Generic Standard Features

Identifying, Classifying and Compiling Component Features in a Wiki and iOS App

Masters of Science Thesis

JOHAN EKBÄCK

ROBIN KARLSSON

Department of Product and Production Development

Division of Product Development

CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden, 2012

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Printed by Chalmers Reproservice
Gothenburg, 2012

Abstract

The work presented in this report is the outcome of a Masters of Science thesis project which has been conducted at Sandvik Coromant in Fair Lawn, New Jersey. The purpose has been to investigate the aerospace industry, analyzing aircraft components in order to break these down into smaller segments, identifying *Generic Standard Features*.

The objective of this Masters of Science thesis was to identify, name, categorize and classify *Generic Standard Features* found on components within the aerospace industry. These were then structured into an ontology and further presented in a Wiki and iOS App.

The project commenced by conducting a literature review where research needs within the area was identified. A bottom-up approach, starting from real components had yet not been attempted. Further, the creation of ontologies in a generic sense, functioning across industries had not been successful when it came to broader applications in industry.

Development was conducted using the methodology of MOKA (Stokes, 2001) as guidance. In total, four stages have been utilized, providing a foundation of methods as well as a structured approach. In the first stage of development, *Identify,* the project was further scoped and business opportunities identified. Eliciting the data and knowledge needed, the *Capture* stage included several interviews and site visits with stakeholders.

Further, components were analyzed in various formats such as CAD models and renderings, illustrations and physical components. The data gathered in the Capture stage was further processed in the stage of *Formalize*. Information models were created using an iterative approach where finally 120 Generic Standard Features could be derived. *Package* was the final stage of development, where the contents derived was incorporated into both an enterprise Wiki[1] as well as an iOS App. Further Use diagrams were created, defining how the applications are intended to be used.

Generic Standard Features have been defined as a features occurring on several components while being generic in the sense that they can occur in more than one industry. Structuring the *Generic Standard Features* an ontology consisting of nine main classes has been used, classifying the *Generic Standard Features* according to their geometry. Naming the features, a solution is proposed utilizing the classification, which systematically derives names that are coherent, generic and easy to understand. The results have shown that features in the context of ontologies have a wider range of use than ultimately being implemented into a CAD/CAM application. This study shows that features can be used as a common denominator, carrying information and knowledge. Using an application such as a Wiki, this could allow Sandvik Coromant to efficiently store and distribute knowledge internally.

The result from the development has provided Sandvik Coromant with an ontology. To further evaluate to what degree the ontology is generic and also add potential features, it is proposed that other industries are to be iteratively analyzed.

[1] *The Wiki used in this project is called Confluence and is provided by Atlassian.*

Preface

We would like to express our gratitude to all of Sandvik Coromant for providing us with the opportunity of conducting our Master of Science thesis project within their organization. This project has been an experience beyond what was initially expected not only academically but personally as well.

A special thanks goes to two persons whom we have worked very closely these past months, Sean Holt and William Durow of Sandvik Coromant. To the both of you, we are sincerely grateful for the guidance and support provided. It has been a pleasure working with you.

We would also like to take the opportunity to thank all of our fellow co-workers in Fair Lawn as well as the people we have meet during our visit. To Jan Lundstrom, Kenneth Karlsson and all of CTA, we thank you for the valuable input, guidance and support.

Further we would also like to express our gratitude to our supervisor and examiner at Chalmers University of Technology, Professor Johan Malmqvist. Your encouragement and assistance has been appreciated throughout the duration of this Master of Science Thesis.

Lastly we would like to thank Johan Israelsson of Sandvik Coromant. Being a part of your organization has been a fantastic experience, thank you for making that possible.

Gothenburg, June 2012

Contents

1 Introduction

This report treats a project carried out as a Master's thesis work at Chalmers University of Technology in the Spring of 2012. The project has been conducted at Sandvik Coromant US, in Fair Lawn NJ, USA. The objective of the project has been to map and analyze aerospace components in order to identify and define *Generic Standard Features.* These have later been named, categorized and structured. Finally two proposals have been developed regarding how to best package and distribute the contents of the project, these proposals being an iOS App [2]and a Wiki[3].

For further reading, the term *Generic Standard Feature* needs to be defined and explained. In an early phase of this project, the term was broken down and defined according to three elements:

Generic - *Not being specifically affiliated to a certain industry*

Standard - *Frequently occurring among select components*

Feature - *The geometric form or appearance of a prominent characteristic*

If the definitions above were to be put into a context for further clarification, Generic Standard Features must be frequently occurring on various components regardless of industry.

1.1 Background

Since founded in 1942, Sandvik Coromant has evolved from a company devoted to manufacturing and distributing cutting tools to a company supplying complete manufacturing solutions. Knowledge and expertise has become an important factor for making it possible to deliver additional value to customers, beyond high quality tools.

Over the past three years, efforts have been directed towards the development of component feature solutions within the aerospace industry. The solutions for how to manufacture different component features include a variety of materials, combined with all machining categories of turning, milling and drilling. A result from these efforts is the release of a number of application guides, some targeting specific customers and some for general release. In turn, these guides have resulted in the development of several new, competitive cutting tools released on the market.

Although research has been conducted concerning features, a major issue remains in that there is no industry standard for how to identify what a feature is, particularly when it comes to the naming, classification and categorization. This issue derives from the fact that almost every major organization has its own definitions of features, providing no consistency among different companies.

Other studies have been targeting this issue, providing various results. How features are to be used, and by whom, are in these studies seldom defined, why the proposed structures remain more of a theoretical framework than anything else. How to integrate the theoretical framework and raw data in applications managing feature knowledge has not yet been extensively studied.

In addition to the need for structuring features, the knowledge concerning features and how to machine these need to be stored and distributed in order for the organization to maximize its benefits from all the extensive knowledge that exists.

[2] *A mobile software application running on Apple iPod, iPhone and iPad*
[3] *A web-based application that is easy to use and edited through a web browser*

1.2 Problem Analysis

As of current there exist no standard in terms of defining features on aerospace components. This leads to confusion and poor re-use of feature knowledge. The same type of components, even the exact same component features, differs in terms of naming and classification amongst companies.

During early phases of product development, developers design intended products from a set of directives and requirements. In production phase the designed product is to be manufactured. An issue lies in the fact that developers and manufacturers can define the same product and its features differently, which creates a problematic transition between them. Devising a common feature ontology[4] could support a more effective process for the collaborative work between development and manufacturing.

When creating a feature ontology, large amounts of industry information and data are needed. Looking into previously conducted studies within similar fields of application, this has been identified to be lacking, which is reflected in the outcome. For an application such as the one intended by this project to be of value, both the industry information and data along with the ontology are of great importance.

Considering that Sandvik Coromant conducts their business within the manufacturing industry, features have traditionally been regarded in terms of how they are manufactured. Identifying features from a manufacturing standpoint comprises the risk that the features only appeal to stakeholders within manufacturing. Allowing features to be named, categorized and classified independent of industry affiliation and appeal to both design and manufacturing stakeholders, this project will attempt to disregard labels such as manufacturing or design, focusing on the feature appearance instead.

Looking at components, they most often relate to a specific industry, a turbine disc in a jet engine belongs in the aerospace industry, for instance. Going one step further than components and considering features, it is much more likely to find that these reach across different industries. This implies that a company being active within a variety of industries can benefit from working with feature solutions as they can be reused in a wider range of applications. With that said, the context in terms of in what industry and on which component typically occurs is still an important element, since where the feature is to be used often dictates how to design and manufacture it. The problem that remains is how to provide generic features, yet not completely removing them from their context.

Sandvik Coromant is a global organization with functions across the world. Within the organization a massive amount of knowledge is present, although somewhat scattered. One problem for such an organization lies in how knowledge, for this project the feature knowledge specifically, can be stored, distributed and allowed to evolve over time.

Related to the issue of knowledge management is the fact that an important business strategy for Sandvik Coromant includes developing best practice manufacturing methods. This along with providing superior tooling allows enables them to optimize their customers manufacturing processes. The amount of knowledge accumulated throughout past years regarding manufacturing solutions, tooling and process optimization is extensive. Finding a method to better share this knowledge internally within Sandvik Coromant, providing all parts of the organization with necessary information could lead to an increase in terms of efficiency and result in better productivity. The knowledge is already present; the issue is to make it easily accessible. A solution to this problem will need to meet many different prerequisites; the knowledge must for instance be regularly updated, controlled and secured.

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[4] *An ontology is a specification of a conceptualization*

1.3 Purpose

This Master's thesis is part of a long-term strategy devised by Sandvik Coromant, addressing how they in the future want to approach component features. This goal has been divided into three separate stages according to.

Stage 1 aims to identify features within different industries, starting with aerospace. The features are then to be structured and categorized, creating a common ontology. Lastly the features need to be capable of being stored, distributed and presented.

Stage 2 is to focus on mapping and incorporating best-practice solutions for the features identified in the first stage.

Stage 3 will involve a joint venture project with other companies where the features along with their best-practice solutions are to be implemented into a CAD/CAM system.

The purpose of this project is to initiate the long-term plan by conducting *Stage 1*. Upon completion this will provide a structured platform facilitating for further work with features in the stages to come. The purpose of packaging the contents of this project is to create a repository of knowledge, making it possible to gather, store and distribute company knowledge among employees.

1.4 Objective

The objective of this Master's thesis is to investigate and analyze components within the aerospace industry, in order to identify *Generic Standard Features*. The *Generic Standard Features* are primarily to be considered from a design perspective, taking little or no consideration to manufacturing aspects. *Generic Standard Features* are to be named, classified and categorized in an ontology.

Each *Generic Standard Feature* is to be individually defined and described, providing a common terminology that later could function if other industry segments are investigated. The ontology created should be coherent and put each *Generic Standard Feature* into a context, allowing information such as best practice manufacturing techniques to be added in later phases of the long-term strategy defined by Sandvik Coromant.

Ultimately a detailed proposal should be devised regarding how the content of the project is to be stored and presented. The proposal does not need to be complete; a prototype is acceptable as an outcome.

1.5 Research Questions

In order for the deliveries of this Master's thesis project to be successfully fulfilled, the following questions need to be answered:

1.) *What defines a Generic Standard Feature and how is it to be represented?*
2.) *How are Generic Standard Features to be named, classified and categorized?*
3.) *What type of application will best facilitate the storing and distributing of feature information and knowledge?*
4.) *What value can a feature-based application bring Sandvik Coromant?*

1.6 Limitations

The project presented in this report is a Master's thesis covering 30 credits, presiding that the duration for the project is to be 20 working weeks. The timeframe and geographical scattering of stakeholders implies that only select stakeholders are included in this project when acquiring information and knowledge. Further delimitations of this project are listed below:

- Only aerospace components from customers of Sandvik Coromant, which are present on aircrafts, are to be investigated.
- Accessing customer's sites or any component related material is to be conducted in accordance to ITAR (International Traffic in Arms Regulation)[5].
- The amount of data possible of retrieving is delimited to the documentation regarding components that customers are willing to provide.
- Any development of best practice solutions is to be disregarded in this project.
- As this project is part of a long-term strategy devised by Sandvik Coromant, this report is only to display material regarded to be harmless from a corporate confidentiality point of view.

1.7 Outline of the Thesis

This section aims to clarify the structure of this report. The main chapters of the report are below mentioned and briefly explained in regards to their contents.

Chapter 1: Introduction - This chapter has provided a background and overall scope of the thesis at hand, providing an understanding for the circumstances under which the project has been conducted.

Chapter 2: Frame of Reference - The frame of reference provides a theoretical framework and critical review of relevant literature that has been covered. It also identifies areas where further research is needed for a successful outcome of the thesis.

Chapter 3: Research Approach - The research approach chapter describes the methodology used to carry out the thesis. It will also provide an insight regarding the steps and decisions made throughout the duration of the thesis.

Chapter 4: Results - In this chapter the outcome and results of the project is presented.

Chapter 5: Discussion - Chapter 5 presents a discussion, evaluating the results presented in this report. Research questions will be answered and discussed along with the level of fulfillment in terms of the goals set up in *Chapter 1.*

Chapters 6: Conclusion - To conclude the report, a summary of the key findings is presented.

Chapter 7: Future Recommendations - The last chapter provides recommendations for future work with Generic Standard Features.

Appendices - The Appendices includes work that has been carried out and documented, but is too extensive to be included in the main sections of the report.

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[5] ITAR is a governmentally enforced regulation controlling import and export of defense related articles or services (U.S. Department of State, 2011).

2 Frame of Reference

The frame of reference consists of two sections, the first containing a brief theoretical summary of studies performed within similar fields of application as the project described in this report. The second section critically reviews the literature from these studies, addressing areas where further research is required in order to fulfill the objectives of this project.

2.1 Theory

This chapter contains a summary and brief definition of the areas that are covered within the context of this report. It aims to provide the reader with a greater understanding for subjects that are later to be mentioned.

2.1.1 Knowledge Based Engineering (KBE)

Although there are no common, widespread definition of what KBE really is, most of the researchers treating the subject have a fairly unified view of it. Calkins et al. provides one definition, stating that KBE is a methodology for capturing and structuring knowledge about a design and its design process and that KBE may also be used to define engineering methods and procedures. (Calkins et al., 1999)

In MOKA, a methodology for knowledge based engineering applications, KBE is defined as "*The use of advanced software techniques to capture and reuse product and process knowledge in an integrated way"*. (Stokes, 2001)

Catic (2011) uses a defintion similar to Stokes, but a little bit more specific. His definition is that *"KBE is a strategic knowledge management method applying explicit engineering knowledge and IT solutions to automate engineering tasks"*. He further says that this definition does not imply any particular IT or software processes, e.g. a CAD modelling process, but instead allow KBE to be defined as something that can be used in a broader sense. (Catic, 2011)

2.1.1.1 MOKA

MOKA (Methodology and software tools Oriented to Knowledge Based Engineering Applications) is a collection of methods and tools developed by the MOKA Consortium, a joint venture of companies within the automotive and aerospace industry. MOKA specifies and give guidance for six different phases of the KBE lifecycle – Identify, Justify, Capture, Formalize, Package and Activate. Most of the tools and methods of MOKA do although focus on the Capture and Formalize phases. (Stokes, 2001)

2.1.1.2 CommonKADS

CommonKADS, an abbreviation of Common Knowledge Acquisition and Documentations Structuring, is a methodology and standard for how to develop knowledge-intense systems. It is mainly used for information systems applications, but can very well be beneficial in the development of other computer software systems as well. (Schreiber et al., 1999)

2.1.2 Knowledge Management (KM)

Knowledge Management (KM) is a very broad subject covering several different aspects of knowledge and how to manage it. As an example of the wide range of topics that might be targeted by KM, Grover and Davenport provide six key concepts that today are considered as part of it: 1.) Tacit vs. Explicit Knowledge 2.) Knowledge Processes 3.) Codification vs. Personalization 4.) Knowledge Markets 5.) Communities of Practice 6.)

Intangible Assets. Although these concepts cover a wide range of areas, the authors states that one should not be precluded to view other aspects than these as Knowledge Management. (Grover & Davenport, 2001)

2.1.3 Features

Features are a central term of this project, why it is important to mention the different definitions of a feature existing in literature. Mäntylä et al. (1995) define a feature as "*modeling entities that allow commonly used shapes to be characterized and associated with a set of attributes relevant to an application"*. Features can although be further divided into two subcategories described in the section below. (Shah & Mäntylä, 1995)

2.1.3.1 Design Features

A design feature can be described as a shape that has meaning to the designer. When a product is modeled with a set of design features, it is called feature-based design. The designer utilizes this method by simply adding more and more features to a basic model for creating a new design. Additionally, each feature contains parameters that can be modified allowing the designer to be as flexible as possible in the design process. (Salomons, 1995)

Kumar & Kumar (1996) describes a design feature similarly: *"Design features are created by the designer in order to solve a design problem or to achieve a design functionality."* The author further exemplifies design features as e.g. fixing holes, keyways or cooling slots. (Kumar & Kumar, 1996)

Compared to Salomons (1995) definition of a design feature, these feature examples stands true.

2.1.3.2 Manufacturing Features

There is no universal definition of what a manufacturing feature is, but one example is provided by Gupta et al. (1995); *"A manufacturing feature corresponds to the volume of material that can be removed by a machining operation."* The definition used by Benhabib (2003) is relatively similar, stating that features from a manufacturing engineering point of view can be seen as specific geometric shapes on a part that can be associated with certain fabrication processes. (Gupta et al., 1995) (Benhabib, 2003)

Discussing features it is common to use the terms additive or subtractive features, i.e. whether material is removed or added to a component. In terms of designing both of these types can be used, but in machining the majority are subtractive. A commonly used example of the different views on features is illustrated in the figure below. (Chen & Hoffman, 1995)

Examples of manufacturing features are drilled holes, islands and slots. (Kumar & Kumar, 1996)

2.1.3.3 Feature Recognition

Feature recognition refers to the automated examination of solid models for the identification of features that have been predefined. The objective of feature recognition is just to identify the features, not to extract manufacturing information. Information extraction for manufacturing is although a common use of the feature recognition technology. (Benhabib, 2003)

2.1.4 Classification schemes

Clarifying the terms taxonomy and ontology, Van Rees (1995) describes taxonomy as a hierarchy created according to data internal to the items in that hierarchy. He also explains that ontology contains *both* taxonomy-like hierarchy structures and other data such as relations and properties. McGuiness (2002) uses "taxonomy" interchangeable with "simple ontology". As there exist several established methodologies for developing ontologies, but few regarding taxonomy development, this equivalence is suitable for the purposes of this thesis project. (McGuinnes, 2002) (Rees, 1995)

As mentioned, there are several methods for ontology development commonly occurring in literature, e.g. IDEF5, TOVE and OTK. According to Pinto & Martins (2004) the basic framework for these methods is similar to each other, containing the phases: *1) Specification 2) Conceptualization 3) Formalization 4) Implementation 5) Maintenance.* Furthermore, there are activities done during the entire process: *Knowledge acquisition, evaluation* and *documentation.* The mentioned methods are more or less focused on the different phases, but together the methods cover all phases. (Pinto & Martins, 2004)

2.1.5 ISO 10303-224

The international Organization for Standardization (ISO) consists of members interested in different subjects, each for which a technical committee has been established. The committees work on creating standards in a variety of areas all around the world.

The ISO 10303-224 specifies the information required for representing and exchanging the product data that is necessary in the manufacturing of a single mechanical part. The standard supports digital representation for CAM and uses machining features as a base for storing product data. It addresses manufacturing part properties, process control documentation, manufacturing specifications, administration data, and requisitions. (International organization of Standardization, 2006)

2.1.6 Wiki

"A wiki is web-based software that allows all viewers of a page to change the content by editing the page online in a browser. This makes a wiki simple and easy-to-use platform for cooperative work on texts and hypertexts."

This definition of a wiki, provided by Ebersbach et al. (2008), defines a wiki in its simplest form. Wikis have emerged and evolved over the last decade, today providing a wide range of additional functionality. (Ebersbach et al., 2008)

Furthermore, wikis have taken the step into the corporate world, taking place on intranets and providing a powerful collaboration tool for managing company knowledge. Leuf & Cunningham (2001) say that the main difference between a wiki and other collaboration tools is that it is exceptionally easy to use, not being as formal as other tools. (Leuf & Cunningham, 2001)

Further differentiating the wiki from other tools, Almeida & Rocha (2011) states four characteristics making the wiki unique. First of all, it is open for any user to add or edit content. Secondly, it comprises a wide range of applications, managing everything from simple text to advanced media. The wiki does also track all changes made to it, which provides a controlling mechanism. At last, it has a dynamic structure, including both networks of information, as well as networks of people communicating. The authors concludes with saying that implemented the correct way, a wiki can free up collaboration and increase engagement of employees, leading to improved knowledge capturing and distribution. (Almeida & Rocha, 2011)

2.1.7 iOS App

iOS is a mobile operating system developed and released by Apple Inc. in the year of 2007 (Apple, 2012). The system is used in selected products released by Apple, such as iPhone, iPad and iPod.

App is short for application, and is a key element of the operating system. Apps are based upon Objective-C, a computer language designed to enable sophisticated and object-oriented programming. (Mac OSX Developer Library, 2012)

In order to develop and distribute Apps, a Software Developers Kit called Xcode is required.

2.1.8 Best practice solutions

Although the best practice solutions are not included in the scope of this project, the topic has a major role in the long-term objective for Sandvik Coromant, hence being important to understand.

O'Dell & Grayson (1998) defines best practices as practices that have been shown to produce superior results; selected by a systematic process; and judged as exemplary, good, or successfully demonstrated. This description is valid for the best practices in this project, being manufacturing solutions of specific features that have been proved to produce great results. On the other hand, Codling (1992) states that the ‘best’ in best practice is very difficult to define, since it depends on what requirements are considered and who is assessing the situation. (Codling, 1992) (O'Dell & Grayson, 1998)

For the Generic Standard Feature project, best practices correspond to the definition stated above and are manufacturing solutions that Sandvik Coromant through systematical tests have proven to give good results. A manufacturing solution involves tooling, CAM programming methods, CNC programming and similar manufacturing processes.

2.2 Earlier Work

A number of studies have previously been conducted within fields concerned to be of interest to this project. Dividing those studies into two categories, one regards features and how to best structure and represent them, while the other deals with managing the knowledge behind those features.

2.2.1 Feature Classification & Representation

According to Pratt (1993) features are to be defined according to their application context. As described in Section 1.1.3, design features and manufacturing features have been considered to be the closest related types to this project.

Within these categories, feature-based modeling is commonly mentioned. A feature-based model is used in order to communicate between tasks within a product development lifecycle. Creating a feature-based model, two different approaches can be used, design by features and feature recognition. (Martino et al., 1994)

Regardless if a feature-model is created using design by feature or feature recognition, a prerequisite for feature based modeling is the classification of features. Owodunni et al. (2002) state that there are research areas concerning classification that need to be adressed, these being; completeness of a feature taxonomy, extendability of a feature library and formalisation of the classification process.

When classifying features, different studies provide different suggestions as of how this should be conducted. As with the case of defining a feature, it all comes down to context, a likely explenation for the variation. Butterfield et al, classifies form features according to; sheet features, prismatic features and rotational features. Owodunni et al. (2002) propose using a coordinate system in order to explain the shape of a feature in the local x,y and z directions. Gindy (1989) suggest that features be classified according to three main categories; protrusions, depressions and surfaces. Regardless of the manner that features in previous studies have been classified, one thing that most of the studies have in common is the utilization of a taxonomy or ontology in order to structure and define the features while classifying them.

As features are identified and classified, they are then to be stored in a media of some sort acting as a library. As time has progressed, so has the selection of media. For instance Ando et al. (2006) propose the usage of a Wiki as a suitable media for storing and extracting information regarding features. This since they claim that a feature library needs to be easily modified and customized due to the progressive nature of information adjoining features.

2.2.2 Managing the Knowledge of Features

Another important aspect of this project has been the managing of knowledge concerning features. Knowledge Management (KM) is a term used within these contexts. Although definitions vary, the main concept is to capture or create, store and finally spread knowledge within a company where it can be utilized. One of many definitions is provided by Davenport & Prusak (1998), stating that KM is the process of capturing, distributing and effectively utilizing knowledge already existing within an organization.

Knowledge Based Engineering (KBE) and Knowledge Based Engineering Systems (KBES) can be considered to be a subset of KM. Poenisch & Clark (2006) state that although no definition of KBE has come to find general acceptance, an essential aspect is an application capable of processing engineering knowledge.

The study shows that by separating the two components, application and knowledge, the field of use can become broader and standardization easier to implement. Also dependencies can be overcome, creating the opportunity of updating the knowledge repository or application separately.

Most commonly KBE and KBES imply knowledge sources being structured according to rules. Schreiber et al. (1999) explains that although all systems contain knowledge of some sort, KBES have an explicit representation of the knowledge included within the system. Developing a KBES, relevant knowledge needs to be gathered, formalized and then can it be incorporated into the intended application.

KBES can be further classified according to what specific task it targets. Generative systems automatically create detailed geometry based upon embedded rules, constraints and user inputs. Advisory systems are capable of evaluations during processes. Selection systems utilize knowledge contained within the system in order to assist users when making selections. (Preston et al., 2005)

Regardless of the intent of an application, a successful outcome when implementing KBE or KBES is to the furthest degree reliant of the knowledge. Poenisch & Clark (2006) state that from a business perspective any engineering with shared knowledge sources requires:

1. The sources must contain comprehensive, correct, and up to-date knowledge.
2. In the product engineering process, the knowledge must be readily available, e.g., through easy search.
3. The knowledge must be applied correctly.
4. Design automation tools must use up-to-date knowledge.
5. Design artifacts must stay associated with the knowledge.

2.3 Identified Research Gaps & Needs

The two topics covered in Section 1.2, *Feature Classification and Representation* along with *Managing the Knowledge of Features* attempt to briefly summarize some of the important findings. In this section some of the gaps found in the literature are discussed. More discussions on these issues will be held in Section 5.3, where the research questions are discussed in relation to the results of this project.

Features, ontologies, taxonomies, KBE and KM all have one thing in common. All of these areas that this project comes to deal with are broad in the sense of definitions. Depending on how the subjects are approach, the context and objective that the research is meant to fulfill, the outcome can differ from study to study.

Features are and have been approached in a variety of ways. Labeling them as design features or manufacturing features for instance is one way of narrowing the scope and targeting specific applications. A question that arises when reviewing studies conducted in the past is if generic features, in terms of being generic across industry segments, do exist. If so, how can such a feature be represented?

An aspect found to be lacking when looking into the identification of features is the source from which they have been found. Most studies provide a theoretical explanation of the features identified, none have yet to entail that the features were obtained from within a specific industry or such.

Further, a significant gap that has been identified relating to the identification and structuring of generic features is that the definitions and structures used often are very abstract, targeting specific computerized applications and hence delimiting the areas of use. There is a need to investigate a broader scope when it comes to the use and structuring of features. It is believed to be possible to utilize features in other applications than in CAD/CAM systems as well, something that have to be further researched.

Methodologies might differ, but a common denominator regarding features and studies conducted is structuring them using a taxonomy or ontology. Most of these ontologies target an implementation into a CAD/CAM system, creating rule-based entities and dependencies when developing them. Some studies have touched upon a broader approach, where applications such as CAD/CAM systems and the knowledge regarding features are separated. This mindset allows for a more versatile use of the knowledge, not only can it be implemented in an application but also across organizations.

Many of the studies point out the vast importance of knowledge and adjoining information within KBE applications. One thing that seems to be somewhat neglected is the fact that knowledge and information can change in time. Dependencies within knowledge repositories and applications make it difficult to add, remove or edit new content. There is a need for a system where feature-based knowledge can be easily updated on a regular basis.

The literature review has targeted select areas of this project. As stated, these areas are loosely defined and highly dependent on the context of which they are placed in. The scope of this project provides a context yet to be discovered in previous studies, this being that features are to be generic not necessarily targeting engineering operations such as design or manufacturing, but rather industries. Further more, features will be identified using real components in the industry today, rather than focusing on feature data existing in IT systems.

3 Research Approach

In order to achieve the objectives set for this project in a structured manner, a research approach according to Figure 3-1 has been followed in this project. The research approach contains four main processes; *Literature Review*, *Problem Analysis*, *Development* and *Reflection of Results*. Further describing the illustration of the research approach, the boxes with square edges describe the main processes and the boxes with rounded edges describe sub-processes. The vertical arrows describe the sequence of which the processes are to be conducted, while the horizontal arrows describe the outcome of the corresponding process.

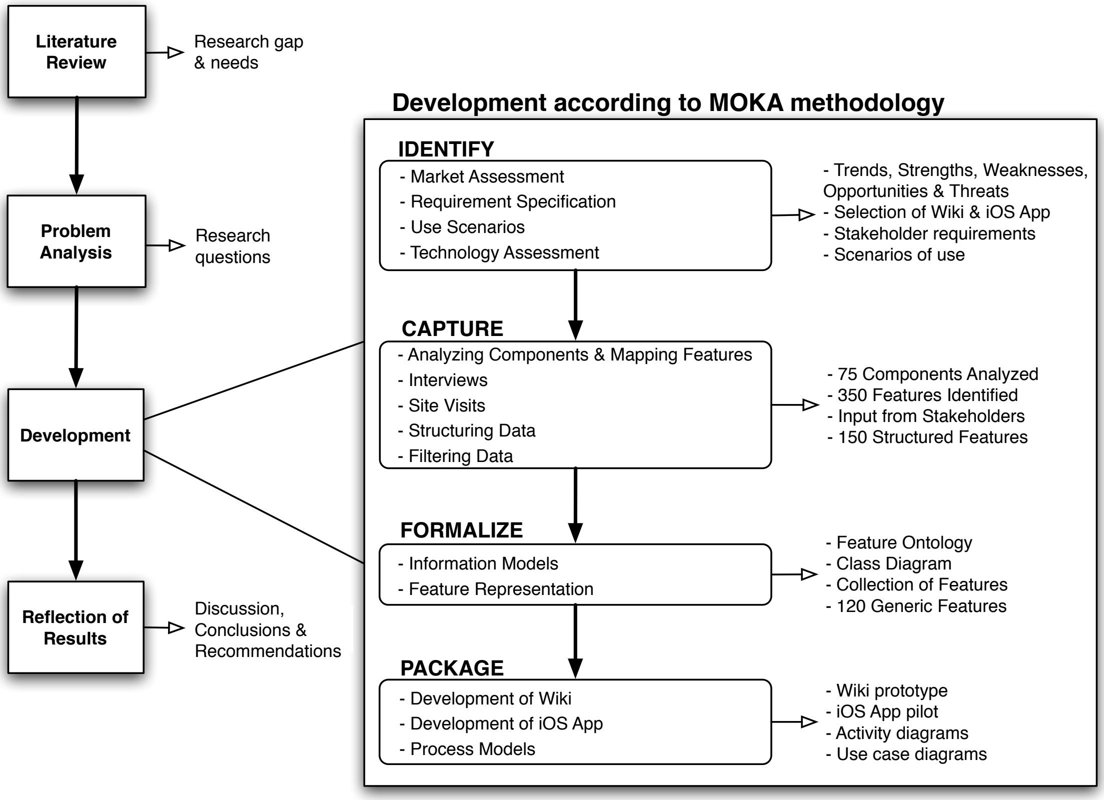


Figure 3-1: Overview of the Research Approach

The *literature review* was the first process conducted in this project. This provided a foundation of knowledge required to initialize and complete a project plan were the project was further scoped and research gaps and needs were identified. It also increased our general level of knowledge within the areas of the project. Throughout the project, literature has been used to find methodologies, acted as guidance or provide data to be analyzed. The literature selected intended to provide both a general overview on the subject as well as more specific knowledge within certain areas where needed. A variety of sources such as Chalmers databases, books and project stakeholders were utilized accessing the literature. Areas being covered included among others research on features, ontology development, knowledge management and product development.

A *Problem Analysis* was devised were the project was further investigated, addressing areas within the research gap that needed to be studied. The final outcome of this process was a set of research questions that needed to be answered in order for the project to be successfully completed.

The process of *Development* has been a major part of this project. *Development* has been divided into several sub-processes; these are further described in the subsequent chapter, called *Development according to MOKA*.

The outcome provided by the *development* process account for the main results of this project. Assessing the research conducted throughout the project the results were reflected upon in a process called *Reflection of Results.* The outcome included a discussion and conclusion concerning the results but also recommendations for Sandvik Coromant in terms of how they can proceed with the overall outcome of this project.

3.1 Development according to MOKA

As the scope of this project was defined and the prerequisites determined, it became apparent that identifying, classifying and storing knowledge were essential aspects. Although not the main focus of the project, one of the intended deliveries was to provide a media suitable for storing not only the contents of this project, but also the contents from the future stages according to Sandvik Coromants long-term objective of implementing a CAD/CAM application. Identifying this project as a part of a KBE application, a supportive methodology was selected to act as a framework throughout the development phase of the project. Amer Catic (2011) explains that MOKA is a KBE development methodology focusing on capturing and formalizing knowledge independent of any commercial software. The focus on capturing and formalizing knowledge deemed to be of relevance for this project and hence the selection of methodology was MOKA. MOKA (Stokes, 2001) has been used providing guidelines rather than the methodology to its full extent during the development.

Four of the six MOKA stages been utilized; *Identify*, *Capture*, *Formalize* and *Package*. These stages will be covered more in depth in the chapters to come.

During the progress of the project, key aspects such as modularity and working with iterations have been taken under consideration (Stokes, 2001). In this case modularity implies that the different stages have been conducted in a manner making it possible to simultaneously work both within or in different stages.

Further clarifying that the MOKA methodology has been used as a guideline, each chapter regarding the stages used will contain a brief introduction. These introductions aim to clarify what was suggested by MOKA and what was actually carried out.

3.1.1 Identify

Identify is the first stage according to the MOKA methodology, aiming to investigate business needs and opportunities in order to determine a suitable KBE solution. The project at hand is to be scoped, deciding upon boundaries, resources available and technical feasibility. Since knowledge is an essential part of a KBE application, it is also important to consider where the desirable knowledge can be found and what techniques that will be used eliciting it in upcoming stages of the project. Further more, stakeholders are to be identified and the requirements of the intended outcome are to be compiled into a specification. (Stokes, 2001)

As Sandvik Coromant AB originally proposed the project at hand, parts of the *Identify* stage had already been conducted prior to initiation. Business trends had been identified but yet to be validated, the technical feasibility needed to be assessed as well as objectives, stakeholders and requirements to be set. Included in the original scope was the source of knowledge, this being limited towards internal company knowledge and select customers. In accordance to this, it was decided that eliciting knowledge from customers, semi-structured interviews and site visits would be used in future stages.

Figure 3-2 below illustrates the process of *identify*, the tasks that were completed and what outcome this generated.

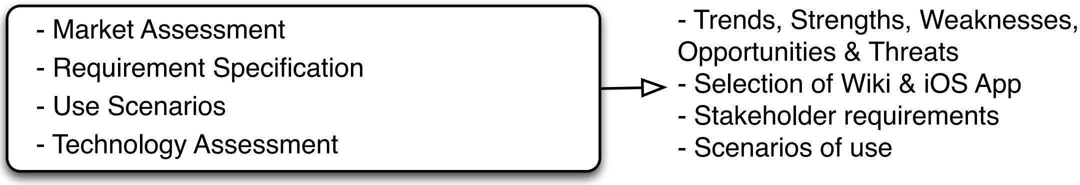


Figure 3-2 - Illustration of the Identify process

3.1.1.1 Market assessment

To clarify and validate the business opportunity identified by Sandvik Coromant, a market assessment was conducted. The assessment includes a SWOT and PEST analysis along with a competitive assessment. The PEST analysis identifies trends while the SWOT analysis looks at strengths, weaknesses, opportunities and threats in a less broad sense. The market assessment obliged to the delimitations of this project only assessing the aerospace industry and focusing on the first stage of Sandvik Coromant AB long-term objective. The complete Market Assessment can be found in Appendix A.

3.1.1.1.1 PEST analysis

The PEST analysis identified several trends within the aerospace industry. External market analyses were the primary sources of reference material. The aim for this analysis was to provide the market assessment with a broad picture of how political, economic, social and technological trends possibly could affect this project.

3.1.1.1.2 SWOT analysis

The SWOT analysis was conducted in two separate phases. Brainstorming identified important aspects within the project, these were then further discussed until strengths and weaknesses could be settled upon. The PEST analysis provided a reference used to determine the opportunities and threats present.

3.1.1.1.3 Competitive assessment

The competitive assessment considered two different categories of competition. The first category of competitors considered was suppliers of machine tools and solutions. Investigations were made concerning if these competitors had a feature-based solution on the market already and if so to what extent these functioned. The second part of the competitive assessment concerned CAD/CAM suppliers, offering solutions for feature-based manufacturing.

3.1.1.2 Requirement specification

In order to compile the expectations, needs and wishes that the finished project was to deliver, a requirement specification was created. The requirement specification only targets the application that is to be delivered within the frame of the project, taking no consideration towards the long-term goal defined by Sandvik Coromant.

3.1.1.3 Use scenarios

Identifying the stakeholders of the intended application, use scenarios were created. These were also supposed to show within what type of context the application would serve to be most useful.

3.1.1.4 Technology opportunity assessment

An important aspect of the *Identify* stage in MOKA is assessing the technical feasibility. In order to prove the technical feasibility, a technology opportunity assessment was conducted.

Research showed a variety of solutions available for storing and distributing knowledge. As promising concepts were found, advantages and disadvantages for each were listed and the concepts deemed unfeasible were discarded. Finding the best media for the outcome of the use case scenarios, the remaining concepts were then screened using a selection of criteria, provided by the requirement specification.

3.1.2 Capture

The stage *Capture* contained two phases, collecting and structuring of knowledge. The first phase aims to collect knowledge using the sources, tools and techniques specified in the *Identify* stage. The structuring of industry knowledge gathered intends to provide a standardized form for reusing and maintaining knowledge. This is the first step towards representing knowledge somewhat ready for a KBE application. (Stokes, 2001)

A wide variety of knowledge sources were considered and used in order to capture feature data. The results were at times interacting and cross-referenced against each other. While the eliciting of knowledge went on, all data was structured in order to simplify the stages to come.

Figure 3-3 illustrates the process carried out in the *Capture* stage. To further clarify, approximately 75 components were analyzed. These 75 components were distributed across 25 different types of components. 350 features were identified, and after structuring, 150 features remained. The interviews and site visits conducted contributed largely towards generating input from stakeholders.

Figure 3-3 - Capture

3.1.2.1 Analyzing components and mapping features

Initially a breakdown of aerospace components being manufactured with some sort of presence of Sandvik Coromant was created. Looking at the components within that breakdown, as much data as possible was gathered for each component. The data came in a wide variety due to difficulties of gathering it because of restrictions, however CAD models were prioritized since they provided a better understanding. All in all approximately 75 aerospace components were analyzed.

When data had been gathered for all components, it was analyzed. The objective was to identify as many features as possible on every component, making sure that nothing was overseen. Finding an adequate level of detail for how the features were to be analyzed proved to be difficult. After several iterations of going over the components, 350 unique features, organized according to the component hosting them, had been identified. At this point each feature was represented with a preliminary name, sketch, a description and explanation on what components it could be found.

3.1.2.2 Interviews and site visits

Increasing the knowledge and understanding regarding aerospace components and features, interviews and site visits were conducted throughout the *Capture* stage. Stakeholders included Sandvik Coromant specialist within a variety of aerospace fields, but also customers.

Conducting interviews and site visits; a semi-structured approach was utilized providing a framework of questions yet allowing the interviewees to speak freely, assuring that their thoughts, opinions and knowledge be captured. Prior to conducting the interviews or site-visits, a form containing guidelines for questions to be asked was created, as seen in Appendix C. The intent was to provide coherency across the different customers visited in terms of questions to be asked or areas to be discussed.

3.1.2.2.1 Sandvik Coromant expert interviews

Sandvik Coromant currently divides an aircraft into three categories; engine, frame and landing gear, where each of these categories have an assigned expert. Attaining a deeper knowledge regarding features within aerospace, an expert within each category was interviewed.

In order to generate further input in terms of how knowledge is to be stored, structured and distributed, interviews were conducted with employees of Sandvik Coromant working in the application development area.

In total, four experts were interviewed. Some of these experts were interviewed multiple times and the duration ranged from 30 minutes up to two hours. Visiting the application development center of Sandvik Coromant, six employees were interviewed, each interview lasting approximately 30 minutes.

3.1.2.2.2 Customer interviews

Customer interviews were conducted including employees representing companies that manufacture different aerospace components. The interviewees ranged from manufacturing engineers, production planners, CAM programmers and business strategists. Dependent on their competence, the interviews focused on different aspects, for instance components, features, software or application development.

3.1.2.2.3 Customer site visits

Site visits were conducted with the purpose of experiencing components in real life, gaining a better understanding as well as realizing the magnitude of size for features within the aerospace industry. The visits combine question- and observation based data collection, giving the features a wider context. Furthermore, the observations provide hands-on experience, something that is very valuable when dealing feature definitions, categorization and naming.

3.1.2.3 Summary of customer interviews and site visits

As mentioned above, several customer interviews and site visits were conducted in this project. Table 1, further clarifies the scope of these, containing information regarding if a site visit, interview or both were conducted. It also states the length of the site visit, number of interviews and length of the interviews.

Appendix C includes a summary in terms of what the outcome of the site visits and interviews were and also key findings from the respective company. Due to confidentiality complete reports containing the outcome cannot be published, also the companies have been provided with fictional names.

Table 1 - Customer interviews and site visits

	Interview/Site visit?	Site visit length	Number of interviews	Approximate interview length
Company A	Interview	N/A	2	30 / 180 min
Company B	Interview	N/A	2	30 / 30 min
	Site visit	3 hours	N/A	N/A
Company C	Interview	N/A	2	45 / 60 min
	Site visit	2 hours	N/A	N/A
Company D	Interview	N/A	1	120 min
	Site visit	1 hour	N/A	N/A
Company E	Interview	N/A	3	20 / 30 / 45 min
	Site visit	2 x 2 hours	N/A	N/A

3.1.2.4 Structuring the data

A template was created in Microsoft Excel, containing a name, illustration, description and data origin. Subsequent to a component being analyzed and a feature discovered, all of the data was stored in the template. This created a coherent and user-friendly way for storing and presenting data as the project proceeded

3.1.2.5 Filtering the data

From the preceding steps, around 350 unique features had been identified. Since the intended application was only to contain features that oblige to the definition of a *Generic Standard Feature*, the ones not regarded as such were removed. The decision on what features to remove was based on the frequency of occurrence, as well as the input from the interviews with experts. When the redundant features had been removed, 150 unique features remained.

3.1.3 Formalize

According to MOKA, the stage of *Formalize* aims to represent the knowledge gathered in a form that the KBE platform can accept. Formalizing is a process of refinement divided into two models, these being of a product and process nature. Product models describe the relationship between one component and another, while Process models describe the flow through processes. (Stokes, 2001)

From a technical standpoint, the intended outcome of this project is less complex than for the type of applications MOKA has been developed for. Due to this, simpler tools were used rather than the ones proposed by MOKA. The intention was to in a clear and structured manner present the knowledge, making it ready to be implemented. Regarding the Process models, it was decided that these would be better suited in later stages of the project, hence it was moved to the package stage, as described subsequent of this chapter.

Figure 3-4 shows the processes conducted in the *Formalize* stage as well as the outcome. The feature ontology and class diagrams are identical in terms of content, but have been presented in different ways. Conducting several iterations concerning the feature ontology, the number of unique features was reduced from 150 to 120 *Generic Standard Features*.

Figure 3-4 - Formalize

3.1.3.1 Information models

While feature data had been identified and captured, there was a need of structuring and placing this data into a context in order for the Generic Standard Features to be of value. A step in this process was the creating of information models. Two separate types of information models have been utilized, serving different purposes.

3.1.3.1.1 Ontology model

In an iterative process an ontology model was set up from the feature data captured earlier in the project. Each feature was studied and categorized in accordance to the type of feature it was considered to be, for instance a hole, pocket or boss. Once all features had been categorized the process was repeated and the features were categorized on a deeper level. After approximately 30 iterations a full feature ontology model had been generated. The ontology was created and stored in a software called Microsoft MindJet.

3.1.3.1.2 Class diagram

In order to make the ontology model more applicable to a future application, it was represented with a more visual class diagram. In terms of contents, these are the same between the ontology model and class diagram.

3.1.3.2 Feature representation

Presenting each *Generic Standard Feature*, a written definition and a CAD rendering created in Autodesk Inventor was added for each feature. Providing a context to the features, the variety of materials as well as on which type of components the features could occur on where documented.

3.2 Package

The last stage taken under consideration, *Package* has the clear objective to produce a working KBE system, portraying the original knowledge. The knowledge from the *Formalize* stage is upon completion to be translated and utilized as a platform when initializing the Package stage. An important aspect throughout is to provide consideration towards how interfaces are designed. (Stokes, 2001)

Since two use scenarios of significant interest were identified, it was decided that two separate applications were needed in order to fully optimize the applications for their purposes. The process of creating the applications was iterative, included testing and updates in order to ensure a fully functional system as the outcome of the final stage.

Figure 3-5 shows the processes conducted, as an outcome a Wiki prototype, iOS App pilot, Activity diagrams and use case diagrams were derived.

Figure 3-5 - Package

3.2.1 Wiki

The *Identify* stage provided a use case scenario for internal purposes. An Enterprise-Wiki was initiated, targeting this scenario of capturing, storing and distributing knowledge within the Sandvik Coromant. The Wiki of choice was Confluence, a semantic Wiki developed by the company Atlassian.

Developing the Wiki, consideration was taken towards Atlassian's own tutorial of how to best develop and set up a Wiki. Studies within the subject also revealed factors that needed to be addressed in order to successfully implement a Wiki.

3.2.2 iOS App for iPad

Targeting the use case scenario where customer interaction is of essence, an iOS App for an iPad was developed. Developing the iOS App, guidance has been taken from the iOS Developer Library. (Apple Inc., 2012)

First off, the process models provided the functionality of the App, while the intended users were identified in the use scenarios. The design of buttons, backgrounds, text etc. was made considering Apple's predefined paradigms for the user interface, making the iOS App user-friendly. It was also assured that all graphics followed the policy of Sandvik Coromant. In the software Xcode, storyboards were created and tested, providing the desired functionality.

3.2.3 Process models

Defining how each respective application are intended to be used, process models for both the Wiki and iOS App were created. The process models were derived from the information gathered in the *Identify* stage along with other data gathered as the project progressed.

3.3 Summary of Research Approach

The project at hand commenced with a literature review were research gaps and needs were identified. These needs were addressed as research questions were devised, aiming to both close the identified gaps as well as delivering the objectives set by Sandvik Coromant.

A large quantity of time was spent on the process of development. The methodology of MOKA was applied supporting the project process by giving it more structure. Although the methodology was not obeyed to its fullest extent, it provided a framework to fall back on.

The first to stage of MOKA, *Identify* aimed to further scope the project and find business opportunities. Achieving this, requirements and stakeholders were specified and the market was evaluated.

The data needed for proceeding with the project was collected in the *Capture* stage. This data included knowledge related to features and was collected by mapping components, conducting interviews and visiting customer sites. Possibly being the most important phase of the project, the data collection provided a foundation of 150 features.

The next phase in the process was the *Formalize* stage. As stated in the project objectives, all features had to be defined, classified and categorized. In an iterative process, the feature ontology was created, allowing features to be organized in a class diagram. In addition to the class diagram, all features were clearly specified textually as well as visually.

In the *Formalize* stage, the raw data was transformed into informative models possible to utilize in future applications. As an overall outcome, the 150 identified features were reduced in iterations down to 120 *Generic Standard Features.*

In the last phase of development, *Package,* the data collected was combined with the formal models created, resulting in two applications. A Wiki was set up to target the knowledge management, while an iOS App was developed as a tool for communicating feature related knowledge with customers.

As the development was concluded and an overall result devised, these results were reflected upon. The last process of this project included a discussion, conclusion and future recommendations for Sandvik Coromant.

4 Results

In this chapter the main results from this project are presented in chronological order. The results are the foundation on which discussions and conclusions are based upon, hence of course being an important part of the work conducted.

4.1 Identify

The results from *Identify* phase facilitates for the work of collecting and utilizing features by assessing the market, defining use scenarios and formulating requirements.

4.1.1 Market Assessment

The Market Assessment clarifies the current the state of the market and support the validation of the business opportunity identified by Sandvik Coromant before initiating this project. The Market Assessment includes a SWOT Analysis and a PEST Analysis, along with a Competitive Assessment. The PEST Analysis can be found in Appendix A, while the other sections are summarized below.

4.1.1.1 SWOT Analysis

The opportunities and threats presented below have been derived from the PEST Analysis in the previous section, providing a brief clarification of the status for the organization in regards to this project Furthermore it the strengths and weaknesses of Sandvik Coromant and the project team. The table below presents the aspects considered to be of most value to the project, several more could be found in Appendix A.

1. Strengths	**2. Weaknesses**
• The required knowledge exists and is available within the company. • The company already distributes knowledge as a part of their product. • The company has some experience of feature-based solutions.	• The existing feature names are fuzzy and confusing, there is no coherence. • There exists no standard for how to classify and name features. • Are there resources to update the system regularly? • Difficult to match each feature with a manufacturing process.
3. Opportunities	**4. Threats**
• Aerospace industry will grow. • Future competition creates need for better processes. • New CAD/CAM systems allow for advanced feature recognition. • There exist no similar libraries in the industry today. • Sandvik Cormorant's many customers in different industry segments can contribute to a wide range of features, allowing for a generic library to be built. • The technology to develop a solution like the intended one does exist.	• Changing processes and technology can outdate the feature library content. • There are no best-practice solutions for each feature. • Large amount of features can make the system complex and difficult to use. • The customers might not want to share their knowledge.

For the strengths and weaknesses, the one most significant aspect found is that Sandvik Coromant possesses a huge amount of knowledge, providing a very good potential for succeeding with this kind of project. Not only does the knowledge exist within the company, but at their customers as well. A risk is though that customers might be reluctant to share their knowledge, making a little bit more difficult to compile a feature library.

The most noteworthy opportunity is the growth of the aerospace industry, that along with the amount of knowledge existing, provide a good chance to capitalize on the outcomes of this project. For a more thorough explanation and discussion of the specific strengths, weaknesses, opportunities and threats, see Appendix A.

4.1.1.2 Competitive Assessment

The Competitive Assessment studies two different competitive markets, one being suppliers of machine tools and manufacturing know-how and the other CAD/CAM system suppliers. The main results of the assessment are summarized below.

Suppliers of machine tools

- As of current no one seems to offer a product similar to the CAD/CAM integrated solution intended to be developed long-term.
- One company provides an application automatically recommending tools based on what type of machining feature that is intended. However the amount of available features are not near as of what this project aims for.

Suppliers of CAD/CAM systems

- Several companies offer some kind of feature recognition software. The features provided by the systems are far too few and simple.
- None of the feature recognition systems seem to contain a larger amount of features gathered from industry.

As can be seen above, the findings of this assessment are not very many or significant, which could be caused by several reasons. First off, there are not many solutions similar to the one intended, making the competition almost non-existing. A second reason for the results being thin is that few companies want to share their knowledge outside their organization, resulting in very little information of what is out there, if there is something.

4.1.1.3 Summary & Conclusion of the Market Assessment

Concluding the PEST and SWOT analyses there are some really good opportunities to aim for. The most important aspect to consider in terms of internal attributes is that there exists a lot of knowledge in different places of the organization. If this knowledge could be packaged into a product, at the same time as the threats and weaknesses are avoided, a powerful tool can be built.

It is clear that there is a need for a system that utilizes generic standard features at Sandvik Coromant today. Not only is there a need, today there are also opportunities to fulfill this need. The trends in the environment, for example the forecast of huge increases in aerospace manufacturing, clearly give hints on the fact that the industry must now, more than ever, be able to manufacture large quantities with less resources. Optimizing the process for doing so will be one important issue to address in order to achieve that. For a richer discussion of the outcomes of this Market Assessment, see Appendix A.

4.1.2 Requirement Specification

The requirement specification, see Table 2, was generated in the early phases of the project, but has been developed as more knowledge was gained during the process. The requirements are divided into two main categories; functional- and non-functional requirements.

Table 2: Requirement Specification

#	Requirement	Wish/ Demand	Stakeholder
1. Functional			
1.1	The application must facilitate a hierarchic feature structure	D	Coromant
1.2	The features must be categorized in the application	D	Coromant
1.3	The application should be capable of handling 1000 features	W	Coromant
1.4	The application must be capable of handling 250 features	D	Coromant
1.5	It must be possible to add features in the application	D	Coromant
1.6	It should be possible to add features while the application is in operation	W	Coromant
1.7	It must be possible to modify features in the application	D	Coromant
1.8	It must be possible to delete features in the application	D	Coromant
1.9	The application must only allow authorized users to add, modify and delete features	D	Coromant
1.10	The application should be consistent in the way features are displayed	W	User
1.11	The application must display a visualization of each feature	D	User
1.12	It must be possible to add "Best Practice" solutions to features	D	Coromant
1.13	It must be possible to modify "Best Practice" solutions in the application	D	Coromant
1.14	It must be possible to delete "Best Practice" solutions in the application	D	Coromant
1.15	The application must be able to link a "Best Practice" solution to a specific feature	D	Coromant
1.16	The application should incorporate a search function for finding intended features	W	User
1.17	The application should allow navigation to a certain feature without text input	W	User
2. Non-Functional			
2.1 Product			
2.1.1 General			
2.1.1.1	The application must be available for all intended users at Sandvik Coromant	D	Coromant
2.1.1.2	The application should be in a digital media	W	Coromant
2.1.1.3	The application must visually follow Sandvik Cormorant's company profile	D	Coromant
2.1.1.4	The application must be able to function independent of metric or empirical units	D	User
2.1.1.5	The terminology used for features must be generic across industry markets	D	Coromant
2.1.2 Usability			
2.1.2.1	The application must be user-friendly	D	User
2.1.2.2	The user should be able to find the intended feature within 30 seconds	W	User
2.1.2.3	The application should be applicable regardless of user manufacturing capabilities	W	User
2.1.2.4	The content of the application should be perceived as trustworthy	W	Coromant
2.1.2.5	The application should take no more than 10 minutes for new users to understand	W	User
2.1.2.6	Visualizations of features must be clear and easy to interpret	D	User
2.1.2.7	The application should provide a description as to how it functions	W	User
2.1.3 Features			
2.1.3.1	Features must be generic across market segments	D	Coromant
2.1.3.2	Each feature must have a unique name	D	Coromant
2.1.3.3	Each feature must have an unique ID	D	Coromant
2.1.3.4	Each feature must be defined by certain category-specific attributes	D	Coromant
2.1.3.5	Each feature must have a 3D-visualization	D	Coromant
2.1.3.6	Each feature must have a description of its geometry	D	Coromant
2.1.3.7	Each feature must have a specified material	D	Coromant
2.1.3.8	Feature descriptions should be extensive enough so that all employees across Sandvik Coromant can understand it	W	Coromant
2.1.3.9	Each feature must be capable of being paired with a "Best Practice" solution	D	Coromant
2.1.3.10	Feature descriptions must be neutral for all customers	D	Coromant
2.1.3.11	Each feature included in the application must belong to a specific category	D	Coromant
2.1.3.12	Each feature must present component affiliation	D	Coromant
2.1.4 Efficiency			
2.1.4.1	The application should reduce the time to find a feature-based solution	W	Customer
2.1.4.2	The application must support 100 simultaneous users	D	Coromant
2.1.4.3	The application should support 500 simultaneous users	W	Coromant

4.1.3 Use Scenarios

Several use scenarios were identified for the utilization of Generic Standard Features and their best practice solutions. Of the use scenarios generated, two were considered to be of major interest and selected as a base for further development. The scenarios provide an idea of in what application features can be used, who could use them and how they are to be used. From the use scenarios it is then possible to derive suitable technologies to use for the intended system.

All identified use scenarios can be found in Appendix B. The two use scenarios selected for further development are explained in the following section.

4.1.3.1 Scenario A1: Store and distribute knowledge internally

When an employee of Sandvik Coromant for some reason needs any knowledge regarding a specific feature, this application can provide this. For example, when a CAM programmer encounters a design feature that he/she is not familiar with, the application can be used as an encyclopedia. The programmer can find the corresponding feature in the application by navigating through a feature structure or by searching for the feature name. When the desired feature is selected, the application will show the best-practice manufacturing method, including tools, operations, tool paths etc. The programmer can then use that information in order to proceed with the CAM model, confident that the best-practice method is used. Almost all employees that for some reason need any information on features or something related to features can benefit from this system. In the future, even more functionality could be built in to the system. For instance, previously conducted projects including certain features can be linked to these features.

For this use case scenario, the systems main purpose is to store, present and distribute knowledge regarding features within the company. The importance of a method or tool to manage knowledge cannot be stressed enough. The users are in this case difficult to clearly define since the system is supposed to be used by all employees that could be in need of knowledge related to features, for instance CAM programmers, operators, service people, specialists etc.

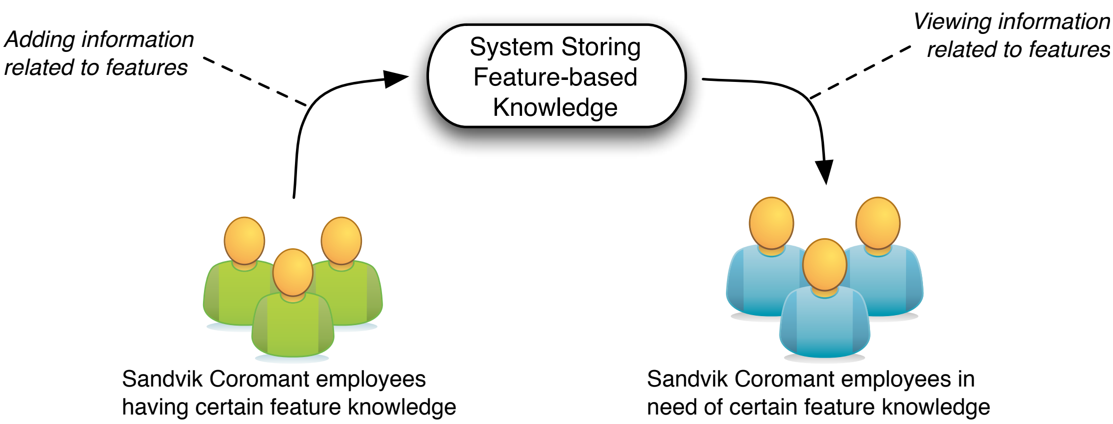


Figure 4-1: Use Scenario A1

4.1.3.2 Scenario B1: Communicating Externally

This scenario implies two or more stakeholders interacting, where one of them is to be a customer. The Sandvik Coromant stakeholder has a tool of some sort that can further explain the importance of using proper cutting technology. The tool acts as a visual and textual aid and might simplify the process of making one understood as well as giving more credibility to the Sandvik Coromant stakeholder. Using a tool does not imply that the Sandvik Coromant stakeholder is uncertain or unaware of the suggested best-practice solution; the relevant part is whether or not the customer perceives the information as trustworthy.

There is a need for a tool that does not mean that customers have to take Sandvik Coromant stakeholders word, they have the confidence that the entire company is behind these solutions. In order for the tool to be as effective as possible, it requires that it be portable, simple and visual. A tool like this would also function as an easy-to-use encyclopedia for when the Sandvik Coromant employee is in need for knowledge he or she does not have. This scenario has been elicited from discussions with the intended users, i.e. customers, salesmen, experts and customer representatives, who have been stating the need for something similar.

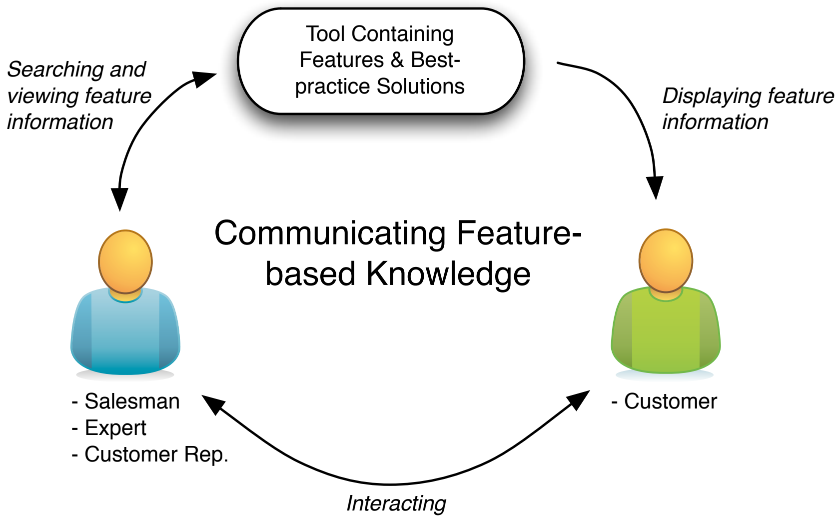


Figure 4-2: Use Scenario B1

4.1.4 Technology Assessment

There are several factors that affected the choice of technology for using utilizing the features, e.g. number of features included in the study, complexity, usability, integrity, targeted users and the level of maintenance. This Assessment delivers feasible concepts as well as motivated selections of the technologies considered to be most suitable for this project.

4.1.4.1 Feasible Technologies

The following concepts were evaluated for their feasibility to facilitate the data collected in the project. A short description along with their major pros and cons are listed.

A. Wiki

A Wiki is a database whose users can very easily add, edit and delete content through a web browser. Such a database uses a simplified markup language and is often powered by so-called Wiki software. The most famous Wiki is the Wikipedia Foundation, but there exist Wiki's for community websites, intranets and knowledge management systems as well. It provides a very open service, but since it does not handle relations in the same way as a more conventional database, the data might become unstructured.

Advantages:

- Easy to use
- Collaborative

Disadvantages:

- Unstructured

B. Database Solution

There are many different database solutions, for this evaluation Microsoft Office Access (MOA) will be assessed. MOA is a database management system developed by Microsoft. It combines the Microsoft Jet Database Engine with a graphical interface for designing the database. It is also possible to link, export or import data from or to other applications such as Microsoft SQL Server, Visual Basic or websites. This system is very versatile and contains a lot of functionality, the question is if a more traditional database like this is the way to go or not.

Advantages:

- Can handle a large amount of data
- Much functionality

Disadvantages:

- Unexciting

C. Thick Web Application

IBM's Lotus Quickr will realize the Thick Web Application technology, since Sandvik Coromant uses Lotus Notes, in which Quickr is integrated, as their mail client. Lotus Quickr is an application that allows for collaboration through sharing and storing of documents and information. One great benefit of using Lotus Quickr is that all employees already have access to Lotus; hence the security and distribution of the database become simple to manage. Sandvik Coromant staff does not seem too excited with Lotus Quickr though, which might be a problem when introducing it.

Advantages:

- Integrated with Lotus Notes

Disadvantages:

- Unexciting
- Poor user interface

D. Mobile Software Platform

The two major mobile systems are Android and iOS. As Sandvik Coromant are using Apple iPhone and iPad, the iOS will realize this technology. Although it is different from the other proposed media types, an application for Apple's iOS might be an interesting format. iOS applications run on an iPhone, iPod or iPad and are developed with a software developer kit from Apple. Sandvik Coromant has recently developed six other iOS applications for similar purposes, why they might see this as a promising solution. Feasibility will primarily depend on how and where the system is to be used.

Advantages:

- Easy to use
- Attractive
- Portable

Disadvantages:

- Only accessible on an iOS device
- Needs considerable resources to update

E. Web Application

Web application is a very broad term that defines a number of solutions. For this project it refers to an application incorporated in Sandvik Cormorant's public website. The intended application would then be storing the information publically using a web interface.

Advantages:

- Very integrated with other IT solutions
- Good for marketing purposes

Disadvantages:

- Does not provide a good way to share a large amount of knowledge

4.1.4.2 Technology Screening & Selection

For guidance in the selection of technology to use for the project, a screening was conducted. Each technology concept was evaluated in relation to certain criteria's derived from the requirement specification. Each criteria was given a rate 1-3 based on how well the concept is considered to fulfill the criteria. Table 3 below shows the criteria's along with the outcome of the screening.

Table 3: Technology Screening with the rates 1 = Bad, 2 = Good, 3 = Very Good

Criteria	A	B	C	D	E
1. User-friendly interface	3	1	1	3	2
2. Quick & Easy to Find the intended feature	3	2	2	2	2
3. Easy and practical to Update	3	2	2	1	2
4. Capable of handling 250+ features	2	3	3	1	2
5. Functionality (Future possibilities)	2	3	1	2	3
6. Mobile	2	2	1	3	2
7. Integrity	2	2	3	2	2
SUM	**17**	**15**	**14**	**14**	**15**
RANK	**1**	**2**	**5**	**3**	**2**

This screening suggests that a Wiki is the best solution, followed by a Database Solution (here realized by MOA) and a Web Application. Looking at the use scenarios though, it was realized that in order to target both of them, a Wiki would not be enough. MOA or a Web application along with the Wiki were not believed to fully fulfill the requirements of the two use scenarios either, even if the screening suggests that they are the next best solutions. Because of that, the selected medias were decided to be a **Wiki** and a **Mobile Software Platform (iOS App).** The Wiki targets *Scenario A1: Store and distribute knowledge internally,* while the iOS App will target *Scenario B1: Communicating externally.* The iOS App were selected since it has some unique capabilities which might not have been enlightened enough in this unweight screening.

4.2 Capture

Although the *Capture*-phase has been an essential part of the project, the results from it can at times be intangible and difficult to put on paper due to the fact that much of what has been captured is knowledge. In the following section the aim is though to display the outcome of the gathering of data and knowledge that has been conducted.

4.2.1 Analyzing components and mapping features

As mentioned in the *Research Approach*, data was collected in an initial stage. This data came in the form aerospace components presented as CAD models, renderings, drawings etc. and was a prerequisite in order to commence the analyzing and mapping of features. Table 4 below displays what type of components that were analyzed. For each type of component, 1- 4 unique components were studied.

Table 4: Analyzed components

Engine	Frame	Landing Gear
Turbine Disc	Structural	Fitting
Fan Disc	Engine Mount	Drag Brace
Turbine Casing	Pylon Bracket	Piston/Slider
Fan Casing	Gear Rib	Truck Beam
Stator/Vane Ring	Flap Track	
Seal/Ring	Slat Track	
Shaft	Carriage	
Blisk	Landing Gear Beam	
Blade	Wing Rib	
Impeller	Wing Skins	
Spool		

The aerospace components were decomposed into geometrical entities, initially rather unspecific. Provided that the features needed to entail more than just the geometrical appearance, further attributes were listed. The attributes contained information regarding the appearance and geometric shape of the feature, orientation of growth, intended purpose, and if it was a main feature or child of a main feature. Other feature attributes of characteristics were present at times, much depending on the complexity of the feature at hand.

The process of analyzing components was conducted iteratively along with other phases of the *Capture* stage. Since the sources of data varied, this implied that different methods were used when analyzing. Ultimately the results of this stage were a collection of deconstructed components. Figure 4-4 exemplifies the method used when approaching images, in contrast CAD models were looked upon using a digital tool and some components were experienced during site visits.

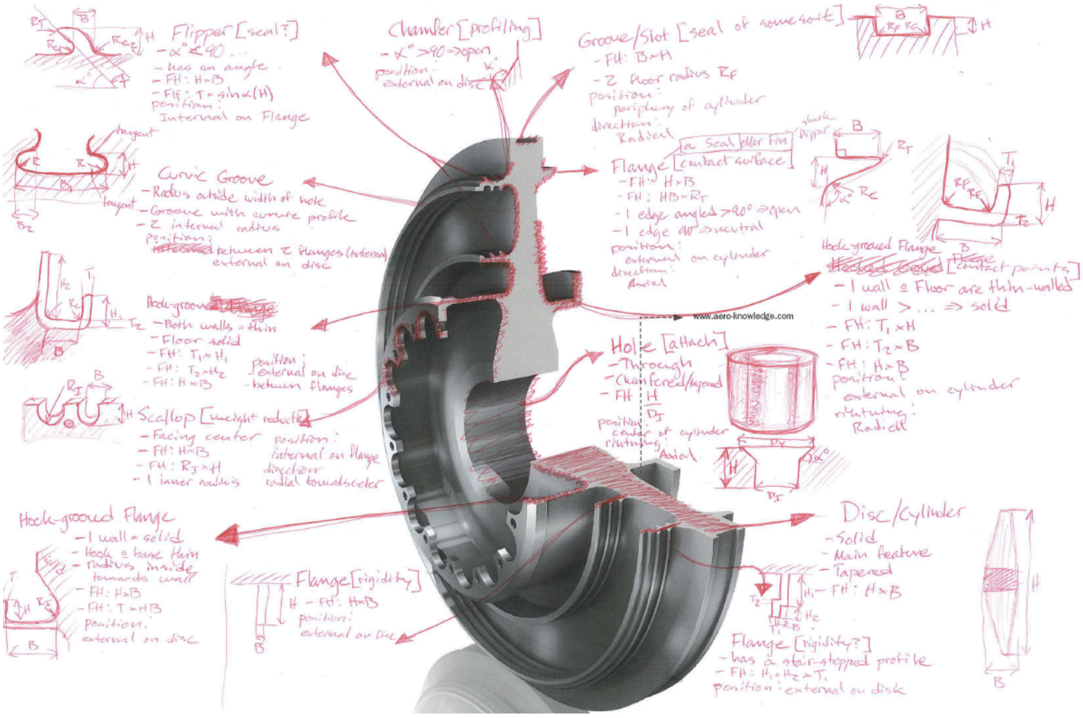
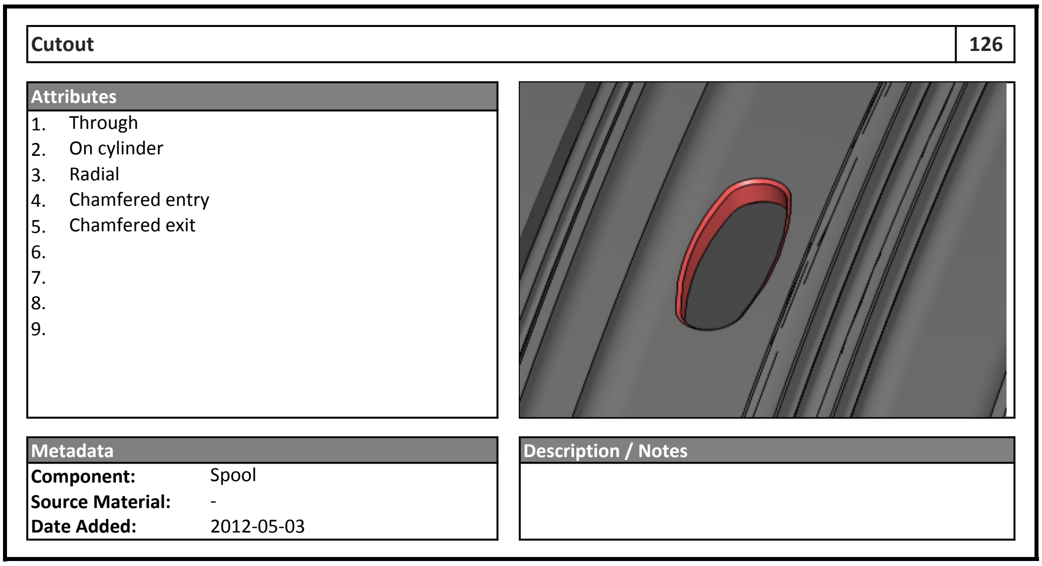


Figure 4-3 - Deconstruction of a turbine disc

4.2.2 Structuring and filtering the data

As components were analyzed, features mapped and interviews and site visits had been conducted, roughly 350 features had been identified. In order to keep track of the features these needed to be structured. As presented in the *Research approach* chapter, a template was created using Microsoft Excel. This template as shown in Figure 4-5, contained a snapshot image of the feature identified, descriptive attributes and other metadata such as the origin of where the feature was found, what component it was found on and the type of material that component was made of.



Cutout	126

Attributes
1. Through
2. On cylinder
3. Radial
4. Chamfered entry
5. Chamfered exit
6.
7.
8.
9.

Metadata

Component:	Spool
Source Material:	-
Date Added:	2012-05-03

Description / Notes

Figure 4-4 - Feature Template

As presented in the Introduction of this report, a definition as for what a *Generic Standard Feature* is was decided upon in this project. The definition is described as the following:

Generic - *Not being specifically affiliated to a certain industry*

Standard - *Frequently occurring among select components*

Feature - *The geometric form or appearance of a prominent characteristic*

Filtering the features gathered in previous phases of the *Capture* stage was a highly iterative process. First and for most, the features had to be compatible with the definition stated, eliminating features not deemed compatible, the number of features was reduces from 350 to approximately 150. Secondly features continued being screened away in parallel with the *Formalize* stage.

4.3 Formalize

The results from this section basically consist of the feature ontology, which is a central aspect of outcome from this project.

4.3.1 Feature Ontology

In order to facilitate for the features to be utilized in the Wiki and App, as well as in other applications in the future, they have to be structured properly. The structure that has been developed, the feature ontology, defines how features are classified and categorized, and how the classifications and categories are related to each other. Each Generic Standard Feature belongs to one of nine the main classes being *Revolved, Pocket, Slot, Hole, Boss, Structural, Edge, Surface* or *General Feature.*

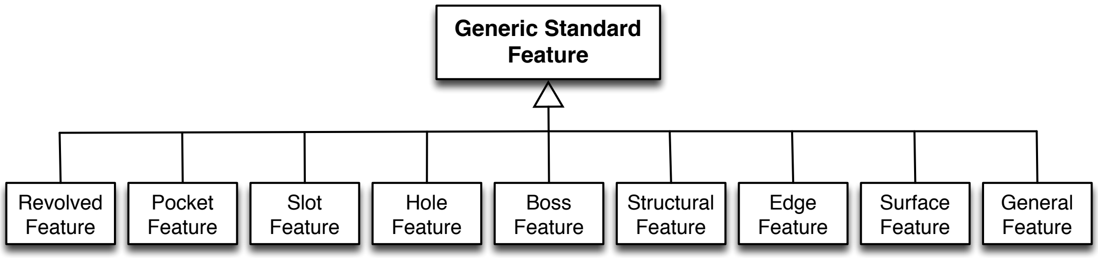


Figure 4-5: Main classes of the feature class diagram

The nine main classes are defined as follows:

- A **Revolved Feature** is defined as a geometric shape being swept an entire revolution around a center axis.
- A **Pocket Feature** is defined as an empty volume created by surrounding walls and floor. Pocket Features can be either a *3D Pocket, 2D Pocket, 3D Cavity, 2D Cavity, Cutout* or *Recess*.
- A **Slot** is defined as a volume removed from a body creating an empty volume with three open faces. A slot can be seen as a pocket that is open at two ends.
- **Hole Feature** is a class including compound elements. By combining features in the sub-classes (*Hole Type, Hole Entry, Hole End, Hole Surroundings, Threaded Hole, Oversized Hole)* it is possible to create a variety of Holes.
- A **Boss Feature** is a feature protruding from the surface of an adjoining body. The direction of a boss is perpendicular from that intersecting surface. Geometric shapes of a Boss Feature can vary between *Circular, Rectangular* and *General.*
- The **Structural Feature** class includes a collection of structural elements occurring on prismatic bodies. Structural Features combined often make up for the main body on which further features are present. Features included in this class are *Walls, Floors, Ribs* and *Struts.*
- An **Edge Feature** is defined as a transition area between the two surfaces making up an edge. An Edge Feature is either a *Chamfer, Fillet* or *Edge Round* and can be present on different geometries regardless of orientation or shape.
- The **Surface Feature** class includes features where surfaces are of a functional importance. Features included in this class are *Boss-*, *Flange-* and *Circumferential Surfaces*.
- A **General Feature** is defined as a feature being unique, yet general, making it not appropriate in another class. The features included in the General Feature class stands to the definition of a Generic Standard Feature, but are not a separate main class on their own. Features in this class are for instance *Clevis*, *Teeth*, *Scallops* and *Gear*.

For each main class the associated features are further classified into different sub-classes. The number of sub-classes under a certain superclass depends on the variance of the features to be organized in that particular superclass. Below is an example of the class *Slot Feature* and its sub-classes:

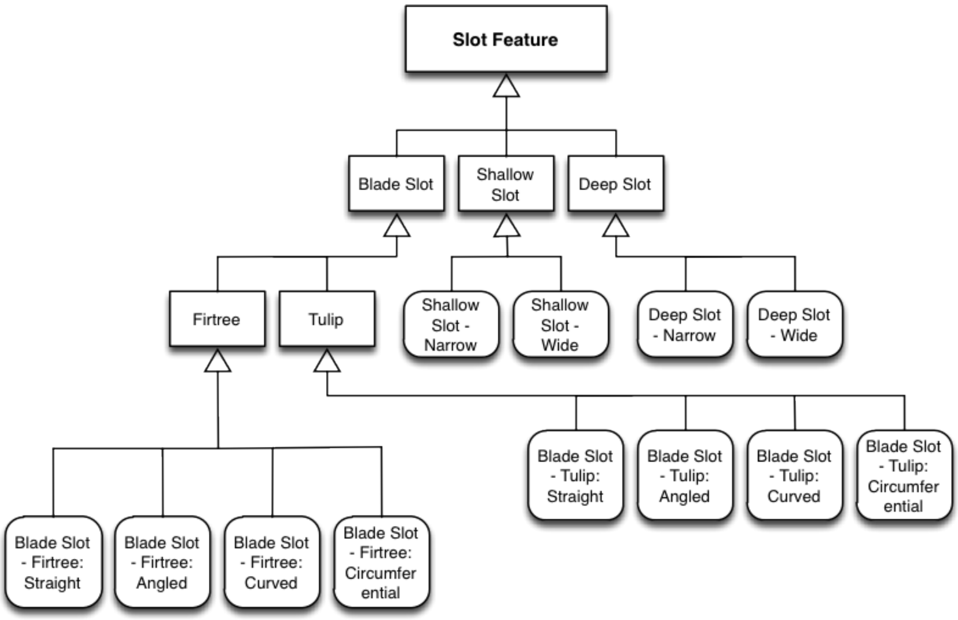


Figure 4-6: Diagram for the class *Slot Feature*

On the lowest level in the tree structure, Generic Standard Feature instances are found. These are marked with a rounded rectangle. The same kinds of sub-structures are found under the remaining main classes as well, some more extensive than others. Similarly as for the nine main classes, each class in the ontology has a set definition.

When it comes to naming of the features, the names are derived from the classification of each feature. Every instance aggregates at least one or more classes, and the name of these classes generate the feature name. The main class is although disregarded, since the name cannot be too long to be easily understood. To further clarify the concept for naming features it is exemplified in Figure 4-7. The name of the highlighted feature is "*Flange - Radial: Internal: Thick*", which consequently corresponds to the classification of that specific feature. The same idea is utilized throughout the 120 Generic Standard Features identified in the project.

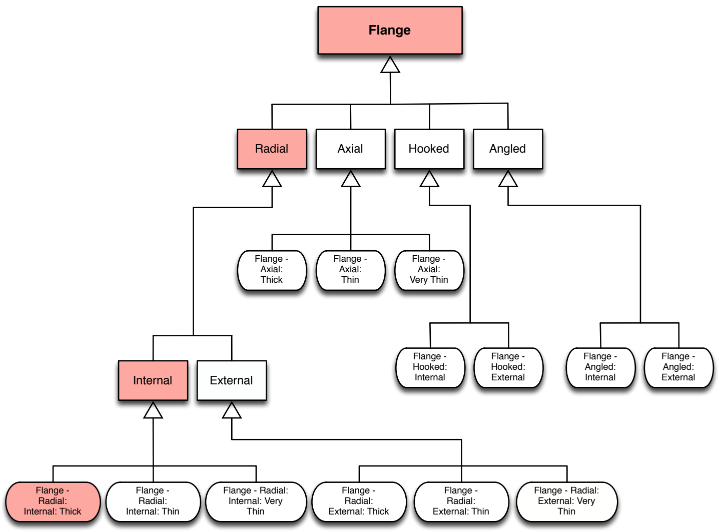


Figure 4-7: Naming concept exemplified by the *Flange* class diagram

The structures under all main classes are relatively similar to each other in terms of how they are composed, with one exception, the *Hole Feature* class. Holes exist in a vast amount of variants, which is derived from the fact that a hole can consist of so many alternate sub-features, they can for instance be counterbored or countersunk, they can have a flat bottom or conical bottom, they can entry a curved surface or a angled surface etc. In the study it was found that if each hole was to be defined with the possible sub-features identified, more than 250 holes could be derived. That number is far too high to be able to grasp.

The solution for this issue is something called *Compound Features*. As the name suggests, these are features being composed by several sub-features. A hole can for example be composed by a through hole, a countersunk entry and an angled exit surface. In the *Hole Feature* class diagram, shown in Figure 4-8, these compound elements are displayed as separate classes. The relations defining what compound elements that require presence of other compound elements are represented with a dashed line.

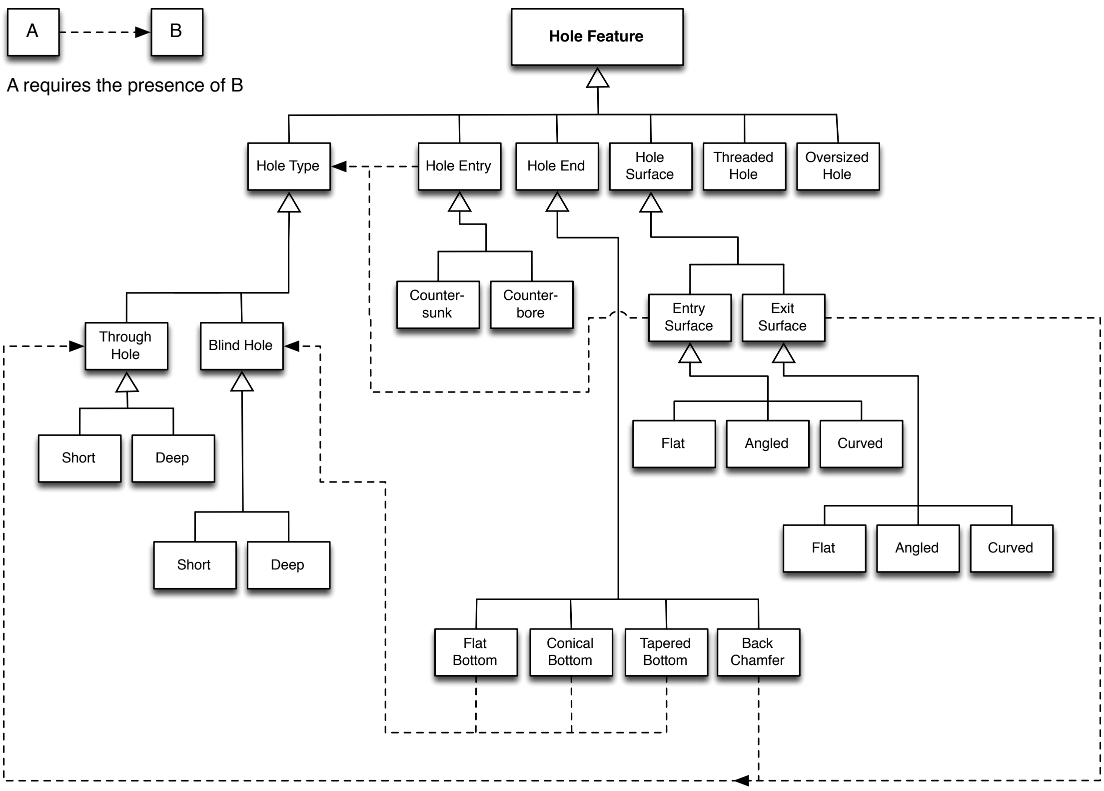


Figure 4-8: Class diagram for *Hole Feature*

To sum up this section, the feature ontology provides a system for structuring a large number of standard features generically. The ontology primarily aims to manage the identified features of this project, suggesting that it is more suitable for organizing feature-based knowledge rather than data directly applicable to a computer system. Apart from providing a structure to build knowledge systems on, the ontology will also assist in the process of gathering and storing more feature knowledge in the future.

4.3.2 Feature Representation

While the ontology in the previous section structures the features in relation to each other, the feature representation provides a clear structure and definition of the individual instances. Every Generic Standard Feature has been provided with some basic information describing it:

- Name
- Definitions of the elements classifying the feature
- Visualization of CAD model
- Materials in which the feature has occurred
- Components on which the feature has been recognized

The definitions of the elements classifying each feature origin from the class definitions and follow the same pattern as the name. To exemplify, the feature *"Flange- Radial: Internal: Thick"* includes definitions for *Flange, Radial, Internal* and *Thick*. The provided visualization is a rendering of the CAD model that has been created for each instance. For some applications, this CAD Model is also attached to the feature. Furthermore, both the materials in which the feature has occurred and the components on which it has been identified are included in the feature representation. Regarding the materials and components listed, it is important to point out that these are no ultimate facts, features might very well be seen on other components and in different materials in the future. In Figure 4-9 a slot feature is presented, with the information related to it.

Slot Feature
Blade Slot - Tulip: Circumferential

Slot features are defined as a volume removed from a body creating a void with three open faces. A slot can be seen as a pocket that is open at two ends.

Blade Slots are defined according to its function, to attach and secure to blades or similar components. Blade Slots are identified according to their unique profiles, either in the shape of a *Firtree* or a *Tulip*.

Tulip Slots are defined as a geometric profile in the shape of a tulip. The profile is then swept Straight, Curved, Angled or Circumferentially creating a void.

Circumferential direction is defined as a sweep around a center axis of a body.

On Component(s):	In Material(s):
- Spool - Fan Disc	- HRSA - Titanium

Figure 4-9: Feature Representation of a *Blade Slot - Tulip: Circumferential*

4.4 Package

In the last phase of the development, a wiki was set up and an iOS App developed. These are presented in the following section.

4.4.1 Wiki

As stated in section 4.1.4, a Wiki was selected to target the internal storing and distributing of feature-based knowledge. The idea of a Wiki is for it to be a living organism that constantly evolves as knowledge and information grows. This also implies that this is not a final version of the Wiki. There will not ever be anything like a final version of the wiki, because if there would be, the objective would have failed. With that said, this section of the report will present the Wiki, its functionality and the outcome of a conducted user test. In the following section, several screenshots will be used to illustrate the functionality and use of the Wiki.

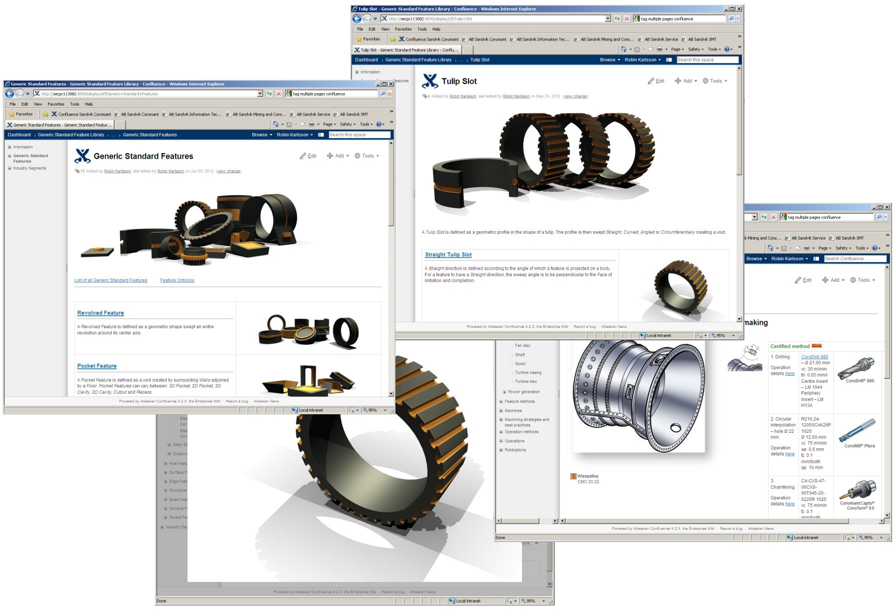


Figure 4-J: Miscellaneous screenshots of Wiki

Many different suppliers offer Wiki software, many with their own niches and advantages. For this project, a Wiki software called Confluence, developed by the company Atlassian, has been used. Confluence is a Wiki software targeting enterprises, providing a very user-friendly, but yet powerful and functional Wiki.

4.4.1.1 Functionality

The wiki contains all information and knowledge regarding features that have been generated during the progression of this project, the core being the collection of Generic Standard Features. Wikis in general consist of a number of pages related to each other, and the same goes for the one set up in this project. Each feature class, as well as each feature instance, has been added as a separate page in accordance to the feature ontology. For the classes, a definition of the class, a visualization of common features in that class and links to instances or other classes is provided. Figure 4-11 displays a screenshot of the page for the class *Revolved Feature* and two of the links leading further down the feature ontology hierarchal structure. Selecting the class "Groove" would consequently bring up a page of the class *Groove*, containing links to its subclasses. Moving on, one would make more selections and finally end up at a page displaying a feature instance.

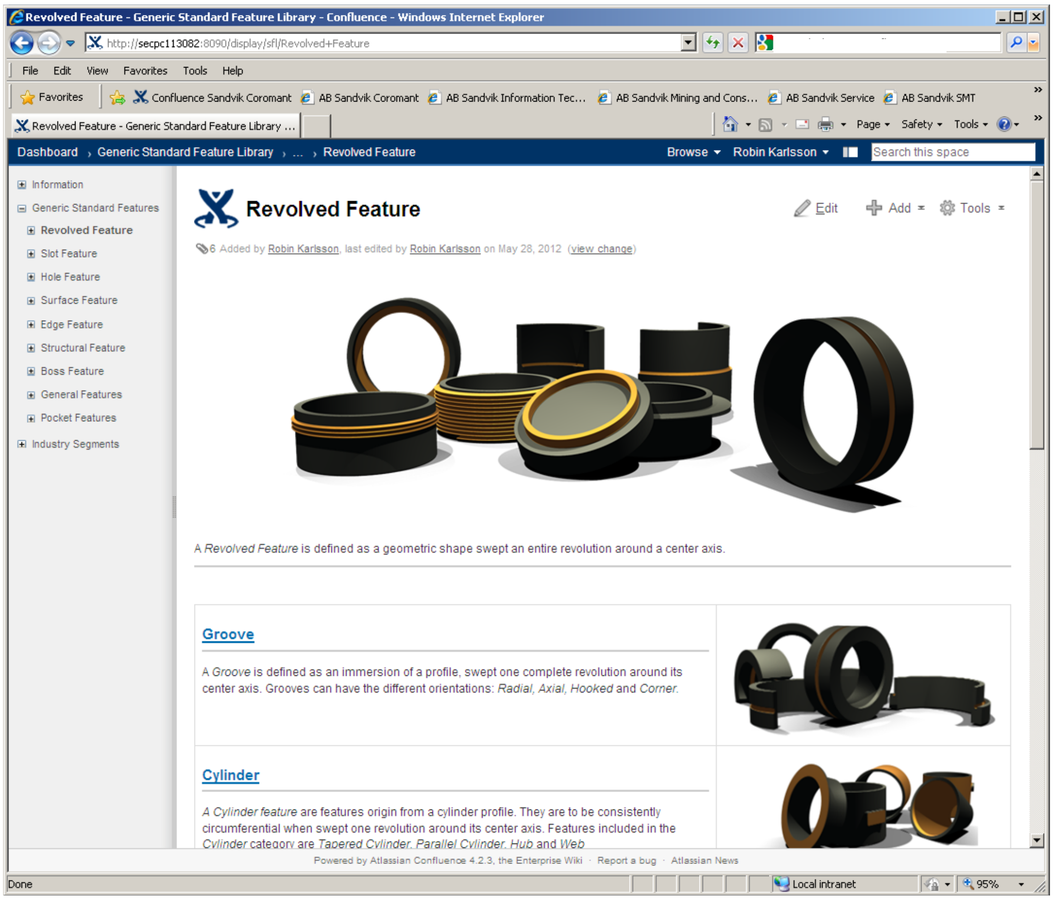


Figure 4-11: Screenshot displaying the page for the *Revolve Feature* class

In coherence with the figure above, all the other pages have got the same layout, providing a description and visualization of the features in that class. The intention is to clarify as much as possible, further extending the usability of the Wiki.

In addition to navigating through the structure explained above, there are three more ways of finding an intended feature in the Wiki. The side panel on the left provides a tree structure of the ontology, where classes and instances can be selected. Also, it is possible to select a feature instance from a provided list of all 120 Generic Standard Features. Finally, Confluence provides a search function where all content can be search by text, including features, classes or visualizations. The search function is shown in Figure 4-12.

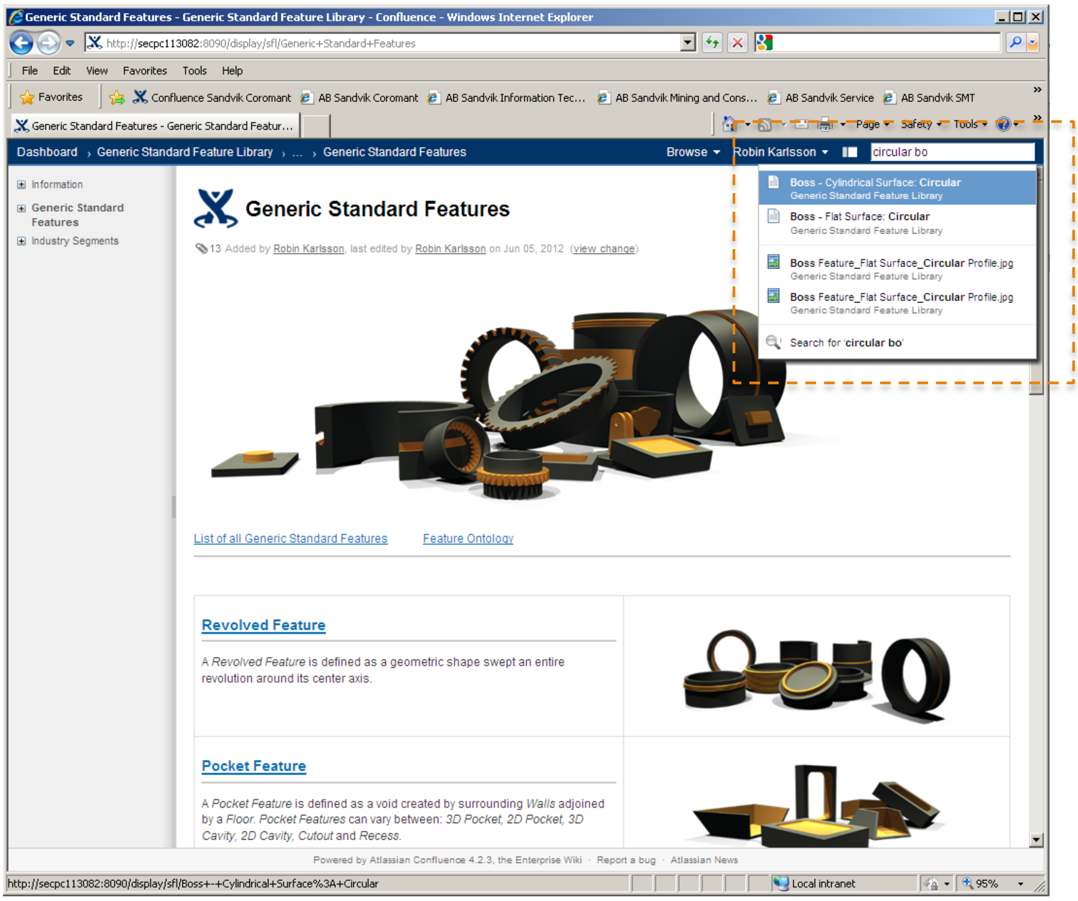


Figure 4-12: Screenshot showing the search function

The different ways of finding a feature allow different types of users to utilize the Wiki as effective as possible. A user familiar with features, their classification and names might want to quickly search for the feature name in order to find what he/she is looking for, while a less experienced user might find it more intuitive to navigate through the hierarchy, looking at pictures and getting textual definitions.

As seen in Figure 4-13 below, the pages containing feature instances essentially include the same information as for how Generic Standard Features have generally been represented in the project. In addition to the name, visualization, components and materials, a CAD model of the feature has been attached and a link to a best-practice solution added. As stated earlier, the best-practice solution will not be mapped or created during this project, but in the future.

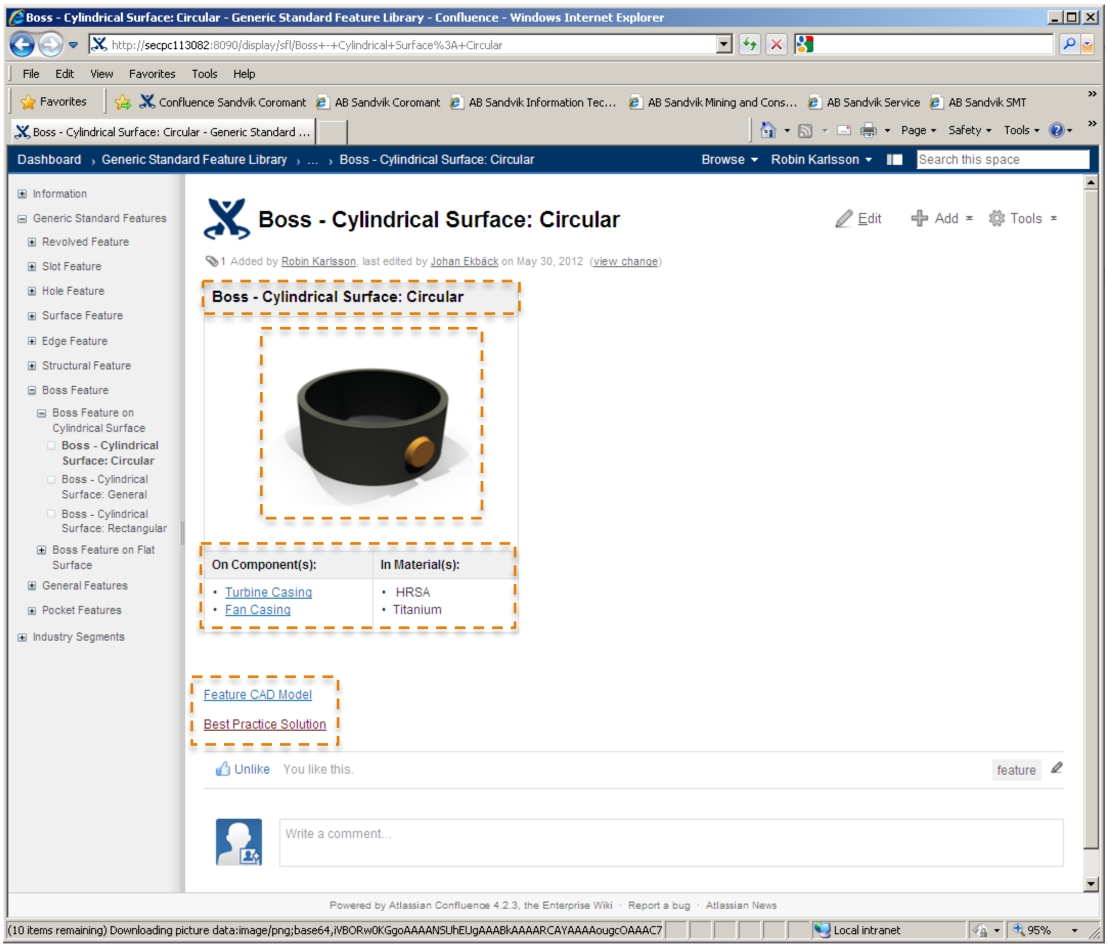


Figure 4-13: Screenshot showing a page for the feature instance *Boss – Cylindrical Surface: Circular*

For all information related to a feature, e.g. the best-practice solution or certain components, the wiki provides a very simple way to associate these by linking pages together. Clicking on the “Turbine Casing” in the screenshot above would for instance bring up a page containing all kinds of information on turbine casings. This functionality illustrates one of the major advantages of a Wiki, namely the possibility for users to easily manage knowledge.

The process for adding content to the Wiki is really quick and user-friendly, an aspect triggering users to contribute. Editing or adding a page is only one click away, minimizing the effort for updating the knowledge. The user involvement does not only concern adding and editing information, the Wiki also enables people to quickly interact by commenting on pages. The aim for the commentary function is to provide a simple way to reach a large group of people, many of who would never have been targeted with conventional ways of communicating. See Figure 4-14 for an example of the commentary function.

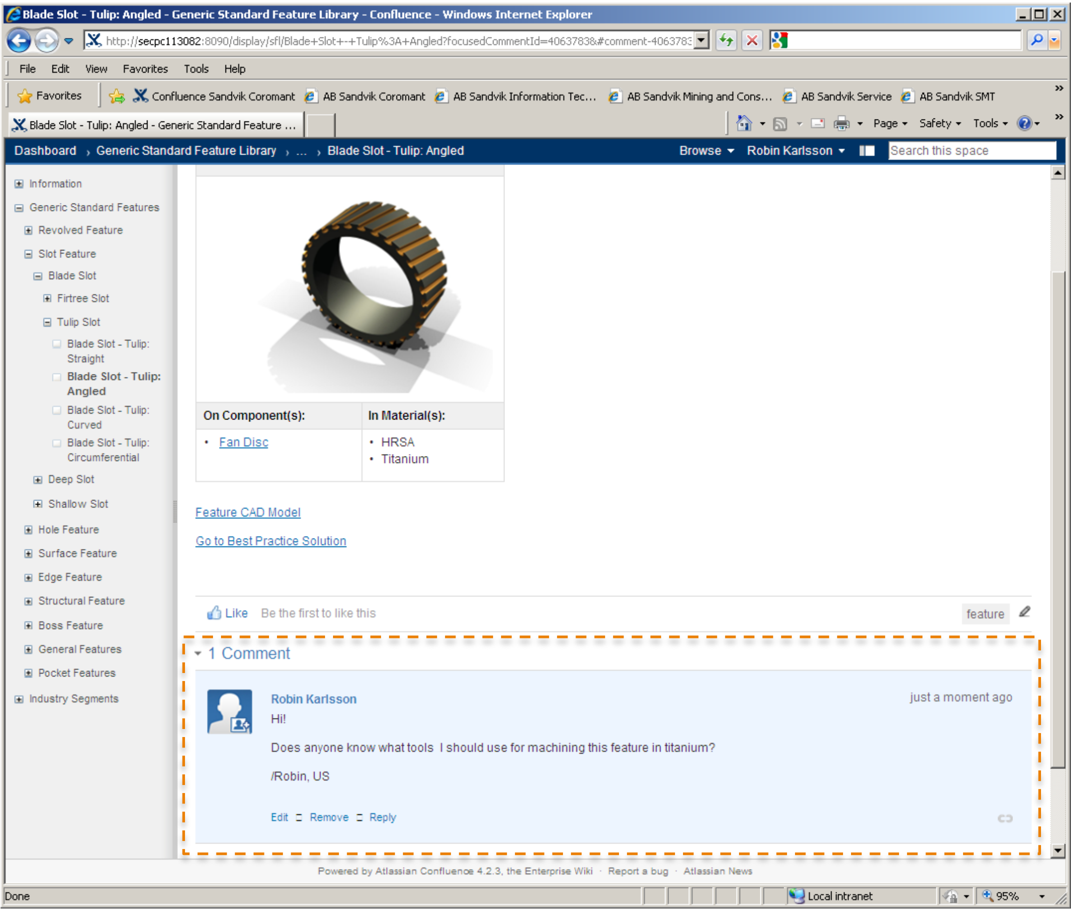


Figure 4-14: Screenshot illustrating the commentary function

To bring even more information to the users of the Wiki, it contains an information section providing material regarding both the Wiki, its purpose and how to use it, as well as the Generic Standard Feature class diagrams, background to this project and why there is a benefit from storing feature-based knowledge.

The Confluence Wiki offers much more functionality as well, e.g. an advanced version control, user profile management, export/import possibilities and the integration of other IT systems. The aim for this project is although not to provide a full specification of the specific Wiki, but the versatility of the tool implies that it will be feasible also in the future.

4.4.1.2 User Test

In order to get feedback from users, a short test of Wiki was conducted among coworker at Sandvik Coromant. The test consisted of two parts:

1. The employee was given a Generic Standard Feature that he/she was supposed to find using the wiki. The idea was to validate the usability of the feature structure, confirming that it is easy enough to navigate the class pages.
2. The second part of the test had a more general approach. The Wiki functionality was briefly explained, and then the users got the chance to browse various pages, try the commentary function, add and edit pages and search for features. Feedback regarding the performance, specific details, user-friendliness and the overall perception was gathered.

The tests resulted in qualitative data concerning the user experience of the Wiki. The key findings in the test are listed below, divided in accordance to the two different test parts:

Finding a feature using the navigation functionality:

- Easy to navigate.
- Simple to get started, many are familiar with the Wiki format.
- Visualizations make it easy to understand what to expect from clicking a certain link.
- It is tempting to use the tree structure in left side panel instead of going through all pages. Quicker, but you miss out on pictures and definitions.
- All test objects found the intended feature. A few people made some incorrect selections of classes, but these were very quickly realized and fixed.
- The *General Feature* class is somewhat abstract.

Overall perception of the Wiki and its functionality:

- Easy to use, user-friendly interface.
- Good structure of the features.
- Many possibilities for adding more knowledge in different areas. Everything can be connected.
- Generally simplistic format and layout.
- Easy to add and edit pages. Some concerns on how to control what is added to the Wiki though.
- Good reactions to the commentary function. Many ideas of how this could make it easy to communicate over borders, reaching a large amount of people.

The test result gave valuable input for what works well and what needs to be reconsidered. Since this Wiki is still a prototype, there are opportunities to further develop both the content and the composition, making it even more usable. The largest concern was of how the Wiki was to be controlled, avoiding it get chaotic and unstructured.

4.4.1.3 Use Case Diagram

The use case diagram in Figure 4-15 presents how the stakeholder interacts with the Wiki.

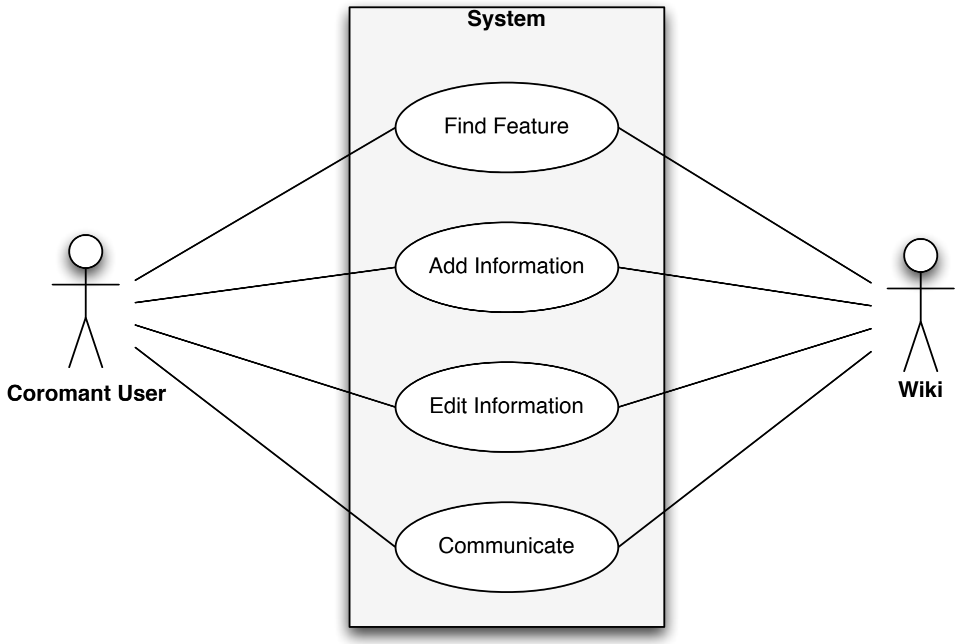


Figure 4-15: Use Case Diagram for the Wiki

As seen in in the Use Case Diagram above, for the Wiki there is only one user. The intention is that the Wiki is to be used by employees in many different roles at Sandvik Coromant, but to define exactly what employees that could use the Wiki would imply a limitation, why only one user is defined. Furthermore, the Use case Diagram provides a broad view on the Wiki use process, in real life the different activities are much more detailed.

4.4.1.4 Activity Diagram

In the Activity Diagram, Figure 4-16, the different activities for using the Wiki are presented.

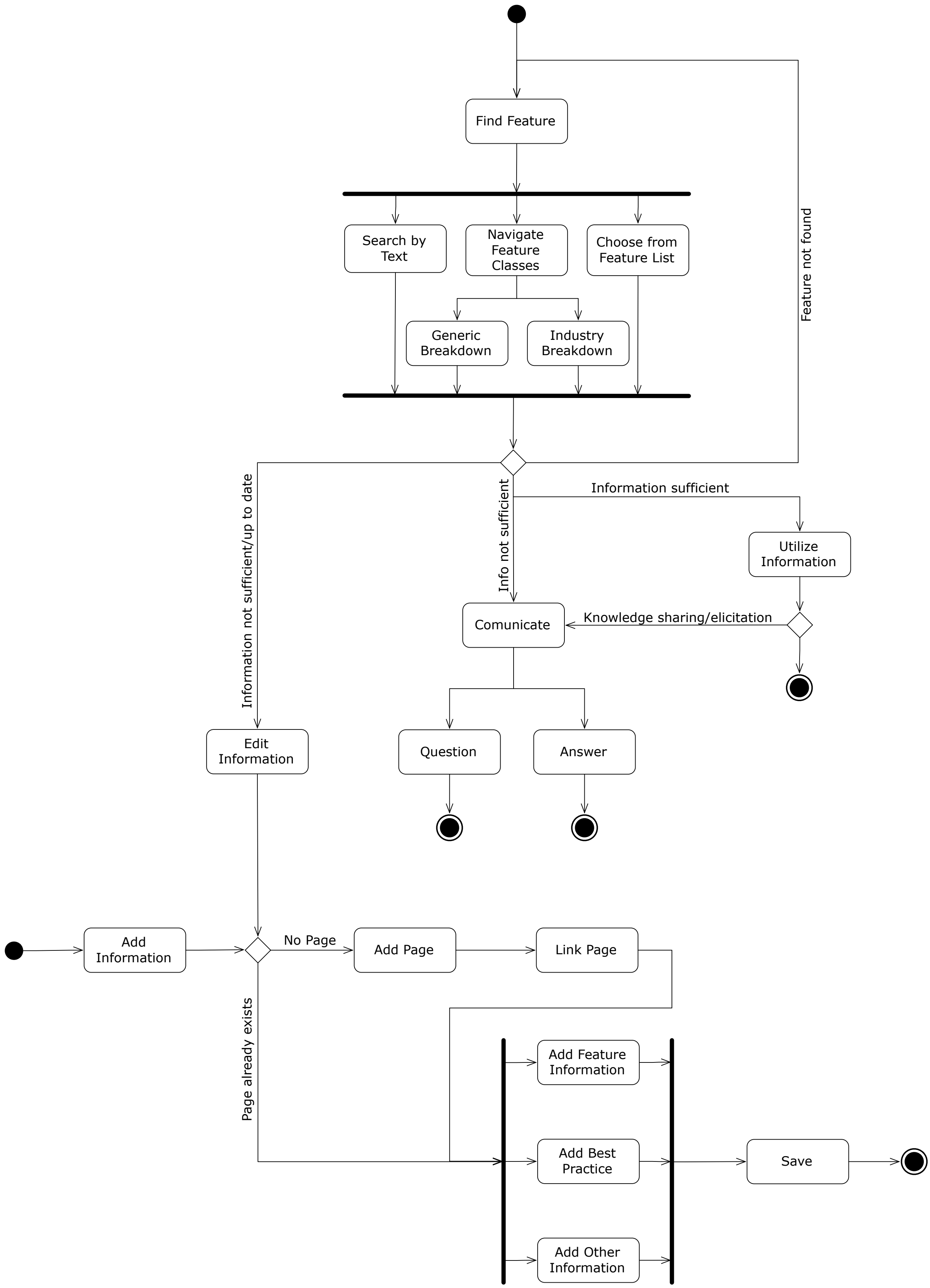


Figure 4-16: Activity Diagram for the Wiki

4.4.2 iOS App for iPad

As defined in the media assessment, developing an iOS App for iPad was argued to be a suitable media targeting external customer communication. The iOS App has been developed with the intention of being a mediating tool. Using the iOS App the user is supposed to have a certain feature in mind. The application should then easily provide a way of searching for that Generic Standard Feature.

4.4.2.1 Functionality

The iOS App created is very simplistic; a less-is-more approach has been utilized during development, taking consideration to the limited screen size. This chapter of the report aims to describe the functionality of the iOS App while illustrating the intended use.

Upon opening the iOS App the *Homepage* as seen in Figure 4-17 appears, greeting the user. At this point of time five selections can be made:

- *Search* function
- *Home*
- *Information*
- *Generic Breakdown*
- *Industry Segment Breakdown*

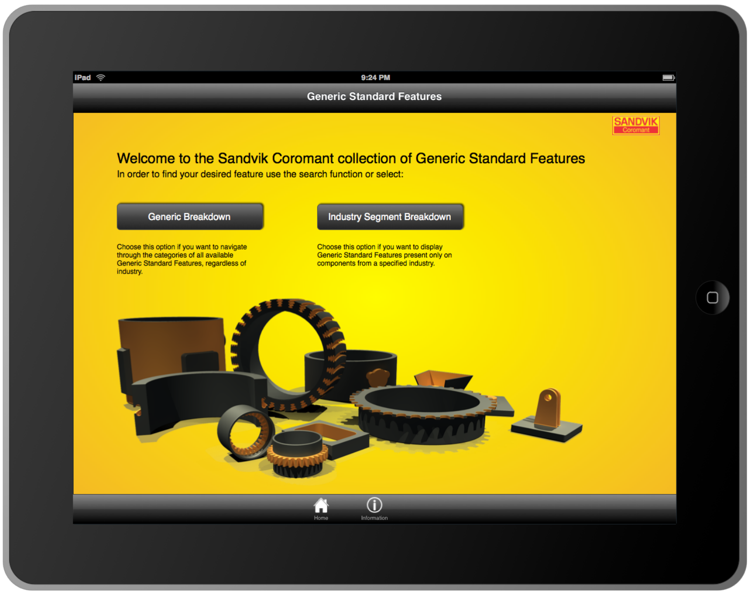


Figure 4-17: The iOS App homepage

Search function
The search function is only available on the homepage. This function allows the user to search for the name of the intended feature. As of current the name needs to be stated explicitly, making the function a bit awkward to use sine the names of the features are long. This is however possible to revise, allowing for only parts of the name to be entered and a dropdown list of names matching that part will appear and allow the user to further select the correct feature.

Home
The home icon is located in the lower tab and can be accessed at all times in the iOS App. Pressing the icon will bring the user back to the homepage.

Information

The Information icon appears in the lower tab, accessible on every page of the iOS App. Pressing the icon will bring the user to the information page as seen in Figure 4-18. This page presents a definition of what a Generic Standard Feature is, a description of how the iOS App is to be used and what functionalities the user can expect to find in the App. In the future, as more content is added to the App, more information can be put under this section.

Figure 4-18: Information page

Generic Breakdown

The Generic Breakdown button allows the user to commence searching for the Generic Standard Feature of interest. Upon selection the Generic Breakdown page appears as shown in Figure 4-19. From this page, further selections are suggested in order for the user to screen away feature classes not conforming to the Generic Standard Feature of interest. When selecting the class of interest, its sub-classes are shown. This process continuous as the user keeps navigating down the class structure.

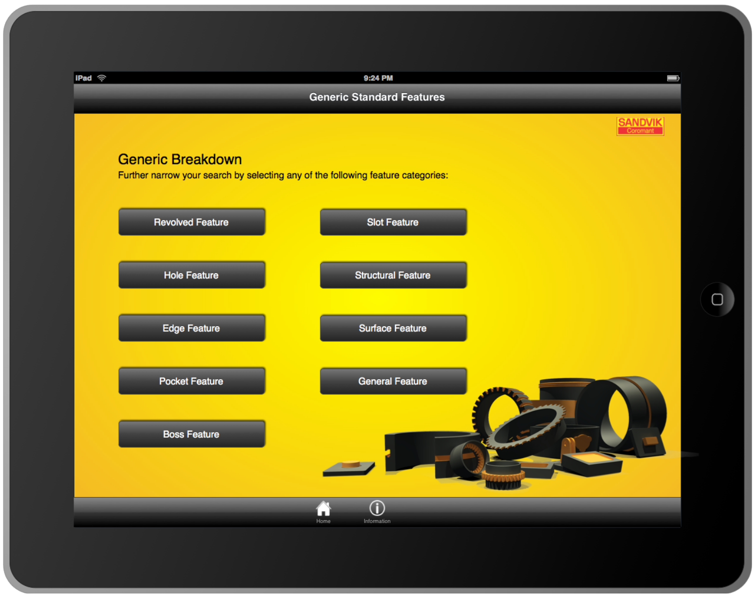


Figure 4-19: Generic Breakdown page

If the user were to regret a selection made, it is possible to go back to the previous scene by using a slide function. This function is activated by the user sliding a finger across the screen in a motion towards the right and can be used for all scenes except the homepage.

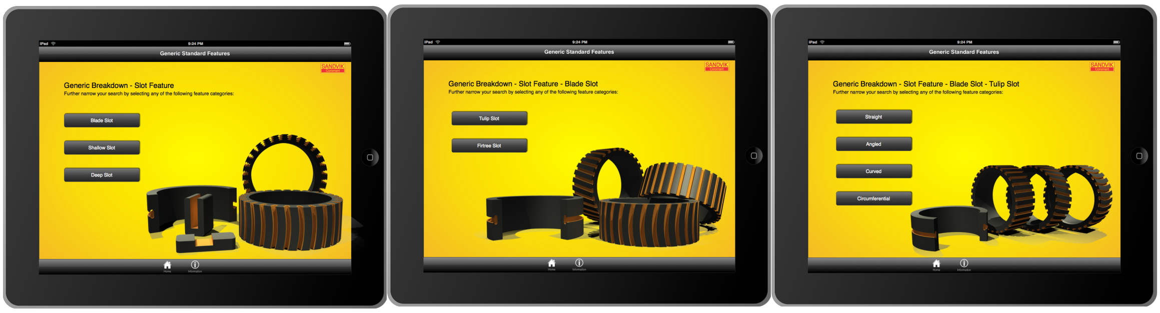


Figure 4-20: Pages for the *Slot Feature* class and its sub-classes

Feature Representation

Once the user has navigated through the screening process, essentially down the structure of the ontology provided in the *Formalize* chapter, a Generic Standard Feature is presented. Figure 4-21 illustrates the form in which the Generic Standard Features are illustrated. Also based upon the outcome of the *Formalize* chapter, the form provides a CAD rendering, description of the categories from the Generic Standard Feature is composed of along with material and on-component occurrences.

Figure 4-21: Feature Representation page

As best-practice solutions are beyond the scope of this project, none have been integrated with the iOS App. However, it is determined that once the user has reached this scene, studied the Generic Standard Feature and making sure that it is the correct one, these can be reached using the slide function. This function is activated by the user sliding a finger across the screen in a motion towards the left.

Industry Segment Breakdown
The Industry Segment Breakdown button is the third option to search from the homepage. Upon selection the Industry Segment Breakdown scene appears as shown in Figure 4-22. Further selections are to be made, breaking down components into features.

Figure 4-22: Industry Segment Breakdown page

4.4.2.2 User Test

In order to validate that the iOS App had sufficient functionality, was intuitive and that the user experience was satisfactory, two tests were conducted:

1.) The first set of testing took place during the initial phases where storyboards hade been created. Buttons and any means of navigation were not incorporated in this phase, allowing for a more unbiased response. Coworkers were asked to comment on the design and layout, as well as the coherency with previously developed iOS Apps by Sandvik Coromant. Further they were asked to describe what type of functionality that was to be used when navigating between scenes.

2.) After completing the pilot of the iOS App, this was loaded onto an iPad and passed around the office. Overall perception of the App was communicated, as well as what was missing.

As an outcome of testing the storyboards, certain aspects of the graphics were altered. Prior to the tests the backsplash had a partially transparent grid, this was removed since it was experienced as “too busy” and to some extent distractive. The slide functionality presented in the section about functionality was something preferred rather than using a back button.

The outcome of the second test was very positive. Nobody really had anything negative to say about the product. It was perceived as being intuitive, easily navigated and had a Sandvik Coromant feel to it.

4.4.2.3 Use Case Diagram

The Use Case Diagram for the iOS App, see Figure 4-23, presents the stakeholders and how they interact with the system.

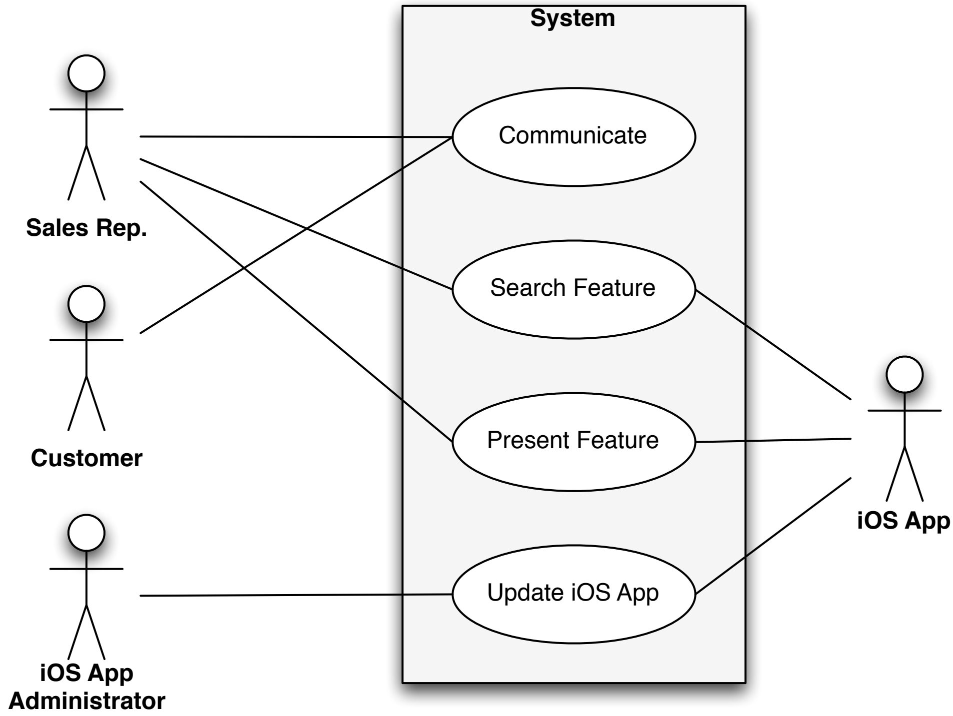


Figure 4-23: Use Case Diagram for the iOS App

As seen in the use case diagram, the sales rep. is supposed to use the App to search and present feature knowledge, while the customer communicates with the App as a mediating tool. An administrator has the responsibility to update the iOS App.

4.4.2.4 Activity Diagram

The Activity Diagram for the iOS App in Figure 4-24 below presents the process for using the App.

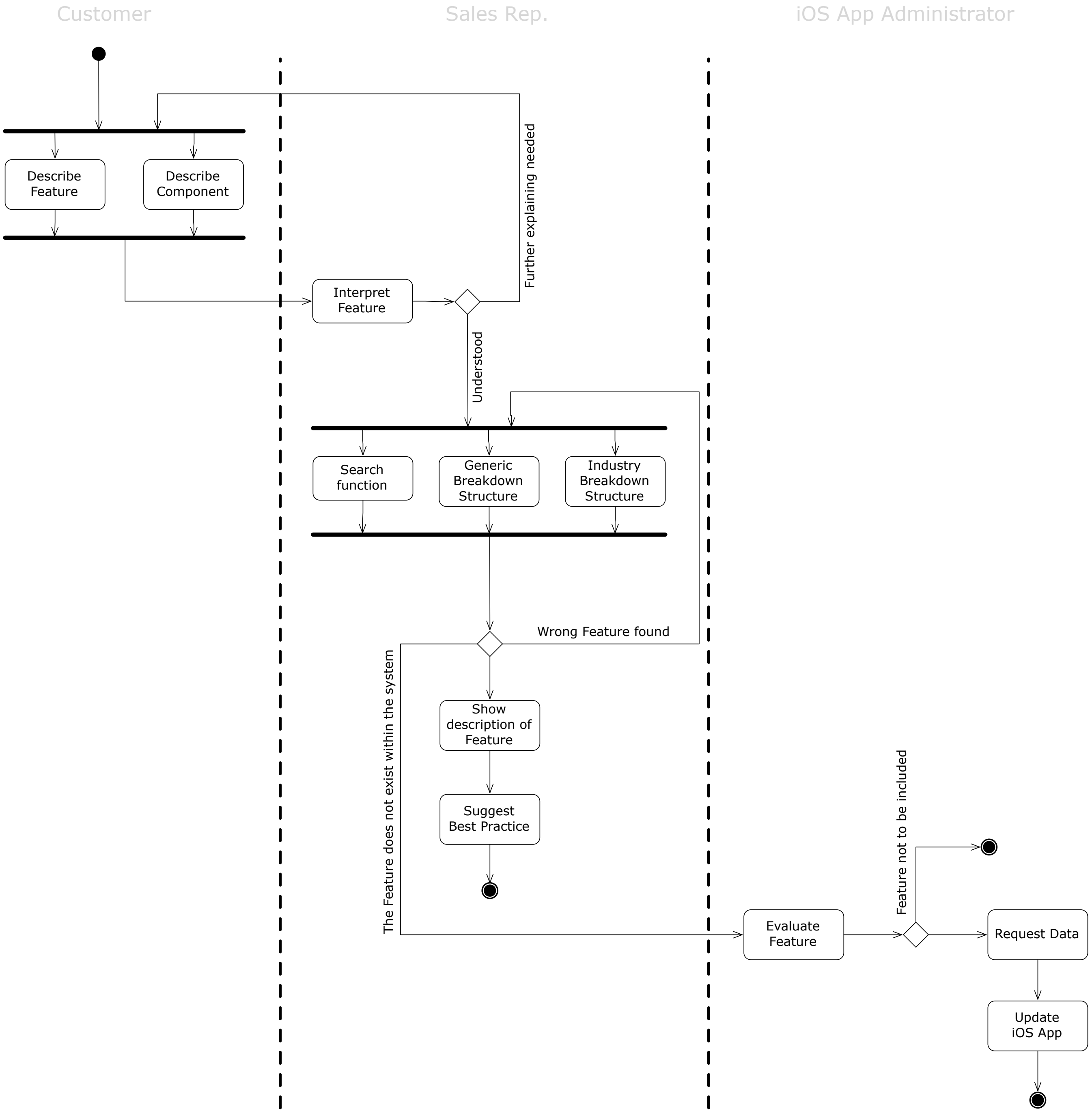


Figure 4-24: Activity Diagram for the iOS App

5 Discussion

In the *Introduction* a set of research questions were posed for the project at hand. The aim of this chapter is to review and discuss those questions from the perspective of the three main sections of this report, Results, Research Approach and Frame of Reference.

Further the discussion strives to evaluate the success of the project, whether or not the objective has been fulfilled and to what extent the results presented can be considered valid.

5.1 Results

The results in this report have been presented in accordance to the MOKA stages. The outcome of the two first stages, *Identify* and *Justify* has provided a foundation, facilitating the generation of results in later stages. Results presented in the stages *Capture*, *Formalize* and *Package* target the objectives for this project.

5.1.1 Identify

A market assessment was conducted, attempting to provide a larger picture and placing the project into a context. As this project is the first phase of a long-term objective it became rather difficult to explicitly assess the entire objective without stepping outside of the delimitations set when scoping the project. In the PEST analysis, the aerospace industry was assessed, however it is believed that further research needs to be conducted in assessing other industries as well. This due to the fact that one of the main tasks within this project is to make the outcome generic. Investigating further industries is likely to increase the value of the PEST analysis in terms of being generic. Another manner in which the PEST analysis could have been approached implies not regarding specific industries. Instead the long-term objective could have been focused upon, hence investigating the trends and markets of KBE applications and implementing best practice solutions into CAD/CAM systems. Regardless, the PEST analysis entails that the aerospace industry is likely to be a fruitful market for years to come.

Apart from the PEST analysis, the market assessment included a SWOT analysis and competitor assessment. Overall the market assessment showed that many of the prerequisites for a successful outcome of the long-term objective are present. The knowledge within Sandvik Coromant and the technology needed exists. Competition is rather low and it seems that no similar products have yet to reach the market.

The objective of this project stated that Generic Standard Features were to be stored in an application facilitating the storing and distributing of feature information and knowledge. Conducting use case scenarios, the aim was to identify users of interest as well as areas for which the application could be used. Previous studies have shown that KBE and similar application areas tend to be precise and rule-based. According to the use cases, these suggest that there is a possibility for a more general use of the knowledge concerning features. Two scenarios were deemed to be of interest, a decision was made stating that it would be of greater value if both of these were to be further investigated. Under other circumstances it would probably have been more convenient and straightforward if only one scenario had been selected. It is likely that the two scenarios selected could have been possible to combine into one, however it was believed that the final result would have consisted of many compromises instead of truly targeting specific applications, hence decreasing the value of the outcome.

The requirement specification created has been a continuous process including much iteration and hence breaching the *Identify* boarders. As the scope of this project has been broad in the sense that it has not targeted any specific application from the start, creating a requirement specification was a difficult task. Rather than specifically stating demands and wishes for the applications alone, the specification collects most of the valuable input from stakeholders such as Sandvik Coromant, customers and future users. This resulted in a specification being very broad, considering aspects regarding features, ontologies and applications. The requirement specification later provided the possibility to validate the medias in which the results of the project were packaged into.

A Wiki and iOS App were selected as medias to target the applications of use. The technology assessment could not provide a single media capable of fulfilling the requirements for both of the applications. Instead of compromising, two separate medias were selected.

5.1.2 Capture

Multiple sources were used when collecting the information for this project. This information originates from prior experiences Sandvik Coromant has within the aerospace industry in accordance with the delimitations of this project.

Breaking down components proved to be a difficult task, especially when looking into the level of detail that the components can be broken down into. In conducting the mapping of features, it became apparent that consistency was very important. As the process was carried out under a long period of time concurrently with other parts of the project, the predefined forms containing the identified features supported the work of keeping the level of detail consistent. The suggested level of detail is believed to be deep enough to give the features value, yet not too deep making them difficult to understand.

One of the aspects that sets this project apart from other studies conducted is the aspect of which features have been approached. Observing real life components in a manufacturing context from a design perspective has provided a new angle, hopefully resulting in generic and unbiased features. Although one site outside the aerospace industry was visited, features gathered could likely have been different if more industries been studied. In order to validate the generality of the features, more industries would have to be studied in the future.

Prior to initiating the stage of *Capture* it was expected that more data to be analyzed was to be available. Due to restrictions such as ITAR, this proved to be rather difficult both in the sense of component material and visits. Although the amount of material concerning components and features collected were not as extensive as expected it provided a platform sufficient to be analyzed.

5.1.3 Formalize

Moving into the stage of formalizing, this was based upon the remaining 150 features devised in the *Capture stage.* A focal point, requiring much effort was the development of an ontology. This process was highly iterative, continuously reducing the number of *Generic Standard Features* down to 120.

As presented in section 4.3.1, the ontology consists of nine main categories. Compared to early revisions, a concern regarding the present ontology is the number of main classes in the first level of the ontology. The issue concerned was that the ontology would be perceived as chaotic. Previous revisions attempted to further classify the nine main classes, creating super-classes such as *Immersions* and *Protrusions*. This approach was disregarded since the overall appearance of the ontology became less intuitive and lacked in clarity. In the end, it is believed that the current version of the ontology as presented in this report is manageable, intuitive and straightforward. In terms of consistency, one deviation has been made regarding the main categories of the ontology, *General*

Features. Rather than adding more main categories, some of the *Generic Standard Features* were best suited in a class containing miscellaneous features.

Structuring the *Generic Standard Features* into an ontology, a concept presented in the ISO 13030-224 Standard was adopted. This concept is called compound features and has been an important factor in the sense that the ontology consists of 120 *Generic Standard Features.* Looking into the main class *Hole Feature,* calculations showed that over 1500 instances could be devised by varying identified attributes present within the class. In using *Compound Features* these 1500 instances can still be achieved with the current ontology. Rather than presenting all of these unique combinations, the user can combine *Generic Standard Features* into the form and shape required.

As the ontology had been structured and the *Generic Standard Features* decided upon, these needed to be represented according to the statements in the requirement specification. A key aspect of the feature representation lies in the naming of the *Generic Standard Features*. As presented in the results the naming of the *Generic Standard Features* is based upon the way they are classified. This provides a consistency among the features and understandable names.

Deciding upon what data should be adjoining each *Generic Standard Feature* proved to be difficult. Initially each *Generic Standard Feature* was to have descriptive attributes of for instance dimensions or angles. This was later found to increase complexity to such an extent that the completion of the project would be unachievable and hence was disregarded. Looking into context however, it became apparent that *Generic Standard Features* without context such as material or component occurrences would leave the *Generic Standard Features* lacking any value.

As described by Sandvik Coromants long-term objective, the subsequent phase of this project includes mapping and creating *Best Practice Solutions* for each *Generic Standard Feature.* Returning to the lack of value, attempting to describe this, if a *Generic Standard Feature* was to be manufactured in two separate materials, this could imply two separate methods of manufacturing depending on the material attributes. Occurrences on different components provide different surroundings and paths for which a machine can move. Conclusively this implies that for the knowledge connected to each *Generic Standard Feature* to be accurate and extensive, context is a key matter.

5.1.4 Package

Utilizing a Wiki as an application for capturing, storing and presenting knowledge has been proved likely to be feasible. It would imply a new approach for Sandvik Coromant in terms of knowledge management, and aims to trigger contribution by being open for users to easily add knowledge. As the Wiki is supposed to be a living organism ever evolving, the use for it might not stop with this project regarding features. Sandvik Coromant is a company founded in 1932, during that time until now a huge amount of knowledge has been created, much of what could be implemented in the Wiki later on.

As of now, the Wiki contains the 120 Generic Standard Features. With the current content the Wiki does provide some knowledge valuable to Sandvik Coromant, but the real value will be generated once the best practice manufacturing solutions are linked to the features. At that point the Wiki will provide a huge amount of knowledge usable across the whole organization of Sandvik Coromant. Since this collection of features is new, that provides some new knowledge, but if the links between features and manufacturing solutions can be created and stored, they will offer new and meaningful information to the company.

The iOS App targets a very specific area of use, where it is to be considered more of a tool than a system. One might think that it has very limited functionality, but as its area of use is narrow it does not need any more functionality. The simplicity and intuitiveness provides a short learning curve allowing many, even without prior experience of working with features, to find *Generic Standard Features*. One of the best qualities of the iOS App is its user-friendliness, which was shown when testing and validating the application.

Although being fully adequate for its intended purpose, the iOS App is not powerful enough to serve as the only system for handling feature knowledge. Provided that it is used as a complement to a knowledge repository there are many strengths that are hard to compare with other medias, such as the use for marketing purposes.

5.2 Evaluation of the Research Approach

The project began by conducting a literature review that both provided the adequate level of knowledge in order to commence the development phase, but also generated the gaps and needs that became to be the research challenge during the project. The literature covered is considered to have been extensive enough, even if more literature than what was covered in the first phase had to be used since new questions were continuously raised during the process. The iterative and on-going process for studying literature proved to work well, as it always provided new input to the work.

During the problem analysis, many interesting research questions were identified as feasible to use during the project. It was though realized that there are three main questions that most of the others are related to, and these were consequently selected to further investigate throughout the work.

MOKA was used as a framework throughout the development phase of this project, where its methodologies served as guidelines. In retrospect MOKA provided a good foundation, kept the flow of the project and offered an objective for each stage. Even though the methods provided by MOKA were considered to be accurate and overall good for the project, it could at time be too oriented towards developing fully automated KBE systems. Using MOKA to its full extent would require using a series of very specific methods and tools. For the applications developed in this project, this would have been too extensive as well as unnecessary. Overall this project has shown that MOKA can be used when developing applications not strictly being of traditional KBE nature. Although, the approach applied in this project requires the methodology to be used as a guideline rather than a step-by-step process.

During the *Identify* stage several methods were used in order to obtain the outcome as presented in this report. One question that has risen is whether or not the aerospace industry was the correct focus area when conducting the PEST analysis. Since this project has revolved around the aerospace industry it seamed logical at the time, but afterwards it can be discussed how relevant the aerospace focus really was. The PEST analysis as a method is good, but it is important to make sure that the correct market is analyzed, and that the result can bring value to what is coming next.

Developing the requirement specification proved to be difficult as the input can be seen as somewhat vague or diffuse since the technology to use was not defined in the initial scope. The idea of keeping the requirement specification evolving during the project is good as well, but at the point where it was decided that an App and a Wiki was to be developed, it could have been valuable to divide the specification into two different versions, one for each application. This could have provided more specific and targeted requirements.

The outcome of the *Capture* stage was affected by the limitations within the aerospace industry, proving it to be more difficult than expected to get hold of components to analyze. Conducting interviews and carrying out site visits, a semi-structured approach was chosen. Provided the type of context it is believed that this selection was good. During the interviews, much more information was elicited than the answers from the questions posed. This could be a consequence of the questions being insufficient, but probably it is a result of the semi-structured approach triggering discussions and thoughts.

Regarding the iOS App it would have been interesting to see what input the actual users, i.e. sales representatives and customers, would have had. As the result from this project was a pilot, the test on other employees was considered to be sufficient and also did provide relevant feedback.

Summarizing the research approach, it has satisfyingly provided a framework allowing for good results to be generated, both in terms of development and research goals.

5.3 Summary and Discussion of Research Questions

In this section the three research questions will be further discussed and explicitly answered. The questions have to some extent already been touched upon in the discussion of the results, below these discussions are intensified and the answers to the questions clarified.

1.) What defines a Generic Standard Feature and how is it to be represented?

During the progression of this project the feature characteristics have changed over the time. In the early stages features were believed to require parameterization and specified attributes in order for them to provide any value in a future applications, similar to the research conducted by others, e.g. Sunil et al. (2008), Salomons et al. (1995) and Martino et al. (1994). As more components were analyzed and more features mapped, it was realized that the attributes would not bring any value as long as there were not a complete compilation of features to be specified. For the objective to implement the Generic Standard Features into a CAD/CAM system it is likely that the features at some point would have to be parameterized and more explicitly defined, but not for the purpose of utilizing features in a more general sense, prior to the CAD/CAM implementation. A more detailed definition of each feature implies much more specific features, which in turn results in the need of a vast amount of features in order for them to cover the range of features being considered as standard. That amount of feature data get very difficult to grasp very soon, resulting in the risk of the collection of features cannot be implemented into any system at all in the organization. The result of the work conducted in this project instead suggests a more soft approach to defining features, allowing them to carry knowledge without being very strictly defined. By doing so, the chance of succeeding in the collection of Generic Standard Features is much greater.

To answer the research question, a *Generic Standard Feature* is proposed to be defined as a feature occurring on several components in industry while also being generic in the sense that the feature is applicable in more than one industry segment. The Generic Standard Feature can advantageously be described by the definitions of the proposed classifications, visualization and the descriptive naming concept that has been suggested earlier. Although being industry generic it has been discovered that the components on which a feature can occur, as well as in what material, are very important elements to link to each feature. These contexts provide a greater possibility for the feature to be associated with certain knowledge, e.g. specific manufacturing processes, in the future.

2.) How are Generic Standard Features to be named, classified and categorized?

Similar to other studies (Gindy (1989), Muljadi et al. (2006)) conducted in the subject, this work suggests structuring features using a feature ontology. In this ontology the features are classified based on their geometry, to a large extent using classifications that are recognized in industry. The proposed ontology starts off in nine main classes, each containing several levels of sub-classes further classifying the features.

For the matter of naming features a solution based on the feature classification is proposed. As the naming is inconsistent in industry and no relevant research addresses the problem, this solution is promising. The names are now systematically derived and easy to understand. The names could be considered long and inconvenient to use on a regular basis, but the aim is not to provide names for everyday occasions, but rather for more formal use in for instance feature-based applications. For that purpose, the suggested names are well suited.

3.) What type of application will best facilitate the storing and distributing of feature information and knowledge?

In this project a Wiki and iOS App have been developed to store and utilize the gathered features. In order to answer the research question it is of great importance to clarify the purpose of storing and distributing the features, since the purpose of the application will highly affect the choice of technology and process for it. As two different use scenarios were targeted in this project, it was found that two different technologies would best fulfill the requirements of them.

For the purpose of storing, distributing and presenting feature-based knowledge the Wiki is considered to be a very powerful application. Using a Wiki for storing feature data is not something completely new, Muljadi et al. (2006) proposes a system were both design and manufacturing features are stored in an ontology using a Wiki. Similar to the findings of this project, the authors conclude that a Wiki is a very feasible solution, mainly because of its simplicity and visibility. It is highly recommended to further investigate the Wiki as a system for storing feature and their related knowledge, as it has great potential.

In addition to the Wiki, an iOS App was also developed for the features to be used in. As mentioned in *Chapter 2*, there are no previous studies on using an iOS App for communicating feature knowledge, why the delivery of this project can provide value for future research. The usage area of an iOS App is much more limited compared to the Wiki for instance. The user tests did although show that for its intended purpose, it can provide some unique capabilities. The App provides a mediating tool when communicating knowledge, but can also act as a marketing tool showing customers the skills of Sandvik Coromant. More research and development would have to be conducted in order for the App to be fully validated, but so far it is a promising concept for its specific purpose.

4.) What value can a feature-based application bring Sandvik Coromant?

As mentioned before, a long-term objective for Sandvik Coromant regarding features is to implement them in a CAD/CAM system. The features and their best-practice solutions could make the process of planning and manufacturing of standard features much more efficient by either allowing engineers to reuse preexisting knowledge in the system, or automating certain parts of the process. Such a solution would shorten the process time as well as assure that an optimized solution is used, providing lowered costs and better results.

Features can although be useful prior to a CAD/CAM implementation. First, a feature mapping by itself can provide a basis for strategy decisions. By looking at what features exist and which of them that have developed manufacturing solutions and tools, decisions on what knowledge and tools need to be developed or enhanced can be taken. That means the features can support in finding gaps in the product portfolio, both regarding knowledge and tools, as well as discovering new business areas.

Another way of utilizing features is to let them carry the knowledge that can be related to them. In this work it is suggested that the knowledge of how certain features are best machined is associated to them. To store features and their best practice solutions offers an encyclopedia of manufacturing techniques and processes to be distributed across the organization. This would result in important knowledge reaching more people, which consequently can use that knowledge to be more productive and gain better results.

Furthermore, other kinds of knowledge could very well be incorporated in order for them to bring even more value to Sandvik Coromant. The features could be used as a common denominator in terms of for instance material knowledge, component information or cost estimations. Different areas such as these can be linked together by letting features be the bond between them. In that case, the features would assist in developing a comprehensive understanding of different aspects of existing knowledge.

As discussed, there is value to be extracted from features. This value is not only hypothetical, it has been shown that there are opportunities to make it real. The knowledge do exist and features can help to capitalize on it, why it is feasible to continue the work of collecting and using features for Sandvik Coromant.

6 Conclusion

This project has treated component features and the engineering knowledge related to these. In the work the features of interest have been defined as Generic Standard Features, implying that they are both commonly occurring and nonspecific regardless of industry. To break components down and collect features such as these can bring value to Sandvik Coromant as they provide an opportunity to store structure the knowledge regarding how to manufacture them. If that knowledge is available, the development of new manufacturing solutions across the organization can be done more efficiently as a lot of the engineering experience can be reused. The features will also give the possibility to offer customers solutions that fit their needs, without having to always start from scratch when developing them. The collection process has proven to be a difficult task, but as Sandvik Coromant is doing business in a variety of industries with many different customers, there organization has good chances to succeed with it.

A feature ontology has been developed, allowing Generic Standard Features to be classified, categorized and named. The ontology provides a framework for how features can be structured and defined in order to utilize and approach feature-based applications systematically and coherently. As of current, the ontology accomplishes to manage the features collected in a good way. In order to verify that it is complete, more iterations of the gathering process will need to be conducted though, looking at more components and features. The initiative to a naming configuration based on inherited classifications proposes a solution to features being named very differently dependent on their context, creating confusion and barriers for knowledge transfer.

The main aspect setting this project apart from what have been previously done in the area is the focus on usability, the usage of hands-on component features that brings a unique touch of practicality to the result. Some might imply that the specified features lack in contained data, in this project it is though argued that what can be perceived as lack of data, actually is a realistic view on what is usable at the moment. The 120 Generic Standard Features compiled might very well stand to be a solid foundation for knowledge storage in the future.

Furthermore, this work has resulted in a Wiki and iOS App utilizing Generic Standard Features from two different perspectives, targeting two separate purposes. The iOS App has proven to be a powerful tool for communicating knowledge, for marketing as well as mediating. Although the iOS App has its clear advantages, the Wiki portraits the successful fusion of a modern and powerful tool with specific engineering knowledge. The capability to keep the knowledge evolving by involving users, triggering them to contribute, results in a system where knowledge is the fundamental core. It provides numerous possibilities to be extended to not only cover features, but also almost all knowledge existing internally in the company.

To conclude, the project outcome successfully contributes to the work conducted by Sandvik Coromant regarding their feature-based applications. It provides a solid collection of Generic Standard Features, a framework for structuring these and tools to really make them valuable. Compared to other studies, a strength of this project is its comprehensiveness, covering the gathering of industry features, structuring them and utilizing them in applications. To further develop the work more iterations are needed, but this project has proven that it is feasible to proceed.

7 Future Recommendations

Although the outcome of this project is considered to be successful, there is still work to be done. The future recommendations for Sandvik Coromant are listed below.

1. **Iterate and continue the process of gathering and structuring features.**

   1.1. First, in order to make sure that the Aerospace segment has been covered, it is necessary to make one more iteration of analyzing aerospace components, confirming that the relevant components have been studied.

   1.2. Secondly, more industry segments can advantageously be investigated, suggestively one at a time. As components in that industry segment are analyzed, the ontology must concurrently be taken into consideration, verifying that its structure is suitable for the new features identified as well. If not, it has to be modified.

2. **Map or create best practice manufacturing processes for the features.**

   2.1. Once more industries have been investigated and new generic features identified, it is time to proceed to the second phase of the long-term objective, the best practice solutions. The first action would be to collect the best practice solutions available and, if possible, link these to specific features.

   2.2. For the features where no best practice solution can be found, these have to be evaluated in regards to if it is feasible to create solutions for them. If so, the solutions can be developed, starting with the features considered to be the most important.

3. **Further evaluate the Wiki for the purpose of storing, distributing and presenting knowledge internally.**

   3.1. The Wiki is believed to be a very useful technology for managing knowledge. In this project features have been implemented in the Wiki, but it can suggestively be used for other kind of knowledge as well.

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Appendix A: Market Assessment

The purpose of the market assessment is to assess the feasibility of the *Generic Standard Feature* project. The case aims to identify current market trends, what business opportunities exist and present risks that must be taken into consideration. A PEST analysis will identify trends in the environment, looking at the big picture, while a SWOT analysis will focus more on the attributes of the project team and organization. Furthermore, a brief competitor analysis will be utilized in order to find out if there are similar products or research out there.

A.1 PEST Analysis

A PEST-analysis assesses a market in terms of trends including competitors from the standpoint of a particular proposition or a business. The analysis itself includes four areas of interest that are to be covered, these being:

- Political
- Economical
- Social
- Technological

The long term objective of this project is for Sandvik Coromant to achieve a generic feature library containing standard features across all active market segments. In a short term perspective this Master's Thesis is delimited only to include the market segment Aerospace. For this reason, the PEST-analysis conducted will include trends only concerning the Aerospace market.

A.1.1 Political forces

- Facilitates a global economy
- Further liberalization
- 60 year old rules
- Open skies
- Increase safety
- Increase environmental awareness
- Increase efficiency
- Promote collaborations
- Incorporation and development of standards
- Internal policies

The Aerospace industry connects virtually every corner of the world together and has vastly contributed towards creating a global economy. Being an international trade there are many political forces present. Air transport is currently being governed by a 60 year old set of rules, the bilateral system. There has been a degree of deregulation targeting specific regions and routes, where for instance the "Open-Skies" agreement between the US and EU is considered. However, only 17 % of international air traffic is currently conducted in a liberalized operational environment. (IATA, 2007)

A.1.1.1 Further liberalization

The Airline industry is still experiencing a liberalization taking place. As new airlines enter the market, airports are being planned, build or renewed this constantly alters the current situation where certain airlines within different regions have access to different hubs or airports. This entire situation is under discussion and further liberalizing the market is expected to come with several benefits.

Lower prices, increase in output and choice as well as service quality are some of the factors that the organization IATA have concluded when mapping the results of previous liberalized industries. The bottom line is that even though there are benefits to be gained, further liberalizing the airline industry will not be seamless but possible and also necessary in order to maximize potential profits within the industry. (IATA, 2007)

A.1.1.2 Organizations and governments within Aerospace

Organizations and associations committed to the Aerospace industry are present within United States industries, the European Communities industries or internationally. Most of these organizations and associations are driven by members within the Aerospace industries and act either as a bridge between governments and the industry or attempt to connect the members within the industry. Focal points of interest that can be considered as trends within these organizations and associations are:

- Increasing safety
- Incorporation and development of standards
- Increase environmental awareness
- Increase efficiency
- Promote collaborations

Apart from the previously mentioned organizations and associations, there are organizations of great importance without any specific connection to the Aerospace industry. One of these is WTO (World Trade Organization), a rule-based, member driven organization dedicated to supervise and liberalize international trade.

A trend that has been stirring up within the past years concerns subsidies. Governments from the United States and the European Union have passed accusations towards one another regarding subsiding Boeing and Airbus respectively in a manner not conformant with WTO rulings. The results of these accusations are still to be determined, however conclusions can be drawn that organizations such as the WTO play an important role when dealing with international trades such as aerospace.

A.1.1.3 Airline policies

A widely spread trend across the airline industry is the dedication towards the environment. It is no secret that a vast amount of fuel is needed to power an aircraft; this is an issue that airlines are addressing in a variety of manners.

The airline company SAS for instance promote the option to compensate for carbon dioxide emissions and are currently undertaking a project called “green letdown” where aircraft engines are turned off for the last part of the flight, saving up 100 kg of fuel. (SAS, 2012)

SAS is not in any way secluded when it comes to identifying that an environmental approach is necessary within this market. Several if not every company within this market such as Lufthansa, Continental or KLM just to mention a few, have come to adapt some sort of environmental strategy in order to achieve a sustainable approach towards air travel.

A.1.1.4 Efficient and green producers

Many of the major producers within the Aerospace industry, whether they be present within the civil or military segment have realized that efficiency in terms of fuel consumption is an essential aspect of the future. Increasing the efficiency of engines, reducing weight of structural components and obtaining environmentally sustainable plans is a trend that shines clearly when looking into this market.

A.1.2 Economic forces

- Recovering from a global recession
- Speed of recovery underestimated
- Increasing prices for fuel
- Shortage of qualified labor in future
- Issues receiving credits and loans
- Predicted economic growth in underdeveloped countries

The global recession dating back to the year of 2008 struck hard against the Aerospace industry. In some terms the depth of the economic downturn within the industry and the speed of recovery were both underestimated. Currently the industry has recovered even though profits are lower than previously.

A.1.2.1 Rising prices for jet-fuel

Fuel is one of the largest operating expenses incurred by the aviation industry, followed by labor. A trend throughout the past years is the increasing cost of acquiring jet fuel. Looking back only a couple of years, the cost of crude oil of jet fuel has nearly doubled; causing profits within the industry to decrease if not prices are altered. This increase in price stresses the fact that aircrafts need to be more efficient in the future and something that manufacturers need to address. (AIA, 2010)

A.1.2.2 Shortage of engineers

Having a skilled and qualified labor supply is an essential part of being competiveness within the Aerospace industry as well as any other industry for that matter. Presently there are worries regarding the supply of qualified engineers in the future, something that has emerged as an important issue not only within Europe or the US but in all mature industrialized countries. (EC, 2009)

A.1.2.3 Difficult to receive loans or credit

Coming out of a global recession have changed the sales market and funding terms within the Aerospace industry. A consequence of this is the difficulty for companies within the Aerospace industry to receiving credits or loans to further invest into their business.

This has scenario where aircraft manufacturers are unable to invest in order to remain competitive has been dampened by government support. Governments within both the US and Europe have either sustained or increased export credit guarantees. (EC, 2009)

A.1.2.4 Projected economic growth in underdeveloped countries

According to most manufacturers of aircrafts as well as airlines, worldwide economic activity is the most powerful driver in terms of growth within commercial air transport, resulting in an increased demand for aircrafts. Boeings publication; *Current Market Outlook* projects that the global gross domestic product (GPD) is bound to grow with 3.3 % in average for the next 20 years to come. To meet the increased demand for air transportation this implies that the number of aircrafts available to the worldwide fleet would need to be doubled from the current 19400 airplanes to more than 39500 airplanes in 2030. (Boeing, 2011)

These predictions are shared with other companies within the Aerospace industry as well, growth is predicted across almost all companies, and however the exact figures vary.

A.1.3 Social forces

- Globalization
- Growing demand for air travel
- Environmental options
- Expanding global middle wealth
- Unemployment
- Pricing

In general the world is shrinking, the human population continues to grow and in pace with the constant increase in terms of globalization so does the urge to travel and explore. Air transport can be broken down into several categories, the most common being civil, business or military. Addressing business and yet again pointing out globalization, business now a day takes place all over the world creating a demand of transportation that needs to be satisfied.

A.1.3.1 Environmental options

To most extent, commercial airlines today offer the option of compensating for emissions. This applies both for civil as well as business travels. On top of that, companies outside of the Aerospace industries have internal policies addressing environmental aspects.

The bottom line is that there is awareness present regarding the environment. This applies pressure towards companies acting within the Aerospace industry regardless of them supplying products or services to act accordingly to what the public opinion wants them to.

A.1.3.2 Expanding global middle wealth

In a press conference held by the aircraft producing company Airbus, *Delivering the future 2011-2030* it is stated that the global middle class is expected to rise to 4.9 billion people by the year of 2030. Airbus considers middle class to be a household with daily expenditures between 10 and 100 dollars. The area of Asia-Pacific will grow the most according to this prognosis and constitute for 66% of the global middle class in the year of 2030. The main driver for this economic growth is the urbanization taking place and continuing to increase. (Airbus, 2011)

A.1.3.3 Unemployment remains the same

Coming out of a recession, global unemployment basically remains unchanged. This elevated level of unemployment stands in stark contrast to the recovery seen in indicators such as real global GDP, private consumption and world trade.

Recovering from the recession has been uneven throughout different markets. Most of the developed countries seem to be experiencing a slight rise in terms of unemployment, while underdeveloped countries have a steady increase in employment. (ILO, 2011)

A.1.3.4 Ticket prices

The process of deregulation and liberalization within the airline industry has triggered consumers to question and demand prices within the industry. The introduction of low-fare airlines has had a great impact on the pricing as well as expectations regarding prices. Consumers are simply aware that there are airlines that can provide a service at a lower cost; this has introduced a larger spread competition between airlines.

A.1.4 Technological forces

- Technology driven industry
- Weight reduction
- New materials
- Machining technology
- Competing technology
- New aircrafts

The Aerospace industry is highly technology driven. A trend the past years that has been affecting the development within the industry is weigh reduction. Manufacturers and OEMs attempt to reduce weight to the furthest amount possible on practically all components, this in order to increase efficiency and increasing fuel economy.

A.1.4.1 New materials

Aerospace is an ever-changing industry; factors such as fuel prices or government funding have long been market drivers, but always out of reach when attempting to increase profitability. Thinking beyond these limitations materials are an aspect that can be altered. Within the past years more new materials or alloys have been used within the Aerospace industry. Especially the use of carbon-fiber-based composite materials has been increasing within the industry, and with this comes the difficulty of how to machine these new materials.

A.1.4.2 Machining technology

Manufacturers within the Aerospace industry are turning towards high-temperature materials that have the capacity to increase engine performance, boost thrust, improve fuel efficiency, reduce noise and meet safety standards, all while reducing manufacturing costs. Materials are harder, stronger, tougher, stiffer and more resistant to corrosion.

Although these materials possess significant amounts of benefits, the downside is that they are impossible to machine using conventional methods. (Dolan, 2011)

What this implies is that knowledge in terms of manufacturing needs to be developed and spread across the industry. Companies such as Sandvik Coromant not only develop tools that are to function in certain materials, but the knowledge of how to process as well.

A.1.4.3 Low impact of competing technology

As of current aircrafts are the most common means of transportation when travelling further distances. This monopoly in terms long distance travels does not seem to be threatened any time soon by emerging technologies. In fact the only aircraft manufacturing company that has taken this threat under consideration in their market prediction is the manufacturing company Rolls-Royce. In their market outlook they identify high speed rail as a technology that might be a potential threat within longer domestic travels. However Rolls-Royce only identifies high speed rails to make up 2% at most of this market segment. (Rolls-Royce, 2011)

A.1.4.4 Demand for new aircrafts

Aircrafts in service within mature markets such as the US or EU are becoming dated in terms of technology. Keeping up with regulations and reducing fuel consumption implies that some of these aircrafts will need to be replaced. (Airbus, 2011)

A.2 SWOT Analysis

The SWOT analysis identifies strengths, weaknesses, opportunities and threats for the Generic Standard Feature Library to be developed. For the strengths and weaknesses internal factors are considered, while the opportunities and threats deal with external trends.

A.2.1 Strengths

- The company already distributes knowledge as a part of their product.
- Digital tools for distributing knowledge do already exist within the company.
- The library will reduce the time for optimizing and planning the manufacturing process.
- Since the library will ensure that the most suitable tools and processes are used, customers can obtain a higher productivity.
- The library creates a consistency for how certain features are manufactured, securing the quality of the service delivered to customer.
- The library increases the internal efficiency as optimization for machining of standard features only has to be conducted once.
- The library is accessible and easy to use.

A.2.2 Weaknesses

- Targeted users might be reluctant to use the tool.
- Employees are unwilling to “give away” their knowledge.
- Difficult to match each feature with a manufacturing process.
- A large amount of features can make the system complex and difficult to use.
- The feature names are fussy and confusing.
- If the library is not updated regularly and always kept up to date, it might be deceptive.
- It is possible to abuse the system, resulting in bad decisions regarding process and tools.

First off, a great strength is the fact that Sandvik Coromant possesses the knowledge required to create the intended system. The know-how regarding what processes and tools to use in different situations is huge within the company, so if this knowledge can be elicited and implemented in the system it has the potential to be very powerful. Additionally, Sandvik Coromant today already distributes a large amount of knowledge as a part of the product that they are selling. Knowledge on machining is distributed through catalogues, web applications, desktop software and mobile devices. This trend has been going on for a couple of years and will support the development this project, both in terms of willingness to distribute knowledge and the belief in digital tools for doing it. The available resources do not only exist within the company, but also in the form of customers. Since the customer base is very widespread, ranging in type of industry, company size and products manufactured, the customer input can contribute to a very generic feature library.

A successful system will be able to reduce the time for optimizing and planning the manufacturing process for customers as it provides an easy-to-use tool for selection of the “best-practice” machining process. If the system is used, and the right tools and processes are selected, an increase in productivity can be obtained as well.

As for now there is no method at Sandvik Coromant to ensure that specific features are machined in a certain way, it all depends on who is handling the specific case. This leads to different approaches to similar problems, some which are better than others. The fact that Sandvik Coromant and their customers are so very geographically spread makes the problem even more difficult to solve. This is however addressed by the system as it secures the quality of the service that each customer is given by storing and distributing the "correct" knowledge. As the most common features are identified, this tool will also ensure that there actually exist "best practice" processes for each and every one of them.

In terms of weaknesses there might be some reluctance to use the new system. People might not trust it, or they feel omitted since the system can "do their job". In order to solve the issue, it will be important to stress that the system can work as a support to their tasks, hence make them a lot easier. Related to this issue, there is also a risk that people will not be willing to put their knowledge into the system as they feel they do not trust the product, or that they might lose their value in the company.

Since the amount of features used in products that Sandvik Cormorant's customers manufacture, problems might arise if features that are not standard, i.e. in this case that they occur in several different products or in large quantities, are put in the library. If that is the case it will be impossible to match each feature with a manufacturing process, basically because there are too many and that the process depends on so many factors, e.g. material, machine, the component hosting the feature etc. The same problem can be a consequence of the features being too basic. In order to be able to connect it to a specific process it has to carry a certain amount of information.

When it comes to the naming and classification of features, there might be an issue if the features are many and the names are unclear. The library can become very complex and users may confuse features, or not find them at all. The fact that there are no standard for naming features means that some users might not recognize some of the names, while others do.

If the system is not used properly, for example if the wrong feature is chosen from the library, it can result in poorly made decisions for how to machine a certain part. This might generate costs in terms of both economy and time.

A.2.3 Opportunities

- The required knowledge exists and is available within the company.
- Aerospace industry will grow.
- More competition creates need for better processes.
- New CAD/CAM systems allow for advanced feature recognition.
- There exist no similar libraries in the industry today.
- The technology to develop a solution like the intended does exist.
- Sandvik Coromant's many customers in different industry segments can contribute to a wide range of features, allowing for a generic library to be built.

A.2.4 Threats

- Changing processes and technology can outdate the feature library content.
- There exists no standard for how to classify and name features.
- Difficult to receive loans or credit for aerospace companies.

One of the largest and most significant trends identified in the PEST analysis was that the aerospace industry is forecasted to grow in the near future. There are several reasons for this, whereas three are more prominent. First of all, an economic growth is projected in underdeveloped countries. This means that countries that have not had the resources to manufacture airplanes, will now be able to. Furthermore, the middle wealth class is expanding. Today, and in the future, more people than ever before are flying all over the world. Lastly, certain aircraft segments are very mature which result in a need for replacing a large amount of the aircrafts within that segment. At the same time, reports states that there will be more competition on the market.

The fact that the aerospace manufacturing industry will grow, at the same time as the aerospace manufacturers need to cut costs because of the competition, implies that there is an opportunity to develop an application that make the manufacturing process more efficient.

Another opportunity lies in the modern CAD/CAM systems. As they are equipped with more functionality, particularly feature recognition and feature based manufacturing functions, there are now possibilities to use the software in new way. By combining the feature recognition and feature based manufacturing parts of the software with a feature library, the time for CAM programming can be reduced.

The largest threat found is that the processes and technology are always changing. For the system to work as a base for decision making it is crucial that it is updated on a regular basis, adding new features as well as feature based solutions. Since the industry and technology constantly changes, so must the system. Otherwise it will be outdated and might lead to costly errors.

A.3 Competitive Assessment

For the competitive assessment two different aspects are considered. The first one is the competitors of Sandvik Coromant, i.e. other suppliers of machine tools and manufacturing know-how. These suppliers will be investigated in order to find out if they provide some similar product to the one to be developed. If so, it is of interest to find out how it performs and is designed. The second part of the competitive assessment will study CAD/CAM suppliers that offer solutions for feature-based manufacturing.

A.3.1 Machine tools suppliers

As for now there seems to be no machine tool supplier providing a tool that does what the product to be developed is intended to do. In this study, none of the bigger competitors to Sandvik Coromant appears to offer a similar product. Seco Tools provides tool and process recommendation based on different applications, but these applications are nowhere near as specific as a standard feature defined in this project.

A.3.2 CAD/CAM suppliers

Several of the largest developers of CAD CAM software offer some form of feature recognition or feature based CAM. The different solutions are pretty much the same, where the software can recognize certain features and produce tool paths from that information. The issue with these solutions is the fact that the defined features in the software are too simple. Since the CAD CAM suppliers do not have the know-how regarding how to optimize the machining of more complex features, nor do they have a library with such features, their present solutions only includes the simplest of features (e.g. plain holes and pockets). If the systems could integrate more complex features, each with a corresponding ‘best-practice’ machining process, they could very well be powerful tools to automate the CAM process. Today no one seems to have gathered such a list of features and connected them to a machining process though.

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Appendix B: Use Scenarios

B.1 Use Scenario A: Internal use

Internally the application can function as a guide for CAM programmers, specialists, service people or operators, but it can also be used for education purposes.

B.1.1 Use Scenario A1: Store and distribute knowledge internally

When an employee of Sandvik Coromant for some reason needs any knowledge regarding a specific feature, this application can provide this. For example, when a CAM programmer encounters a design feature that he/she is not familiar with, the application can be used as an encyclopedia. The programmer can find the corresponding feature in the application by navigating through a feature structure or by searching for the feature name. When the desired feature is selected, the application will show the best-practice manufacturing method, including tools, operations, tool paths etc. The programmer can then use that information in order to proceed with the CAM model, confident that the best-practice method is used. Almost all employees that for some reason need any information on features or something related to features can benefit from this system. In the future, even more functionality could be built in to the system. For instance, previously conducted projects including certain features can be linked to these features.

For this use case scenario, the systems main purpose is to store, present and distribute knowledge regarding features within the company. The importance of a method or tool to manage knowledge cannot be stressed enough. The users are in this case difficult to clearly define since the system is supposed to be used by all employees that could be in need of knowledge related to features, for instance CAM programmers, operators, service people, specialists etc.

B.1.1.1 Stakeholders

- CAM programmers
- Operators
- Service people
- Specialists
- Other employees in need of feature knowledge

B.1.1.2 Summary Scenario A1

In order for this scenario to be beneficial the application needs to be easy to use and provide a quick way to find the desired knowledge. If the application were to be used as described above it would not only decrease the lead time, it would also ensure that verified manufacturing methods are used every time.

B.1.2 Use Case Scenario A2: Education material

The application can also be used for education purposes. The learning process for new recruits takes time, by offering an application storing and easily providing features and their best-practice solutions the learning time can be reduced. The application can also be used to update employees on new machining processes and features.

B.1.2.1 Stakeholders

- Educators
- New recruits
- Other employees to be educated

B.1.2.2 Summary Scenario A2

This use case scenario might not be the main purpose of the application to be developed, but nevertheless could it be powerful for education. The application can be used as an interactive learning tool, allowing employees to learn by them self.

B.2 Use Scenario B: Internal and external usage

The second Use Scenario is oriented towards including customers, hence taking an external approach. It can be considered as a result of a short term effort that could be introduced within a near future.

B.2.1 Scenario B1: Communicate externally

This scenario implies two or more stakeholders interacting, where one of them is to be a customer. The Sandvik Coromant stakeholder has a tool of some sort that can further explain the importance of using proper cutting technology. The tool acts as a visual and textual aid and might simplify the process of making one understood as well as giving more credibility to the Sandvik Coromant stakeholder. Using a tool does not imply that the Sandvik Coromant stakeholder is uncertain or unaware of the suggested best-practice solution; the relevant part is whether or not the customer perceives the information as trustworthy.

There is a need for a tool that does not mean that customers have to take Sandvik Coromant stakeholders word, they have the confidence that the entire company is behind these solutions. In order for the tool to be as effective as possible, it requires that it be portable, simple and visual. A tool like this would also function as an easy-to-use encyclopedia for when the Sandvik Coromant employee is in need for knowledge he or she does not have. This scenario has been elicited from discussions with the intended users, i.e. customers, salesmen, experts and customer representatives, who have been stating the need for something similar.

B.2.1.1 Stakeholders

- Sales persons
- Customer representatives
- Yellow coats
- Customer

B.2.1.2 Summary Scenario B1

In order for the tool to be as effective as possible, it requires that it be portable or remotely accessible, simple and illustrative. It could in that case provide a mediating tool supporting employees of Sandvik Coromant working close to customers.

B.2.2 Scenario B2: Customers gain exclusive access

The intended library including Sandvik Coromants best practice solutions is distributed to customers of choice. These customers then have complete access in terms of how to best utilize Sandvik Coromants tools in different applications. The customers are then free to distribute the library internally for purposes similar to the ones stated in Use Scenarios A.

This scenario comes with risks, first and for most the best practice solutions are to be considered to be a rule of thumb. If customers believe that all of their processes that are conformant with these guidelines should be perfect, issues might occur where the customer holds Sandvik Coromant responsible. Secondly, although Sandvik Coromants best practice solutions for specific features are designed to be used along with Sandvik Coromant tools, it is most likely that a competitive company has an offering of tools that could act as a substitute. In this case Sandvik Coromant would have given away a part of the advantage towards that competitive company in terms of selling tools for that application.

B.2.2.1 Stakeholders

- Sandvik Coromant
- Customer

B.2.2.2 Summary Scenario B2

This scenario does not seem viable since it simply isn’t beneficial for Sandvik Coromant giving away knowledge that gives them an edge compared to customers. It does raise the question concerning how the intended tool is to be distributed without compromising a breach of security that the information be accessed outside of the company.

B.3 Use Scenario C: Long term CAD/CAM implementation

The third Use Scenario aims to address the implementation of a standard feature-based taxonomy into a CAD/CAM system. This scenario can be considered long term compared to the first two scenarios.

B.3.1 Scenario C1: CAD/CAM implementation

As of a couple of years back, a technology called feature recognition emerged within CAD/CAM. In general this implies that CAD/CAM software has the capability of recognizing features in an early design phase. The software however needs to have a frame of reference in terms of what features to identify. This third scenario implies that Sandvik Coromant compiles features that occur amongst their customers within different market segments. These features along with the best practice solutions that go along with them can then be implemented on top of ordinary CAD/CAM software. The best practice solutions would have tool-paths automated and could possibly include a tool selection process.

This allows CAD/CAM programmers whether they be internal or customer to optimize a manufacturing solution from an early state. In doing so, focus can be directed where truly specialized efforts are needed and the reoccurring features are handled automatically.

B.3.1.1 Stakeholders

- Sandvik Coromant
- Siemens
- CCAM
- Customer

B.3.1.2 Summary scenario C1

Compared to previously mentioned scenarios, the CAD/CAM implementation is of a long-term character. Achieving the intended outcome is most likely to require collaboration amongst CCAM stakeholders such as Sandvik Coromant, Siemens, Rolls-Royce, etc. If achieved it would serve as a powerful tool allowing for reduction of time within fields such as design, production planning and hence overall development cycle times.

A thoroughly crafted ontology compiling standard features among Sandvik Coromant customer's needs to be created in a universal language for different developers and systems to understand. The media of choice would be a CAD/CAM system of some sort, most likely Siemens due to the CCAM collaboration.

Appendix C: Customer interviews and Site visits

The different companies visited are listed below together with a short description of the company along with the key findings from the visit.

C.1 Company A

Company A conducts its business within the aerospace industry. As of a couple years back, they have transitioned from being a devoted subcontracting company into a company conducting its own research. The company works actively within the fields of KBE, a number of supportive applications have been developed, facilitating design and process planning by implementing standardized knowledge into CAD/CAM software.

Visiting Company A, two separate interviews were conducted. These interviews ranged from 30 minutes up to three hours.

Key Findings

Being a subcontractor, Company A has experienced a variety of components and hence features from different OEMs. They predicted that defining features as standard would be difficult due to interpretations differing in terms of name and function, from manufacturer to manufacturer.

Looking at the KBE applications developed by Company A, these have targeted smaller subsets rather than entire systems. In short, the visit provided further knowledge and a real life example as of how a KBE application could be developed.

C.2 Company B

Company B is a subsidiary of one of the world's largest corporations. Within the aerospace industry they are considered to be the top global supplier of aircraft engines. The site visited manufactured aircraft engines in a variety of models and materials for different intended aircrafts. Company B experience with features includes breaking down components into features in order to map adjoining manufacturing techniques, later reusing this knowledge on other components. The newly established factory that was visited only focused on production planning and manufacturing while an off-site center handles the designing aspects.

Company B provided a site visit lasting for approximately three hours. Questions were asked during the visit and afterwards two interviews were conducted lasting 30 minutes each. In association with visiting Company B, the local sales representative from Sandvik Coromant was also interviewed, this lasted 2 hours.

Key Findings

As components were deconstructed and explained, this enlightened the understanding in terms of what functions certain features intend to fulfill. Listening to employees also shined a light as to how Company B approach features, defining them according to what level of detail and also some terminology.

Key features where discussed and explained what makes these features difficult to manage, both from a manufacturing and design point of view. Further a discussion with Company B representatives regarded the intended application from Sandvik Coromant. This provided input for desirable functionality and areas that could be focused upon.

C.3 Company C

Company C differs from other companies visited due to the fact that their target industry is not aerospace. They target the energy industry for which they manufacture products such as wind turbines. The site visited was a manufacturing facility, however the company was not restricted to manufacturing and assembling alone, they also conducted product design, development and process planning on site.

The visit provided a tour around the facility lasting for approximately 2 hours during which questions were asked. A short interview was also conducted ongoing for 45 minutes. In association with visiting Company C, the local sales representative was interviewed, this lasted 1 hour.

Key Findings

A complete tour around the manufacturing facility was conducted in which components were broken down into features and discussed. Comparing the components with engine-component within the aerospace industry, similarities in terms of feature appearance and function were extensive. Although many similarities were identified, aspects such as magnitude of size and component requirements differed from the aerospace industry.

Visiting a non-aerospace facility provided experience of how components and features across industry segments can be similar. The visit gave further insight in how features could be identified and structured making them generic and also raised the question as to how similar features should be categorized separating size as an issue.

C.4 Company D

Company D is a top global actor within the aerospace industry, mainly focusing on the development and manufacturing of engines. Prior to this project, Company D has conducted research of their own attempting to device a repository of features. Development was ongoing for a long period of time until the project was shut down without reaching the point at which an implementation into any applications could be done.

The visit contained an interview lasting 2 hours and a tour about a new research facility where further questions were answered; the tour lasted for 1 hour.

Key Findings

The interview was conducted with Company D representatives having experience from their prior approach towards features. Discussions were held regarding learning outcomes based on their experience, providing the much important aspect regarding what level of detail features should be identified at and implications of what could happen if this not be abided to.

Company D provided their input regarding aspects needed to be included in future applications. The applications in mind target Sandvik Coromant long-term objective of CAD/CAM implementation rather than the outcome of this project. Concerning the long-term objective, Company D believed that any feature repository must be included in a PLM system of some sort.

C.5 Company E

Company E is a joint venture established by one of the world's largest aircraft manufacturers and a European University. The venture focuses on advanced manufacturing research within the aerospace industry among others. Limited research has been conducted regarding features, however these studies primarily targeted manufacturing. A machining facility is present, where a big part of the research conducted aims to identify new ways of manufacturing aerospace components.

The visit to Company E lasted in total for three days. During the visit, the facilities were toured twice and three interviews were conducted. The tours lasted approximately 2 hours and the interviews ranged in duration from 20 to 45 minutes.

Key Findings

A tour of the facilities provided the opportunity to observe and ask questions regarding components and features. Some features that previously had been unidentified were observed and described. Difficulties and key operations within manufacturing of features were looked upon in detail.

Interviews were also conducted concerning features and the intended repository of feature-knowledge. During these interviews, insight and recommendations were provided based upon working from a manufacturing point of view with features.

Appendix D: Interview Guideline

The interview guideline suggests a semi-structured approach to discussions with both customers and Sandvik Coromant employees. Below are the main areas of discussion listed. These are supposed to be used as guidelines, keeping the free discussions on track.

- What features are common?
- Which features are difficult to machine? Which are simple? Why?
- In what situations would an application like the intended (*Explain*) be useful?
    - Where?
    - When?
    - By whom?
- What kind of features would be the most beneficial to incorporate in an application?
- How could generic standard features in the future be implemented in a CAD/CAM system?
    - What value would it bring?