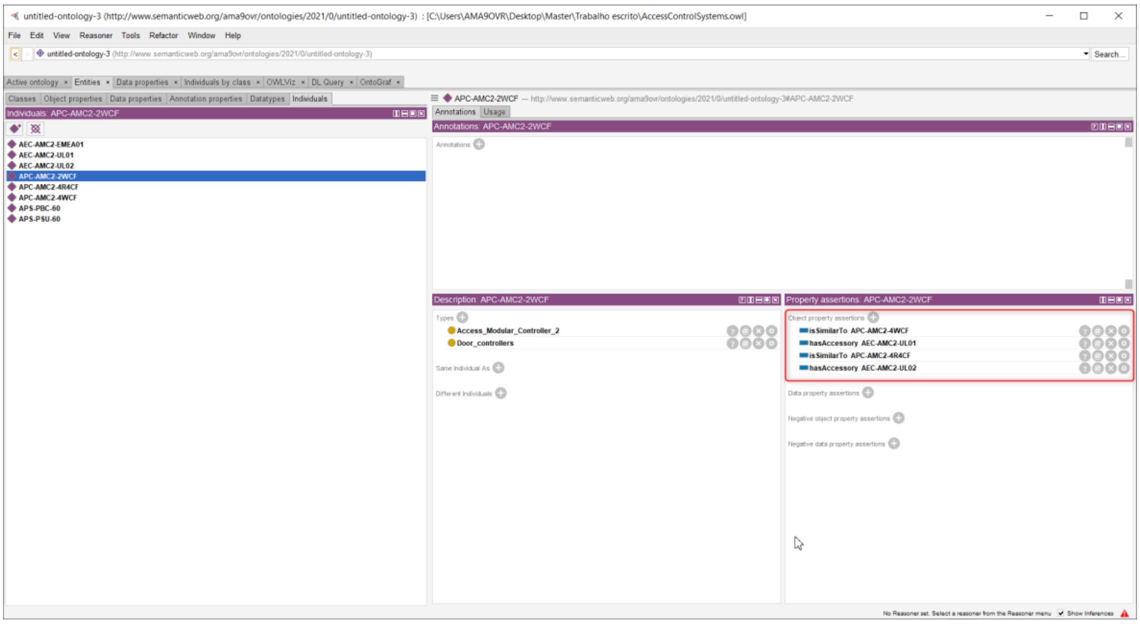


Figure 46 - List of property assertions for APC-AMC2-2WCF

Further adequate assertions have been done to all the other previously mentioned products: APC-AMC2-4WCF, APC-AMC2-4R4CF (door controllers), AEC-AMC2-UL02, AEC-AMC2-UL01 (enclosures) and APS-PSU-60, APS-PBC-60 (power supply units).

Moving forward and, to demonstrate how metadata could be added and managed in a machine-readable manner in the Protégé ontology editor, the researcher proceeded by importing the previously created "Technical Specifications Master List" with the PIM project team at Bosch Security Systems into the "Data property" tab (see Figure 43).

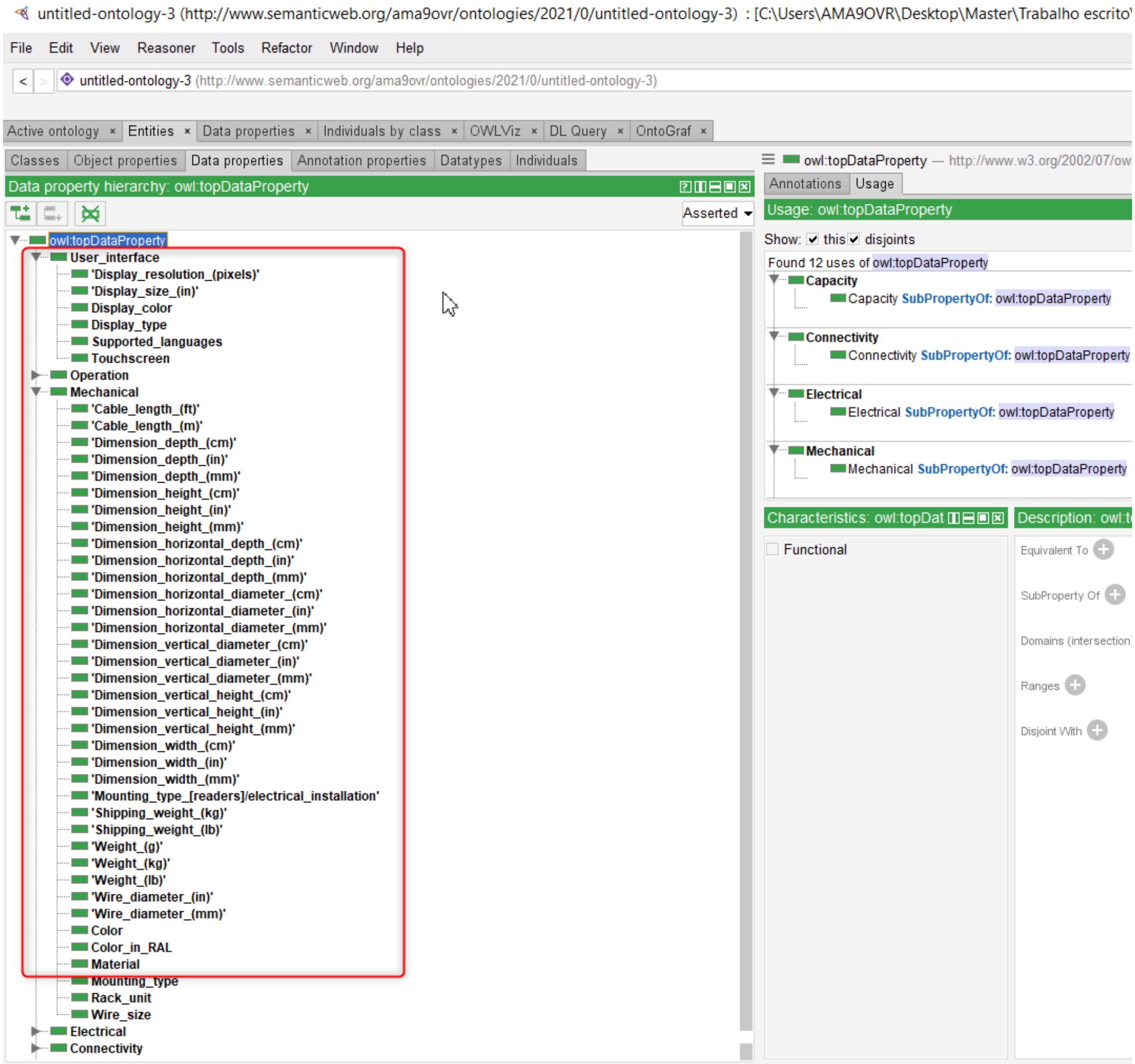


Figure 47 - Data properties tab after importing the "Access Control Systems" Technical Data Master List

After importing this data, it was possible to allocate it to classes and instances, giving the respective individual values to each product. This will later constitute the metadata, or rather, the so called, "Technical specifications" (see Figure 48).

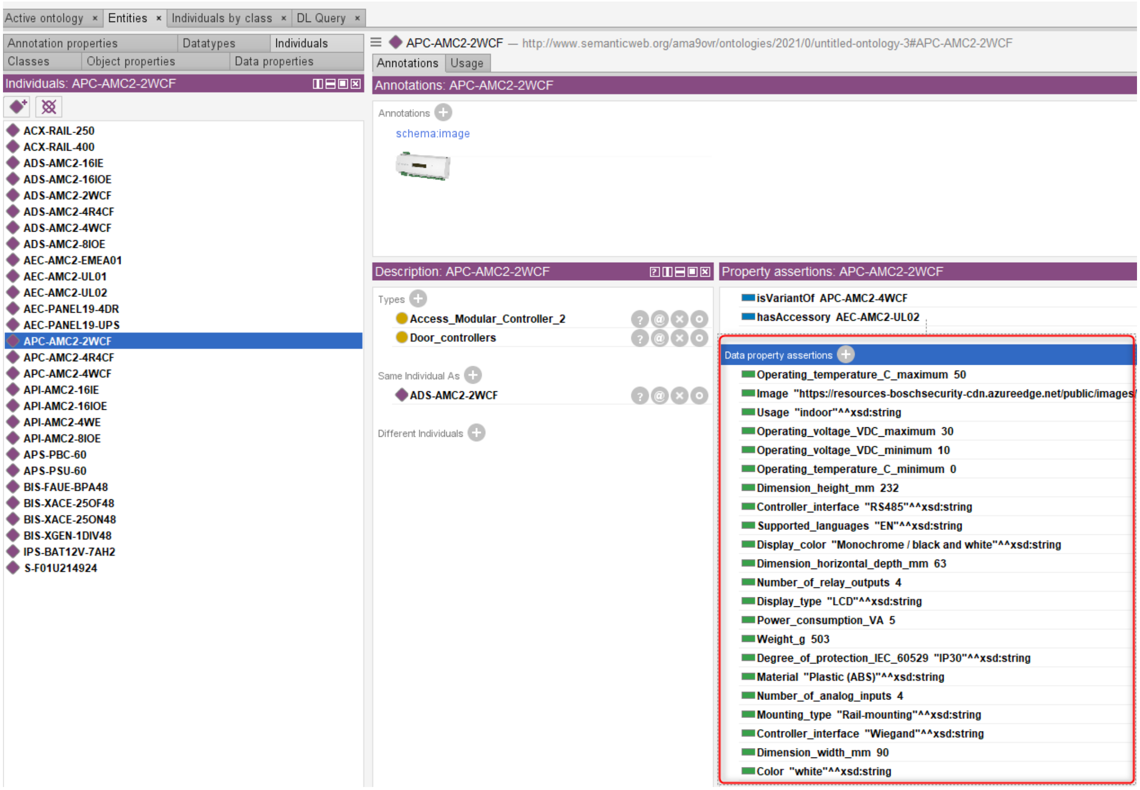


Figure 48 - Some of the data property assertions allocated to the product/instance APC-AMC2-2WCF in Protégé

Under "Property assertions", the "Object property assertions" were added with the respective product relationship allocations (see Figure 49).

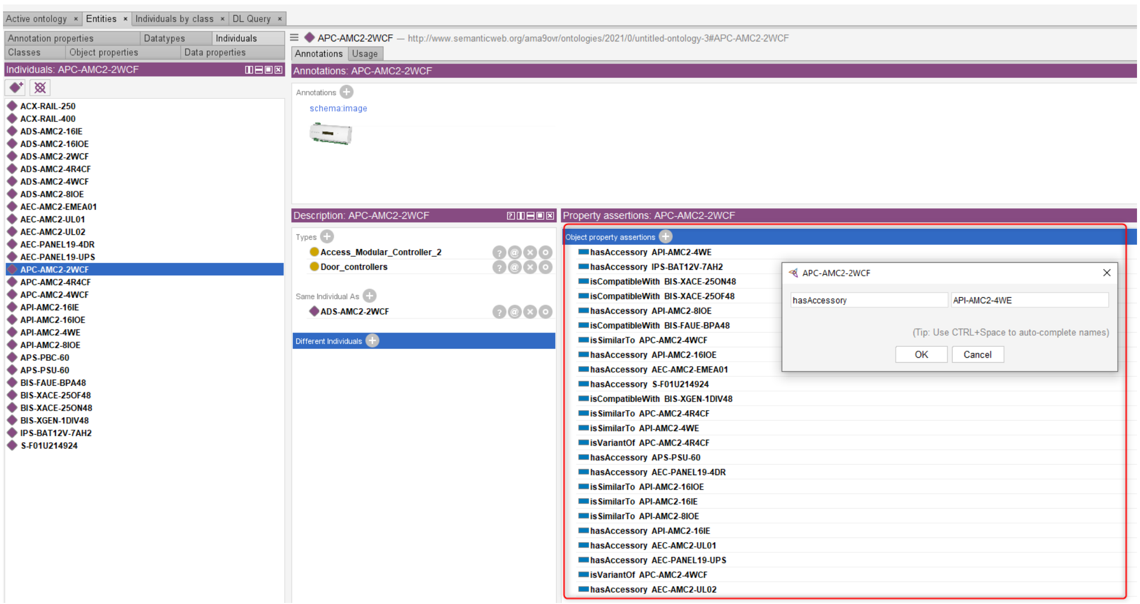


Figure 49 - Object property assertions allocated to the products which have a relationship with APS-AMC2-2WCF

A few more detailed information was added. For instance, it was made clear that both APC-AMC2-2WCF and ADS-AMC2-2WCF are the same individual (see Figure 50).

This CTN differentiation was made due to sales that are done Local for Local in China and these cases have to be specified in the ERP system.

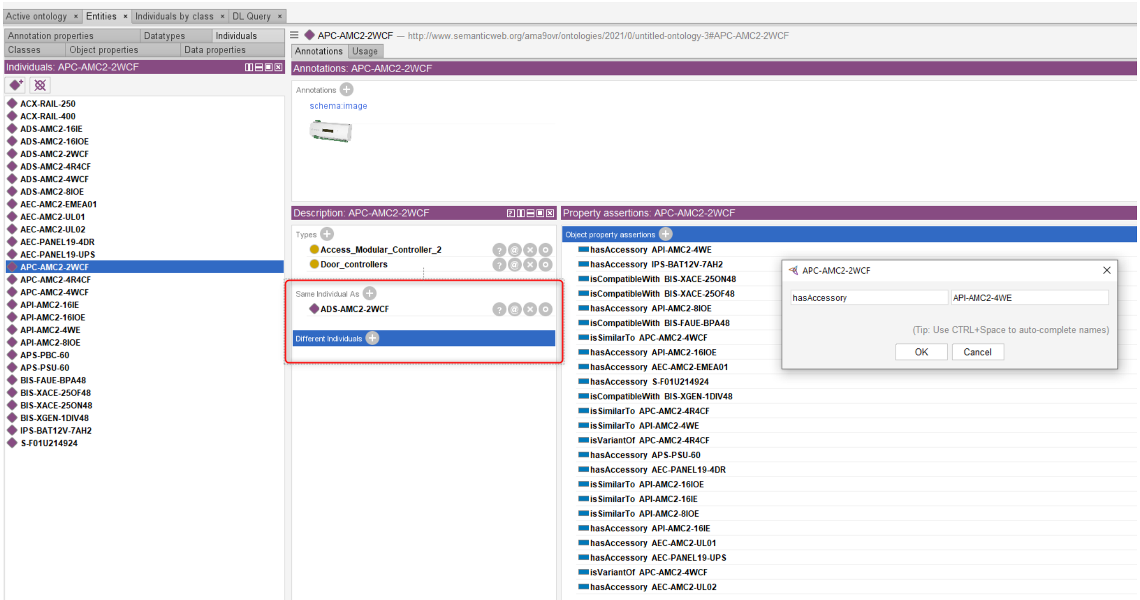


Figure 50 - APC-AMC2-2WCF and ADS-AMC2-2WCF are the same individual (specification)

As another source of data, it added an image which depicts the APC-AMC2-2WCF product (see Figure 51).

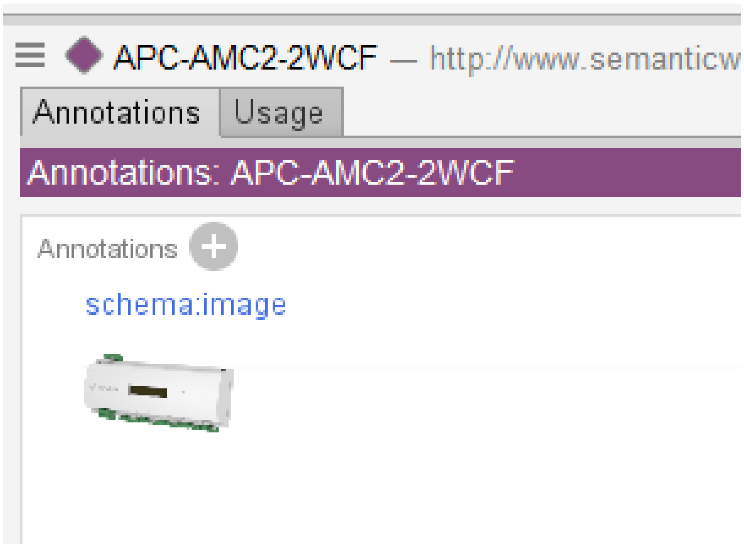


Figure 51 - Product picture of APC-AMC2-2WCF in the Protégé system

On this level it was also possible to see that the same product (APC-AMC2-2WCF) was allocated to both classes: “Access_Modular_Controller_2” and “Door_controllers” (see Figure 52).

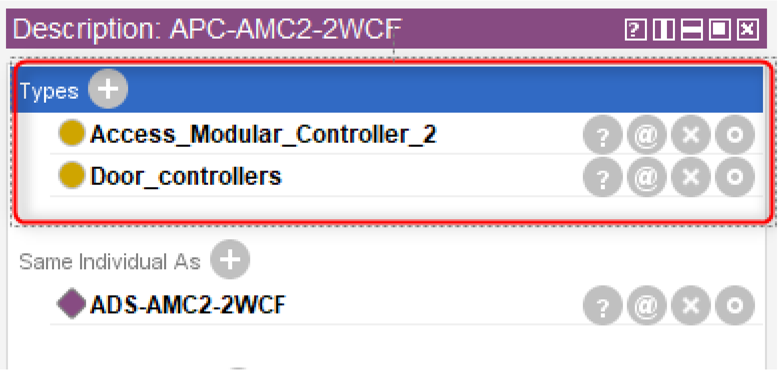


Figure 52 - APC-AMC2-2WCF allocated to both classes: "Access_Modular_Controller_2" and "Door_controllers"

4.4 Phase 4 – Evaluating

In order to be able to evaluate the final results to see if all requirements have been fulfilled, i.e., the data set and the respective links between them that have been previously created, a tab was imported, which allowed a graphical visualization that facilitates the interpretation of all the information entered previously. The tab that will be used for this purpose is called "OntoGraf" (see Figure 53) and is available in the Protégé tool itself. The graphic visualization is generated automatically, according to the data and connections that have previously been made at the basis of the system by the researcher.

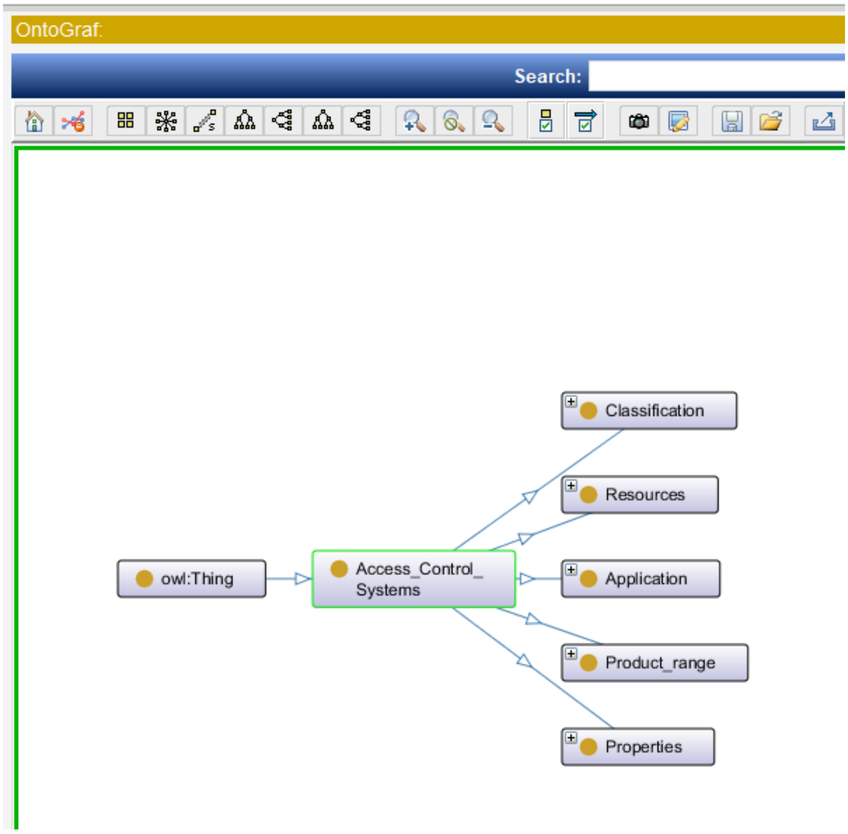


Figure 53 - Tab "OntoGraf" with visualization of the five perspectives previously created

At this stage, it was important to remember our research question, "How to manage product information for complex modular security systems?", and the main challenge/goal within this question.

To make it clear to all users which products are compatible with which systems, i.e., be able to establish a relationship or connection between a system and product families or single products and/or accessories; be able to establish more than one relationship for a single entity/class (see Figure 36 and Figure 37).

In this specific case, to set the example, we focused on the product APC-AMC2-2WCF, which can be a product bought by itself, but can also be combined with other products, reflecting the modularity of the Bosch Security Systems. The other products can be bought by themselves, but can also be part of a system called "Access Modular Controller 2" which then can form a complete complex system.

In Figure 54, we can see that the product APC-AMC2-2WCF is allocated within the "Classification" perspective, under the subclass "Door_controllers". The blue arrow sets the relationship "has_subclass". The purple arrow sets the relationship "has_individual" (see Figure 55). The orange-striped arrows mean that one product is similar to another product (see Figure 56). All these relationships have been previously set in the system by the researcher.

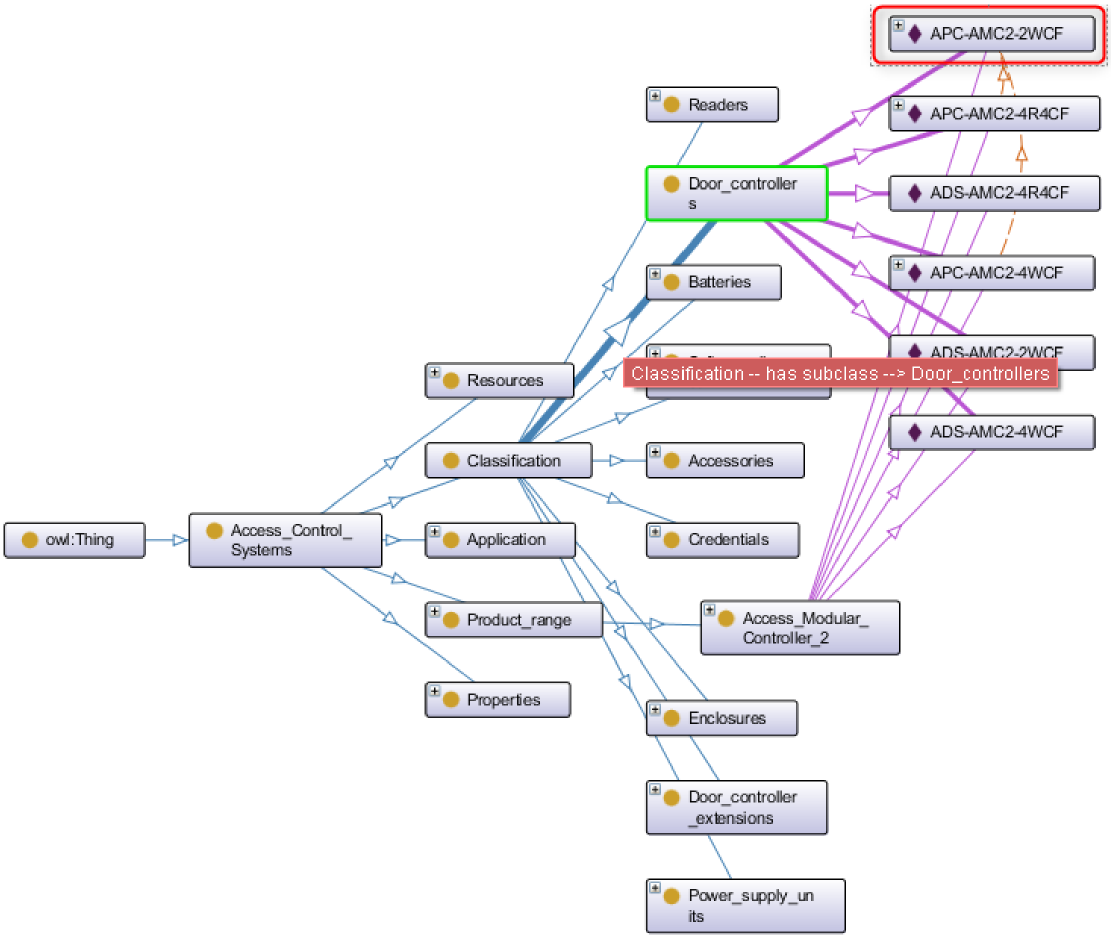


Figure 54 - OntoGraf visualization of APC-AMC2-2WCF linked to the "Classification" perspective. Blue arrow means "has_subclass".

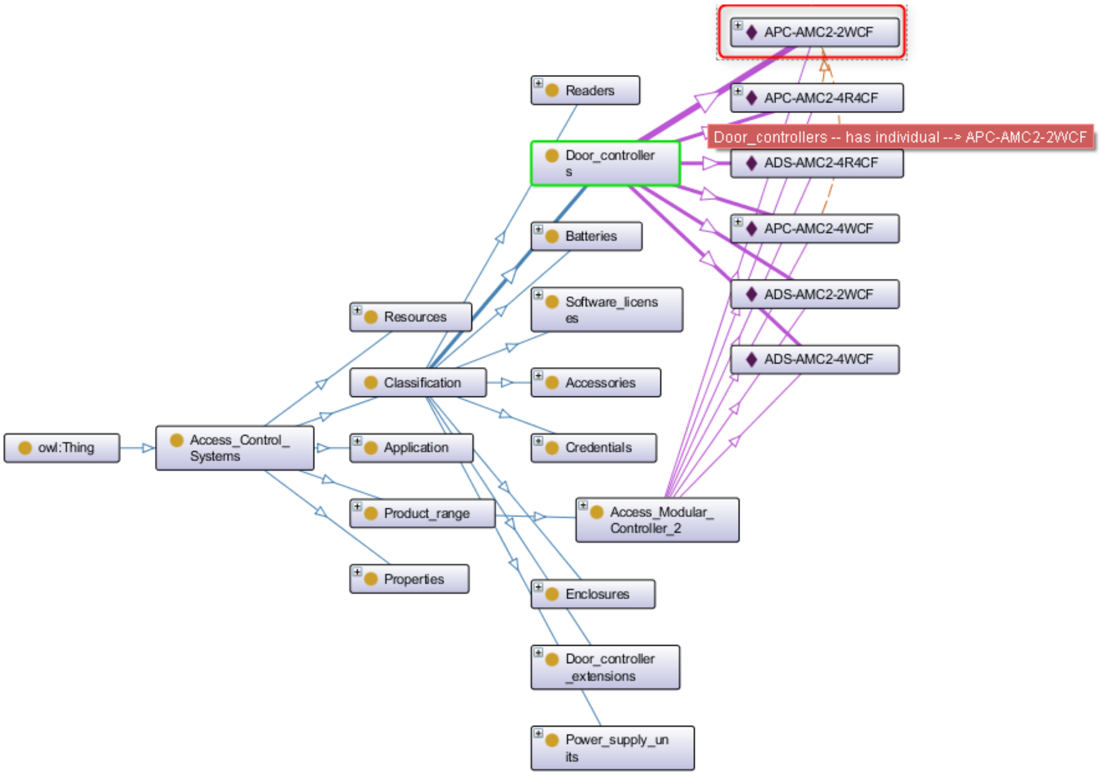


Figure 55 - OntoGraf visualization of APC-AMC2-2WCF linked to the "Classification" perspective. Purple arrow means "has_individual".

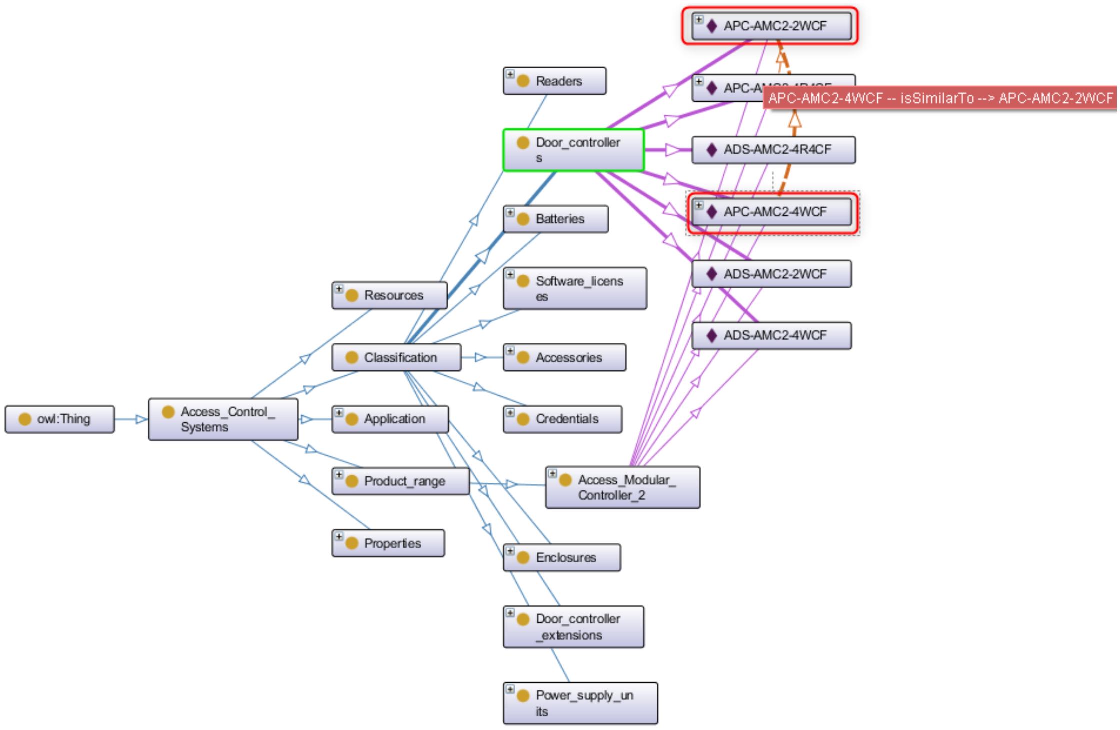


Figure 56 - OntoGraf visualization of APC-AMC2-2WCF linked to the "Classification" perspective. Orange-striped arrow means "isSimilarTo".

All the arrow-marked relationships in the OntoGraf are automatically shown in a red box once the cursor is dragged onto the respective arrow (see Figure 54, Figure 55 and Figure 56).

In Figure 57, we can also see that according to data that has been previously introduced by the researcher. the product APC-AMC2-2WCF is now also part of the “Product range” perspective, i.e., system, “Access_Modular_Controller_2”.

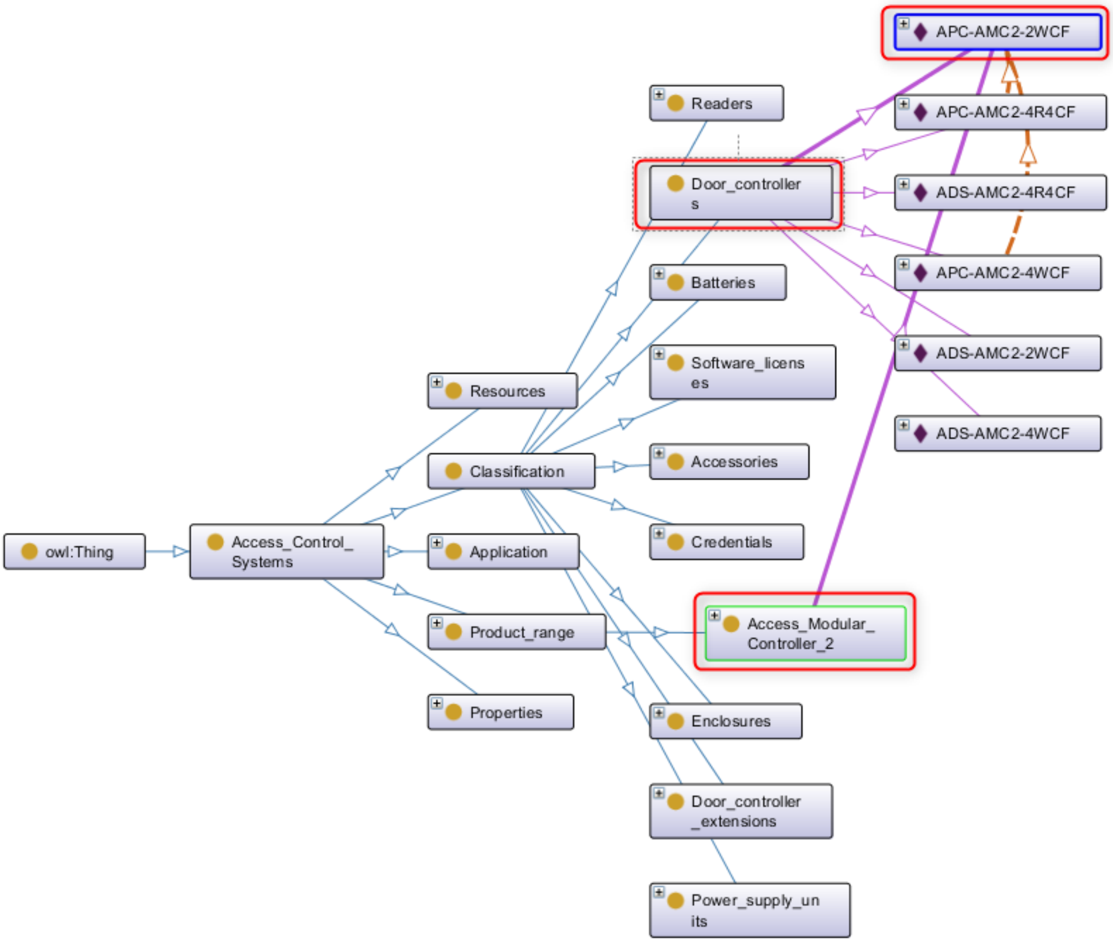


Figure 57 - OntoGraf visualization of APC-AMC2-2WCF linked to the "Classification" perspective, as well as to the "Product range" perspective, within the subclass "Access Modular Controller 2".

In Figure 58, if we drag the cursor onto the APC-AMC2-2WCF product, the OntoGraf presented a viewlet which displays all the metadata related to that product, which has been previously inserted by the researcher.

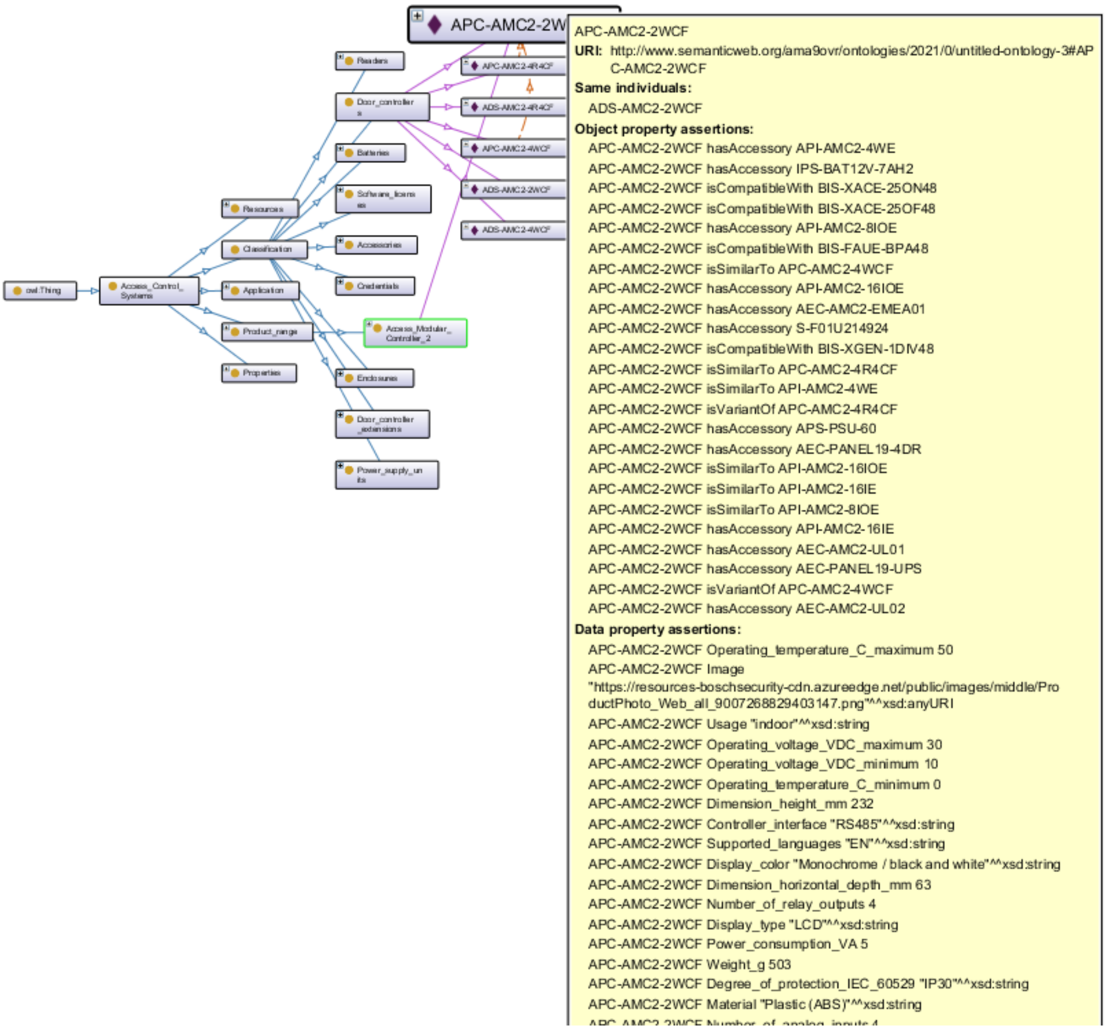


Figure 58 - OntoGraf presents a viewlet which displays all the metadata related to a product

In Figure 59, the OntoGraf also visually displays all the products with which our main product APC-AMC2-2WCF has any connection with. Grey-striped arrows represent the relationship “isCompatibleWith“. Yellow-striped arrows represent the relationship “hasAccessory“.

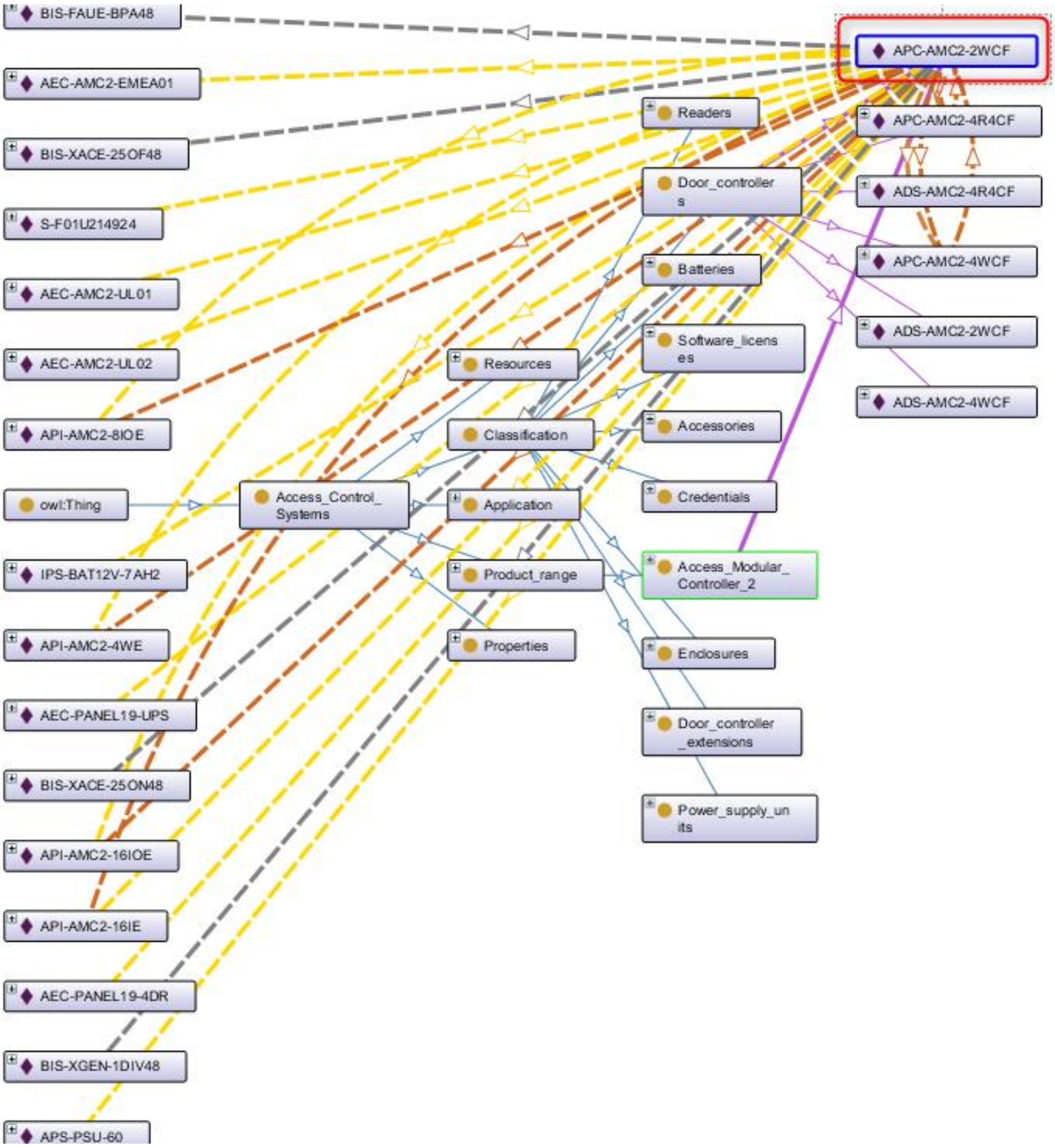


Figure 59 - All the products with which the main product APC-AMC2-2WCF has any connection with.

With OntoGraf it was possible to have a graphical idea of what has been done at the basis of the Protégé system by the researcher and conclude that the main objective of this project has been fulfilled, i.e., the researcher was able to establish a relationship or connection between a system and product families or single products and/or accessories; be able to establish more than one relationship for a single entity/class.

Thus, knowing that an ontology created in the Protégé system can be exported in the most diverse existing formats, the ontological model defined by the researcher can serve as a basis for any system that must follow this data and metadata structure.

4.5 Phase 5 – Specifying learning

Once the part considered the most complex of this work, i.e., the creation of the ontology, has been resolved, it was necessary to understand how it will be managed and applied in the future.

Regarding the management of the ontological model, it was necessary to clarify that, in the specific case of Bosch Security Systems, the future PIM system will be the main source of data collection for any other system, be it ERP or CCMS. Therefore, in a first phase it will be necessary to complete the ontological model with the remaining products in the remaining perspectives and with their respective data. In this way, it makes sense that those responsible for managing the ontological model are members of the team that is responsible for the PIM project as well. The researcher suggests a small team, of about two to three people, so that there can be a peer-review approach, whenever changes are made, or data are adjusted.

The ontological model should then be imported into the PIM, ERP and CCMS systems in the format that best suits the computer engineers (usually, in XML format).

New products that are added to the ERP and that were introduced already after the implementation of the ontological model in the respective systems, should be consulted in the ERP's daily report every morning. The new products will be automatically imported into the new PIM system, and the respective ontological model must be updated by the team responsible for the task of information management.

5 CONCLUSIONS

Nowadays, information, namely data, play a fundamental role in practically all organizations and their most unique areas. Scarce or inaccurate data generate costs and financial losses, compromising actions aimed at the company's audience. Thus, taking the importance of data into account is essential to reach good results, achieve success and keep a company running smoothly. Certainly, already established as one of the central pieces, data and its main uses and applications are essential to guide companies of any size and segment.

More important than only talking about data, is talking about its management, i.e., having control over it and being able to manage data efficiently. Due to the greater dependence on the internet, companies of all sizes have had to dedicate themselves to this mission. Data is available and collected by all areas and employees of an organization, which calls for efficient management to avoid their loss or misuse.

In the context of the Bosch Security Systems organization, namely in the management of product information for complex modular security systems, the creation of an ontology proved to be fundamental for the design of a good basis for an efficient management of product information and the data structure. The ontology brings not only great potential for an efficient management of information from individual products and complex modular systems, but also for the future automation of data management and the way it is presented to the customer on the output platform. In addition, ontology has enormous potential for the AI areas of the Robert Bosch GmbH organization and for creating digital twins of security systems. An example is that the ontology created within the scope of this project work, is currently also being used as the basis for the creation of a digital twin for a Bosch Security Systems project. At this moment, and based on the information provided in this work, the digital twin of a security system is being created, with a focus on the organization's access control systems.

Durante o processo de trabalho foram encontradas algumas limitações vistas como desafios que tiveram de ser superados, tais como, a dimensão da organização, as inúmeras equipas, a distância, por vezes a língua e a complexidade dos sistemas e dos produtos.

During the work process, the researcher encountered some limitations that she has seen as challenges that had to be overcome, such as the size of the organization, the numerous teams, the distance, sometimes the language, and the complexity of the systems and products.

Despite this, it should be underlined that the main objective of the project was completed fulfilled and validated by organization managers. The work was to create a solution that answered the research question: “How to manage complex modular systems?” whose answer in this paper ends up being addressed through the construction of an ontology that can be used in the future by the organization, in order to serve as a basis for the management of products and product information presented in the Bosch Security Systems’ online catalog.

It was important that the proposed solution was an important contribute to allow greater control of all relevant and machine-readable product data, and that both the structure and the information were feasible to implement in secondary management systems inherent to the company's internal information management. It was intended that this implementation would answer the question initially proposed and that it would be able to contribute positively to the organization's performance not only in the short, but also in the long term.

An important factor, as mentioned above, would also be to reduce human intervention during content creation, i.e., to avoid, as much as possible, the need to add information in free-text form in the various content creation systems. This would avoid errors or inconsistencies in the final result. This objective is fulfilled, since, in addition to the information becoming machine-readable, the ontology will represent the basis information for any system that requires information about products or systems.

Thus, the use of this ontology will bring greater control over the entire organization, a more centralized and planned management, and optimization of the organization's internal processes. The implementation of the proposed solution brings major changes to the processes previously implemented, since all processes were performed in a traditional way, and therefore should also be reformulated.

After the creation and presentation of the ontological solution, it was found that it fulfilled the needs described by the organization and that the same logic, structure and information could be implemented in the PIM system and even be improved over time, since implementation is a process that is necessarily iterative, and allows continuous improvement. The researcher suggests a small team, of about two to three people, so that there can be a peer-review approach, whenever changes are made, or data are adjusted.

Always with an eye on the future, and already with some additional potential recognized, the researcher believes there is still a lot of room to explore, study and investigate by the Academia further the theme of ontologies in the context of digitization, namely, for the development and evolution of organizations of today and tomorrow. For instance, it would be important to study how effective an implementation of an ontology can be, not only in terms of user's opinions but also in terms of business sales. It would be interesting to monitor and investigate how can an ontology help the sales process, namely, in each step that are usually considered in a sales funnel approach.

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