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An Investigative Study Of Patents From An Engineering Design Perspective

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AN INVESTIGATIVE STUDY OF PATENTS FROM AN ENGINEERING DESIGN PERSPECTIVE

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
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Master of Science

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ABSTRACT

Preservation and reuse of valuable design experience aids in the design of new products and processes. Product design repositories are presently being used as a means to preserve and later reuse design knowledge. As such, patent databases such as the United States Patent office and the European Patent Office offer design knowledge in the form of patents. Unfortunately, these sources of novel design solutions do not appear to have been effectively used in the context of engineering design.

In this research, the role of patents in a systematic design process is reviewed to understand its utility in the design process. A major hurdle, in the reuse of patent design knowledge, is the lack of formal tools to support designers in understanding and applying the available information to new problems. Information theory fundamentals are used to study patent claim text, which describes the subject matter of the patent and to develop an understanding of the information content within the text claim and other representations of the claim.

Graph based representations are recognized as an effective way to represent design information. They are considered as ideal for modeling patent claims as they enable the direct use of the information as input to existing design processes and tools, such as function models, the core product model, and function-behavior-structure scheme. This new approach provides a designer-friendly model of patent claims and also enables the use of intelligent search mechanisms. Existing graph based product representation schemas are studied for their suitability to model patent claims. A new representation tailored for patent claims is proposed since, the existing
schemas where found to be insufficient to efficiently model patent claim. Patent claims modeled using multiple representation schemas are compared with the models developed using the proposed representation, for the information content captured from claim text.

The representation technique proposed here may aid in the retrieval of the relevant patent design information, thereby promoting use of patent information to aid designers. Further refinement and evaluation of the scheme along with the development of grammar and ontologies for a vocabulary is needed. This representation scheme, with existing search and retrieval methods, should help designers in generating both novel and practical concepts based on patent information.
DEDICATION

I dedicate this work to my grandparents, Mum, Dad and everyone back home in India. This work was possible due to their love, support and enduring confidence.
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Chapter 1.

INTRODUCTION

Patents are an important document with regards to intellectual property. These documents have been used over the years as a showcase of the technological progress of a company. These documents have been in origin since the 1400s. This chapter presents a brief history regarding the origins of the patenting system. It takes a look at patents as a document concerning engineering design and studies the sections that make up a patent. This chapter studies the patents document, as a part of the systematic engineering design process. Most importantly, this chapter presents the motivation for a new approach to representing the information found in patents from an engineering design perspective.

1.1 Introduction to patents

The following section provides an overview of the patents, with regards to their origin and the different components that form the fundamental structure of patents from around the world. The classification scheme currently used to sort the vast number of patents with regards to the United States Patent and Trademark Office (USPTO) is also discussed.

1.1.1 Background

Patents represent a form of intellectual property rights for an invention, granting exclusive rights for the invention to an individual or a group for a fixed period. The government, in exchange for public disclosure of how the invention works, grants these rights. In the United States, the patent rights are granted to the inventors for duration of 20 years from the date of application (USPTO, General
Information Concerning Patents, 2005). The patent gives inventors the right to exclude others from making, using, offering for sale or selling the invention. In principle, patents date back to the Renaissance era and are believed to have descended from ancient Greece.

The system of patents as understood today, was established in England in 1449, when King Henry VI awarded a exclusive rights to John of Utynam for stained glass manufacturing (Ganguli & Blackman, 1995). Patent laws have since been incorporated in various countries. The patent laws govern the conditions for patentability of inventions and specify the subject matter for which a patent may be obtained. The patent law states that a patent cannot be obtained on a mere idea or suggestion. The patent is granted on the new machine, manufacture, or process but not on the idea or suggestion of the new machine. A complete description of the actual machine or other subject matter for which a patent is sought is required during the patent application process. This makes the patent databases, a continually updated source of knowledge concerning products, processes, and technology in general (Carr, 1982; Walker, 1995; USPTO, General Information Concerning Patents, 2005).

The patenting system in the United States was initially introduced to advance sciences and technology by enabling, inventors to store, share, and promote ideas, by granting them property rights to their inventions for a specified duration. This intent can be seen in Article I, Section 8, Clause 8 of the Constitution of the United States of America, “The Congress shall have power …to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive right to their respective writing and discoveries”. However, it seems that most industries no longer consider patents to be a significant means of protecting their innovations in
comparison to trade secrets and being the first to market (Cohen, Nelson, & Walsh, 2000).

The United States Patent and Trademark Office (USPTO) broadly differentiates patents into three types based on the invention that is described in them. These three types of patents are as follows (Carr, 1982; USPTO, General Information Concerning Patents, 2005):

- Utility patents, which are granted for inventing or discovering any new and useful process, machine, product etc and useful improvement of the same.
- Design patents, which are granted for inventing a new, original, and ornamental design for a product.
- Plant patents, which are granted for inventing, discovering or asexually reproducing any distinct or new variety of plant.

Patent applications in industry generally precede the commercial release of the technology thereby ensuring that the company can share the knowledge about the product or the process while safeguarding their commercial gains from the product. Thus, typically the patent is a product document that is written after completed production, and operating documents (Pahl & Beitz, 1996). An important aspect of this document is that critical knowledge about the product or process has been acquired before the patent document is compiled. Hence, the patent becomes an important record of the different activities, decisions, or rationale that were executed or developed during the project life.
1.1.2 **Components of a patent.**

Patents document are intended for people skilled in the trade to reproduce the invention with information found in the patent. The components address different roles of a patent document. The fundamental components that can be found in patent documents in general include: claims, descriptions, and related work.

1.1.2.1 **Claims**

The claims are short descriptive statements that clearly claim the subject matter of the invention. The claims form the basis of distinguishing the invention from prior inventions and define the parameters relating to the invention. These form the basis of the evaluation of a patent application. The claims define the scope of the invention, thereby identifying the devices or components that would be covered under the patent monopoly. They claim usually describe the components in a means and functions structure, which permits the adoption for further technological progress. Claims form the most important legal component of a patent, as the infringement cases surround the claims rather than any other section of the patent. Some claims, describing the operation of a controller for an automatic bicycle transmission, from a patent can be seen below (Satoshi & Kazuhiro, 2007):

> 'What is claimed is:

1. *A control apparatus for an electrically operated bicycle transmission that has a plurality of gear ratios, wherein the apparatus comprises: a running condition time sensor that senses a time interval of a running condition of a bicycle; and a control unit operatively coupled to the running condition time sensor, wherein the control unit provides a signal to operate the bicycle*
transmission to move to a predetermined gear ratio when the time interval of
the running condition passes a selected value.

2. The apparatus according to claim 1 wherein the selected value of the
time interval is greater than or equal to five minutes.

3. The apparatus according to claim 1 wherein the running condition
comprises a velocity of the bicycle.

4. The apparatus according to claim 1 wherein the running condition
comprises a crank rotation speed.

5. The apparatus according to claim 1 wherein the predetermined gear
ratio includes a ratio of crank rotation speed to wheel rotation speed in a range
of from approximately 1.2 to approximately 1.5.’

1.1.2.2 Description of process or product to be patented

A written description of the invention is to be provided in the patent applicant.
This description is useful to understand the complete workings of the invention. It
contains details about the invention, which do not form part of the claims. The
product details pertaining to the relation with the previous inventions can also be
found in this section of the patent. This part of the patent holds information that is
relevant for a person who is “skilled at the trade to practice the invention”.

‘FIG. 1 is a side view of a particular embodiment of a bicycle 1. Bicycle
1 is a light roadster recreational bicycle comprising a double-loop frame body
2 formed from welded tubes, a front fork 3 mounted to the frame body 2 for
rotation around an inclined axis, a handlebar assembly 4, a drive component 5,
a front wheel 6 on which an alternating current generating dynamo hub 8 with
brakes is mounted, a rear wheel 7 on which a bicycle transmission such as an internal shifting hub 10 is mounted, a saddle 11, a shift control unit 12 to control shifting of the internal shifting hub 10, and a shift controller 20 for operating the shift control unit 12.

The handlebar assembly 4 comprises a handle stem 14, fastened to the upper part of the front fork 3, and a handlebar 15 fastened to handle stem 14. Brake levers 16 and grips 17 are mounted on both ends of handlebar 15. In this embodiment, shift controller 20 is integrated with the right-side brake lever 16. Drive component 5 comprises a crank 37, mounted on the lower part (bottom bracket component) of the frame body 2, and a chain 38 that engages crank 37 and internal shifting hub 10. Internal shifting hub 10 is capable of producing four gear ratios (gears). These four gear ratios can be selected by means of a motor unit 29 (FIG. 4) in shift control unit 12. The dynamo hub 8 of front wheel 6 can be fitted with a roller-type front brake, and it houses an alternating current generating dynamo (D) 19 (FIG. 6) that generates electricity in response to the rotation of front wheel 6. As shown in FIG. 3, shift control unit 12 is electrically connected to the alternating current generating dynamo 19 housed in dynamo hub 8 by electrical wiring 40, and it is electrically connected to shift controller 20 by electrical wiring 41. Shift control unit 12 is mechanically connected to internal shifting hub 10 by a shift control cable 42.

1.1.2.3 Record of a relation present work with previous work

Patent applicants are required to incorporate their study of previous work done in the area of the invention prior to filling the application. The section relating to the
previous work is useful in understanding the prior approaches to the problem addressed by the invention.

In addition to these fundamental components, patents contain information that aids in a better understanding of these components. For example, figures and diagrams are used to explain the claims and the solution principle of the invention. Some of the information that can be found on the front page of a patent, which includes information related to organization of the patent within the database, can be seen in Figure 1.1.
Figure 1.1: Patent front page: Title, Inventor, Application Number, Date Filed, Authorizing Country, Subject Index, Benchmark Patents, Abstract (Satoshi & Kazuhiro, 2007)
These fundamental components of a patent resemble some of those of a technical publication. For example, the prior art, mentioned in a patent is analogous to the previous work section found in technical publications. Both patents and technical publications present novel solutions to problems. The description of problem, that is found in both the patent and technical publication forms the basis of solution concept presented in the subsequent sections.

1.1.3 Patent classification scheme

The USPTO uses a classification system to sort and organize the large database of patents. The United States Patent Classification (USPC) system is used for organizing the patent documents based on common subject matters, established in mid 1800. The earliest USPC system included just 22 classes (Carr, 1982). USPC is a dynamic system, which is updated annually to include new technologies and processes. The system was established to facilitate the easy retrieval of the patent documents for both patent examiners and inventors for studying prior art.

The major component of classification is known as class and the minor is known as sub-class. A class is a general category that covers related subject matter, for example Class 100, “Presses”, Class 260, “Chemistry, Carbon Compound”. The Classes also help differentiate between technologies, for example Class 903 is for Hybrid Electric Vehicles and Class 280 is for Land Vehicles.

These Classes are further broken down into smaller categories known as Sub-Classes, which define the subject matter that is included under it. A subclass differentiates between processes, structural features and functional features (USPTO, Overview of the U.S. Patent Classification System, 2007). These can be further divided into sub-classes to further refine the subject matter of the said sub-class. The
class/subclass pair is used to uniquely identify a subclass within the class. For example 280/29 represents class Land Vehicles (280), subclass wheeled (29). The Manual of Classification, a USPTO publication lists the titles and number of all class and sub-classes.

Each patent receives at least one mandatory classification usually based on the information found in the claims. The classification is usually based on the form of the claimed objects. A patent can be classified under multiple class-subclass pair, having only one “Original Classification”, which is one of these class/subclass pairs. Therefore, a patent relating to a complex invention would have to be classified under multiple class/subclass pairs without uniquely being associated with any one class. Thus, the classification system is not an orthogonal taxonomy but a static ontology. This classification system is revised once or more every year to include new technologies or to incorporate developments in existing technologies, resulting in addition and omission of classes and subclasses. Currently, the classification system includes over 150,000 subclasses (USPTO, Overview of the U.S. Patent Classification System, 2007). Since these are based on form, function, and process, identifying the appropriate class/subclass pair requires an extensive knowledge of the classification system.

1.2 **Patents in engineering design process**

Patents were originally intended to be a means of sharing information about a product. This information relates to the design and the operation of the product. It is widely argued that this information can be used during the course of the design process (Ullman, 2003; Pahl & Beitz, 1996; Fey & Rivin, 2005; Ernst, 2003; Daim, Rueda, Martin, & Gerdsri, 2006). Figure 1.2 illustrates a typical systematic design
process (Pahl & Beitz, 1996) with call outs for where patent related information can be found, tools utilizing patent information are also identified. The systematic design process as described by Pahl and Beitz is aimed at providing guidance for the process of planning and designing technical products. This process describes the necessary generic steps involved in the product development process.

Figure 1.2 Role of patents in generic design process (Pahl & Beitz, 1996).
The patent applications in the industry precede the commercial release, so the details of the design are well developed and documented before this stage. Patents therefore document the design artifact and hence incorporate the detailed design information. The patenting of a design can be represented as (a) in Figure 1.2. This is the actual creation of the document containing information related to the operation and functioning of the product.

Patents are considered a constantly updated source of information relating to a technology or product. Patents thus form a vital resource in understanding the latest developments relating to a particular technology. Information thus obtained from patents can not only be useful during the development of related products but also serve as a sign for the future development of the said technology (Ernst, 2003).

Thus, strategy relating to product research and development can be developed using patent information. As seen in Figure 1.3, competition benchmarking using patents as a source of information can be a powerful tool in understanding the market, the product requirements, the best practice in production, and to gain new insights into advanced technologies (Ullman, 2003; Fey & Rivin, 2005). Patents can thus play a role in benchmarking and determining state of art of the fast changing technologies (Carr, 1982; Walker, 1995; Daim, Rueda, Martin, & Gerdsri, Forecasting emerging technologies: Use of bibliometrics and patent analysis, 2006). This information can be useful in pre-conceptual design stage as shown in (b) Figure 1.2. Patents present solution principle to problems, in terms of a conceptual process or product. Information regarding the functionality and the working of a concept can be learnt from a patent. The information regarding the solution principles can serve as inspiration to designers of newer products. These solutions therefore form a good
source of ideas and can be useful during the conceptual design phase (Ullman, 2003) as shown in (c) Figure 1.2.

Altschuller, after an examination of a large number of patents, translated some of these novel solutions to fundamental working principles. These principles form the basis of ‘The Theory of Inventive Problem Solving’ (TIPS or TRIZ) (Fey & Rivin, 2005), which aim at resolving the technical conflicts using the derived principles.

Figure 1.3 Scope of Patent based Benchmarking
TRIZ relies on an exhaustive study of past innovations and technology, across domains, rather than psychology for problem solving.

Figure 1.4 Scope of TRIZ

The tool is primarily aimed to help the designer by guiding them. The guidance is based on a collaborative study of a large volume of patents as seen in Figure 1.4. It aims at making productive use of past innovations for future
innovations, thus helps resolve difficult problems with relative ease. Since the foundation of the technique is based on an extract of different solutions, developed across various domains, and fundamental principles of problem solving, making it a multidisciplinary approach towards problem solving. This method can be represented as (d) in Figure 1.2.

Patents describe product information with regard to its working and construction. However, these are seldom viewed as an available design repository. Knowledge reuse has been researched in engineering design for many years, resulting most recently in the development of intelligent knowledge based design systems and computer-aided design repositories (Bohm & Stone, 2004; Szykman, Racz, Bochenek, & Sriram, 2000; Regli & Gaines, 1997), as seen in (e) in Figure 1.2.
Researchers have attempted to capture the rationale used to justify choices made in the design process, the historical changes encountered during the product development lifecycle, and the requirements evolution of the design problem (Shah, Bliznakov, Rogers, Jeon, & S.D., 1996; Stahovich & Bal, 2002). Each of these approaches is focused on company specific, in-house documentation where developers of future products within the organization are ideally able to capitalize on
previous experience. There have been efforts to retrieve and reuse the product design knowledge by the use of design repositories, specially created with the intentions of storing and reuse (Bohm & Stone, 2004; Ranta, Mantyla, Umeda, & Tomiyama, 1996; Sudarsan, Fenves, Sriram, & Wang, A Product Information Modeling Framework for Product Lifecycle Management, 2005). Available design repositories like the patent database have not been amalgamated into these techniques for knowledge reuse because patents may not have been considered as a source of design information.

Patents lack a representation that are easy for designers to understand them and hence hinder their application of the information that can be found in patents. Previous research on patents has focused mainly on addressing the searchability of the database with the incorporation of computerized search mechanism and development of search algorithms. For example, recent work has focused on developing software tools enabling the electronic searching of the vast database of patents (Larkey, 1999). However, direct use of patent information during the systematic design process remains largely unaddressed. Formal support tools for systematically utilizing the information found are absent. The possible scope of these tools is indicated by (f) in Figure 1.2 and includes concept generation, developing the form and structure, fixing weak points, and evaluating.

For concept generation, novel solutions present in patents can be adapted, in part or completely, for developing solution to new design problems. These inputs to the concept generation stage can be based on the ideas derived from patents. For example inputs to a morphological matrix, an idea generation tool, can be derived from proven concepts based on patents. These concept adaptations can be based on
the functionality of the inventions as described in patents. This will lead to sharing of conceptual knowledge across domains, as solutions would be described based on the functionality.

In developing the form and structure, it is recognized that the form of the design evolves as the concepts are refined and embodied into a structure composed for different components and mechanisms. If concepts are based on patents, the form can be easily derived from the relevant patents. Both complete systems and sub-systems can be developed based on previous design found in patents. Since patents describe functionality of a product with regards to its components, they can be used as a good starting point while developing the form for new designs.

During the design process, as the design iterations take place, the design develops by eliminating and fixing weak points. The development of designs can also incorporate patents for elimination of weak points, minimizing cost, eliminating disturbances, as the ideas present in patents are considered established ideas. This can be applied to the complete system as well as sub-systems. For example, underperforming sub systems can be easily swapped for more established and proven systems.

Designs are evaluated at various stages during the design process. Each design iteration is usually followed by an evaluation. With the incorporation of designs from patents, improvements external to the design iteration can be mapped. This can form an evaluation tool, for a developmental design, and help determine a suitable end point for the iterations.
The scope of the patent information use, in the generic design process, is determined by the part of the patent information that aids new design. During the pre-conceptual stage, when the problem is well defined and the functional model of the desired product has been developed, the functional model can be used to search the patent database. The functional model can be used to determine functionally similar patents. The information that would be derived from these patents will be the means or working principles to achieve the desired functionality. These means will be useful in the conceptual phase. This step can be represented in the generic design process as (a) in Figure 1.6.
Figure 1.6: Scope of patent information use approach

During the later part of the design process when the preliminary layout, of the solution, has been developed, the database can be searched for products/processes that utilize similar layouts. The information regarding the assembly structure and the embodiment of the working principle will be useful during this stage. This step can be represented in the generic design process as (b) in Figure 1.6.
These steps will be effective individually, however, they can also be used together to help during different stages of the design process. This approach will help address the void in the design support tools identified earlier. In addition, the relevant information can be found in the claims section of a patent. This thesis presents a new representation scheme for capturing the information contained in engineering patents such that this information may be queried, retrieved, and reused in early design processes. The next chapter introduces the specific research questions of interest, in this thesis.
Chapter 2.

RESEARCH QUESTIONS

A product’s function and assembly information, as recorded in patents, can be used in multiple ways as described in the previous section. Information regarding the functionality and the working of a concept can be learned from a patent and applied in different problem scenarios. TRIZ, a popular design tool, has demonstrated that patent information can be utilized, albeit indirectly, to solve problems. Newer technologies have since been developed and the patent databases have been continually updated. The direct use of patents, other than for inspiration during conceptual stage, is not widely proposed in literature with even little specific guidance. This could possibly be attributed to the issues relating to intellectual property rights that may arise from it. However, the original intent of the patent system was to promote knowledge sharing and a design tool is missing which can enable designers to effectively use the patent information. Such a tool would help promote knowledge sharing and help designers use the design knowledge gathered over the years across different domains. The utility of such a tool can be clarified by answering the following questions.

2.1 Can patent information in present form be used for new design?

Patent information reuse is often suggested in different design texts but these suggestions lack formal tools or methods to guide the designers for using patent information. Information about novel solutions can be found in the claims sections of a patent, which is presented in a textual format aided with figures and sketches. The information about the working principles of a product or process can be useful to
designers in, developing completely new designs and design variants, using patents information from different domains. However, one needs to understand if this information can be used in its present form (textual). This question can be answered by answering a few sub-questions:

2.1.1 **What information is contained within a patent?**

Patents contain varied information about a product or process. Therefore, understanding and classifying the information that is found in a patent is important to correctly and effectively use the information. The information classification can also help identify existing design tools that can be used to effective incorporate the information into the design process for new product. Classification of the information based on the form, functional and behavioral attributes, will led to identification of major source of information

2.1.2 **What part of this information within a patent is useful?**

A greater understanding will also help identify the design stages for which the patent information will be the most appropriate. Classification of this information, based on design stages that are recommended in literature, will identify the information content that can be utilized.

2.1.3 **During which design stage can it be used?**

Other design stages that can utilize patent information during the design of new products can also be identified based on the understanding of the information content. Understanding patent content of different patents can also be used to identify general trends with regards to information content.
2.1.4 **What are the major difficulties encountered while using this information?**

On gaining an understanding of the information content and its applicability during the design process, the next step will be to identify means to use this information. Difficulties that arise during this step, to utilize patent information in textual format, can be documented. An understanding of the steps that will be required to implement this step are also needed in order to isolate the difficulties in using text based patent information for designing new products. Based on these difficulties, best practices in regards to information representation can be identified.

The answers to these sub-questions will not only help us understand if the text-based representation of patent information is useful in its present format, but also frame requirements for improvements to the same. The understanding relating to the content of the design information that is found in patents will help maximize the support that patent information can provide during new design.

2.2 **Can the information be modeled using existing representation schemes?**

Patents report new processes, functionality, and various means for achieving the desired functionality. Since most of this information is represented in a graphical format in the design process. Representing the patent information in a similar format will facilitate its use during new design. It has been reported that graph representations are useful during conceptual phase as well as embodiment phase (Summers, Vargas-Hernandez, Zhao, Shah, & Lacroix, 2001). The graph-based representation of patents will therefore help represent information in a format that can be used in the design process.

Some fundamental requirements for a graph based representation scheme include:
• **Representation of function**: to understand what the object does.

• **Representation of behavior of the components**: to understand how the functionality is achieved.

• **Representation for assembly structure**: to understand how the object is made.

Product representation schemas which satisfy at least some of the requirements where studied in order to determine whether patent information can be modeled using existing tools. Function modeling is a tool extensively used to model the functionality of artifacts (Pahl & Beitz, 1996). In this scheme, the functions are represented as blocks with interconnecting flow of energy material and signal. Functions, as seen in Figure 2.1, are therefore described with relation to the input and output.

![Energy](Energy) ![Material](Material) ![Signal](Signal)  

**Figure 2.1 Function representation in functional modeling**
Bond graphs model the energy and signal flows among components in a system using a small set of ideal elements. Bond graph can thus be utilized to model the behavior of the artifact (Sinha & Khosla, 2001; Karnopp, Margolis, & Rosenberg, 2000). Bond graphs, seen in Figure 2.2 can be used to model different engineering systems, making them domain independent.

![Figure 2.2 Bond Graph](image)

However, modeling mechanical systems using bond graphs is reported to be difficult and inconvenient (Karnopp, Margolis, & Rosenberg, 2000; Triengo & Bos, 1985). Connectivity graphs, seen in Figure 2.3, model the physical layout of an artifact (Lin & Chang, 1993) by modeling the relationships between components of the artifact.

![Figure 2.3 Connectivity graph](image)

This scheme however, has limited ability to model product functions and behavior. The Function Behavior Structure can be used to model artifact features,
functionality and behavior (Regli & Gaines, 1997). It models the structure of the artifact based on artifact’s assembly features.

2.3 Do these schemes model all the information contained in a patent?

Some of the representation schema can be used to represent patent information in a graph-based format. However, it is necessary to check if existing schema can completely model the patent information. Determining the degree, to which the schema can model information, can be a basis to decide on an appropriate scheme to model patent information. The primary aim of the research is to represent the product information found in the patent in a format that would be easy to search and readily applicable in systematic design process.

The research questions are aimed at understanding the design related information contained within patents and thus determine its utility towards the design of new products. The information content analysis of patent claims will help understand this type of information contained. The understanding of the information content will help determine if suitable representation schemes exist to model this information in a manner that can aid designers.
Chapter 3.

INFORMATION ANALYSIS EXPERIMENTATION

As mentioned Chapter 2, understanding the patent information is key to understanding if the information can be used and how to apply it in a new design. In reviewing several different patents for this study, it was found that patents contain information relating to product functionality, assembly, and often times behavior. Table 3.1 illustrates the list of patents that were formally reviewed and the type of information that was found within them. However, a quantitative study was needed to understand the proportion of the information relating to the function, assembly, and behavior.
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Patent Number</th>
<th>Patent Title</th>
<th>Assignee</th>
<th>Issue date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5632578</td>
<td>Exhaust stator and fan for a power tool</td>
<td>Ryobi North America</td>
<td>27-May-97</td>
</tr>
<tr>
<td>2</td>
<td>7090032</td>
<td>Electric power tool</td>
<td>Ryobi Ltd.</td>
<td>15-Aug-06</td>
</tr>
<tr>
<td>3</td>
<td>US2006/026858</td>
<td>Handheld computing device</td>
<td>Apple Computer, Inc.</td>
<td>8/7/2006</td>
</tr>
<tr>
<td></td>
<td>(application)</td>
<td></td>
<td></td>
<td>(filing date)</td>
</tr>
<tr>
<td>4</td>
<td>7287887</td>
<td>Vehicle headlamp</td>
<td>Koito Manufacturing Co., Ltd.</td>
<td>30-Oct-07</td>
</tr>
<tr>
<td>5</td>
<td>7201194</td>
<td>Non-pneumatic tire</td>
<td>Michelin Recherche et Technique S.A.</td>
<td>10-Apr-07</td>
</tr>
<tr>
<td>6</td>
<td>7150503</td>
<td>Automotive seat reclining device</td>
<td>Fuji Kiko Co., Ltd.</td>
<td>19-Dec-06</td>
</tr>
<tr>
<td>7</td>
<td>7318662</td>
<td>Vehicular headlamp</td>
<td>Koito Manufacturing Co., Ltd. (Tokyo, JP)</td>
<td>15-Jan-08</td>
</tr>
<tr>
<td>8</td>
<td>7224078</td>
<td>Electric rotating machine for vehicle</td>
<td>Mitsubishi Denki Kabushiki Kaisha (Tokyo, JP)</td>
<td>29-May-07</td>
</tr>
<tr>
<td>9</td>
<td>6506139</td>
<td>Transmission with an electro-mechanical energy converter</td>
<td>LuK Lamellen und Kupplungsbau Beteiligungs KG</td>
<td>14-Jan-03</td>
</tr>
<tr>
<td>10</td>
<td>6736109</td>
<td>Knock control system</td>
<td>Nissan Motor Co., Ltd.</td>
<td>18-May-04</td>
</tr>
<tr>
<td>11</td>
<td>6543549</td>
<td>Electrically driven handheld tool</td>
<td>Hilti Aktiengesellschaft</td>
<td>8-Apr-03</td>
</tr>
<tr>
<td>12</td>
<td>6325157</td>
<td>Striking tool with an improved cooling mechanism</td>
<td>Makita Corporation</td>
<td>4-Dec-01</td>
</tr>
<tr>
<td>13</td>
<td>4518180</td>
<td>Automobile power door latch</td>
<td>Kiekert GmbH &amp; Co. Kommanditgesellschaft</td>
<td>21-May-85</td>
</tr>
<tr>
<td>14</td>
<td>4389818</td>
<td>Power operated automobile window glass regulating mechanism</td>
<td>Toyo Kogyo Co. Ltd.</td>
<td>28-Jun-83</td>
</tr>
<tr>
<td>15</td>
<td>7270591</td>
<td>Electric sander and motor control therefor</td>
<td>Black &amp; Decker Inc.</td>
<td>18-Sep-07</td>
</tr>
<tr>
<td>16</td>
<td>4580202</td>
<td>Adjustable support for optical unit of the headlight of an automotive vehicle</td>
<td>Jacques Morette</td>
<td>1-Apr-86</td>
</tr>
<tr>
<td>17</td>
<td>3174713</td>
<td>Vehicle Light Resilient Mount</td>
<td>Philip L. Cala</td>
<td>23-Mar-65</td>
</tr>
<tr>
<td>18</td>
<td>5055981</td>
<td>Automotive projector type headlight</td>
<td>Koito Manufacturing Co., Ltd.</td>
<td>8-Oct-91</td>
</tr>
</tbody>
</table>
An experimental study was conducted on exclusively on the claims within a patent, as these were identified in Chapter 1 as short descriptions of the critical and unique aspects of the invention. Patents, that were reviewed and some randomly selected from the USPTO database, were considered as a representative of the patent database were selected for the study. In order to analyze these patent claims, an information metric based on the information theory was developed. The information theory considers the information as a stream of discrete events occurring from a set vocabulary. The probability of the occurrence of these events is used as a measure of the information (Shannon, 1948). If the information that is obtained from a discrete event is defined in terms of the probability of the event occurring, then the measure of the information is indicated as:

\[ I = \log(1/p_i) \]

Where I is the information measure and \( p_i \) is the probability of the event \( i \) occurring. If the log is taken to base 2, then the magnitude of I is indicative of the number of binary (yes/no) questions that need to be answered to determine the event. Thus the information magnitude ‘I’ can be expressed in bits. The probability of the event occurring being the function of the available vocabulary, indicate by X, then the information measure can be expressed as:

\[ I = \log_2(X) \]
The expression provides the information bits required to transmit one word in a vocabulary of size X. The application of these information theory fundamentals to analyze patent claim information is discussed in the later sections.

### 3.1 Selection of sample patents for experimentation.

The USPTO currently has over 7 million patents, selecting a few patents that can represent this vast database is a challenging task. An understanding of the building blocks of patents helped identify the source of information in a patent. The patent claims contain the information regarding the invention and also identify the distinguishing features of an invention. Upon review of patents listed in Table 3.1 and various other patents, some from the other countries like Japan and the European Union, it was observed that the patents contain information about the products functionality, its form and often times its behavior. This information about the product would be useful for a designer looking for design solutions in the patent database. The scope of use of this information about the products form and functionality is explained in section 1.2.

Patents reviewed earlier provided the starting point of the selection of patents. The review, which involved studying the patent, helped develop an understanding the invention described. This familiarity with the invention was useful in understanding the legal jargon found in the claims section of the patent. To prune the list down further, qualitative analysis of the content was conducted by studying the claims and the solution description section of the patent. This analysis was aimed at selecting patents describing different types of design information, which would be useless for designers of new solutions. The patent information was rated for the content based
upon the description it provided about the product. The patent content was examined for function, behavior, assembly and features. Information related to what a product does was classified as function intensive information. Information relating to the manner, in which the product’s components are put together and the relation between the different components, was classified as information relating to the products form or assembly. Information related to features of the components was found to be a major component in such information and hence it was considered as a separate information category. Information which provided an understanding of the product’s behavior, generally observed as a cascading events as a means to achieve the product’s functionality, was classified and behavior intensive information.

The information content, in the patents reviewed earlier, the information content was ranked on a high (H), medium (M), and low (L) scale for its functionality, behavior assembly and features. From the study of the information content it was observed that, patents describing behavior where related to both functionality of the product as well as the assembly structure. This relation is true as behavior can be described as change in functionality of the product or in terms of relationship between components. It can also be noted that assembly in patents is mostly described in terms of features of individual components, however, it is not dependent on features to completely describe product assembly structure.

The patent database contains patents describing products and product sub-systems. The sample patents, for the study were chosen to include different product and their sub systems. This helps the study incorporate products with varying level of detail. Simple electromechanical products formed an ideal choice to incorporate the
varying level of detail to be found in the database, since it possible to easily obtain patents describing the complete product or product subsystems.

Patents describe the subject matter using text as the primary means of communicating the information. The textual description is subject to variation due to writing styles of the authors. It was observed, during the review, that patents assigned to companies as opposed to individuals were more consistent with the textual description. The quality of information found in the patents assigned to individuals was also found to lesser on an average compared to patents assigned to companies. Therefore, only patents issued to companies were selected for the study as this insured the quality of the work in the patent and also in the belief, that the work patented was a product of the design process and hence well documented. Table 3.2 below presents the patent selection matrix, which shows the selected patents, which where chosen as a representative of the patent database, based on the various aspects as discussed.
Table 3.2 Patent Selection Matrix

<table>
<thead>
<tr>
<th>No.</th>
<th>Patent Number</th>
<th>Patent Title</th>
<th>Function</th>
<th>Behavior</th>
<th>Assembly</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Behavior</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B1</td>
<td>7287887</td>
<td>Vehicle headlamp</td>
<td>L</td>
<td>H</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>B2</td>
<td>7224078</td>
<td>Electric rotating machine for vehicle</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>B3</td>
<td>7270591</td>
<td>Electric sander and motor control thereof</td>
<td>M</td>
<td>H</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Function</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>7090032</td>
<td>Electric power tool</td>
<td>H</td>
<td>L</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>F2</td>
<td>7318662</td>
<td>Vehicular headlamp</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>F3</td>
<td>6736109</td>
<td>Knock control system</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Assembly</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>7201194</td>
<td>Non-pneumatic tire</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>A2</td>
<td>6543549</td>
<td>Electrically driven handheld tool</td>
<td>L</td>
<td>M</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>A3</td>
<td>7273303</td>
<td>Headlamp for two-wheel vehicle</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>

3.2 Color Coding Scheme

In order to understand and quantify the information that is contained in the patent claims, a study was carried out on the claims section of the patent. The choice of this section for the study was apparent as this section describes the novel portion of the invention in short descriptive sentences. This section also forms the legal backbone of patents, hence important information relating to the product can be found.
in the section. For the analysis of the information present in the claims section of the selected patents, independent claims of the selected patents where extracted and the important elements relating to the functionality, assembly and the behavior of the assembly where highlighted using a color code system. The color-coding scheme helped highlight the various components and patent claims could be observed with individual components separated. The fundamental scheme used to identify the different components in the claims is explained along with relevant examples. A single individual did the color-coding of the claims in order to maintain uniformity in the coding.

3.2.1 Function

The color used to represent functional words in the patent claims is Red. Functions represent actions; in relation to patent claims, verbs were found to represent actions. For example, the verb ‘convert’ in the claim, ‘planetary gear train to convert rotational motion’ represents action. However, in patent claims verbs are also used to represent some assembly characteristics. For example: A part of the claim is ‘A power tool comprising: a motor housing...’ here the verb ‘comprise’ does not relate directly with the functional aspect of the invention but describes how the invention is made.

3.2.2 Claim object

A product is often composed of different objects, the color Blue is used to represent these. These components with their respective detail and functionality are seen in the claims of a patent. Claim objects are defined as the independent physical objects described in the patent. These objects are related to functions and are not a result of the function. For example, the in a claim for a power tool, ‘An electric power
tool comprising: a housing in which a motor having a drive shaft’, the highlighted words are viewed as claim objects.

3.2.3 Attributes

Patents describe working of objects and provide detail on the objects. These details are considered attributes or properties of the said claim object and can be seen as adjectives. For the study, form based attributes (Green) are separated from the general attributes (Yellow), as these often relate to the assembly of the product. Example of the these attributes can be seen in the following patent claim ‘planetary gear train’ and ‘rotary armature’ where the words planetary and rotary add detail to the gear train and armature respectively.

3.2.4 Object of function

Objects of the function are described as claim objects upon which the functions of the claim act on, represented by the color Violet. These can also be viewed as the outcome of the functions. For example, in the claim describing a motor speed controller ‘motor controller changing the speed at which it runs the motor from an idle speed’, the motor speed is viewed as the object of function. In some cases, there is a subjectivity associated with this classification, as these are based on the overall objective of the claim.

3.2.5 Energy/Motion

The color Orange is used to distinguish the motion and energy described in the claims. For example, in the following claim, ‘driven by the engine to generate an AC power’, the word power is associated with electrical energy based on the context.
3.3 Information Loss through Pruning

The color-coding enabled observing the inter-dependency between the different functional, assembly and behavioral components of the patent. The principle of subtraction of a particular component of the information content from claim was possible after segregating different components. This study of subtraction of information, establishes a qualitative importance of the different information components. A constant loss in terms of an understanding of the information is observed after the subtraction of each information component. A claim, from US Patent 7270591, can be seen below along with the corresponding color-coded claim. The claim explains a motor controller with application in a hand held sander. The claim explains how and when the controller changes the motor speed by sensing a rise or drop of the same.

‘A hand held orbital sander, comprising: a. a housing having an electronically commutated motor disposed therein and an orbit mechanism disposed beneath the housing; and b. a motor controller coupled to the motor, the motor controller changing the speed at which it runs the motor from an idle speed to a sanding speed upon the motor speed dropping from idle speed to an idle speed threshold value and changing the speed at which it runs the motor from sanding speed to idle speed upon the motor speed increasing from sanding speed to a sanding speed threshold value wherein the motor controller slows the motor by reverse commutation when it changes the speed of the motor from sanding speed to idle speed.’

In the color-coded claim presented below, it can be observed that important information relating to the functional aspect of the product, an electric handheld tool, is easily identifiable.
A hand held orbital sander, comprising: a. a housing having an electronically commutated motor disposed therein and an orbit mechanism disposed beneath the housing; and b. a motor controller coupled to the motor, the motor controller changing the speed at which it runs the motor from an idle speed to a sanding speed upon the motor speed dropping from idle speed to an idle speed threshold value and changing the speed at which it runs the motor from sanding speed to idle speed upon the motor speed increasing from sanding speed to a sanding speed threshold value wherein the motor controller slows the motor by reverse commutation when it changes the speed of the motor from sanding speed to idle speed.

In the color-coded claim presented below, only the colored sections are retained. This represents the core information that is present in the claims of the patent. A slight decrease in the understanding of the text can be attributed to the missing context.

Hand held orbital sander, comprising housing having electronically commutated motor disposed orbit mechanism disposed beneath housing; motor controller coupled motor motor controller changing speed runs motor idle speed sanding speed motor speed dropping idle speed idle speed threshold value changing speed runs motor sanding speed idle speed motor speed increasing sanding speed sanding speed threshold value motor controller slows motor reverse commutation changes speed motor sanding speed idle speed.

In the color-coded claim presented below, with the attributes eliminated from the color-coded text. This represents information that relates mainly with the functional aspect of the invention. A slight decrease in the understanding of the text can be observed due to the missing attributes, usually associated with the claim objects.
Sander comprising housing having motor disposed mechanism disposed housing motor controller coupled motor motor controller changing speed runs motor speed speed motor speed dropping speed speed threshold value changing speed runs motor speed speed motor speed increasing speed speed threshold value motor controller slows motor commutation changes speed motor speed speed.

In the color-coded claim presented below, with functions and the objects of the functions. This represents information that relates only with the functional aspect of the invention. A major decline in the understanding of the text can be observed in comparison with the original text.

Comprising having disposed disposed coupled changing speed runs speed speed motor speed dropping speed changing speed runs speed speed motor speed increasing speed slows commutation changes speed speed speed.

A similar study for the remaining patents selected is included in the appendix. The trend of the diminishing understanding of the claims of the patent is observed in all the patents. The principle of information subtraction provides an understanding of the interrelationship between the information content. The relative importance of the different components of the information content in the color-coded text can also be noted from the study. The color-coded text covers the majority of the patent information, as seen in the relatively less drop in understanding between the original text and the color-coded text. This study provides a qualitative analysis of the importance of the different aspects of patent information, i.e., functionality, assembly and behavior.
3.4 Quantitative Analysis of Information Content

The subtraction of the color-coded text from the original text provides a qualitative understanding of the important information content of patent claims. The use of information theory fundamentals provided a means to quantify the information that was contained within the patent claims. As discussed earlier the measure of information \( I \), where \( X \) is the size of the available vocabulary, is expressed as

\[
I = \log_2 (X)
\]

In case of patent claims the available vocabulary was difficult to ascertain, hence the vocabulary that was contained in the patent was considered to be the available vocabulary. The number of distinct entities present in the particular claim was considered to be a measure of the vocabulary. The product of measure ‘\( I \)’ with the number of instances of occurrence of the distinct entities helped determine the total information bits contained in them.

The color-coded claims formed the starting point for the study. An information measure associated with the components of the claim, highlighted during the color-coding of the textual claim, was determined. The number of instances of each of these components was determined and the number of distinct entities present in these helped determine the vocabulary size. This information was represented as a simple bar seen below in Figure 3.1. This bar chart was used to determine the information measure for the individual components, in terms of information bits. The bar chart also helps understand the type of information that is contained in the patent. For
Figure 3.1, it is observed that the functions and the claim objects are the dominating entities, it can be said that the patent would be richer in terms of the functional information.

![Chart showing information analysis for Claim 1 of US Patent 7270591](chart.png)

**Figure 3.1 Information analysis for Claim 1 of US Patent 7270591**

The information measure of each of the complete color-coded text was determined based on the total information being observed as a whole. A subtraction study was carried out to understand the influence of loss of a particular information component, on the entire information contained within the claim. For example, as seen below in

**Table 3.3** below, the greatest loss of information, in the claim for the patent 7270591, is attributed to the claim object and the next to the function. However, the influence of the object of function is also significant in this claim. As explained earlier, since the claim objects and functions together represent functionality, the claim would probably represent the functionality of an invention. This patent however, has a significantly higher content of objects of function, which represent the outcome of the function, indicates that the claim probably describes a sequence of
functions. This can be attributed to the invention’s behavior description in the claims section.

Table 3.3 Information analysis of US Patent 7270591

<table>
<thead>
<tr>
<th></th>
<th>Instances</th>
<th>Distinct Entities</th>
<th>Information bits</th>
<th>% Loss in information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove Attribute</td>
<td>47</td>
<td>24</td>
<td>215.49</td>
<td>30%</td>
</tr>
<tr>
<td>Remove Function</td>
<td>46</td>
<td>20</td>
<td>198.80</td>
<td>35%</td>
</tr>
<tr>
<td>Remove Claim</td>
<td>43</td>
<td>22</td>
<td>191.75</td>
<td>38%</td>
</tr>
<tr>
<td>Remove Object of Function</td>
<td>50</td>
<td>27</td>
<td>237.74</td>
<td>23%</td>
</tr>
<tr>
<td>Remove Energy/Motion</td>
<td>62</td>
<td>31</td>
<td>307.16</td>
<td>0%</td>
</tr>
</tbody>
</table>

Such an analysis of the patent claims helps understand what the patent claim describes, in terms of the production functionality and form. As seen below in Table 3.4 below, the greatest loss of information is attributed to the claim object and the next to the function. Since the claim objects can be physical entities which are acted upon by functions, the patent claim presented here is probably explains the functionality of an invention.

Table 3.4 Information analysis of US Patent 6506139

<table>
<thead>
<tr>
<th></th>
<th>Instances</th>
<th>Distinct Entities</th>
<th>Information bits</th>
<th>% Loss in information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove Attribute</td>
<td>44</td>
<td>23</td>
<td>199.03</td>
<td>31%</td>
</tr>
<tr>
<td>Remove Function</td>
<td>44</td>
<td>21</td>
<td>193.26</td>
<td>33%</td>
</tr>
<tr>
<td>Remove Claim Object</td>
<td>30</td>
<td>16</td>
<td>120</td>
<td>59%</td>
</tr>
<tr>
<td>Remove Object of Function</td>
<td>59</td>
<td>30</td>
<td>289.50</td>
<td>0%</td>
</tr>
<tr>
<td>Remove Energy/Motion</td>
<td>59</td>
<td>30</td>
<td>289.50</td>
<td>0%</td>
</tr>
</tbody>
</table>

Such an analysis is conducted for each of the independent claims of selected patents. This helped understand the major contributors to the information contained in the patent claims and information share with regards to the functionality, assembly and behavior. Table 3.5 presents the information analysis of the combined sample
patents. This combined analysis helps understand the significance of the various components identified with relation to the total information present in the claim. The table presents the results of after subtracting the individual components from the total tally and the information content lost by subtraction of the components. From the results it can be observed that the claim objects, attributes and functions together form the majority of the information content. Thus in patents, the claim objects help describe the form of the product and functions help the functionality of the product. The attributes help define the uniqueness of the claim.

Table 3.5 Information analysis of sample patents

<table>
<thead>
<tr>
<th></th>
<th>Instances</th>
<th>Distinct Entities</th>
<th>Information bits</th>
<th>% Loss in information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove Attribute</td>
<td>822</td>
<td>399</td>
<td>7102.28</td>
<td>36.91%</td>
</tr>
<tr>
<td>Remove Claim Object</td>
<td>743</td>
<td>431</td>
<td>6502.40</td>
<td>42.24%</td>
</tr>
<tr>
<td>Remove Function</td>
<td>941</td>
<td>425</td>
<td>8216.17</td>
<td>27.01%</td>
</tr>
<tr>
<td>Remove Object of Function</td>
<td>1152</td>
<td>586</td>
<td>10592.36</td>
<td>5.90%</td>
</tr>
<tr>
<td>Remove Energy</td>
<td>1206</td>
<td>607</td>
<td>11150.14</td>
<td>0.95%</td>
</tr>
</tbody>
</table>

These observations are relevant in understanding the structure of the claim text of the patent database. Thus by understanding the major contributors to patent claim’s information content, the aim of the textual description in the claims can be understood. These observations were inline with our hypothesis that regarding patents containing information about the product’s form and function. The information analysis of the patent shows, for the selected patents shows that the information share for the functional information and the assembly information is fairly the same. The behavior content in the claim text cannot be identified easily, since it is only apparent by observing the textual information as a whole. Thus making the functional and form information the vital blocks in understanding the products behavior. This product
behavior can be observed in the text-based claims upon review, however measures to quantify the behavior are beyond the scope of the present work.

Since the selected patents are treated as a representative of the patent database, the same can be said to be true for the rest of the 7 million patents currently present in the database. After establishing the content of the patent database, the next step will be to understand the manner in which this information can be used to aid the designers as they go through the design process to design new artifacts. As mentioned in an earlier section, the information identified is most commonly represented in a graph-based format. Representing the information using existing representation schemes in a format, which is used in the design process, can help promote direct use of the information. A better choice of these representation schemes can now be made, as the content of the information that needs to be represented is well understood.
Chapter 4.

SEARCHABILITY OF PATENTS

The patent database contains a large volume of patents, currently over 7 million. Retrieval of the relevant patents is vital for the patent information to be able to support new design problem. This problem needs to be analyzed from the information retrieval perspective pertaining to large databases. Since the volume of the patent data is organized, the use of keyword based search has been commonly used for locating information. The information pertaining to the design of the product is often presented in different formats. In addition, the information organization of the patent database was developed with a different aim of locating the information. In this chapter the some problems associated with the search for relevant design information within patents is discussed.

4.1 Database Size

Presently the USPTO offers electronic keyword based search for the complete text of the patents present in electronic format, this includes patents issued since 1976. The older patents are contained in the database as image files. The use of Optical Character recognition technology has permitted limited keyword based electronic search of the database. The keyword based search includes, searching for the keywords, then ranking the results based of computed relevance based on weighing statistical properties of the words. The use of Boolean operators permits the search of patents for multiple keywords.

This process however, is subject to inaccuracies and often fails to retrieve complete results and accurate results. The choice of the keywords affects the results of
the search, while a general keyword may yield lot of results, a specific keyword query may retrieve none. For example, a keyword search for the term ‘bicycle’, carried out in June 2008, returns 19127 results using the USPTO’s web based search tool. Relevance established by the user, after reviewing some or all of the results is used as feedback and helps refine the search. Establishing this relevance is difficult as the size of the database increases (Croft, 1995). This necessitates evaluating a significant amount of patents to locate relevant ones. The textual representation of the information makes the evaluation of the results cumbersome and time consuming, thereby limiting the information search carried out by design teams.

4.2 Patent classification system

The patent classification system is used to classify the inventions and thus helps index the patent database. The patent classification as explained in section 1.1.3. The classification consists of a code, which is typically expressed as ‘100/10’. The first number, 100, is used to identify the class of the invention. The subsequent number represents the subclass of invention within the class. There are about 450 Classes of invention and about 150,000 subclasses of invention in the USPC. Each patent and each published application is assigned one or more classifications (i.e., class/subclass designations).

The patent database was primarily indexed to help examiners locate relevant patents during the approval process of a patent. A patent classification (class/subclass designation) represents a collection of patents grouped together according to similarly claimed subject matter. A patent search can be conducted by searching for the desired classification, as locating the relevant class/sub-class pair helps narrow down the
search space. This therefore requires extensive knowledge of the patent classification system. Moreover, this classification system is updated on a regular basis to incorporate new classifications. In addition, since the classification is primarily based on the described form of the invention, the examination of the patent is therefore needed before the relevance of the patent can be determined. For example, patents related to a bicycle were found classified under classes land vehicles, spring devices, etc. Thus, relevant patents can be scattered across different classes and subclasses.

Thus a patent search conducted by locating the relevant classification may be a little better than the keyword based search, but it requires extensive knowledge of the classification system. The classification based on the form and product technology helps the examiners locate the relevant patents fairly quickly, but would not be of much use to designer searching for a product’s design information with regards to its function and behavior. A search using the classification system would definitely be more focused and directed than a keyword based search, however it has it limitations relating to the vast, complex and changing classification system.

4.3 Patent Vocabulary

The patent search, either keyword based or classification based requires the user to evaluate the relevance of the patents. Presently, the design team can determine the relevance only, by examining individual patents for relevance. This requires the user to understand the information in the claims section presented in a textual format. Thus quantifying the relevance of old designs recorded in patent to the design under development is difficult. With authors of patent, from different geographical area and different companies, this textual information is subject to influence by the writing
styles of the authors. Since there is no prescribed vocabulary often, different words are used to describe seeming similar subject matter. In addition, the legal vocabulary that is use in the patents is often difficult for technical experts to comprehend; also there is a lot of variation between patents authored by different companies (Larkey, 1999). The use of company specific terms is also a major source of the variation in explaining similar ideas. Patents are also required to contain figures of the invention in most cases; however, the USPTO does not provide an engineering standard for the figures. Therefore the patents often contain hand drawn sketches, which are of little engineering significance to a technical reader.

The data that is generated from patent search, represented in textual format often find little application in the new design problems as the data during engineering design is represented graphically. The inconsistency in the writing styles of the authors and the non-uniform vocabulary make the description difficult to analyze for the user. This presents a significant challenge in aiding the user for examining the relevance of the search results.

Summarizing the major issues relating to the searching of relevant patents within the patent database is common to most modern information retrieval systems. The patent database poses challenges with respect to its size and also the rate at which the database is updated, with over a 100,000 new patents every year. Thus keyword based searches often result in a significantly large number of results, requiring careful analysis of vast amounts of data by the user. The patent classification system, designed to aid in the searching of patents, has evolved into a complex system in itself containing large number of classifications. This classification system usually requires a separate keyword search to identify the correct classification. The inconsistent
vocabulary makes it difficult for the user to understand and utilize the information found in the patents. These limit the effective searching of the patent database for solution principles. In addition, the data extracted if any is based in textual format, this is poses difficulty for integrating the data with the design problem scenario at hand. These problems must be addressed in order to promote the use of patent information for new design problems.
Chapter 5.

REPRESENTATION OF PATENTS

A non-textual representation format being recognized as the suitable representation form for the patent information, study of existing design representation schemes was conducted. The representation schemes were selected based on the information present in patents. Information about the product or a sub-system’s function, form and behavior is found in patents, a representation that incorporates this information is required. These information models for patents are also required to uniquely represent all the information contained in the patent. Therefore an approach utilizing mathematical model, in the form of graph representations, to represent patent information was considered. The graph representation is a widely applied approach in engineering design, as it permits uniquely identifying a product with a specific representation (Shai, 2003). Furthermore engineering analysis and reasoning can be conducted on these representations and mathematical rules can also be applied to them. The mathematical form of these representations will also aid in developing computer based synthesis tools for the representations. In case of patent information this will permit unique representation and tailoring specific search queries for specific form, function or behavior.

5.1 Existing Representation schema

A study of these existing schemas is essential to determine their application towards representation of patent information. Fundamentally these schemas need to model;
a. Functionality, which describes what the product does. Functions are considered in general as input/output relationships of a product, which aid it to fulfill customer requirements.

b. Form, describes how a product is put together. The form of a product is considered to be the geometric and assembly level relationship between the individual components of a product.

c. Behavior, describes how the product accomplishes the product’s functionality. It can also be described as a combination of functions and component interactions.

5.1.1 Function Modeling

Function modeling is a generic term used for a model, which represents the product in terms of its functionality. This approach is commonly used to decompose complex systems, during the initial design phases (Pahl & Beitz, 1996). This division of design objectives is often used to assist the understanding of complex systems and also to as a communication by between various engineering disciplines by providing a common communication platform. The functional model of a system represents how individual functions help the product achieve its desired functionality, which determines what the product does. This mode of achieving the overall functionality by fulfilling sub-functions is particularly useful during the conceptual stage of design. Besides this the functional model can also be used for other product development activities like Failure Mode Effect Analysis (FMEA), Fault Tree Analysis (FTA).

Functions in engineering design as described by Pahl and Beitz, is “the intended input/output relation of a system whose purpose is to perform a task”. The
functional model of a system is derived by understanding the black box relation between the input and output parameters. The sub-functions of the system are a designer’s interpretation of this black box. Thus the generic function of the product is described interrelated sub-functions, these sub-functions are linked by means of flows, and this constitutes a function structure. The functions in the structure are related to each other with the logical operators, AND, OR and NOT. The function structure thus represents a hierarchical representation of the product function, which provides the designer an overall representation of the design problem.

5.1.2 **Functional Behavior State (FBS) Modeling**

The model is aimed at capturing design information by associating it with the CAD models of a design object. A Functional Behavior State Model is used to describe the functional and the physical state of a design object. The behavior of the design object in the model is described as “sequential change of states” (Umeda, Takeda, Tomiyama, & Yoshikawa, 1990). The state, represented by entities and attributes describes the physical structure of the object at a given instant. The entities and relationships between them describe the physical structure of the complete object. The change of a state of an object is governed by, physical laws. The sequential change is used to describe the behavior of the object. For example, a ball (entity) placed at height X (attribute) is in a particular state and the behavior of the ball falling can be described by a change in state, in turn associated with change in height. This behavior, change from state 1 to state 2, is governed by a physical law like the law of gravitation. This relation between state and behavior is known as B-S relationship. The function is defined as “description of behavior abstracted by human”, thereby a function is represented as something that needs to be done in order to get a particular
behavior. For example, the function of producing sound can be associated with the behavior of colliding objects. This relation between function and behavior is known as F-B relationship. Thus the complete object can be described as a web of states, B-S relationships and F-B relationships as seen in Figure 5.1.

![Figure 5.1 Relationship between function behavior and state (Shimomura, Takeda, Yoshioka, Umeda, & Tomiyama, 1983)](image)

5.1.3 **Core Product Model**

This model to represent product information was developed primarily to support PLM systems, and make available product data as and when required. It is intended to be a generic, abstract model with generic semantics, which enables it to model different systems (Sudarsan, Fenves, Sriram, & Wang, A Product Information Modeling Framework for Product Lifecycle Management, 2005). The Core Product model (CPM) is based on the fundamental principle that the artifact is represented by form, function behavior. The core product model is presented as a means to capture the product’s design information as the design itself evolves during the design process. It therefore incorporates additional information like the customer specifications and material.
The core product model considers the product’s form as a representative of the product’s functional solution. It is modeled by the CPM in terms of the product’s physical characteristic pertaining to its geometry and material properties. Assembly is modeled as relationships between the individual components. Function, which is considered to be the intended behavior of the artifact, describes what the product does. Input/output type functions are described as a special form of functions, known as transfer functions. Behavior of the artifact in a CPM describes the implementation of its functionality by the form, thus behavior is governed by engineering principles.

Seen in Figure 5.2 below is a snippet of the CPM for a planetary gear system.

Figure 5.2 CPM of a planetary gear system (Fenves, Foufou, Bock, & Sriram)

5.2 Patent Representation.

The representation schemas, discussed in the earlier section, were used to model the information content in a patent claims. It was assumed that each of these representation schemes would suffice for modeling patent information. An
understanding, of the shortfalls and the advantages of these with regards to modeling patent information is discussed in the following sections. Specific cases that highlight the shortcoming of these representation schemas are discussed in the following section.

5.2.1 Function Modeling

The function model is usually prepared during the conceptual stages of design. They function model of a product serves as the skeletal framework on which the design of the product evolves. The function structure therefore is independent of the means that are used to achieve the particular functionality. The function model therefore doesn’t model solutions and patents being solutions to problems would be difficult to model. Function models being representative of a product’s functionality are unable to distinguish between products have similar functionality. For example the function of a hair dryer and a heat gun would be the same, i.e. to produce flow of hot air. The function models for these therefore would be quite similar. Thus requiring a context of the design scenario for interpreting the model.

In order to highlight the ineptitude of the function modeling for representing patent information, a claim from the US Patent 7270591, describing the controller for a handheld power tool is modeled using function model. The claim describes the manner in which the controller alters the motor speed on detecting a change in it.
‘A hand held orbital sander, comprising: a. a housing having an electronically commutated motor disposed therein and an orbit mechanism disposed beneath the housing; and b. a motor controller coupled to the motor, the motor controller changing the speed at which it runs the motor from an idle speed to a sanding speed upon the motor speed dropping from idle speed to an idle speed threshold value and changing the speed at which it runs the motor from sanding speed to idle speed upon the motor speed increasing from sanding speed to a sanding speed threshold value wherein the motor controller slows the motor by reverse commutation when it changes the speed of the motor from sanding speed to idle speed.’

Figure 5.3: Claim 1. US Patent 7270591

The function model of the patent claim seen in Figure 5.3 can be seen in Figure 5.4. The function model contains two sub models. These models describe the two different operating states of the controller. The controller is shown to process the speed signal with reference to a threshold signal and produces a signal in order to regulate the motor, described by the function convert. The function model of the claim is not able to describe the means by which the motor speed is altered. The model describes a very general understanding of a control, thereby not incorporating the unique and distinguishing components of the patent claim.
Figure 5.4 Function model US Patent 7270591.

5.2.2 Functional Behavior State Model

In the FB model of the FBS the function is considered as an interpretation of behavior, thus behavior is an abstracted form of the function in some instances and it can also be described as the means to a function in some instances. Thus there is some overlap between the function and behavior in the FB part of the FBS model. This overlap can cause problems while describing patent information as the distinction between the function and behavior may be difficult to obtain, based on textual description of complex objects. The association of behavior with the physical entities or claim object is not always clearly present in the textual information in patents. Due to the overlap between function and behavior, description of logic would be difficult, since distinction into function and behavior would be hard to establish.

In order to highlight the deficiencies of the FBS model to represent patent information, a claim from the US Patent 7201194, describing a Non-pneumatic tire is modeled using the FBS model. The claim describes the structure of the Non-pneumatic tire with respect to the components, their properties and relationship between the individual components.
A structurally supported tire, comprising: a reinforced annular band comprising an elastomeric shear layer, at least a first membrane adhered to a radially inward extent of the elastomeric shear layer and at least a second membrane adhered to a radially outward extent of the elastomeric shear layer, wherein each of the membranes has a longitudinal tensile modulus greater than a shear modulus of the shear layer and wherein a ratio of the longitudinal tensile modulus of one or more of the membranes to the shear modulus of the shear layer is at least about 100:1; a plurality of web spokes extending transversely across and radially inward from the reinforced annular band; and means for interconnecting the plurality of web spokes with a wheel.

Figure 5.5 Claim 1 US Patent 7201194

The FBS model of the patent claim seen in Figure 5.5 can be seen in Figure 5.6. The model presents the graphical representation of the claim and the associated description of the model. The model describes the function and description of the tire, which is abstracted from the textual description in the claim. The model is able to represent the tire, however, the information about the hierarchy of the component assembly is not clear. The relationship, defining the state of the tire, helps understand the structure of the tire. This however, relies on the textual description. The extensive use of textual means to represent the claim make the model susceptible to the vocabulary and other textual representation issues associated with this form of representation.
Function: Form Tire
Behavior 1: Components form tire
State 1
Entities: Annular Band
Shear Layer
First Membrane
Second Membrane
Web Spokes

Attributes
Ratio Longitudinal Tensile modulus of membranes to shear layer at least 100:1

Relations
First membrane adhered to elastomeric shear layer
Second membrane adhered to elastomeric shear layer

Figure 5.6 FBS model of Claim 1 of US patent 7201194

5.2.3 Core Product Model for patents
The core product model is developed, to support Product Lifecycle Management applications. It is an information management and archiving tool, which promotes structuring information so that it can be channeled and manipulated in modern design environments. The generic nature of the model is useful to represent information of different product classes. The model is used to represent information relating to the products form, function and behavior using generic semantics. The model is based on the form of the product and incorporates the functional data of the product with relation to its form. The model is unable to distinctly incorporate information regarding how the product is put together. The behavior description in a CPM is attributed to the core object, thus neglecting the behavior of the individual
components and or sub-assemblies. Assembly relationship in a CPM model, modeled using association classes, are not easily modeled and not able to sufficiently capture assembly relationships and assembly related functions. Expressing multiple flows using transfer functions, used to express input-output type functions, in a CPM doesn’t capture information related to the flow.

In order to highlight the difficulties encountered while using the CPM to represent patent information, a claim from the US Patent 7270591, describing the controller for a handheld power tool is modeled using function model. This claim was used earlier to demonstrate the use of functional model to represent patent claims. The claim, as seen in Figure 5.3 describes the manner in which the controller alters the motor speed on detecting a change in it.

![Figure 5.7 CPM representation for Claim 1 US Patent 7275091](image-url)
The core product model of the patent claim seen in Figure 5.3 can be seen in Figure 5.7. The model capture most of the information regarding the form of the product in terms of the assembly details but the information about the operation of the controller is not captured with the level of detail described in the claim. The motor speed, which is the outcome of the motor operating, could not be incorporated into the model. Due to the model’s inability to incorporate parameters resulting from an artifact description of the operational principle or the operation logic cannot be incorporated into the model. This missing element of the claim information leads to an incomplete description of the artifact. Thus representation of dynamic systems using the CPM poses a problem for patent claim representation.

5.3 Summary

Graph based representation for patent was considered because of the benefits it offers the choice of better search mechanism as well a means to directly use search results in the design process. A few design representation schemas, used for representing product information were studies. The choice of these schemas was influenced by the information found in patent claims. It was found that the chosen representation schemas are not sufficient capture the patent claims completely. Function modeling was found to be inadequate to represent the information with sufficient detail and it lacked the information regarding the form. The Function Behavior Structure model was unable to adequately capture information regarding the functionality and component relationships. The Core Product Model was found to be unable to capture the information regarding the form of the product with sufficient detail. The transfer functions, in the CPM, are not able to capture the information
about flow in sufficient detail. Logic represented using the CPM cannot be represented in detail.

The shortcoming of these representation schemas studied provides a closer understanding of the difficulties associated with representing information in patent claims compared to product information in design reports. The primary requirements of the patent representation scheme would be:

- Model the product form and functionality information
- Provide a unique and clear representation
- Incorporate the varying level of detail
- Ability to represent varying levels of abstraction
Chapter 6.

PROPOSED REPRESENTATION OF PATENTS

Since the primary aim of the research is to represent the product information found the patent in a format that would be easy to search and readily applicable in systematic design process. The patent claims studied in Chapter 3 shows that product information related to its functionality, behavior and form, form a major share of the information found in claims. Study of the engineering design process with respect to the applicability of the information shows that a graph based representation of this information will make it easier to feed the information into it. A graph-based representation will also help make patents searchable from an engineering perspective. The study of existing graph-based product representation schemes highlights their inability to completely express this patent information. The primary challenges being the varying level of detail of the information found in the patent and the inconsistencies in the explanation of the content.

In order to address the inabilities of the existing representation schemes to model the patent claims, a graph based representation scheme is proposed. The proposed representation scheme is aimed at making the information machine searchable and also easily interpretable for direct application into the systematic design process. The work presented in the following section, builds on various product representation schema. However, the significant difference being the adaptation of the representation, to suit information present in the claims of a patent and easy of searching and analyzing this information. The chapter introduces the graphical vocabulary developed for the proposed representation and the manner in
which the vocabulary can be applied to the patent claims to generate graphs for the same.

6.1 Graphical vocabulary

The information contained in patent claims studied in Error! Reference source not found.3, provided an understanding of the elements of patent claims. The color-coding scheme study formed the baseline for the components required to completely model the information contained in patent claims. Simple geometric shapes associated with these components were developed to form the vocabulary for the representation. The fundamental guiding principle here being that the direct mapping the information present in the textual format to the graphical representation will enable to completely represent the same. The vocabulary that evolved from the various iterations is presented in Table 6.1. This preliminary vocabulary consists primarily of the elements of the claims section; these include the functions, components performing the desired functions and also the collective behavior of the components.
Table 6.1 Graphical vocabulary

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Term</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Function</td>
<td>Action/activity (Verb)</td>
<td>Produce</td>
</tr>
<tr>
<td></td>
<td>Claim object</td>
<td>Component of the artifact/design/product.</td>
<td>Gear</td>
</tr>
<tr>
<td></td>
<td>Attribute</td>
<td>Assignable Property</td>
<td>Elongated</td>
</tr>
<tr>
<td></td>
<td>Object of Function</td>
<td>Component/artifact/product, which is being, acted upon/affected by the function.</td>
<td>Saw dust produced from a sawing operation (Not part of Artifact)</td>
</tr>
<tr>
<td></td>
<td>Energy/Motion</td>
<td>Energy or motion</td>
<td>Electrical Energy</td>
</tr>
</tbody>
</table>

6.2 Representation of Patent Claims using developed vocabulary.

The vocabulary presented in the earlier section was used to represent the text of patent claims in a graphical format. The implementation used the graph-based vocabulary to distinguish the various entities in the patent claims. The natural language vocabulary used to describe the graphical entities was extracted from the patent claims. The technique for transforming the text into a graph is described in this section with the help of an example. To demonstrate it, Claim 1 of the US patent 7090032 is modeled using the graphical vocabulary.
‘An electric power tool comprising: a housing in which a motor having a drive shaft is disposed, said housing being composed of a pair of half portions that are to be assembled into a united body; an inner case for receiving a planetary gear train having an input side and an output shaft, said input side of the planetary gear train being connected to the drive shaft of the motor to transmit power of the motor to the output shaft at reduced speed, said inner case being received in the housing; and a hammer case for receiving a hammer unit having an input side and an output shaft, said input side of the hammer unit being connected to the output shaft of the planetary gear train to convert rotational motion of the output shaft of the planetary gear train into an intermittent striking power outputted from the output shaft of the hammer unit, said inner case being received in said hammer case, wherein: said inner case has on an outer peripheral surface thereof at least one recess; said hammer case has at least one elongated hole that is aligned with said at least one recess of the inner case; and each of said half portions has bosses through which fastening members pass to fasten the half portions into said united body, at least one of said bosses being engageable with said at least one elongated hole of the hammer case, which is aligned with said at least one recess of the inner case.’

Figure 6.1 Claim 1 US Patent 7090032

The different components of the claim text are identified and classified based on the object that can be represented based on the developed vocabulary. The user parses the text, which is indexed and expressed in the parenthesis beside the original text. This can be seen in the parsed and indexed form of the patent claim in Table 6.2. The indices used are indicative of the term with respect to the graphical vocabulary and hence indicative of the symbol corresponding to the term. For example in line 1 of Table 6.2 the electric power is considered as energy indicated by E1, the nature of the energy being electrical is indicated by A1. The electrical here is considered to be
an attribute of the energy. Similarly housing is classified as a claim object indicated by the index O1. Similar functions are indicated by the index starting with the alphabet F and object of function is indicated by OF.

**Table 6.2 Patent Claim Text**

|   | An electric power (E1, A1) tool comprising: a housing (O1) in which a motor (O2) having a drive shaft (O3) is disposed, said housing being composed of a pair of half portions (O4, O5) that are to be assembled (F1) into a united body; an inner case (O6) for receiving (F2) a planetary (A2) gear train (O7) having an input side (O8) and an output shaft (O9), said input side of the planetary gear train (O7) being connected (F3) to the drive shaft of the motor to transmit (F4) power of the motor to the output shaft at reduced speed (A3), said inner case (O6) being received (F5) in the housing (O1); and a hammer case (O10) for receiving (F5) a hammer unit (O11) having an input side (O12) and an output shaft (O13), said input side of the hammer unit being connected (F3) to the output shaft (O9) of the planetary gear train (O7) to convert (F6) rotational (A4) motion (E2) of the output shaft of the planetary gear train (O7) into an intermittent striking power (E3, A5) outputted from the output shaft (O13) of the hammer unit (O11), said inner case (O6) has on an outer (A6) peripheral (A7) surface (O14) thereof at least one recess (O15); said hammer case has at least one elongated (A8) hole (O16) that is aligned (F8) with said at least one recess (O15) of the inner case (O6); and each of said half portions (O4, O5) has bosses (O17) through which fastening members (O18) pass to fasten (F9) the half portions (O4, O5), into said united body, at least one of said bosses being engageable (F6) with said at least one elongated hole (O17) of the hammer case (O11), which is aligned (F8) with said at least one (O16) of the inner case (O10).’

The claim text from Table 6.2 was represented in a graphical format, as seen in Figure 6.2 by the use of the developed vocabulary. The terms indexed are represented using the respective symbols from the vocabulary. These are then represented as a web of interconnected individual entities. The connecting lines, representing relationship between the different entities provides an understanding overall system explained in the patent. The graph can be understood with the help of an example; consider, sub-graph A in Figure 6.2 which represents a part of the
functionality of the object motor corresponding to the index O2 in the claim. The sub-
graph A contains two claim objects, motor and drive shaft, the relation between these 
objects can be explained with the help of the functions produce and transmit and 
connecting lines. The motor (O2) produces motion (E2) of the rotational type (A4), 
which is in turn transmitted (F4) to the drive shaft (O3), which a part of the motor. 
The connecting lines are used to represent the presence of a relation between the 
connected entities. However, these lines do not describe the relationships, these can 
be understood in context with the connected entities and symbols. Thus, textual data 
present in the claim is translated into the representation, which attempts to capture 
majority of the information present in the claim.
The functionality, behavior and assembly structure can be represented in the graph developed using the vocabulary. The functionality can be observed by studying the functionality related units. For example, sub-graph seen in Figure 6.3 the functionality of conversion of the rotational motion to intermittently striking motion. This is represented by the units E2 (rotational motion), F6 (convert) and E3 (striking motion).

Figure 6.2 Preliminary representation for Claim 1, US Patent no 7090032
The assembly structure can be understood in the same representation, the principle difference being the units connected. The functions and the claim objects in conjunction form the product’s assembly structure described in the claims. For example in Figure 6.4, the structure for the housing can be understood.

The behavior of the product cannot be independently represented, since the behavior of the product is representative of the components and function of the product. Observing the functional and assembly models in conjunction helps understand the behavior in the developed model. The interactions between these models represent the behavior of the product or its sub-systems. Behavior being
abstract and dependent on the interpretation of the user cannot be singled out in the model. This is representative of the understanding to of the actual claim based on the model. In order further clarify the representation, Claim 2 of the US patent 7090032 stated as;

```
'The electric power tool as claimed in claim 1, wherein: said at least one of said bosses has an innermost end surface; said inner case is provided in said at least one recess with a bottom wall by which said at least one recess is defined, said bottom wall being coming into contact with said innermost end surface of the at least one of said bosses; and said hammer case is provided along said at least one elongated hole with a first pair of opposite edges, said first pair of opposite edges being coming into contact with said innermost end surface of the at least one of said bosses.'
```

**Figure 6.5 Claim 2 US Patent 7090032**

This claim is represented using the graphical representation scheme as shown in Figure 6.6. This representation was developed using the technique described in the earlier section.
Figure 6.6 Preliminary representation for Claim 2, US Patent no 7090032

Claim 3 of the US patent 7090032 as seen in Figure 6.7, is represented using the graphical representation scheme as shown in Figure 6.8.

‘The electric power tool as claimed in claim 2, wherein: said at least one of said bosses has a pair of opposite outer surfaces; and said inner case is provided in said at least one recess with an inner wall by which said at least one recess is defined, said inner wall being coming into contact with one of said pair of opposite outer surfaces of the at least one of said bosses, respectively; and said hammer case is provided along said at least one elongated hole with a second pair of opposite edges, said second pair of opposite edges being coming into contact with said pair of opposite outer surfaces of the at least one of said bosses, respectively.’

Figure 6.7 Claim 3 of the US patent 7090032
6.3 Discussion

The vocabulary was used to represent patent of describing different inventions. It was found to be suitable to model the information contained with a reasonable level of detail. It was observed that the use of natural language based vocabulary within the representation helped in the understanding of the representation. However, the terminology used to describe similar terms is not consistent in patents. This variation was greater for patents from different companies, authored by different agencies. This variation will affect interpretation of the graphs produced by different individuals or companies.
One method to control the variation would be, the use of a consistent and controlled vocabulary would help overcome some of these issues. For example, the functional basis, which describes the fundamental vocabulary for functions of different products or artifact, can help achieve uniformity with respect to the functions that are mentioned in the different function blocks (Hirtz, Stone, McAdams, Szykman, & Wood, 2002). A similar generic vocabulary for the components would be the next step in removing the ambiguity that would result from an inconsistent vocabulary.

Further, the present representation scheme incorporates different independent claims present in a single patent individually. This would translate into many graphs relating to a single patent. The different claims found in a patent usually have some overlap; in such a case the different graphs for the claims would have some the same overlap too. These can be represented on a single combined graph, with each claim forming a layer, on the combined graph, so that it can be studied individually or in conjunction with the other claims found in the same patent.
Chapter 7. 

VERIFICATION AND VALIDATION

Chapter 5 introduced an evaluation of existing engineering design knowledge representation schemes that could be used to capture the different types of information found within the patent claims that are critical to engineering design. Then, Chapter 6 built on these representations by offering a new scheme that is tuned for capturing the identified information while satisfying the defined requirements. The chapter studies the ability of the representation to capture design information compared to the existing representation schemas and also the textual representation. The patents examined in section 5.2 highlighted the difficulties in using existing design representation schema to represent patent information. The representations generated using the schemas where analyzed for the information content contained along with representations generated using the developed representation scheme.

7.1 Comparison Procedure

The proposed patent representation scheme is intended to model the claim information in a format that is readily accessible and easily interpretable for both a human design engineer and an automated reasoning system. The representation therefore must be able to completely capture patent information content. As identified in section 5.2, existing methods used to model product information were unable to capture the complete information content. The different models formulated are analyzed using information theory fundamentals. The models when considered as discrete information sources enable the application of information theory to calculate
the information content measure. In this way, two models of the same patent formulated through different representations can be compared in a common metric.

Two different comparisons are done on a selected sub-set of patent claims. The first analysis uses the complete available vocabulary of the initial patent claim for calculating the information content for each representation. In this manner, a coverage measure is determined to compare how much of the initial information found in the patent claim is recaptured in the different representation schemes. In this way, the first measure is an extrinsic comparison measure that is dependent on the initial vocabulary of the patent claim. The second comparison is an intrinsic comparison that uses the employed vocabulary of each model. This measure can compare the relative representational efficiency of the schemes in capturing the patent claim information.

Table 7.1 below provides an overview of the claim and the representations developed for each of these claims. The text representation represents original text from the patent and is used as a baseline for the developing the other representations. These representations are used in the following sections for the information analysis. The capability of the representation scheme to address the shortfalls of the existing representation schemas, will determine if it can be used to model patent claims sufficiently.

**Table 7.1 Patent representations overview**

<table>
<thead>
<tr>
<th>Patent No.</th>
<th>Claim</th>
<th>Text</th>
<th>Function Model</th>
<th>FBS</th>
<th>CPM</th>
<th>Developed Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>7270591</td>
<td>1</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>7201194</td>
<td>1</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>
7.2 Extrinsic Comparison Results

The representation constructed from the vocabulary described must be able to model the claim information patents correctly and unambiguously. The representation scheme forms the relationship between the syntactically correct textual representation and the graph. This relationship can be seen in Figure 7.1, where the different possible relationships can be seen while representing data from base domain expressed as Domain 1 to the model domain expressed as Domain 2.

![Figure 7.1 Representations across Domains](image)

Each of the domains contains multiple data sets; multiple relationships between the data sets from the different domains are possible. The representation scheme would be invalid if it unable to establish a relationship between data sets in the two domains. If multiple data sets from base domain map to a single data set in the model domain, the representation scheme, defining the relationships would not be
unique. Inversely if a single dataset from the base domain maps to multiple datasets in the model domain, the representation scheme is defined as ambiguous.

Summarizing it, a representation in the model domain is invalid if it does not correspond to any claim text. A valid representation is ambiguous if it corresponds to several claims. A claim text will have a non-unique representation if it can be represented in multiple ways using the representation scheme. The ideal representation scheme must have a one to one relationship between the datasets in the two domains. Thereby the representation based on such a scheme will be unique, unambiguous and valid. The properties that control the relationship between the domains, with relation to the developed representation scheme are discussed in this section

*Representation Domain* covers the entities that can be defined using it. This in turn signifies the extent to which various entities can be defined using the representation scheme. The graphical vocabulary developed is based on the entities that were found in patent claims. These entities are generic entities and can be spotted in patent claims describing variety of inventions. The inclusion of the graphical vocabulary, in conjunction with the natural language vocabulary permits the representation to cover different types of patent claims. The coverage of the developed representation scheme can be checked with that of the existing representation schemas by analysis the information content of the respective models of the claims. The ability of the representations to effectively model information using existing vocabulary of the textual representation will help establish a coverage measure. It will also help determine the amount of information lost during the conversion from textual to graphical representation.
The functional model and the core product model developed for the claim from US patent 7270591, describing a motor controller, as seen in Figure 7.2, is compared with the developed model. The information measures, in terms of information bits that are present in each of the representation are calculated by using the information theory fundamental described in Chapter 3. The original vocabulary, from the claim text is used to calculate the information content in each model. The information loss during the conversion of the text will determine the coverage of scheme.

‘A hand held orbital sander, comprising: a. a housing having an electronically commutated motor disposed therein and an orbit mechanism disposed beneath the housing; and b. a motor controller coupled to the motor, the motor controller changing the speed at which it runs the motor from an idle speed to a sanding speed upon the motor speed dropping from idle speed to an idle speed threshold value and changing the speed at which it runs the motor from sanding speed to idle speed upon the motor speed increasing from sanding speed to a sanding speed threshold value wherein the motor controller slows the motor by reverse commutation when it changes the speed of the motor from sanding speed to idle speed.’

Figure 7.2: Claim 1. US Patent 7270591

The function model developed from the claim text can be seen in Figure 7.3.
Figure 7.3 Function model for Claim 1 US Patent 7270591

Table 7.2 *Error! Reference source not found.* presents the information measure for the original textual representation of the patent claim. The information measure of the functional model based on the vocabulary of the text can be seen in Table 7.3.

**Table 7.2 Information measure for Textual Representation Claim 1 US Patent 7270591**

<table>
<thead>
<tr>
<th>Entity</th>
<th>Instances</th>
<th>Distinct entities</th>
<th>Information Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute (including form)</td>
<td>15</td>
<td>6</td>
<td>38.77</td>
</tr>
<tr>
<td>Function</td>
<td>14</td>
<td>10</td>
<td>46.51</td>
</tr>
<tr>
<td>Claim Object</td>
<td>15</td>
<td>6</td>
<td>38.77</td>
</tr>
<tr>
<td>Object of function</td>
<td>13</td>
<td>2</td>
<td>13.00</td>
</tr>
<tr>
<td>Energy/Motion</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>57</td>
<td>24</td>
<td>261.34</td>
</tr>
</tbody>
</table>

**Table 7.3 Information measure (extrinsic) for Function Model of Claim 1 US Patent 7270591**

<table>
<thead>
<tr>
<th>Entity</th>
<th>Instances</th>
<th>Distinct entities</th>
<th>Information Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>6</td>
<td>10</td>
<td>19.93</td>
</tr>
<tr>
<td>Flow</td>
<td>14</td>
<td>2</td>
<td>14</td>
</tr>
</tbody>
</table>
Based in the information bits contained in the functional model of the claim, it can be noted that conversion of the text to a functional model, results in significant information loss. The functional model is able to cover around 27\% of the claim text. The loss can be attributed to the fact that the functional model is unable to capture information relating to the assembly structure.

A similar analysis of the information content covered by the CPM, seen in Figure 7.4, is seen in Table 7.4. The conversion of the claim text to CPM, results in an information loss illustrated the inability of the CPM to cover the claim text. The Core Product Model is able to cover around 21\% of the claim text.
The representation of claim text based on the developed scheme, seen in Figure 7.5, was conducted. The information analysis of the model can be seen in Table 7.5. The conversion of the claim text to model. The model, based on the developed representation scheme, is able to cover around 68% of the claim text.
The FBS model of the claim of US patent 7201194, seen in Figure 7.6, was compared with the model based on the developed representation scheme.
A structurally supported tire, comprising: a reinforced annular band comprising an elastomeric shear layer, at least a first membrane adhered to a radially inward extent of the elastomeric shear layer and at least a second membrane adhered to a radially outward extent of the elastomeric shear layer, wherein each of the membranes has a longitudinal tensile modulus greater than a shear modulus of the shear layer and wherein a ratio of the longitudinal tensile modulus of one or more of the membranes to the shear modulus of the shear layer is at least about 100:1; a plurality of web spokes extending transversely across and radially inward from the reinforced annular band; and means for interconnecting the plurality of web spokes with a wheel.

Figure 7.6 Claim 1 US Patent 7201194

- **Function:** Form Tire
- **Behavior 1:** Components form tire
- **State 1**
- **Entities:** Annular Band, Shear Layer, First Membrane, Second Membrane, Web Spokes
- **Attributes** Ratio Longitudinal Tensile modulus of membranes to shear layer at least 100:1
- **Relations** First membrane adhered to elastomeric shear layer, Second membrane adhered to elastomeric shear layer

Figure 7.7 FBS model of Claim 1 of US patent 7201194
The FBS model of the claim can be seen in Figure 7.7. Table 7.6 presents the information measure for the original textual representation of the patent claim. The information measure of the functional model based on the vocabulary of the text can be seen in Error! Reference source not found.

**Table 7.6: Information measure for Textual Representation Claim 1 US Patent 7201194**

<table>
<thead>
<tr>
<th>Entity</th>
<th>Instances</th>
<th>Distinct entities</th>
<th>Information Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute (including form)</td>
<td>18</td>
<td>11</td>
<td>62.27</td>
</tr>
<tr>
<td>Claim Object</td>
<td>17</td>
<td>7</td>
<td>47.73</td>
</tr>
<tr>
<td>Function</td>
<td>7</td>
<td>5</td>
<td>16.25</td>
</tr>
<tr>
<td>Object of function</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Energy/Motion</td>
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<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>44</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>204.33</td>
</tr>
</tbody>
</table>

**Table 7.7 Information Measure (extrinsic) for FBS Claim 1 US Patent 7201194**

<table>
<thead>
<tr>
<th>Entity</th>
<th>Instances</th>
<th>Distinct entities</th>
<th>Information Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
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<td>5</td>
<td>2.32</td>
</tr>
<tr>
<td>Entities</td>
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<td>7</td>
<td>14.04</td>
</tr>
<tr>
<td>Behavior</td>
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<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td>Attribute</td>
<td>1</td>
<td>11</td>
<td>3.46</td>
</tr>
<tr>
<td>Relations</td>
<td>2</td>
<td>2</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>47.55</td>
</tr>
</tbody>
</table>

The study of the information bits contained in the FBS model reveals that there is a significant loss of information during the conversion of the text to the FBS model. This loss, illustrates that the FBS is unable to cover a significant portion of the claim text. The FBS model covers around 23% of the claim text.
The model of the same claim developed using the proposed representation can be seen in Figure 7.8. The information analysis of this model, seen in Table 7.8 shows
that there is a slight loss of information during the conversion of text to graph. The model covers about 70% of the textual information.

**Table 7.8 Information measure (extrinsic) for developed representation Claim 1**

US Patent 7201194

<table>
<thead>
<tr>
<th>Entity</th>
<th>Instances</th>
<th>Distinct entities</th>
<th>Information Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute (including form)</td>
<td>11</td>
<td>11</td>
<td>38.05</td>
</tr>
<tr>
<td>Claim Object</td>
<td>12</td>
<td>7</td>
<td>33.69</td>
</tr>
<tr>
<td>Function</td>
<td>6</td>
<td>5</td>
<td>13.93</td>
</tr>
<tr>
<td>Object of function</td>
<td>2</td>
<td>2</td>
<td>2.00</td>
</tr>
<tr>
<td>Energy/Motion</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>31</td>
<td>25</td>
<td>143.96</td>
</tr>
</tbody>
</table>

Summarizing the analysis, the developed representation is able to incorporate more information compared to existing representation schemas. The loss of information during the conversion can be attributed to the fact that in the textual representation, the terms are often repeated. However, in a graph model, the repetitions are addressed by having multiple relations between the graphical units. This prevents the repetition of the terms, without the loss of the information. This can be considered to be a drawback of using information theory to compare graphs with text. The linearity of the textual form of representation is transformed into a multidimensional graph, which makes it unsuitable to compare the graphs with text.

### 7.3 Intrinsic Comparison Results

The information measure of the representation schemas is compared with that of the proposed representation scheme. This helps quantify the information content of the various models developed using the existing representation schema as well as the developed representation. The vocabulary of each of the models forms the finite
vocabulary, used in the information analysis. The information measure of the textual claim, which is computed as described in Chapter 3, is considered to be the baseline for the comparative study. The graphical representation that captures the entire information measure of the textual representation is considered to be the ideal graphical representation for the patent claim.

The claims discussed in section 5.2, where represented using the developed representation scheme. Considering Claim 1 from the US patent 7270591 seen in Figure 7.2, which describes a motor controller for a handheld power tool. This claim was represented using functional modeling, seen in Error! Reference source not found., and the core product model, seen in Figure 7.4 Error! Reference source not found.. The claim was represented using the developed representation scheme as seen in Figure 7.5 Error! Reference source not found.. Graph B and Graph C represent the two modes of operation, while Graph A represents the product structure. It should be noted that Graph B and Graph C are to be are an extension of Graph A depending on the mode of operation of the controller.

Figure 7.3 Function model for Claim 1 US Patent 7270591

Table 7.2 Error! Reference source not found. presents the information measure for the original textual representation of the patent claim. The information measure of the functional model based on the vocabulary of the text can be seen in Table 7.3.
Table 7.2 Error! Reference source not found. presents the information measure for the original textual representation of the patent claim. An ideal representation scheme would have the same information measure as this textual representation. However, function modeling is only able to represent the functional information contained in the claim. Therefore, in theory, function model should be able to represent the function and the object of function entities from the textual representation. The information measure for the actual graph representation is also seen in Table 7.9. The difference in the theoretical and the actual information can be attributed to the fact that the function entities in the textual representation also include the assembly related function. The information measure contained in the actual function model of the claim is only 22.96% of the total information measure of the textual representation. This highlights that the function model is not sufficient to represent all the patent information.

Table 7.9 Information measure (intrinsic) for functional modeling Claim 1 US Patent 7270591

<table>
<thead>
<tr>
<th>Function Modeling</th>
<th>Instances</th>
<th>Distinct entities</th>
<th>Information Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>6</td>
<td>3</td>
<td>9.51</td>
</tr>
<tr>
<td>Flow</td>
<td>14</td>
<td>5</td>
<td>32.51</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>8</td>
<td>60</td>
</tr>
</tbody>
</table>

The CPM was also used to represent the same claim. In theory this model should be able to represent all the information of the claim. The information measure for the CPM of the claim can be seen in Table 7.10. The difference in the information measure in the actual and theoretical CPM of the claim can be attributed to the fact that model was unable to represent most of the information regarding the
operating logic of the controller. The information measure contained in the CPM is just 14.56% of the textual representation.

Table 7.10: Information Measure (intrinsic) for CPM Claim 1 US Patent 7270591

<table>
<thead>
<tr>
<th>CPM</th>
<th>Instances</th>
<th>Distinct entities</th>
<th>Information Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Entity</td>
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<td>0</td>
</tr>
<tr>
<td>Artifact</td>
<td>4</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Association</td>
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<tr>
<td>Function</td>
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<td>2</td>
</tr>
<tr>
<td>Form</td>
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<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>11</td>
<td>38.05</td>
</tr>
</tbody>
</table>

The claim when represented using the developed representation was able to capture most of the information in the claim. The representation however, was unable to incorporate the information relating to the means by which the motor was slowed down. This shortfall was due to the lack of a direct function associated with the means, based on the natural language in the textual representation. The information measure, seen in Table 7.11, contained in this model is 64.5% of the textual representation. Thus the developed scheme is able to represent information that the functional model and the CPM cannot.

Table 7.11 Information measure (intrinsic) for developed representation Claim 1 US Patent 7270591

<table>
<thead>
<tr>
<th>Developed Representation</th>
<th>Instances</th>
<th>Distinct entities</th>
<th>Information Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute (including form)</td>
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<td>6</td>
<td>33.60</td>
</tr>
<tr>
<td>Function</td>
<td>10</td>
<td>7</td>
<td>28.07</td>
</tr>
<tr>
<td>Claim Object</td>
<td>10</td>
<td>6</td>
<td>25.85</td>
</tr>
</tbody>
</table>
Claim 1 from the US Patent 7201194, was represented using FBS model in section 5.2. It was noted that the model was insufficient to represent the textual information in the claim. The claim, seen in Figure 7.6, describes a structural non-pneumatic tire. The FBS model, seen in Figure 7.7 was unable to incorporate the information pertaining the relationship between the components. This claim was represented using the developed representation scheme as seen in Error! Reference source not found.. The information regarding the assembly relationship of the tire was captured in this model.

The information measures, in terms of information bits that are present in each of the representation are calculated by using the information theory fundamental described in Chapter 3. Table 7.6: presents the information measure for the original textual representation of the patent claim. The FBS was also used to represent the same claim. In theory this model should be able to represent all the information of the claim. The information measure for the FBS of the claim can be seen in Table 7.12. The difference in the information measure in the actual and theoretical FBS of the claim can be attributed to the fact that model was unable to represent much of the assembly relationships. The information measure contained in the FBS is just 16.26% of the textual representation.

Table 7.12 Information Measure (intrinsic) for FBS Claim 1 US Patent 7201194

<table>
<thead>
<tr>
<th></th>
<th>Instances</th>
<th>Distinct entities</th>
<th>Information Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7.6 presents the information measure for the original textual representation of the patent claim. The FBS was also used to represent the same claim. In theory this model should be able to represent all the information of the claim. The information measure for the FBS of the claim can be seen in Table 7.12. The difference in the information measure in the actual and theoretical FBS of the claim can be attributed to the fact that model was unable to represent much of the assembly relationships. The information measure contained in the FBS is just 16.26% of the textual representation.
The claim when represented using the developed representation was able to capture most of the information in the claim. The information measure, seen in Table 7.13 contained in this model is **74.45%** of the textual representation. Thus the developed scheme is able to represent information that the FBS model cannot.

**Table 7.13 Information measure (intrinsic) for developed representation Claim**

1 US Patent 7201194

<table>
<thead>
<tr>
<th>Developed Representation</th>
<th>Instances</th>
<th>Distinct entities</th>
<th>Information Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute (including form)</td>
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<td>11</td>
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</tr>
<tr>
<td>Claim Object</td>
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<td>12</td>
<td>43.02</td>
</tr>
<tr>
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<td>13.93</td>
</tr>
<tr>
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<td>2</td>
<td>2.00</td>
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<tr>
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<td></td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>30</td>
<td>152.11</td>
</tr>
</tbody>
</table>

The comparative study, between the existing representation schemas reviewed and the developed representation scheme, show that the developed representation scheme is able to represent the textual information in the patent claim comprehensively. The use of the specific cases shows that the developed scheme overcomes the shortfalls of the existing representations schemas.
Chapter 8.

CONCLUSION AND FUTURE WORK

Design experience and knowledge is valuable information, whose preservation and reuse aids in the design of new products and processes. Chapter 1 introduced the patents, and studied the components of the patents. The study on the role of patents in a systematic design process showed that the use of patents was limited to the conceptual stages. It also revealed the difficulties in locating relevant patents and the lack of a systematic procedure to incorporate patent data into the design process. Chapter 2 presented the research questions aimed at understanding the usefulness of patent data and the information content of the patent data. Chapter 3 provided the analysis of the patent claims aimed at identifying the data within patent claims, which can be used in the design process. The study revealed that patent claims contain information regarding the product functionality and assembly structure.

Organization of the patent database and the problems relating to retrieval of the relevant patents is studied in Chapter 4 looks at the organization of the patent database and the patent classification system. Problems in retrieving relevant patents, in terms of representation of the data, vocabulary used and the size of the patent database are also discussed in the chapter. Chapter 5 discusses the possibility of using existing design representation schemes that can be used to model patent information, in order to facilitate the direct use of the information and a fast and accurate means retrieval of desired information. Problems encountered in the using these representation schemas to model patent claims are also discussed, which are used to develop requirements for the patent representation scheme.
Chapter 6 presents an alternate representation scheme capable to model patent claims as a graph. The representation scheme builds on existing representations and provides a simple graph based representation intended to facilitate the direct use of the information from patent claims. The representation will enable the establishment of a product knowledge repository with an intelligent and provide a designer-friendly search mechanism.

Chapter 7 compares the developed representations ability model patent claims with the existing product representation schemas studied. The information analysis also helps establish the coverage and the representation efficiency of the developed representation scheme. This chapter summarizes the results of the research presented in the earlier sections, with relation to the research questions. Observations noted during the use of the modeling of product information using existing representation schemes are presented. The chapter also discusses the future work required to develop the representation. The possible extensions of the representation scheme and the steps leading to the implementation of the representation are discussed.

8.1 Conclusion

The patent database has become easier to search over the last few years due to the advent information age. The Internet has made it possible to search the patent databases across the globe. It has been made possible to search through the faster, however the effectiveness of the search has not increased at a similar rate, with human intervention being required too often. These search tools were developed as means for inventor and patent examiners to check inventions for patentability and patent
infringement. The research has examined patent for their content and developed graph based representation scheme for modeling them.

8.1.1 Information Types Found in Patent Claims

The information analysis of the patent claims identified the type of information found in the claims. Sample patent chosen as representative of the vast patent database, showed relative proportion of the product’s function and assembly related components of the claim. It is observed that majority of the information is contributed by the claim objects, attributes and functions. The claim objects and the functions represent the form of the product and the object of function and the functions together describe the product functionality. The behavior of the product is present in the textual description, however it cannot be distinctly identified. The behavior of the product can be seen as the interaction of the form and function.

The analysis of the sample patents shows a drop in the understanding of the text when the different components are subtracted from the main text. An information measure for components of claim text was established by using information theory. This showed that, contribution of the claim objects and the functions to the information measure is nearly equal. Thus the analysis helped perceive claim text from a designer’s point of view and extract the portion that can be useful while designing new products.

8.1.2 Evaluation of Proposed Representation

Graph based representations are identified as an effective way to represent design information contained in patents. Modeling patent claim using existing design representation schemas led to an information loss during the conversion from text. This loss illustrates the inability of existing design representation schemas to model
patent claims. An alternate representation scheme, addressing the shortfalls of existing representation schemas is proposed. This scheme was compared with the existing representation schemas for comparing their effectiveness to model patent information. Information theory fundamentals used compute the information bits that are contained in the model provided the basis of the comparison. An extrinsic comparison measure was used to determine the coverage of the representation scheme, by comparing the information loss during the conversion from textual to graphical representation. An intrinsic comparison measure was used to compare the relative representational efficiency of the schemes in capturing the patent claim information. The proposed scheme, modeled patent information relatively better than the existing representation schemas for the both coverage and representational efficiency based on the computations.

8.2 Modeling Observations

Observations regarding information modeling and analysis were noted during the course of the research. These observations can be incorporated into future variations of the proposed patent representation scheme. Modeling claim text using functional modeling was comparatively more time consuming. The functional modeling required developing an understanding of the text to identify the different functions and flows not distinguished and clearly present in claims. The solution independent function model was not clearly indicative of the actual product described in the claim text, as the distinguishing characteristics of the invention were lost.

Modeling the claim text using Function behavior structure scheme and the Core product model scheme was time consuming due to the inherently complicated
structure of these scheme. The simplified structure of the proposed representation scheme makes it apt for representing information from claim text and also without the text. This will enable the automatic generation of claim text based on the models.

Information theory fundamentals are unsuitable to analyze information content in graphs. Text model often contains repeated words but in a graph model the graphical entities are usually not repeated. In a graph model multiple connections to an element thus repetition of the graph entities is prevented without the loss of the information. The information theory fundamentals need to be revised for analyzing multidimensional graph models.

### 8.3 Future Work

The representation scheme presented in as part of the work done is a preliminary representation structure. Further work, in terms of refining the representation and validation regarding the completeness of the representation need to be done. Further development of the representation scheme into a formal computer based representation, which can be used to perform simple Boolean operations with the graphs. This development will aid in processing the information and also facilitate the development of complex queries. The section discusses some of the directions of future work on the representation.

#### 8.3.1 Representation Evaluation

The ability of the representation to model the form and function related information found in patent claims was evaluated in comparison with some existing representation schemes. The representation needs to be further evaluated to check for
its ability and efficiency in modeling patent information found in different types of patents and also be compared with other product representation schemas.

The ability of the representation scheme in modeling the information uniquely needs to be evaluated. This can be studied by means of user studies and understanding if the representation scheme in its present form leads multiple users to generate the same models. The ability of the representation scheme of modeling information clearly also needs to be studied. This property influences the understanding of similar models differently by multiple users. User studies to evaluate how the patent models generated using the representation scheme are interpreted can understand this property.

Other properties like the ability of the representation scheme in aiding the user to distinguish between the high value and the low value information need to be studied further. The ability of the representation to capture the different levels of detail of similar information without a significant loss in value is important. Since different users tend to describe information differently, often times some information is hidden and implicit in the description. The representation must be able to account for these factors so that the information contained in the database is at a certain minimum useful level of detail.

8.3.2 Query structure

A graphical query structure based on the representation is presented in the following section. The graphs can be searched for sub-graphs within them. The query will include target sub-graphs, which form part of a desired output claim or the combined claims. A simple target object, to query for a specific type of arrangement
of two objects with clamshell type structure would look like the sub-graph in Figure 8.1.

![Figure 8.1 Assembly-Component Query.](image)

A similar approach can be used for function based searching of the database. A simple target function structure query can be developed as sub-graph shown in Figure 8.2. The query is intended to look for means X to satisfy the function of producing striking motion using rotary motion. Different pattern matching algorithms available today can help us check for this graph against our database, for matches. However, here the control vocabulary would be more important as a similar graph can exist for multiple objects.
8.3.3 **Representation Implementation**

Future work includes adapting existing algorithms or developing new ones to automate the search. Since finding the relevant information is critical to the applicability of the information, it makes the search tool development important. Locating the relevant information in a timely manner will help utilize the information effectively. The search tools can also be used to automate the search for information to check the patent applications. The representation is used to represent the functionality and allied information of the product; search for patentability can be automated, presently requiring manual examination for patent infringement. Developing a tool to automate the process of the developing the graphs from textual matter is also a direction for future work. Such a tool is specifically important considering the sizing of the existing patent database and the growing size of patent database.
8.3.4 **Representation Extension**

Development of extension tools for the representation scheme will add to the utility of the representation models. The use of the natural language in the representation was observed to influence the understanding of the model. Thus evaluating the need for and developing a suitable standardized vocabulary would be a useful addition to the representation scheme. The vocabulary could be developed to include patent specific terms, similar to the functional basis for the functional modeling. This extension will thus help eliminate the ambiguity due to the use of natural language and also aid in the development of the query system for the representation.

The patent representations were developed so that they could provide better search mechanism of the patent database to the user. Manipulation of the graphs would a logical next step to design automated search systems. Automated graph manipulation will also permit the development of intelligent systems, capable of designing systems autonomously using the patent database. This would require the development of grammatical rules to allow for “correct” composition of models. Development of Logical connectors would be a first step in development of the graph grammar.

Graph grammar development will aid in computer interpretation and manipulation of the graphs. A tool, which could interpret a graph model and generate the appropriate claim text would be a development ushering the automation of the patent authoring. This would eliminate the inconsistency in the claim text across the database and ensure uniformity in the database. The use of graph as a primary representation of patent claims can also be used to automate the process of evaluation.
of infringement of patents. The manual evaluation of infringement, presently lasting a couple of years, can be automated with the use of similarity evaluation tools. These and more extensions to the representation scheme will help promote the use of patents in aiding future designers.
An electrically driven hand-held tool, comprising a housing (2; 12; 22; 32) having a plurality of air suction openings (6; 16; 26; 36), and electromotor (20; 30; 40), a gear set for transmitting rotation of an output shaft of the electromotor to a drive spindle, and a fan-wheel all arranged in the housing (2; 12; 22; 32), the fan-wheel providing, during operation of the tool, for aspiration of air through the suction openings (6; 16; 26; 36), for directing the aspirated air past the electromotor and the gear set for cooling same, and for expelling warm air, which was heated as a result of absorbing heat generated by the electromotor and the gear set during the operation of the tool, out of the housing (2; 12; 22; 32); and means for directing the warm air out of the housing (2; 12; 22; 32); the directing means comprising a warm air channel (7; 17; 27; 37) arranged downstream of the electromotor and the gear set and spaced from a tool handle (3; 13; 23; 33) and having a plurality of blow-out openings (8; 18; 28; 38) arranged in such a way that during use of the hand-held tool, the expelled warm air flows in a direction away from the tool operator.
A headlamp for a two-wheel vehicle, comprising a lamp body that has a concave portion opened to a front of the lamp, a translucent cover that covers the front open portion of the lamp body, and a reflector that is provided in the concave portion of the lamp body and to which a light source is attached, said headlamp further comprising: an extension element provided along a peripheral edge portion of the reflector and between an open edge portion of the lamp body and the peripheral edge portion of the reflector, said extension element comprising a cover portion that extend along the open edge portion of the lamp body and covers, from the front, the are between the peripheral edge portion of the reflector and the open edge portion of the lamp body; a position bulb provided in the lamp body; a light transmitting member provided so as to cover transmitting openings formed in the cover portion of the extension element; and a reflective portion formed in a peripheral area of the lamp body which substantially faces the light transmitting member from behind; wherein light from the position bulb is reflected by the reflective portion, transmitted through the light transmitting member, and radiated forward; and whereby the entire light transmitting member appears to be lighted and the headlamp is visible clearly.
A structurally supported tire, comprising: a reinforced annular band comprising an elastomeric shear layer, at least a first membrane adhered to a radially inward extent of the elastomeric shear layer and at least a second membrane adhered to a radially outward extent of the elastomeric shear layer, wherein each of the membranes has a longitudinal tensile modulus greater than a shear modulus of the shear layer and wherein a ratio of the longitudinal tensile modulus of one or more of the membranes to the shear modulus of the shear layer is at least about 100:1; a plurality of web spokes extending transversely across and radially inward from the reinforced annular band; and means for interconnecting the plurality of web spokes with a wheel.
A structurally supported wheel-tire, comprising: a reinforced annular band comprising an elastomeric shear layer, at least a first membrane adhered to a radially inward extent of the elastomeric shear layer and at least a second membrane adhered to a radially outward extent of the elastomeric shear layer, wherein each of the membranes has a longitudinal tensile modulus greater than the shear modulus of the shear layer and wherein a ratio of the longitudinal tensile modulus of one or more of the membranes to the shear modulus of the shear layer is at least about 100:1; a tread adhered to a radially outer extent of the reinforced annular band; a plurality of web spokes extending substantially transversely across and radially inward from the reinforced annular band; and a wheel radially inward of the plurality of web spokes and interconnected therewith.
A structurally supported tire, comprising: a reinforced annular band comprising an elastomeric shear layer, at least a first reinforcement membrane adhered to a radially inward extent of the elastomeric shear layer and at least a second reinforcement membrane adhered to a radially outward extent of the elastomeric shear layer, wherein each of the membranes has a longitudinal tensile modulus greater than a shear modulus of the shear layer and wherein a ratio of the longitudinal tensile modulus of one or more of the membranes to the shear modulus of the shear layer is at least about 100:1; and a plurality of web spokes extending transversely across and radially inward from the reinforced annular band and interconnecting with a surface of the reinforced annular band.
A vehicle headlamp comprising: a projection lens; a reflector; a light source movable with respect to the reflector between a first light source position and a second light source position; and a movable shade movable between a first shade position and a second shade position, wherein the light source and the movable shade are able to interlock.
A vehicle headlamp comprising: a projection lens; a light source movable between a first light source position and a second light source position; a reflector; a movable shade movable between a first shade position and a second shade position; and a stationary shade disposed in the vicinity of rear focal point of the projection lens and intercepts part of reflected light from the reflector, wherein the light source and the movable shade are able to interlock, and wherein the height position of an upper end edge of the stationary shade is positioned between a height position of an upper end edge of the movable shade when the movable shade is located at the first shade position and a height position of the upper end edge of the movable shade when the movable shade is located at the second shade position.
A vehicle headlamp comprising: a projection lens; a light source movable between a first light source position and a second light source position; a reflector; a movable shade movable between a first shade position and a second shade position, wherein the light source and the movable shade are able to interlock, wherein the light source and the movable shade are supported by a common support member, and wherein the support member is moved by a driving device between a first shift position where the light source is located at the first light source position and the movable shade is located at the first shade position and a second shift position where the light source is located at the second light source position and the movable shade is located at the second shade position.
A vehicle electric rotating machine that is driven by an electric power of a battery to start an engine at the time of start-up of said engine, as well as that is driven by the engine to generate an AC power after said engine has been started, said vehicle electric rotating machine comprising: a power section in which there are provided plural sets of a pair of switching elements connected in series between positive and negative terminals of said battery, and diodes connected in parallel to said switching elements respectively, and in which a connection point of the switching elements connected in series is connected to a stator winding of said vehicle electric rotating machine; and a control circuit section that controls said power section so that an electric power of said battery is supplied to said vehicle electric rotating machine to drive a rotor by ON/OFF control of said switching elements at the time of start-up of said engine, and an AC power, which is generated at said vehicle electric rotating machine, is rectified to a DC power with said switching element and diode group to charge said battery in a normal engine speed region of said engine at the time of power generation; wherein with respect to flow of cooling air made by a centrifugal fan that is fixed to said rotor, there are separately located the control circuit section on the upstream side, and the power section on the downstream side; and the mentioned control circuit section is provided with a through hole so that the mentioned cooling air flows linearly through the mentioned power section.
A hand held orbital sander, comprising: a. a housing having an electronically commutated motor disposed therein and an orbit mechanism disposed beneath the housing; and b. a motor controller coupled to the motor, the motor controller changing the speed at which it runs the motor from an idle speed to a sanding speed upon the motor speed dropping from idle speed to an idle speed threshold value and changing the speed at which it runs the motor from sanding speed to idle speed upon the motor speed increasing from sanding speed to a sanding speed threshold value wherein the motor controller slows the motor by reverse commutation when it changes the speed of the motor from sanding speed to idle speed.
A hand held orbital sander, comprising: a. a housing having an electronically commutated motor disposed therein and an orbit mechanism disposed beneath the housing; and b. a motor controller coupled to the motor, the motor controller changing the speed at which it runs the motor from an idle speed to a sanding speed upon the motor speed dropping from idle speed to an idle speed threshold value and changing the speed at which it runs the motor from sanding speed to idle speed upon the motor speed increasing from sanding speed to a sanding speed threshold value wherein the sander has an on/off switch and the motor controller senses whether the on/off switch is on when the sander is first coupled to a source of power and if it is, does not start the motor until the on/off switch is first switched off and then back on.
A hand held orbital sander, comprising: a. a housing having an electronically commutated AC synchronous motor disposed therein and an orbit mechanism disposed beneath the housing; and b. a motor controller coupled to the motor, the motor controller changing the speed at which it runs the motor from an idle speed to a sanding speed upon the motor speed dropping from idle speed to an idle speed threshold value and changing the speed at which it runs the motor from sanding speed to idle speed upon the motor speed increasing from sanding speed to a sanding speed threshold value.
A hand held orbital sander, comprising: a. a housing having an electronically commutated brushless DC motor disposed therein and an orbit mechanism disposed beneath the housing; and b. a motor controller coupled to the motor, the motor controller changing the speed at which it runs the motor from an idle speed to a sanding speed upon the motor speed dropping from idle speed to an idle speed threshold value and changing the speed at which it runs the motor from sanding speed to idle speed upon the motor speed increasing from sanding speed to a sanding speed threshold value.
A hand held orbital sander, comprising: a. a housing having an electronically commutated motor disposed therein and an orbit mechanism disposed beneath the housing; and b. a motor controller coupled to the motor, the motor controller changing the speed at which it runs the motor from an idle speed to a sanding speed upon the motor speed dropping from idle speed to an idle speed threshold value and changing the speed at which it runs the motor from sanding speed to idle speed upon the motor speed increasing from sanding speed to a sanding speed threshold value wherein the sander has an on/off switch and the motor controller senses a collapse in an input voltage when the on-off switch is turned off and reverse commutates the motor to brake it.
A hand held orbital sander, comprising: a. a housing having an electronically commutated motor disposed therein and an orbit mechanism disposed beneath the housing; b. a motor controller coupled to the motor; c. a current sensor coupled to the motor controller that provides a signal indicative of motor current; and d. the motor controller changing the speed at which it runs the motor from an idle speed to a sanding speed based upon at least one of change in motor current and change in motor speed as the sander is removed from a work piece and changing the speed at which it runs the motor from sanding speed to idle speed based upon at least one of change in motor current and change in motor speed as the sander is applied to the work piece.
A knock control system for an internal combustion engine comprising: a variable valve mechanism configured and arranged to change at least an intake valve closing timing; a knock detector configured to output a knock signal indicative of the engine knocking condition during a knock detection interval; a signal-to-noise ratio estimating section configured to estimate a signal ratio based on at least one of an engine rotational speed and an engine load, the signal ratio being a ratio of an estimated knocking signal estimated when the engine knocking condition is occurring and an estimated noise signal estimated when the engine knocking condition is not occurring; an estimated noise signal updating section configured to update the estimated noise signal depending upon on the intake valve closing timing; a knock detectability determining section configured to determine if the knock signal can be detected or not based on the signal ratio; and a knock control section configured to execute knock control based on the knock signal when the knock detectability determining section determines the knock signal can be detected.
A knock control system comprising: variable valve means for changing at least an intake valve closing timing; knock detection means for detecting an engine knocking condition and for outputting a knock signal indicative of the engine knocking condition during a knock detection interval; signal-to-noise ratio estimating means for estimating a signal ratio based on at least one of an engine rotational speed and an engine load, the signal ratio being a ratio of an estimated knocking signal estimated when the engine knocking condition is occurring and an estimated noise signal estimated when the engine knocking condition is not occurring; estimated noise signal updating means for updating the estimated noise signal based on the intake valve closing timing; knock detectability determining means for determining if the knock signal can be detected or not based on the signal ratio; and knock controlling means for executing knock control based on the knock signal when the knock detectability determining section determines the knock signal can be detected.
A method of controlling engine knocking comprising: detecting an engine knocking condition and for outputting a knock signal indicative of the engine knocking condition during a knock detection interval; estimating an estimated knocking signal based on the knock signal when the engine knocking condition is occurring; estimating an estimated noise signal that is indicative of noise occurring when the engine knocking condition is occurring; updating the estimated noise signal based on an intake valve closing timing relative to the knock detection interval; estimating a signal ratio based on at least one of an engine rotational speed and an engine load, the signal ratio being a ratio of an estimated knocking signal when the engine knocking condition is occurring and an estimated noise signal when the engine knocking condition is not occurring; determining if the knock signal can be detected or not based on the estimated noise signal; an estimated noise signal calculation section configured to calculate an estimated noise signal based on the intake valve closing timing; and executing knock control based on the knock signal when the knock signal exceeds a prescribed level that was detected.
An electric power tool comprising: a housing in which a motor having a drive shaft is disposed, said housing being composed of a pair of half portions that are to be assembled into a united body; an inner case for receiving a planetary gear train having an input side and an output shaft, said input side of the planetary gear train being connected to the drive shaft of the motor to transmit power of the motor to the output shaft at reduced speed, said inner case being received in the housing; and a hammer case for receiving a hammer unit having an input side and an output shaft, said input side of the hammer unit being connected to the output shaft of the planetary gear train to convert rotational motion of the output shaft of the planetary gear train into an intermittent striking power outputted from the output shaft of the hammer unit, said inner case being received in said hammer case, wherein: said inner case has on an outer peripheral surface thereof at least one recess; said hammer case has at least one elongated hole that is aligned with said at least one recess of the inner case; and each of said half portions has bosses through which fastening members pass to fasten the half portions into said united body, at least one of said bosses being engageable with said at least one elongated hole of the hammer case, which is aligned with said at least one recess of the inner case.
A vehicular headlamp comprising: a first light source module having a plurality of semiconductor light emitting elements; and a second light source module connected in series to the first light source module, having at least one semiconductor light emitting element, wherein a number of semiconductor light emitting element in the second light source module is smaller than a number of semiconductor light emitting elements in the first light source module of the first light source module, and the second light source module generates light of brightness higher than light generated by the first light source module when an electric current substantially equal to that of the first light source module is supplied.
LIST OF REFERENCES


