PRODUCT DESCRIPTION IN TERMS OF ADVANTAGES AND DRAWBACKS: EXPLOITING PATENT INFORMATION IN NOVEL WAYS

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Abstract

Patents are an enormous source of valuable information. Unfortunately only a limited number of elements are targeted in them (mainly legal) and most of the design knowledge is lost or not exploited. Advantages and drawbacks belong to such a group. The paper presents a method to automatically extract advantages and drawbacks from patent texts and proposes a classification framework to organize the gathered knowledge. The organization of advantages and drawbacks follows the evolution of energy material and signal flows, typical of the functional analysis, and allows to organize them in structured documents where the designer can find useful triggers to avoid failures or hints to conceive a more appealing product.

Keywords: Design informatics, Design methods, Information management, Knowledge management

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1 USE PATENTS TO EXPLOIT ADVANTAGES AND DRAWBACKS OF TECHNOLOGIES FOR DESIGN

Due to the complexity and volatility of user needs, companies increasingly ask product designers and engineers to create ideas that meet needs in novel and better ways, rather than just making existing technologies more attractive (Brown and Wyatt, 2010). As a matter of fact, these professionals are nowadays involved in the process of understanding in depth what users want and desire (Haley, 1968; 1984; Day, Shocker and Srivastava, 1979).

Unfortunately, it is well known that user needs are usually examined in separate business departments, such as marketing or business development, and are described in a language that is remote from the professional practice of product designers and engineers. The relation between the understanding of user needs by marketing departments and the development of new products by technical departments is a deeply troubled one. There is a large agreement within the design community that this state of affairs is not optimal and that dedicated efforts should be made to reconcile the engineering approach with a more articulated understanding of user needs, particularly of consumer needs (Pahl et al., 2006; Ulrich and Eppinger, 2011).

A promising approach is based on the description of products in terms of *advantages* and disadvantages, or *drawbacks*. Users typically choose an artifact considering the advantages that it brings and the disadvantages that it solves. Advantages and drawbacks exist if they have an impact on the user and if they affect the product in terms of effectiveness (the level at which the product reaches its goals) and efficiency (how many resources does the product have to consume to reach its goals).

At the state of the art, the two main tools to manage advantages and drawbacks developed by the design community are QFD and FMEA/FMECA. Companies frequently make use of Quality Function Deployment (QFD) in order to map requisites, users' needs, users' requirements and to guide the design process (Carnevalli and Miguel, 2008). They use FMEA/FMECA to gather and study drawbacks, failure modes and their effects and causes (Liu, Liu, and Liu, 2013). On the other hand, the notion of advantages is also at the core of marketing techniques used in the segmentation of markets (benefit segmentation) and in the identification of alternative design solutions to achieve desired benefits (means-and-ends-chain analysis).

The interest in the description in terms of advantages and drawbacks is that it can be interpreted smoothly from the two sides of this troubled relationship: engineers can easily link them to performance specifications (usually described with a functional language) and hence technical specifications, while marketing experts can read them with the language of social sciences (for example, psychology, semiotics, sociology or anthropology). Given the promise of this description, why is it used so rarely?

There are several reasons. First, information on user needs is typically owned by users, and is stored in implicit and non-codified formats. Second, and consequently, in order to access this information product developers must enter into direct and personal contact with users, listening and understanding the voice of the customer. Not only this is very expensive, but the experience shows that the earlier the stage of development of needs, the more ambiguous, fuzzy and uncertain the information obtained by users. Third, most of this information is not publicly disclosed but is kept confidential as company know-how. Researchers have hard time to access structured analyses of products based on advantages, even more so for descriptions based on drawbacks. Thus, the goal of building up full scale descriptions based on advantages and drawbacks is still elusive.

In the present work, we consider patents as a possible alternative information source for advantages and drawbacks. As stated by the World Intellectual Property Organization (WIPO), an invention is a solution to a specific technological problem (WIPO, 2004). The problem that an invention solves in a technological field is a certain negative effect that the state-of-the-art technologies cannot overcome; on the other side, a solution is the way to solve this problem. A solution can lead to some advantages with respect to the known state of the art. Thus, starting from the definition of invention, it is clear how it can be characterized by its advantages and the problems it solves. Based on these definitions, the WIPO explicitly suggests as a guideline for applicants to write patents in this language. The applicant (the person or company that applies for the patent) is led to include this information in patent documents in order to have more chances of success in the patenting phase.

An important feature that makes patent information valuable is that the information that is contained in these documents today will be contained in other documents, like manuals, handbooks and market

reports, to which designers are more accustomed, in the future: information anticipates availability of products on the market by a factor varying from 6 to 18 months (Golzio, 2012). In addition, these documents are freely accessible by many different databases nowadays (Kim and Lee, 2015).
To claim that patents include descriptions in terms of advantages and drawbacks is one thing, to show how this information can be used effectively, however, is a completely different business. To test the hypothesis of the presence of advantages and drawbacks information in patents and to exploit this information for design purposed, there is a need to overcome two main problems:

- Analyzing patents requires skilled personnel and long time (León-Rovira, 2007)
- Due to the increase in the number of patent publications, there is a massive information overflow (Bergmann et al., 2008).

In this paper, we present a methodology for the extraction of information on advantages and drawbacks of technologies from patents, that is able to fully overcome these problems. In order to manage massive information in output we propose a classification framework for advantages and drawbacks of technologies. To reach these goal state-of-the-art Natural Language Processing (NLP) techniques have been proved to be adequate (Vicedo and Tomás, 2013).
While the final goal is to make available patent-based structured information to the design community, hence to product designers and engineers, in the rest of the paper we do not refer to "products" but to "technologies", in order to emphasize the general nature of the information generated. Technologies can be considered classes of solutions to given problems, while products are specific instantiations of a solution.

2 MANAGING INFORMATION ON ADVANTAGES AND DRAWBACKS OF TECHNOLOGIES. STATE OF THE ART REVIEW

2.1 Towards formal definitions of Advantages and Drawbacks

Even if the terms "advantage" and "drawback" are largely used in the product design field, it must be noted that a clear, unique and formal definition is not available. Under such circumstances a correct approach is to start with the meaning assigned in standard dictionaries (Dictionary, 2016) (English dictionary, 2016) and to instantiate this meaning within the design framework. Here the word "*advantage*" is considered synonym of the words "*benefit*", "*gain*" or "*profit"*. Furthermore, a concept close to that of advantage is widely exploited in the QFD literature, i.e. the concept of "*customer requirement*". A requirement is a statement that identifies a necessary attribute, capability, characteristic, or quality of a system for it to have value and utility to a customer, organization, internal user or other stakeholder.
Conversely, products could present also negative aspects or failures. Also in this case, different nuances of meaning can be found. In the engineering lexicon, we can find terms as "*drawback*", "*disadvantage*" and "*failure*" that are often used as synonyms. Even if they are not perfect synonyms, a drawback is defined as "*undesirable feature*" or "*hindrance*", while a failure has a more complex definition in both dictionaries and standard technical lexicons. In particular, part of the definition of failure refers to:

- Nonperformance of something due, required, or expected;
- A quantity or quality that is below normal;
- Deterioration or decay.

In other words, the notion of failure is implicitly normative: a failure can be defined with respect to something that is expected from an engineering perspective (Cascini, Fantoni, and Montagna, 2013).
From this preliminary analysis, we are led to the conclusion that a clear distinction between failures and drawbacks is hard to be made, either in conceptual and practical terms. We will therefore consider them as belonging to a unique set.
Two important remarks can be made at this point. The first is that, in general, advantages and drawbacks can be defined one with respect to the other: drawbacks are the negative occurrence of advantages, and viceversa. The second remark is that, due to the normative structure of the definitions, there are two other broad concepts that are relevant here: *effectiveness*, and *efficiency*. Their standard definitions are as follows:
Effectiveness: adequate to accomplish a purpose; producing the intended or expected result. (Dictionary, 2016).

Efficiency: the state or quality of being efficient, or able to accomplish something with the least waste of time and effort (Dictionary, 2016).
The notion of effectiveness makes it explicit the normative structure of advantages, referring them to the intended or expected result. The notion of efficiency introduces another important dimension, that is, the amount of resources needed to achieve the intended or expected result. Given that the amount of resources is finite, increasing efficiency can be considered an additional normative assumption (and also a broad empirical generalization from the history of technology), as it is reflected in the notion of ideality.
Summing up, we propose that all useful definitions of advantages and drawbacks can be collapsed into three categories, each with a positive or negative sign, as follows:

1. More/less wanted output obtained . A wanted output is a desired effect of the system.
2. More/less unwanted output obtained. An unwanted output is undesired effect of the system.
3. More/less resources needed. More resources needed to achieve a desired effect imply less efficiency.

This classification can be labelled ADIO classification (Advantages-Disadvantages-Input.Output).
The operationalization of this classification for purposes of automatic information extraction and processing is the object of the rest of the paper. Before that, let us illustrate the sources of information used, i.e. patents.

2.2 Patent Analysis

Recent developments in the patent analysis literature have made available software systems that are able to automatically extract information from patent documents, transforming raw texts into structured data. Researchers in this field follow two main approaches:

- Keyword approach: methods that are able to produce vector representations of the analyzed documents (Montecchi, Russo, and Liu, 2013).
- Grammatical and syntactical approach: methods based on the extracted grammatical and syntactical structures by NLP tools, such as Part-of-Speech taggers and syntactical parsers. Unlike the keyword approach, these methods are able to capture the relationships between the entities mentioned in sentences (Yoon, Park, and Kim, 2012).

The present work exploits the second approach. In particular, the task we need to address is labeled Named Entity Recognition (NER), or the automatic identification of words or phrases that correspond to predefined entity classes (in our case advantages and drawbacks).
Methods and algorithms to deal with the entity extraction task are numerous, but the most effective ones are *supervised methods*. Supervised methods tackle this task by representing the text as vectors of features. For example, the sentence “Good design is obvious, great design is transparent” could be represented by: (i) the number of times the word “design” appear; (ii) the part of speech tag of the first word; (iii) the length of the sentence. By accepting these features as relevant, the vector for this sentence becomes [2, adjective, 8]. As a general rule, the stronger and the more reliable the features, the more effective the identification of the entities in the analyzed text.
The NER methodology then dictates that text corpora are separated into a train set and a test set. The training of the corpus can be made by using two different annotation methods: (a) human based, which is time expensive, but usually more effective in the classification phase; (b) automatic, which can lead to systematic annotation errors due to language ambiguity.
Needless to say, there is large interest from both academia and business in the automatic extraction of specific entities in patents. To the best of our knowledge, the most impressive achievements in improving the accuracy of domain-specific patent retrieval systems have been obtained in the field of chemistry (Krallinger et al., 2015). In this field the entity-tagging systems deliver very good performances for three main reasons: first, chemical entity names (such as molecular formulas) follow very structured orthographic patterns; second, contexts where these entities are embedded are very similar; third, many external information sources, such as lists of chemicals or product names, are available.
None of these conditions can be found in our case. In addition, while the described systems use manually annotated training sets, we adopt a novel method that automatically creates a large training set.
As far as the authors know the most similar research work compared with the present one has been proposed by Cascini, G., & Russo, D. (2007). There the goal is to extract technical/physical conflicts from patents, as defined by TRIZ theory. In particular similarities exist between the concept of

advantages and disadvantages and useful and harmful functions, respectively. However, we prefer to keep a distinct terminology because the concepts of advantage and disadvantage are more general and abstract than the couple useful/harmful functions given by the TRIZ.

3 METHODOLOGY

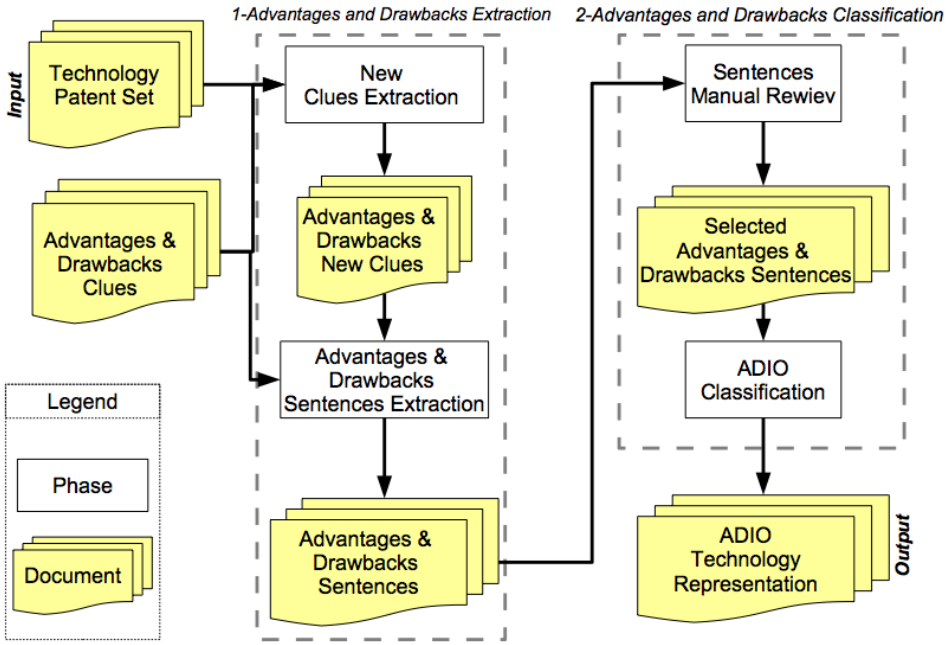


Figure 1. Work flow diagram followed to extract the ADIO technology representation from a patent set.

The goal of our system is to automatically extract short sentences that contain information about the advantages and the drawbacks of the technology from patent texts. Furthermore, we propose a taxonomy that organizes the output of the system focusing on advantages and drawbacks that have impacts on the systems thus influencing its input or output.

A flow diagram representing the adopted method for the semi-automatic ADIO extraction and classification of a technology is shown in Figure 1.

The method takes as entry a patent set representing the technology to analyze. The patent set and the list of advantages and drawbacks clues are entries of the process of advantages and drawbacks extraction (see subsection 3.1) and generate the phrases containing the advantages and the drawbacks. Than they become the entry of the process of Advantages and Drawbacks classification that exploits human knowledge to classify the technology according to the ADIO representation (see section 3.2).

3.1 Advantages and drawbacks extraction: Named Entity Recognition and phrases extraction from patents

The process of advantages and drawbacks extraction is the first of the two-macro processes used in our system. The first process starts from a patent set containing patents inherent to a technology and extract relevant sentences in output. Each sentence describes an advantage or a drawback of the specific technology. All steps of this process are fully automatic. The patent set should be very large, in the order of several hundred (in our case study n > 1000 items).

To describe with a certain degree of precision an advantage or a drawback, patent applicants have to use sentences of a certain length. Since NER systems are designed to extract single words or short n-grams, we need to extract entities that are clues of the whole sentence that describes the advantage or the drawback. However, our interest is not on the clue but rather on the words that follows the clue: the real advantage or the real drawback. We refer to these words as target. Considering the ADIO classification, proposed in the present work, these are words that help to classify whether the advantage or the

drawback have an impact on the input (influencing efficiency) or the output (influencing effectiveness) of the system.

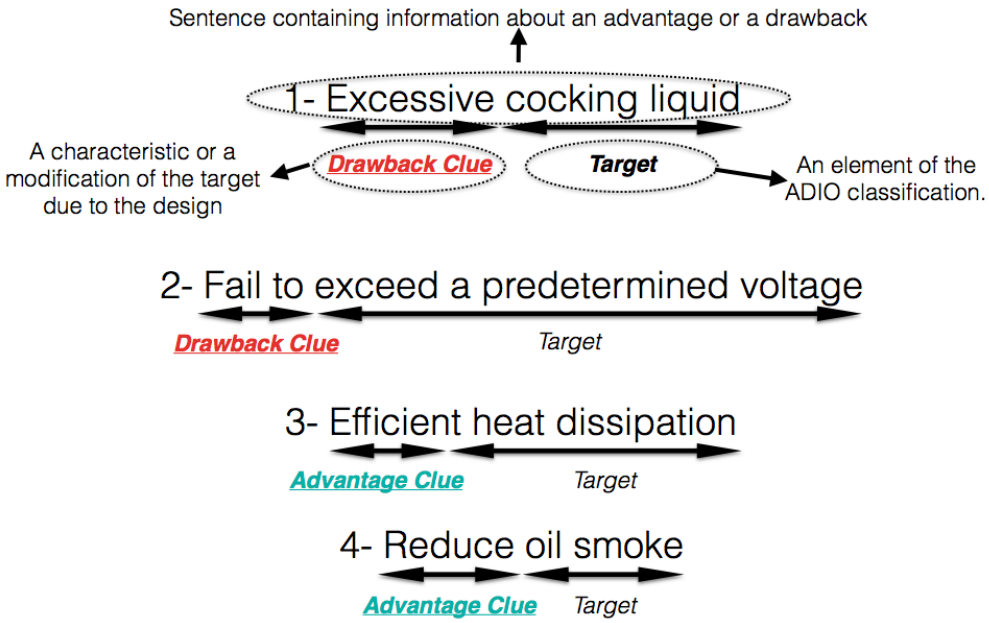


Figure 2- Examples of advantage or drawback sentences divided in its clue and target.

The few examples of Figure 2 show how clues are words that indicates a characteristic of a flow or its modification (positive or negative); the clue and target together specify the entity and direction of the modification of the flows that evolve within the system.

3.1.1 Advantages and Drawbacks clues collection

As stated above, we introduce a crucial concept, that of a "clue" for the identification of a complex text structure describing advantages or drawbacks. We describe here the process for collecting clues.
The process is not trivial because the sources are heterogeneous, fragmented and sparse. For example, we can find lists of failures in repositories published in the car industry, lists of diseases or infections in medical treatises, lists of positive and negative words in sentiment analysis tool-chains. Some of them are very accurate but extremely short, domain specific and rarely occurring in patents (e.g. new diseases), while others are broad but ambiguous thus introducing noise in the analysis (e.g. sentiment annotated words).

Table 1. Examples of clues of advantages and drawbacks extracted manually from patents

Approach 1 – semi-manual tagging		*Approach 2 – clue combination*	
Advantage-clues	Drawback-clues	Advantage-clues	Drawback-clues
ability	damaged	non damaged	un-aiblity
comfort	corrosion	anti-corrosion	diminish comfort
efficacy	defect	defect free	issue with efficacy
user-friendly	errors	reduction of errors	non user-friendly
usability	improperty	less improperness	lacks of usability

We followed a twofold approach. The first approach consisted in the manual collection of clues of advantages and drawbacks directly from patent texts. This process was performed on 2000 patents in several patent classes. This has led to collect 3254 advantage-clues and 5142 drawback-clues. Two persons worked separately on the analysis and then only the clues for witch there were agreement were

taken in to consideration. Some examples of the extracted clues are shown in the first two columns of Table 1.
The second approach consisted in looking for alternative methods to indicate advantages or drawbacks clues, finding defined word patterns. The most relevant are the negations of advantages to obtain drawbacks, and the negation of drawbacks to obtain advantages. Some examples are shown in the second two columns of in Table 1. It is worth noting the cases of suffixes like as -less or -friendly, -free and the like, and prefixes like as anti-, dis-, de-, un- and the like, that allow a rapid and systematic expansion of the database.
At the end of the process, advantages numbered 6568 and the drawbacks numbered 14809. This is a fairly large knowledge base for the system, and gave us a reasonable number of clues to be used in the next step of the process.
The first approach has the limitation that lists were extracted from a random but relatively small sample of patents (n= 2000). Another limitation is that the rules used in the second approach are not exhaustive, and they can create non-sense clues, due to the possible combinations of words (e.g. “anti-ability” or “un-problem”). On the positive side, it is reasonable to assume that using these approaches it is possible to collect a large set of clues that are relatively independent from the patent set.
In addition, it is now clear how new clues could be easily extracted when changing patent sets. In order to obtain a larger and complete collection of clues it is unsuitable to use the manual extraction on each domain patent set. For this reason, new clues were iteratively used to train machine learning algorithms.

3.1.2 New Clues Extraction

In this section, we briefly describe the system used to automatically extract new word clues from patent texts. The system is based on the work discussed in Fantoni et al. (2013). This process takes in input a corpus of patent documents regarding a certain technology. After the tokenization of the corpus, each token (word or n-gram) is represented by series of features. Then the advantage and drawback clues are re-projected on the text, generating a training set of words to be given as an input to a classifier system. The classifier builds a model able to detect words that have *similar* behavior (in terms of the selected features) with respect to the behavior described in the training set. The model is used to classify the words contained in patents as potential new advantages or drawbacks word clues. These new words clues are technology specific clues or generic clues that did not belong to the starting list of advantages and drawbacks generic word clues.

3.1.3 Advantages and Drawbacks Phrases extraction

Once all the new advantages and drawbacks clues are extracted, these are merged with the ones belonging to the original knowledge base, obtaining a final list which will be processed by the advantages and drawbacks sentences extractor.
The advantages and drawbacks sentences extraction is the activity through which the system catches the shortest informative sentence containing each word clues. To do that the patents are processed through a phase of part-of-speech tagging (POS tagging). Starting from the clues, only the POS sequences that match a certain pattern were extracted. The pattern, expressed using a regex regular expression is:

(Clue) + Noun.* Noun.* Noun.*

This structure has proven to be able to catch a reasonable number of words of the target, exhaustively expressing an advantage or a drawback without catching very long phrases.

3.2 Advantages and Drawbacks ADIO classification

The process of advantages and drawbacks classification is the second of the two processes involved in our system. This process takes in input the advantages and drawback sentences extracted in the advantages and drawback extraction process and gives in output the ADIO representation of the technology.

3.2.1 Sentences Selection

As stated above, we suggest a clear classification of advantages and drawbacks in a 3*2 structure. After the extraction each sentence is assigned to one of the following classes:

1. More/less wanted output obtained. A wanted output is a desired effect of the system.
2. More/less unwanted output obtained. An unwanted output is undesired effect of the system.
3. More/less resources needed.

If a sentence does not belong to one of these classes it is not taken in to consideration for the next analysis, even if expresses advantages or the drawbacks of the invention. This classification makes it possible to represent the technology using the ADIO representation.

3.2.2 ADIO Technology Representation

Given the classification described above, we obtain three possible kind of advantages and three possible kinds of drawbacks. Considering a wanted or desired output, the achievement or the increase is an advantage, while the negation or the reduction is a drawback. On the other side, considering an input to the system or an unwanted output, negation and reduction constitute an advantage, while achievement and increase are clearly a drawback. It is important to specify that the both the input or the output (wanted or unwanted) could involve flows of matter, energy, or signal.

4 CASE STUDY

4.1 Patent set

To test the proposed process, we selected a patent set composed of a sample of 3,000 patents. The patent sets belong to the A47J37 IPC patent class defined as "*Baking; Roasting; Grilling; Frying*". We will refer to this patent set as cookers set.

4.2 4.2. Extraction of Advantages and Drawbacks

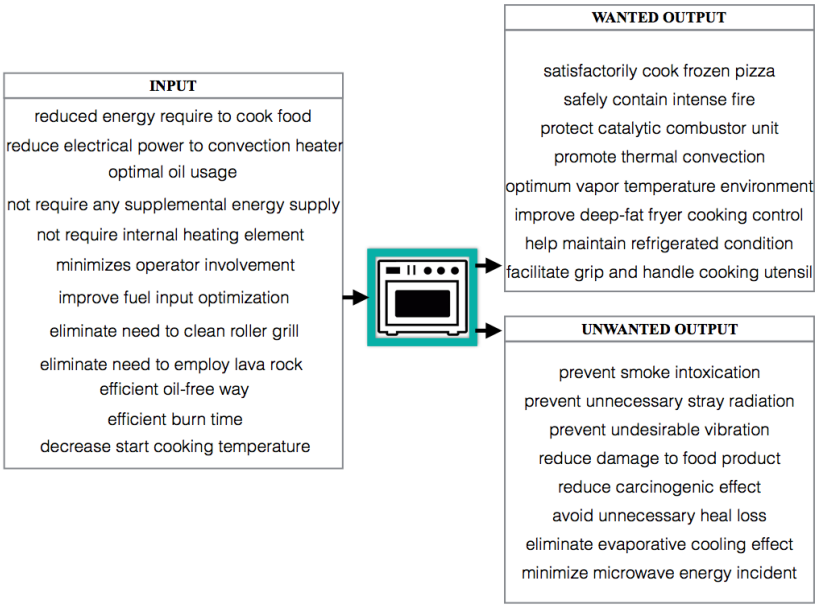
Total extracted advantages numbered 4129, drawbacks numbered 1835. After manual review of sentences the total number went to 2509 and 1532, respectively. During the manual review phase, each sentence was assigned to one of the three classes of the taxonomy, considering the target of the sentence. The system itself decides if a sentence indicates an advantage or a drawback, considering the clue. The results in terms of cardinality of the classes of the taxonomy are shown in Table 2. As we can see from this table, the sentences review process has led to a balance between the extracted advantages and drawbacks. It is interesting to see how the wanted outputs are more likely expressed as advantages (1786 sentences are advantageous wanted output while 660 are drawbacks); the situation is reversed for the unwanted output (431 sentences or that advantages and 682 for the drawbacks).

Table 2. Examples of clues of advantages and drawbacks extracted manually from patents.

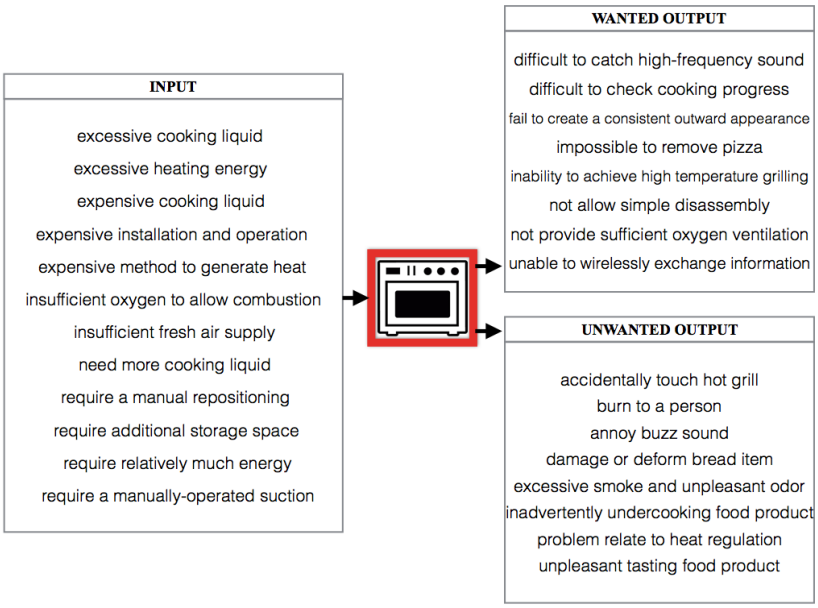
Class	Number of Advantages Sentences	Number of Drawback Sentences
Input	292	190
Wanted Output	1786	660
Unwanted Output	431	682
TOT	2509	1532

4.3 I-O Representation

The two ADIO schemes for the advantages and drawbacks of cookers are shown respectively in Figure 3. The sentences shown in this figure are a sample of all of the 2662 extracted sentences. Furthermore these sentences are taken as-is from patents, misprints and errors included.



(a)



(b)

Figure 3. Figure (a) and (b) are the ADIO representation respectively for the advantages and the drawbacks of cookers.

Both the results are promising for future applications in the design fields. In particular Figure 3 (a) allows designers to focus on the positive side of the effects provided by the product and to better meet the explicit and implicit user needs. Similarly, Figure 3 (b) helps designers to redesign of the product in a proactive way, to keep attention to the critical issues identified by the drawbacks and to conceive possible corrective actions to solve such drawbacks.

5 CONCLUSION AND FUTURE DEVELOPMENTS

This paper has proposed a method to extract and summarize sentences that describe advantages and drawbacks of technologies from patents. Advantages and drawbacks are considered as phenomena that influence the efficiency or the effectiveness of products by modifying their inputs or their outputs. Advantages and drawbacks information are useful for designers who want to design new products or to redesign old ones so to meet user needs in novel and better ways. The proposed approach allows patent readers to analyze a massive quantity of patents and to reduce the time needed for research and analysis.

In the future, we want to focus on the application of the proposed ADIO framework to a wider number of patents set and hopefully we would like to automate the classification of advantages and drawbacks. Then we want to give a measure of the recall about advantages and disadvantage extraction the system is able to achieve in an automatic way. Once the recall is computed and demonstrated to be reasonable, it is possible to focus on the explanation of unexpected behaviors of input/output entities distribution in patent documents.
Finally, the research will continue on the extraction of new entities of interest for designers.

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