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Sede Amministrativa: Università degli Studi di Padova
Sede Consorziata: Università degli Studi di Bergamo

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CICLO XXIV

ANALYSIS OF METHODS FOR PRODUCT INNOVATION: CLASSIFICATION OF PATENTS AND SCIENTIFIC PUBLICATIONS TO DEFINE THE TECHNICAL VALUE

Direttore della Scuola: Ch.mo Prof. Paolo Bariani
Coordinatore d'indirizzo: Ch.mo Prof. Enrico Savio
Supervisore :Ch.mo Prof. Caterina Rizzi

Dottorando: Dott. Ing. Roberto Nani

Dedication

To the victims of unemployment.

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Abstract

In the most recent years the market has required an increasig number of search engines more and more specialized in comparing different set of documents, which are not in a sintagmatic relationship but in a paradigmatic one, thus targeting discrimination of those features which clearly define the state of evolution of a product, which is actually contained in the state of the art as described by patents, but is not explicitated in the patents themselves.

In other words the market has been asking for methods apt to classify documents and based on the definition of a common Technical Value of Patents and Scientific-Publications in order to test the opportunity of defining technologies, which even if originated in a Branch A could be translated in a Branch B or C etc., this offering market available solutions.

First step has been investigating the state of the art of those search engines able to organize and classify both types of documents, patents and scientific documents, by discriminating them temporarely. The state of the art showed an easy applyable search engine, available for free in the web: Scirus.

Second step has been defining a method of extracting the features of a technological system, by comparision of clusters present in both patent-collections and scientific publications, while investigations can be diversified within specific temporal ranges.

Said method employs Scirus and allows to contextualize a technological system by means of a sequence of queries which are built through a horizontally-structured comparison of clusters within a scientific web-collection, which has been previously split in two sets of documents: patent documents and scientific publications. At the same time the comparison is also vertically structured according to different temporal ranges, thus forming a 4-field table.

Once the last query has been completely fullfilled, new clusters are retrieved by the search engine.

Third step has been using said new clusters, resulting at the end of the last query, to fill-in a 9-screen-diagram. This is a tool for performing forecasting analysis, and defining innovation and technological diffusion.

This method is non–expertee oriented. Actually, operators are not supposed to be expertees in the field key-words and clusters refer to, in fact these are sorted automatically. The first query is nothing but the title of the topic to investigate and the definition of at least one subsequent query does not imply any subjective choice but is performed automatically.

A second level query includes key-words with a rating R calculated while analyzing the structure of clusters. A rating R represents the involvement level of each of the four cluster structures containing all major data necessary to describe a technological system.

Clusters undergo a temporal discrimination. This discrimination is not arbitrary, on the contrary it is objective.

Fourth step has been collecting parameters of clusters. Said parameters result by using a method that can influence the definition of the hand-over moment.

The method developed for forecasting the life-cycle of industrial products is here illustrated by an industrial case study.

Keywords:

Search engine, cluster, clustering, node ranking, query, level query, key-word, rating, vertical and horizontal rating, temporal range, Master and Slave Document, hand-over moment, pioneer evolutionary phase, diffusion evolutionary phase, technological diffusion, 9-screen-diagram, Subsystem-System-Supersystem triplet, migration, Δ Cluster, cumulative Δ Cluster, life-cycle, downsizing, miniaturization.

Riassunto

In anni recenti il mercato ha richiesto un numero crescente di motori di ricerca sempre più specializzati nella comparazione di diversi insiemi di documenti, che non sono legati da un rapporto sintagmatico ma paradigmatico. La definizione di quelle caratteristiche che definiscono chiaramente lo stato di evoluzione del prodotto, contenuta nello stato dell'arte descritto nei brevetti ma non esplicitata dai brevetti stessi, è dunque l'obiettivo che ci prefiggiamo.

In altri termini, il mercato chiede metodi atti a classificare i documenti e basati sulla definizione di un valore tecnico condiviso dei brevetti e delle pubblicazioni scientifiche. Questo al fine di verificare la posibilità di definire le tecnologie che, anche se originate in un dato "settore A", possono essere traslate in un dato "settore B" o "settore C" e così via, comunque offrendo sempre al mercato soluzioni già ampiamente disponibili.

Il primo stadio si è concentrato sull'analisi dello stato dell'arte di quei motori di ricerca in grado di organizzare e classificare per mezzo di una selezione temporale sia i brevetti che i documenti scientifici. Lo studio dello stato dell'arte ha fatto emergere un motore di ricerca di facile utilizzo e disponibile gratuitamente nel web: Scirus.

Il secondo stadio ha definito il metodo per estrapolare le caratteristiche di un sistema tecnologico tramite comparazione di una classificazione stilata sia nell'insieme "brevetti" che in quello delle pubblicazioni scientifiche e con ricerche diversificate all'interno di specifici intervalli temporali.

Questo metodo impiega Scirus e permette di contestualizzare un sistema tecnologico per mezzo di una sequenza di richieste costruite attraverso una struttura orizzontale di classificazione nell'ambito di un insieme di documenti presenti in rete preventivamente suddivisi in due insiemi di documenti: documenti brevettuali e pubblicazioni scinetifiche. Allo stesso tempo la comparazione avviene anche in senso verticale con riferimento a intervalli temporali diversi così da formare una tabella a quattro campi.

Una volta soddisfatta definitivamente l'ultima richiesta, il motore di ricerca porta alla nostra attenzione delle nuove classificazioni.

Il terzo stadio utilizza le classificazioni di cui allo stadio precedente, cioè emerse soddisfando l'ultima richiesta, al fine di compleare con il loro inserimento un diagramma a nove finestre.

Questo ultimo si connota come strumento per tracciare un'analisi di previsione e per definire la diffusione della tecnologia e dell'innovazione.

Questo metodo non è orientato ad una specializzazione degli operatori, essi infatti non devono essere necesariamente degli esperti di settore, e segnatamente del settore a cui le parole chiave e le classificazioni afferiscono, dato che queste sono selezionate in maniera automatica.

La prima richiesta non è altro che il titolo dell'oggetto della ricerca, e la definizione di almeno una richiesta successiva alla prima non inmplica alcuna scelta soggettiva, ma avviene in automatico.

Una richiesta di secondo livello include quelle parole chiave che abbiano una valutazione R calcolata mentre si analizzano le strutture delle classificazioni. Ogni valutazione R rappresenta il grado di coinvolgimento di ognuna delle quattro strutture di classificazione che contengono tutti i dati fondamentali necessari per descrivere un sistema tecnologico.

Le classificazioni sono soggette a selezione temporale che non è arbitraria ma al contrario oggettiva.

Il quarto stadio è formato dalla raccolta dei parametri delle classificazione come questi risultano con l'uso di un metodo che può influenzare la definizione del momento di transizione.

Il metodo sviluppato per prevedere il ciclo di vita di un prodotto industriale è illustrato nella presete tesi con un caso di studio reale.

Parole Chiave:

Motore di ricerca /Search engine, classificazione /cluster, classificare /clustering, nodo di valutazione /node ranking, richiesta /query, richiesta di livello /level query, parola chiave /key-word, qualifica /rating, qualifica orizzontale e verticale/vertical and horizontal rating, intervallo temporale /temporal range, Documento Principale e Secondario /Master and Slave Document, momento di transizione/ hand-over moment, fase evolutiva pionieristica/ pioneer evolutionary phase, fase evolutiva di diffusione /diffusion evolutionary phase, diffusione tecnologica/ technological diffusion, diagramma a nove finestre /9-screen-diagram, triade Sottosistema-Sistema-Sueprsistema/Subsystem-System-Supersystem triplet, migrazione /migration, Δ classificazione/ Δ Cluster, Δ cumulativo classificazione / cumulative Δ Cluster, ciclo di vita/ life-cycle, riduzione dimensioni /downsizing, miniaturizzazione/miniaturization.

CHAPTER 1

Introduction

The ongoing economic crisis has split, in its intermediate evolutionary stage, the product-market system into two distinct phases.

A first phase, placed in the second half of the last century, regards the competitive systems based on technological superiority, research and development of those products which enjoy a very wide margin in terms of innovation. Just immediately after World War II, all technological sectors proove extremely receptive towards both use and distribution of ready-made products on an industrial scale, such as prestressed concrete, some plastics (PVC, polystyrene, polyethylene), lasers, and towards the improvement and optimization of already in use technologies dating back to World War I, such as rolling bearings.

A second phase, shows competitive systems aligned on achieving high performance product through the solution of inventive problems, whose competitive margin is characterized by development of logistic, information technology, financial credit. Life-cycle design and downsizing in the automotive, low-cost transport, cloud-computing in information technology, are the hard core capable of typifying each company in comparison to its competitors. In both cases, evolution aims at increasing benefits, decreasing costs, decreasing harm according to a strategy directed to:

- eliminate the deficiencies of the original system;
- preserve the advantages of the original system;
- reduce complications;
- avoid introduction of new disadvantages.

Similarity of results and high level of performances characterize the evolution of product during said second phase. In this constellation enterprises need to outline the technical features of a new product and find those parameters which optimize the performances of the product and dramatically reduce costs related to time and economical resources dedicated to testing. The capability to manage intellectual property (IP) is becoming essential for enterprises that actively try to face competition. The activity of searching and managing of concrete pieces of information has to focus the intrinsic and extrinsic characteristics of product exploring the structure of a collection of documents. This means not only to find a direct answer to a query, but more often just locate a resource (document) that possibly contains the answer. In fact, the focus to a collection of textual documents (possibly very large) distinguishes two types of information needs: (1) searching for a concrete piece of information, information needs and (2) exploring the structure of a collection of documents [Weiss, 2006].

The latter are called document-retrieval systems or, in short, search engines.

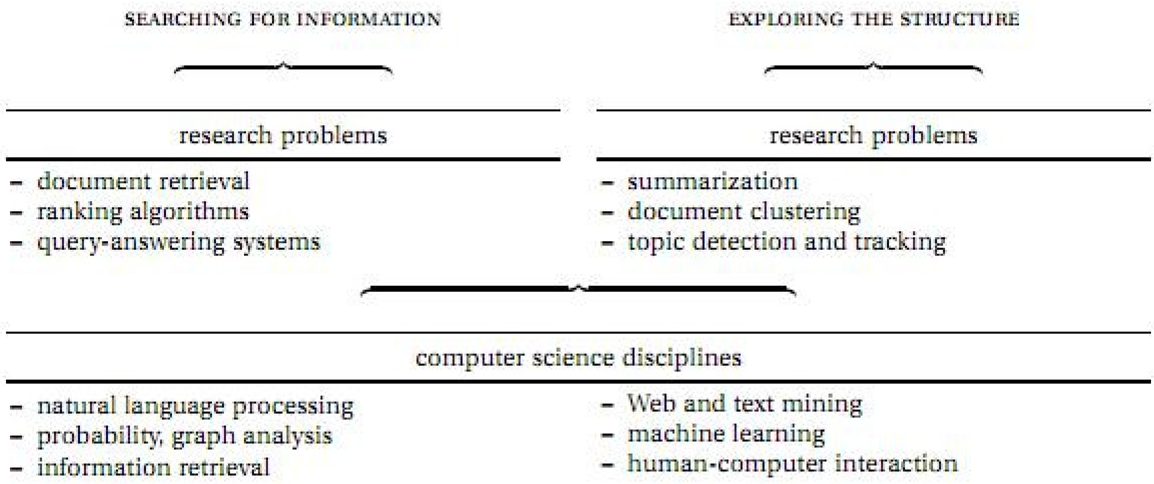


Figure 1-1: Selected computer science problems, disciplines and their relation to the two types of information needs (Weiss, 2006).

Aim of the present research is defining a technological system, formed by components, within an environment and market context, by means of a search engine capable to organize a web-documents collection according to a structure of clusters.

The main activity regards the extracting of key-words to form query capable to identify said technological system. Identification must occur in an easy and unambiguous way where the query is built deriving the intrinsic and extrinsic features from the structure, which has been previously defined by means of clustering.

These targets are reached thanks to a method for classifying documents based on the definition of a common Technical Value of Patents and Scientific-Publications.

This dissertation focuses on text clustering methods developed primarily in information retrieval and attempts to improve their applicability to the task of exploration of document collections by making sure clusters are described in a meaningful way.

In particular this dissertation explores the document-retrieval systems capable to locate a source (document) corresponding to a definition of one system, distinguishing and considering the interaction between patents documents and scientific-publications.

A procedure for semi-automatic identification of the most important parameters, intrinsic and extrinsic characteristics of a system:

uses the source represented by a collection of documents indexed by particular scientific search engines;

investigates about the symbiosis of intrinsic and extrinsic features on separate clusters of patents and scientific publications;

analyzes clusters of patents and scientific publications, considering how the parameter time changes the rating of two structure of clusters.

The above document-retrieval procedure, discriminating and considering the interaction between patents documents and scientific-publications, arises from a classification of inventive solutions [Altshuller, 1999]. In particular said classification of inventive solutions depends of the level or the degree of inventiveness and the used knowledge.

Moreover, a distinction between *invention, innovation, transfer, and penetration* or *diffusion* is necessary. Invention refers to the birth of an idea for a product, a process, or a procedure, with some claims to novelty and priority. The whole technological change rests upon invention - not necessarily discovery - but only a small fraction of inventions which actually have any application in technology. When such an application is formulated, resulting in new products, approaches or ways of doing or making things, an *innovation* has taken place [Ayres, 1969].

A classification of inventive solutions includes five levels [Souchkov, 2007].

Level 1: Quantitative Improvement within a technical system. Solutions that only require a quantitative change of a value of a certain parameter or a couple of parameters within a technical system. These solutions can also be obtained as a result of optimization. These solutions do not require any inventive thinking. To obtain the desired result, changing the value of a parameter or a combination of parameters is sufficient.

Level 2: Qualitative Improvement within a technical system. Solutions at level 2 address qualitative changes and improvements of components or their configuration within a technical system. Usually these solutions result from relatively simple modifications of the existing subsystems to improve quality and performance of a system without replacing the existing working principles behind subsystems.

Level 3: Diffusion, new markets. Solutions at level three result from using a knowledge within a new context to provide a specific purpose in a new market. In most cases, solutions at level 3 require re-engineering or adaptation of existing designs based to satisfy new demands.

Level 4: First market. Solutions of level four result from creating radically an invention on the basis of a scientific principle discovered at level five. At level four a particular idea for a product, a process, or a procedure, with some claims to novelty and priority, is introduced in a first market area.

Level 5: Discovery. This is a starting point that can later result in a breakthrough innovation. Discovery has little to do with technology or engineering; it expands the borders of science and provides access to new type of resources through creating new scientific knowledge. Discoveries of level 5 (or, to be more exact, "scientific solutions") do not address any market. These are scientific discoveries yet to be used to design new technical systems.

Table 1-1 shows, generally speaking, the patent production and the scientific publications in percentage as they are distributed in the five levels of solutions in technology. The reported values comes from the results of the investigations developed in this dissertation (Chapter 4, Chapter 5). It must be stressed that 90% out of the total released scientific publications refers to technological solutions regarding expansion towards new market branches - Level 3 -. 60% of the total of the patents regards del technological improve - Level 1 -.

Only a part of the patents at Level 1 refers to the same technological system of scientific publications at Level 3. The submitted document-retrieval systems nullifies this discrepancy by setting up queries able bring out those only those documents distributed in the five inventive levels belonging to the same technological system.

Table 1-1: Five Levels of Solutions in Technology.

		Percentage of scientific publications	Percentage of patents
Level 5	Discovery	-	-
Level 4	First market	10	40
Level 3	Diffusion	90	-
Level 2	Qualitative Improvement within a technical system	-	-
Level 1	Quantitative Improvement within a technical system.	-	60

A variation to the solution of the stated problem can be supplied by the use of the International Patent Classifcations (IPC). The definition of the technological class taken into consideration allows in fact to riduce our field of action. All common patent data-bases allow to discriminate the technological field of interest by selecting only one class of technology. This approach shows some major limits which make it non-suitable to define a technical system exactly:

1. IPC is not trustworthy;
2. the selection of a IPC class retrieves anyway a high number of patent documents causing difficulties in reading all of them. This causing an inaccurate choice of the subsequent queries aimed at refining the investigation;
3. a technological system usually refers to several classes. This means that when selecting a class through IPC, major data, regarding the application of the investigated technological system in one or more different technological systems, go lost.

The activity of exploring a collection of documents takes place when there is no information need or it is too vague to formulate a specific query. Computer science responds to the above information needs by specifying problems and devising solutions rooted in a number of disciplines. In the emerging new wave of applications where people are the ultimate target of text clustering methods, cluster labels are intended to be read and comprehended by humans. The primary objective of a clustering method should be to focus on providing good, descriptive cluster labels in addition to optimizing traditional clustering quality indicators such as document-to-group assignment. In yet other words: in document browsing, text clustering serves the main purpose of describing and summarizing a larger set of documents, the particular document assignment is of lesser importance.

Text clustering or shortly clustering is about discovering semantically related groups in an unstructured collection of documents. Clustering has been very popular for a long time because it provides unique ways of digesting and generalizing large amounts of information.

A cluster is basically a group of documents, typically discovered by means of a mathematical model that is unexplainable in plain text. Most clustering algorithms used very simple display techniques: selected titles of documents within the cluster, excerpts of documents, and the most popular — a list of the most prominent cluster terms called keywords [Weiss, 2006].

The content of the present dissertation is structured as follows.

Chapter 1. Introduction.

Chapter 2. Results of a patent investigation and of a scientific literature investigation aimed at defining the state of the art of search engines based clustering tecniques.

Chapter 3. Further investigations about the most important forecasting methods come out from the invastigations reported in chapter 2. Patended methods referring to free software available in the web are consedered, with specific reference to Scirus search engine, which allows discriminating both patents and scientific publications by features as well as by time.

Chapter 4. It goes into details of the analysis of a technological by means of the search engine desribed in Chapter 3. The same Case study is analysed by means of three seach engines in order to determine information about the synergic usage of different softwares in order to consolidate the process of defining a technological system. Describing a technological system implies creating a query. First level queries and subsequent queries created by means of a search engine. Each query contains key-words belonging to clusters set up by means of a search engine.

Chapter 5. It applies the method analysed in Chapter 4 to describe a new technological system. A criteria of automatic creation of queries oa a level different than the first is described in this chapter. A rating R is defined as indicator of the relevance of the clusters chosen to set up a specific query. Moreover, the application of clusters, coming out of first and second level queries and apt to fill-in a 9-screen-diagram, is described in this chapter, where clusters are analysis tools regarding the analysis of technological systems in the forecasting field and as to technological change.

Chapter 6. It complets the filling-in of the 9-screen diagram (Chapter 5) and aims at defining manually an innovating system by means of clusters retrived by this method, as stated in the previous chapters. A particular emphasis is laid upon Δ clusters which exactly state the exact hand over moment from one technology phase to a new one.

Chapter 7. It shows the technical specification of a ultimate innovative technological sytstem. It considers the criteria which have led to the definition of the system. Brief description of the prototytpe realized.

Chapter 8 .Conclusion and future developments.

CHAPTER 2

Patents and Literature Review

2.1 Introduction

This chapter provides a list of the literature and patents referring to clustering methods and systems as well as document-retrieval systems.

The state-of the art of clustering of document collections refers to digital computing or data processing equipment or methods, specially apt to specific functions: information retrieval, compilation of abstracts, database structures of unstructured textual data, document management systems.

Literature essentially refers to two main branches.

- document management systems based on associated metadata or manual classification, using citations;
- clustering or classification (manual classification ,including class or cluster creation or modification).

The former branch considers methods to produce ranking of nodes, pictorial representations in which nodes of different clusters may belong to the same rank, ranking of the particular hypertext documents determined by considering the parent documents.

The latter considers methods which includes the necessary steps for creating a set of fingerprints for each respective document belonging to a certain class which has been determined by means of the clustering analysis, and where each fingerprint contains one or more citations related to the respective document. This creating a plurality of clusters aimed at establishing a dataset which is based on the sets of fingerprints common to all the documents within the class; the latter branch also provides techniques for comparing two documents, in which a fingerprint or sketch of each document is computed, using specific algorithms to compute the fingerprint of the document.

2.2 Patent Review

Page, Lawrence (Stanford, CA) (1998)'s patent relates about a linked database (i.e. any database of documents containing mutual citations, such as the world wide web or other hypermedia archive, a dictionary or thesaurus, and a database of academic articles, patents, or court cases) represented as a directed graph of N nodes, where each node corresponds to a web page document and where the directed connections between nodes correspond to links from one document to another. A given node has a set of forward links that connect it to children nodes, and a set of backward links that connect it to parent nodes. FIG. 2-1 shows a typical relationship between three hypertext documents A, B, and C, where the first links in documents B and C are pointers to document A. In this case B and C are backlinks of A, and that A is a forward link of B and of C.

The main characteristic of this method considers a citation from a highly ranked backlink as more important than a citation from a lowly ranked backlink (provided both citations come from backlink documents that have an equal number of forward links). In the present invention, it is possible, therefore, for a document with only one backlink (from a very highly ranked page) to have a higher rank than another document with many backlinks (from very low ranked pages).

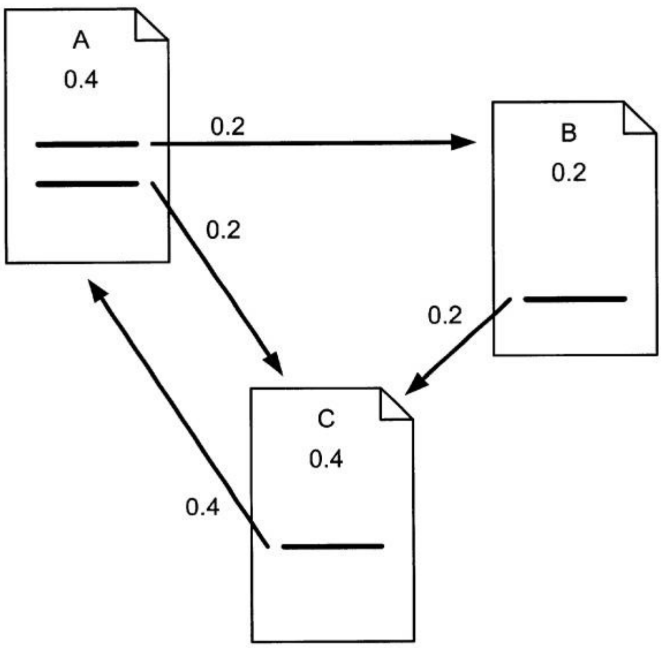


Figure 2-1: Page, Lawrence (Stanford, CA) (1998)'s method for node ranking in a linked database (US Patent No. 6,285,999).

GANSNER EMDEN R [US]; NORTH STEPHEN C [US]; VO KIEM-PHONG [US] (1989)' patent relates to a computer-implemented technique for drawing directed graphs providing reduced crossings and improved picture quality. An edge list description provided by a user is processed to produce a ranking of all nodes that minimizes the weighted sum of all edges, an edge cost being the product of its weight and length. Nodes within a ranking are then positioned to reduce edge crossings using a heuristic based on node positions in adjacent ranks. Such heuristic uses a generalized median as a weighting function plus node transposition to avoid senseless edge crossings before proceeding to a next rank. Nodes are then positioned to minimize the weighted sum of horizontal distances among connected nodes.

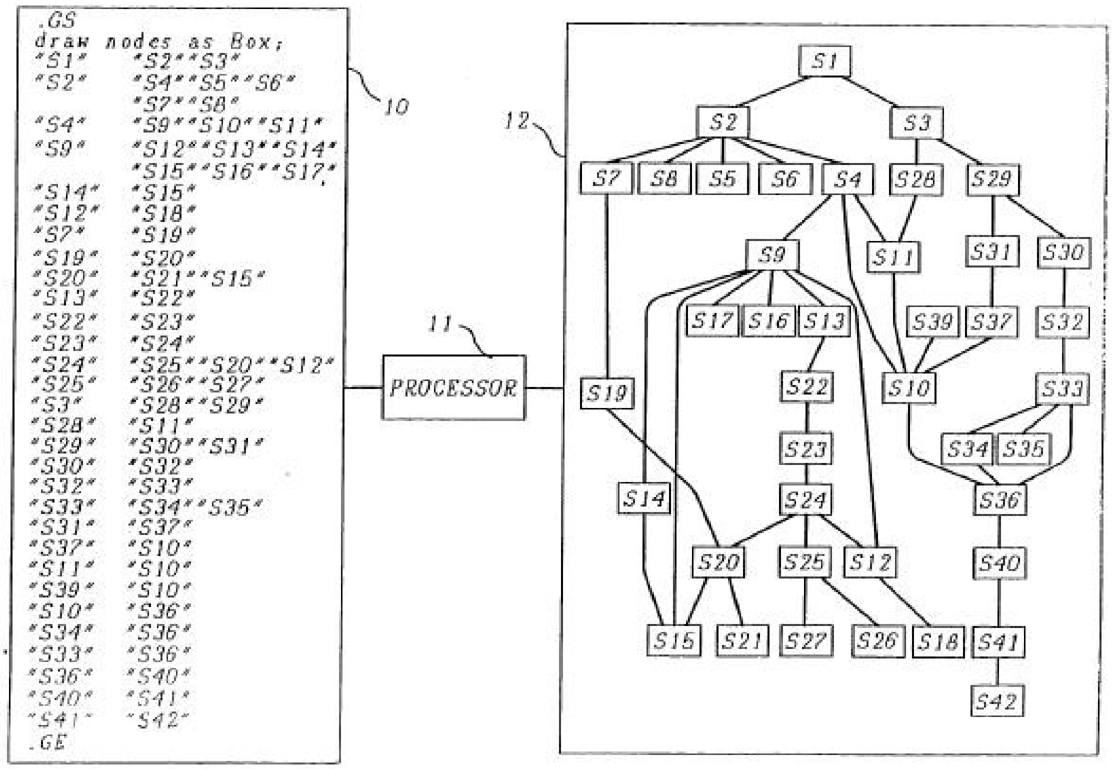


Figure 2-2: GANSNER EMDEN R [US]; NORTH STEPHEN C [US]; VO KIEM-PHONG [US] (1989)' Technique for drawing directed graphs (US Patent No. 4,953,106).

NORTH STEPHEN C [US] (1993)' patent relates to techniques for automatically laying out directed graphs with clusters of nodes and free nodes. The techniques produce pictorial representations of the graphs in which a node in a cluster and a free node may belong to the same rank in the graph and nodes belonging to more than one cluster may belong to the same rank. The techniques have been added to the well-known DOT system for laying out directed graphs, and include a recursive technique for ranking nodes of the graph, a technique for ordering nodes within ranks which collapses subclusters into skeletons when the nodes within a cluster are ordered, and a technique for positioning the nodes after they have been ranked and ordered which obtains the x coordinates for the nodes by producing an auxiliary graph which is in effect the original graph "turned on its side" and assigning ranks to the nodes in the auxiliary graph.

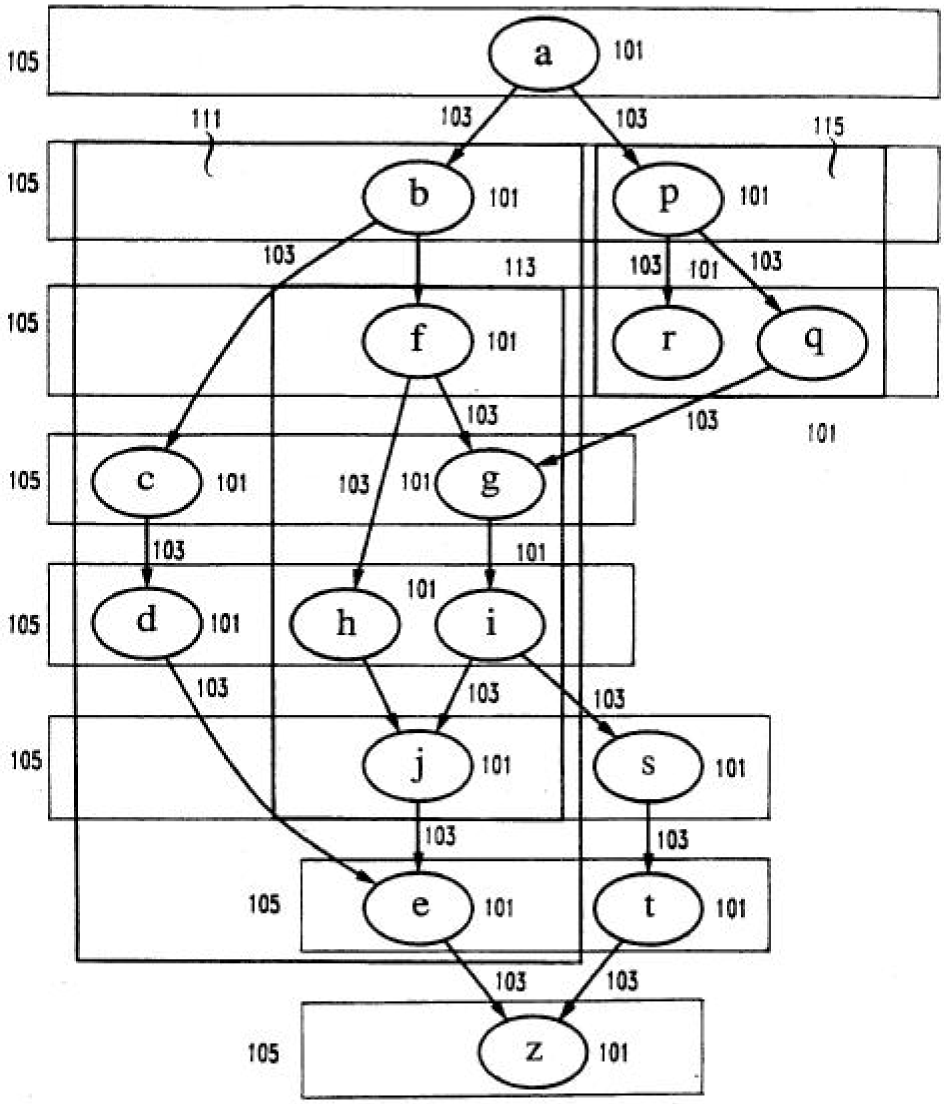


Figure 2-3: NORTH STEPHEN C [US] (1993)' Graphs employing clusters (US Patent No. 5,450,535).

EGGER DANIEL [US]; CANNON SHAWN [US]; SAUERS RONALD D [US] (1993)' patent relates to a computer research tool for indexing, searching and displaying data. Specifically, a computer research tool for performing computerized research of data including textual objects in a database or a network and for providing a user interface that significantly enhances data presentation is described. Textual objects and other data in a database or network is indexed by creating a numerical representation of the data. The indexing technique called proximity indexing generates a quick-reference of the relations, patterns and similarity found among the data in the database. Proximity indexing indexes the data by using statistical techniques and empirically developed algorithms. Using this proximity index, an efficient search for pools of data having a particular relation, pattern or characteristic can be effectuated. The Computer Search program, called the Computer Search Program for Data represented in Matrices (CSPDM), provides efficient computer search methods. The CSPDM rank orders data in accordance with the data's relationship to time, a paradigm datum, or any similar reference. An alternative embodiment of the invention employs a cluster link generation algorithm which uses links and nodes to index and search a database or network. The algorithm searches for direct and indirect links to a search node and retrieves the nodes which are most closely related to the search node. The user interface program, called the Graphical User Interface (GUI), provides a user friendly method of interacting with the CSPDM program and prepares and presents a visual graphical display. The graphical display provides the user with a two or three dimensional spatial orientation of the data.

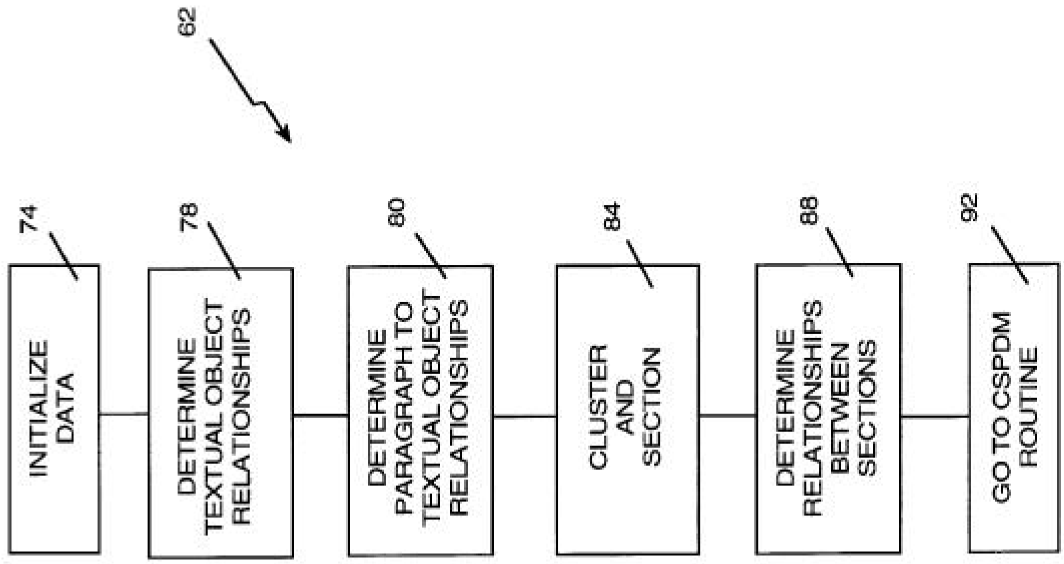


Figure 2-4: EGGER DANIEL [US]; CANNON SHAWN [US]; SAUERS RONALD D [US] (1993)' Method and apparatus for indexing, searching and displaying data (US Patent No. 5,832,494).

ISHIKAWA MASATO [JP]; SATO MITSUHIRO [JP]; HOSHIDA MASAKI [JP]; NOGUCHI YOSHIHIRO [JP]; YASUKAWA HIDEKI [JP] (1996)' patent relates to a hypertext document and anchor sentences of parent documents for the hypertext document, being registered with a hypertext document identifier as document information for each of hypertext documents having reference relationships with each other. A user can refer to one hypertext document according to an anchor sentence of another hypertext document functioning as a parent document. Also, occurrence positions of one word in hypertext documents and parent documents are registered as word information for each of words. When a keyword is input, a plurality of particular hypertext documents and particular parent documents in which the keyword appears are specified according to the word information, one particular hypertext document and corresponding particular parent documents are unified to a unified hypertext document for each particular hypertext document, an occurrence frequency of the keyword in each unified hypertext document is calculated according to the document information, importance degrees of the unified hypertext documents are calculated as those of the particular hypertext documents according to the occurrence frequencies, and ranking of the particular hypertext documents are determined according to those importance degrees. Because the occurrence frequency is calculated by considering the parent documents, the particular hypertext documents can be appropriately ranked.

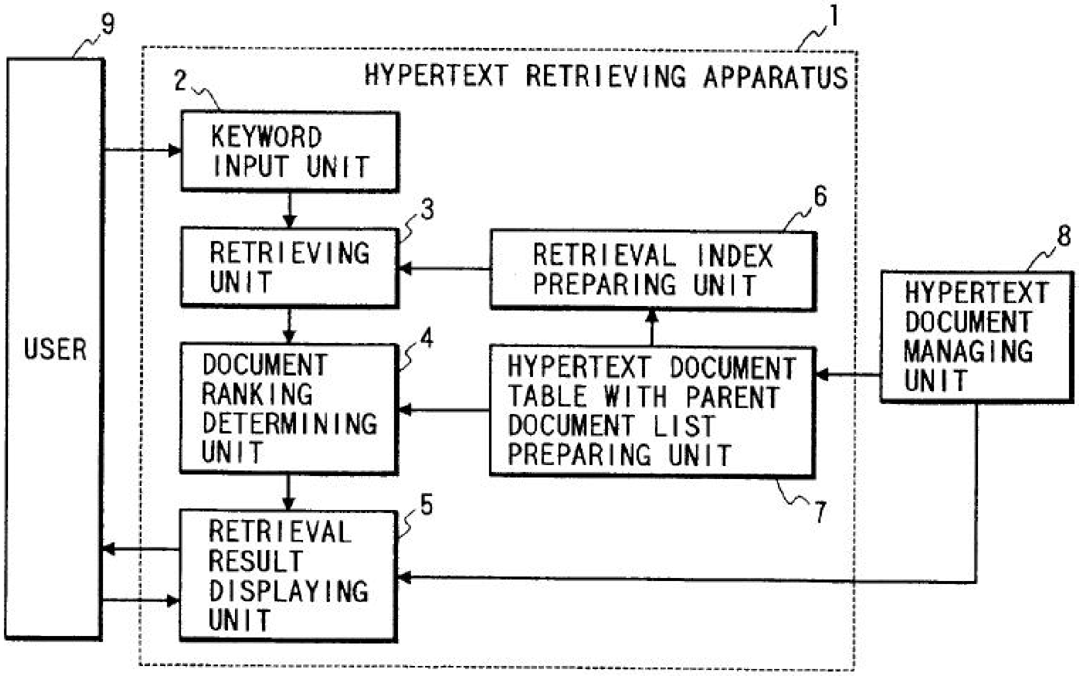


Figure 2-5: ISHIKAWA MASATO [JP]; SATO MITSUHIRO [JP]; HOSHIDA MASAKI [JP]; NOGUCHI YOSHIHIRO [JP]; YASUKAWA HIDEKI [JP] (1996)' Hypertext document retrieving apparatus for retrieving hypertext documents relating to each other (US Patent No. 5,848,407).

MAULDIN MICHAEL L [US] (1995)'s patent relates to a method of constructing a catalog of files stored on a network comprised of a plurality of interconnected computers each having a plurality of files stored thereon. The method is accomplished by establishing a queue containing at least one address representative of a file stored on one of the interconnected computers, ranking each address in the queue according to the popularity of the file presented by the address, downloading the file corresponding to the address in the queue having the highest ranking, processing the downloaded file to generate certain information about the downloaded file for the catalog, adding to the queue any addresses found in the downloaded file, and determining the popularity of file represented by the addresses in the queue according to how often a file is referenced by a computer other than the computer on which the file is stored.

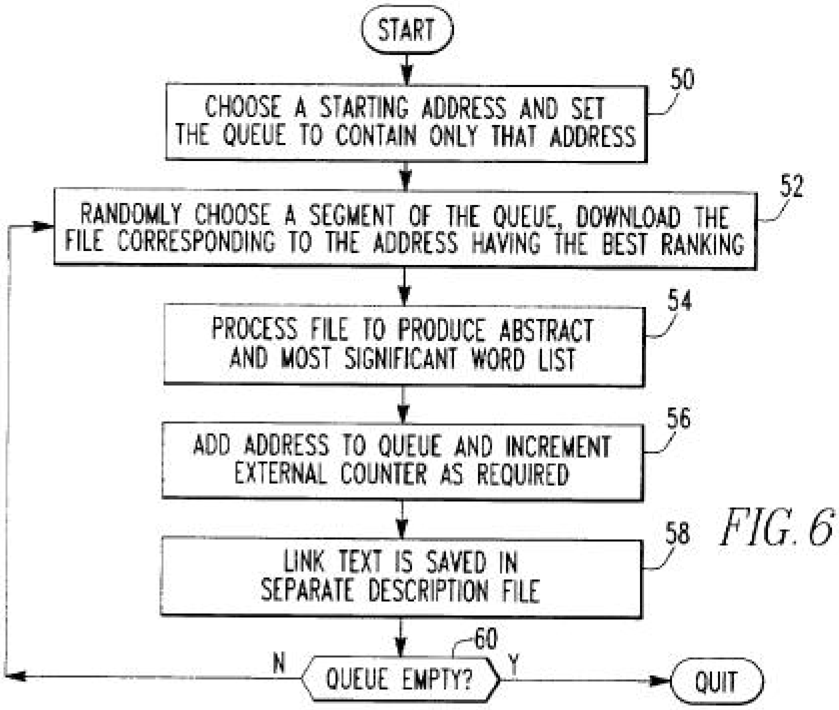


Figure 2-6: MAULDIN MICHAEL L [US] (1995)'sMethod for searching a queued and ranked constructed catalog of files stored on a network (US Patent No. 5,748,954).

Dorie, Vincent Joseph (San Mateo, CA, US) and Giannella, Eric R. (Saratoga, CA, US) (2008)'s patent relates to a method of organizing a plurality of documents for later access and retrieval within a computerized system, where the plurality of documents are contained within a dataset and where a class of documents contained in the dataset include one or more citations to one or more other documents. In one embodiment, the method includes the steps of creating a set of fingerprints for each respective document in the class, where each fingerprint has one or more citations contained in the respective document, creating a plurality of clusters for the dataset based on the sets of fingerprints for the documents in the class, and assigning each respective document in the class to zero or more of the clusters based on the set of fingerprints for the respective document, where each respective cluster has documents assigned to it based on a statistical similarity between the sets of fingerprints of the assigned documents.The method further has the steps of, for each remaining document in the dataset that has not yet been assigned to at least one cluster, assigning each remaining document to one or more of the clusters based on a natural language processing comparison of each remaining document with documents already assigned to each respective cluster, creating a descriptive label for each respective cluster based on key terms contained in the documents assigned to the respective cluster, and presenting one or more of the labeled clusters to a user of the computerized system.

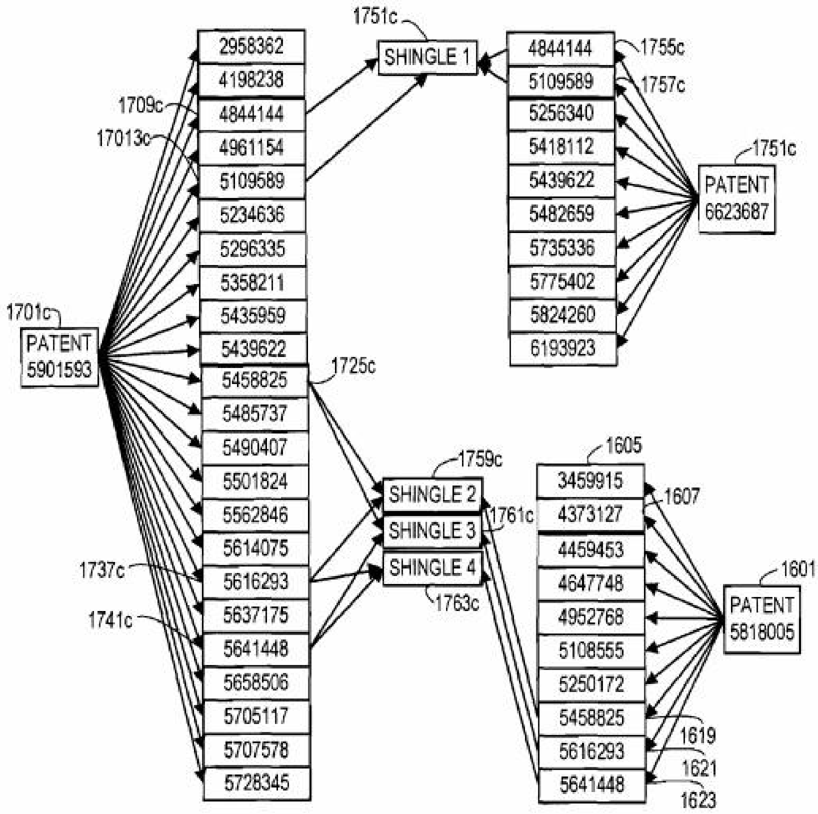


Figure 2-7: Dorie, Vincent Joseph (San Mateo, CA, US) and Giannella, Eric R. (Saratoga, CA, US) (2008)'s System And Methods For Clustering Large Database of Documents (US Patent Application No. 2009/0043797).

Gollapudi Sreenivas and Cupertino (CA, US) (2005)'s patent relates to a system that automatically classifies documents in a collection into clusters based on the similarities between documents, that automatically classifies new documents into the right clusters, and that may change the number or parameters of clusters under various circumstances. A second embodiment of the invention provides a technique for comparing two documents, in which a fingerprint or sketch of each document is computed. In particular, this embodiment of the invention uses a specific algorithm to compute the document's fingerprint. One embodiment uses a sentence in the document as a logical delimiter or window from which significant words are extracted and, thereafter, a hash is computed of all pair-wise permutations.; Words are extracted based on their weight in the document, which can be computed using measures such as term frequency and the inverse document frequency.

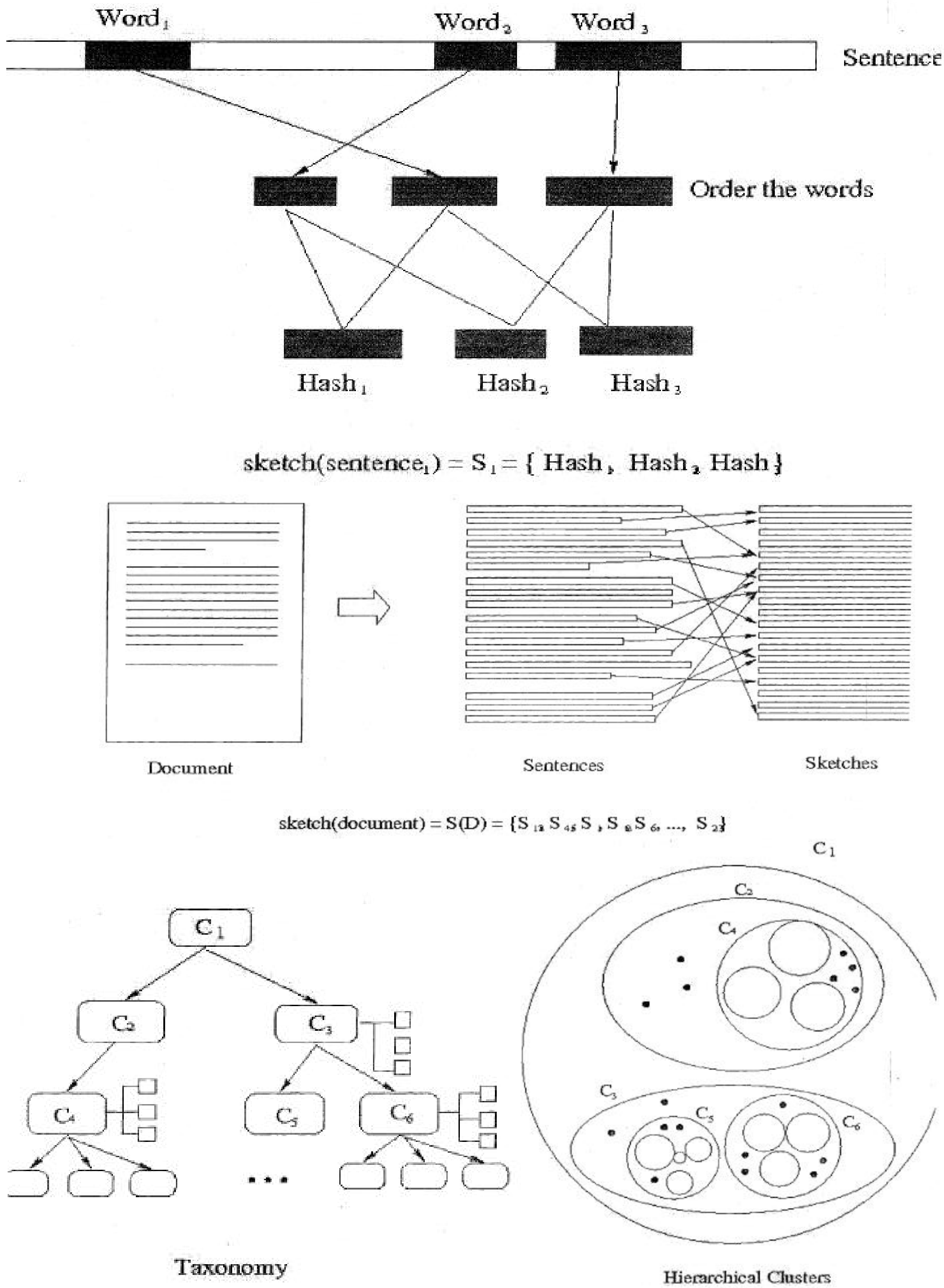


Figure 2-8: Gollapudi Sreenivas and Cupertino (CA, US) (2005)’s METHOD AND APPARATUS FOR DOCUMENT CLUSTERING AND DOCUMENT SKETCHING (US Patent No. 7,433,869).

COLBATH SEAN [US]; KUBALA FRANCIS G (US) (2002)'s patent relates to a system (520) generating labels for clusters of documents. The system (520) identifies topics associated with the documents in the clusters and determines whether the topics are associated with approximately half or more of the documents in the clusters. The system (520) then generates labels for the clusters using the topics that are associated with approximately half or more of the documents in the clusters.

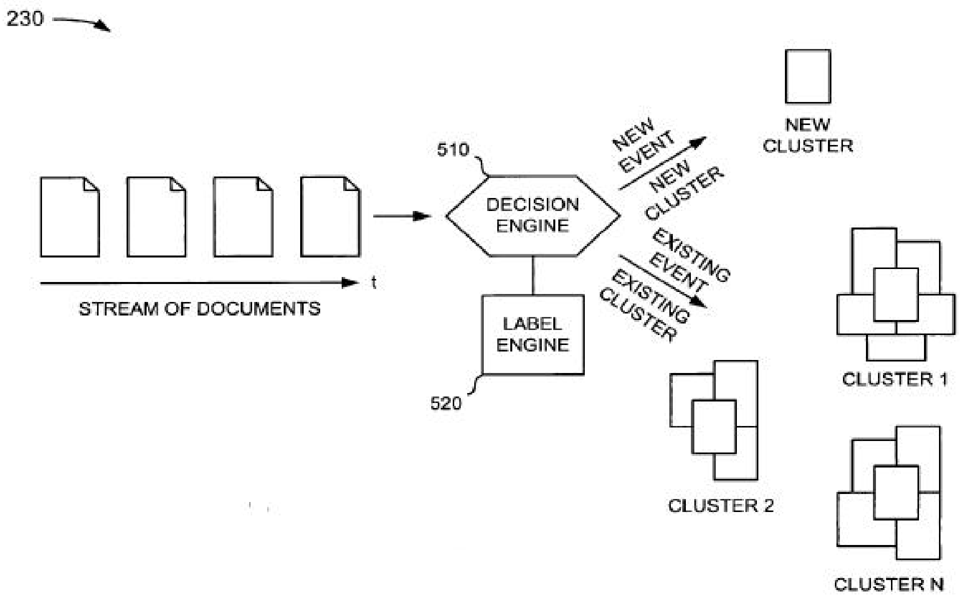


Figure 2-9: COLBATH SEAN [US]; KUBALA FRANCIS G (US) (2002)'s Systems and methods for labeling clusters of documents (US Patent Application No. 2004/000163034).

ANDREWS DAVID C, HASLAM BRIAN D, DUMAIS SUSAN T and HOLMES DANIELLE J (CA, US) (2005)'s patent relates to a system and method for analysis of portfolios that may comprise patent-related documents, academic articles, product literature, or any other textual material. In one aspect of the invention, a user-defined classification schema is developed, and predictions for associations with classifications from the user-defined classification schema are used directly, or compared for two portfolios via an analysis computer program. In yet another aspect of the invention, the results from the automatic classifier are combined with a custom classification schema to find and rank related documents. In yet another aspect of the invention, a citation computer program compares citation statistics between entire portfolios of documents. In yet another aspect of the invention, two aspects of the invention can be combined, such that citation statistics are presented for documents that have been classified.

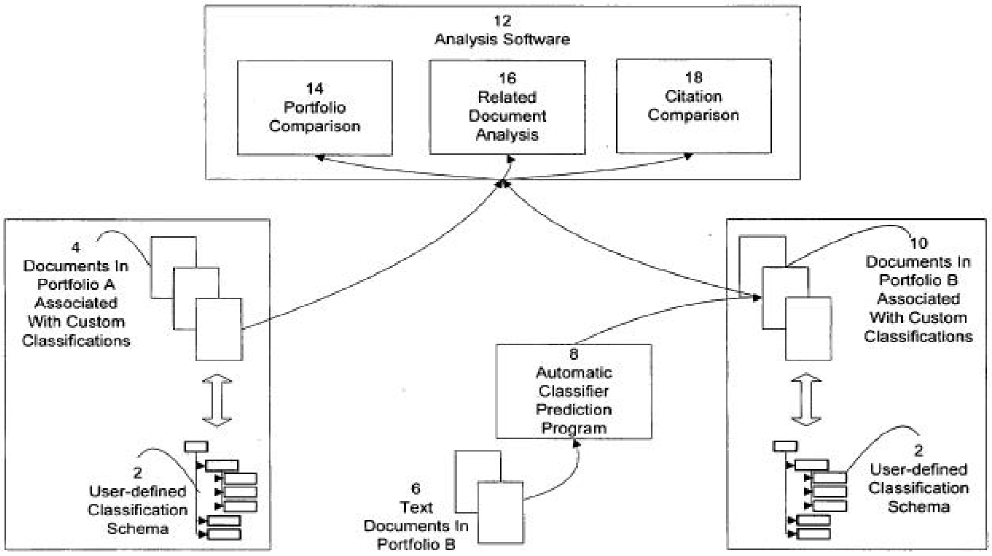


Figure 2-10: ANDREWS DAVID C, HASLAM BRIAN D, DUMAIS SUSAN T and HOLMES DANIELLE J (CA, US) (2005)'s Analysis and comparison of portfolios by citation (US Patent Application No. 2006/000248094).

GREEN EDWARD A [US]; KROSLEY RAMON [US]; MARKEY KEVIN L [US] (2000)'s patent relates to a method and apparatus for transforming information from one semantic environment to another. In one implementation, a SOLx system (1700) includes a Normalization/Translation NorTran Workbench (1702) and a SOLx server (1708). The NorTran Workbench (1702) is used to develop a knowledge base based on information from a source system (1712), to normalize legacy content (1710) according to various rules, and to develop a database (1706) of translated content. During run time, the SOLx server (1708) receives transmissions from the source system (1712), normalizes the transmitted content, accesses the database (1706) of translated content and otherwise translates the normalized content, and reconstructs the transmission to provide substantially real-time transformation of electronic messages.

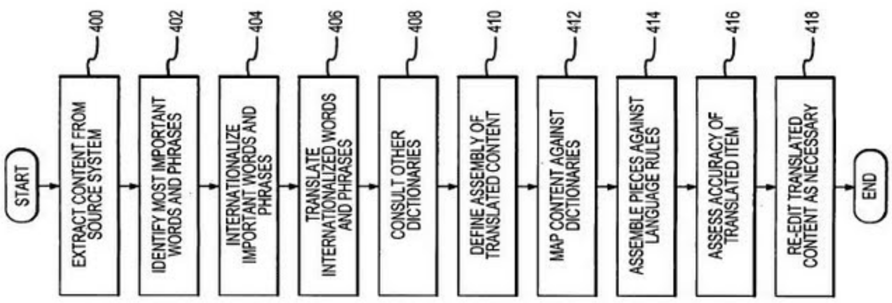


Figure 2-11: GREEN EDWARD A [US]; KROSLEY RAMON [US]; MARKEY KEVIN L [US] (2000)'s Method and apparatus for normalizing and converting structured content (US Patent No. 7,680,867).

CHITRAPURA KRISHNA PRASAD [IN]; POOLA KRISHNA LEELA [IN] (2007)’ patent relates to techniques for organizing structurally similar web pages for a website. Fingerprints are made of the structure of the web pages using shingling by placing the web page's HTML tags and attributes in sequence and encoding the tags and attributes using a standard encoding technique. Fixed-size portions of the encoded sequence are taken and a set of values extracted using independent hash functions to compute the shingles. Alternatively, a DOM tree representation of HTML of the web page is generated and each path of the DOM tree encoded and values extracted using independent hash functions to compute the shingles. A specified number of shingles are retained as the fingerprint. The pages are then clustered based upon the URL and the similarity of the shingles. The clustered hierarchical organization of pages is further pruned by various criteria including similarity of shingles or support of the cluster node in the hierarchy.

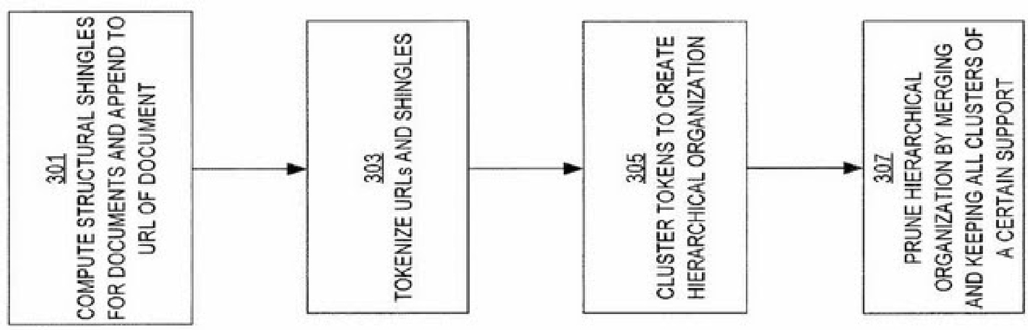


Figure 2-12: CHITRAPURA KRISHNA PRASAD [IN]; POOLA KRISHNA LEELA [IN] (2007)’ Method for Organizing Structurally Similar Web Pages from a Web Site (US Patent No. 7,941,420).

VYDISWARAN V G VINOD [IN]; MEHTA RUPESH R [IN]; MADAAN AMIT [IN] (2006)’ patent relates to techniques to automatically learn a template that describes a common structure present in documents in a training set. The structure of the template is compared to the structure of the documents (or at least a part of each document) in the training set, one-by-one, and generalized in response to differences between the template and the document to which the template is currently being compared. If the structure of any particular document is considered too dissimilar from the structure of the template, then the template is not modified. Various generalization operators are added to the template to generalize the template. One such generalization operator is an "OR", which indicates that only one of "n" sub-trees below the "OR" operator in the template is allowed at the corresponding position in a document.

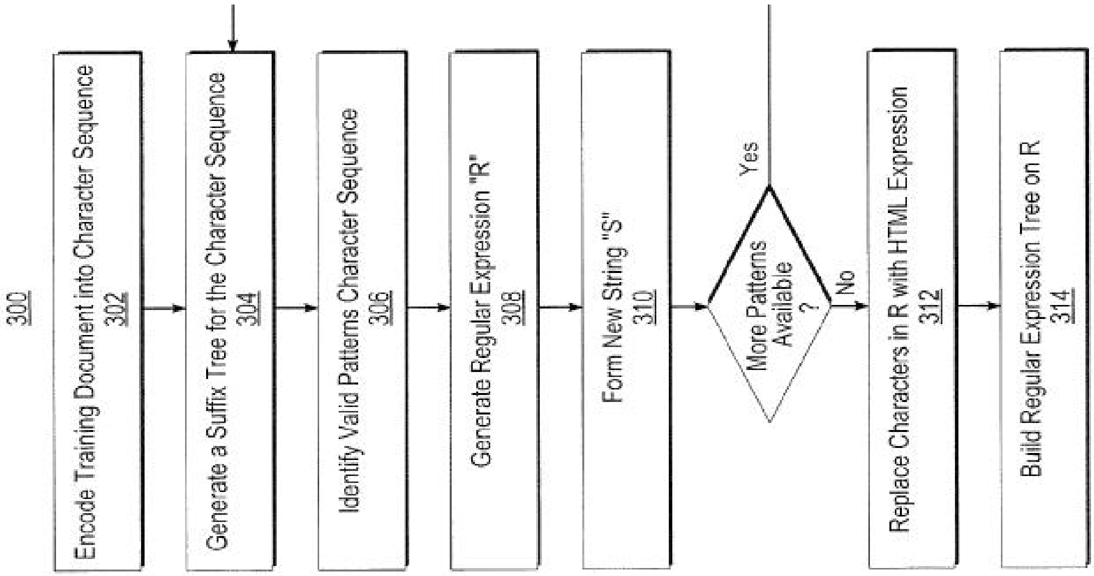


Figure 2-13: VYDISWARAN V G VINOD [IN]; MEHTA RUPESH R [IN]; MADAAN AMIT [IN] (2006)' TECHNIQUES FOR INDUCING HIGH QUALITY STRUCTURAL TEMPLATES FOR ELECTRONIC DOCUMENTS (US Patent No. 8,046,681).

2.3 Literature Review

David Gibson Ravi, Ravi Kumar, Andrew Tomkins (2005)'s in VLDB '05: Proceedings of the 31st international conference on Very large data bases, present a new algorithm for finding large, dense subgraphs in massive graphs based on a recursive application of fingerprinting via shingles, and is extremely efficient, capable of handling graphs with tens of billions of edges on a single machine with modest resources. Said algorithm characterizes the large, dense subgraphs of a graph showing connections between hosts on the World Wide Web.

This algorithm constitute the main reference of Dorie, Vincent Joseph (San Mateo, CA, US) and Giannella, Eric R. (Saratoga, CA, US) (2008)'s System And Methods For Clustering Large Database of Documents (US Patent Application No. 2009/0043797).

An algorithm for extracting large dense bipartite subgraphs in massive graphs allows to enumerate as many such disjoint subgraphs as possible. The desirable features of a good algorithm for finding dense subgraphs are that it should: 1) be able to identify large dense subgraphs and in the worst, be able to identify most of the nodes in large dense subgraphs; 2) be extremely efficient in terms of running time; 3) preferably be realizable in the data stream model, i.e., use very little main memory and process data on the fly with read/writes to secondary storage; 4) be scalable.

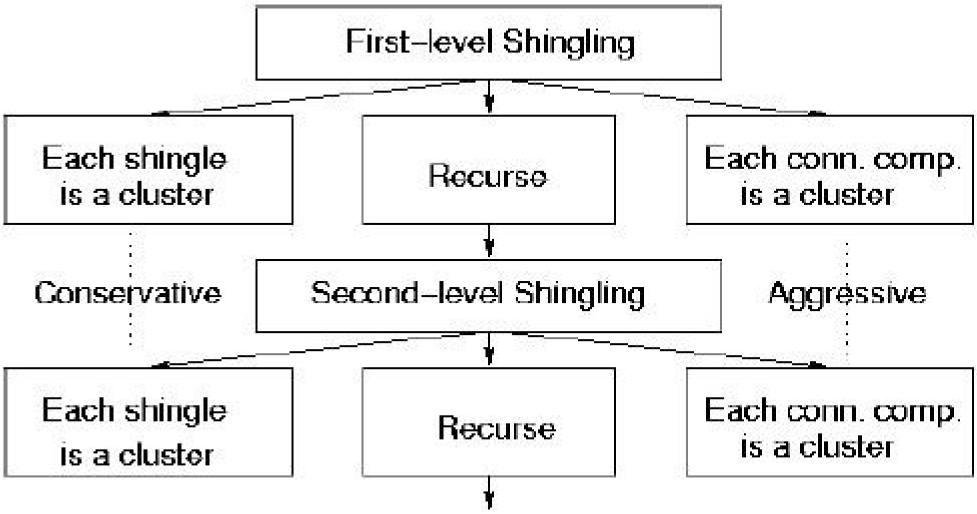


Figure 2-14: David Gibson Ravi, Ravi Kumar, Andrew Tomkins (2005)'s Discovering Large Dense Subgraphs in Massive Graphs.

2.4 Employed Search Engines

The state of the art described above points out two interesting patents:

- Page, Lawrence (Stanford, CA) (1998)'s method for node ranking in a linked database (US Patent No. 6,285,999);
- Dorie, Vincent Joseph (San Mateo, CA, US) and Giannella, Eric R. (Saratoga, CA, US) (2008)'s System And Methods For Clustering Large Database of Documents (US Patent Application No. 2009/0043797).

These patents concern respectively two search engines: Scirus and Prior-ip, which will be described and used in chapter 3.

CHAPTER 3

Science-specific search engine on the Internet

3.1 Introduction

This chapter refers to both analysis and use of some clustering-based engines: Scirus, Carrot2, Delphion, Prior-ip.

At point 3.2 we describe Scirus [www.scirus.com] as a clustering-based engine as described in Page, Lawrence (Stanford, CA) (1998)'s patent, regarding a method for node ranking in a linked database (US Patent No. 6,285,999). Scirus aollows to create science-specific index formed by a unique combination ranging from free Web sources to article databases. Thanks to Scirus Both patent collections and scientific publications can be analysed while investigations can be diversified:

- horizontally, by separating patent documents from scientific publications;
- vertically by separating documents published within specific temporal ranges.

The numerous parameters to be entered and checking the data vertically and horizontally make Scirus a search engine apt to highlight the structure of a collection of documents according to a method of document-retrieval systems.

In paragraph 3.3 we describe Carrot2 [http://project.carrot2.org] which organizes small collections of documents into thematic categories. Compared to Scirus, Carrot2 does not allow any vertical splitting of the investigation. Nevertheless Carrot2 offers a very effective rendering.

Paragraphs 3.4 e 3.5 are dedicated to the describing the applications of citation link text clustering methods of Delphion [www.delphion.com] and Prior-ip [www.prior-ip.com].

Prior-ip is the pragmatic application of the Dorie, Vincent Joseph (San Mateo, CA, US), Giannella, Eric R. (Saratoga, CA, US) (2008)'s System And Methods For Clustering Large Database of Documents (US Patent Application No. 2009/0043797).

3.2 Scirus

Scirus is a free Web search engine for scientific information to create science-specific index comprised of a unique combination ranging from free Web sources to article databases.

Scirus is powered by search technology provided by Fast Search & Transfer™ (FAST™). FAST search technology is currently deployed by a wide range of global customers and partners including AT&T, CareerBuilder, Dell, Freeserve, IBM and Reuters.

Speciality search engines – also called vertical or topical Web search engines – focus on specific subject areas. Elsevier has worked in partnership with FAST to create unique processes that:

- Focuses only on websites containing scientific content and indexes those sites in-depth.
- Searches the world-wide-web for free sources of information such as scientist home pages and university websites.
- Searches the world's largest database of scientific, technical and medical journals.
- Locates pre-print, peer-reviewed articles and patents.
- Provides an intuitive interface and advanced search features that makes it easy to use.
- Provides unique science-specific Web search functionalities, such as searching on author, within specific sources or subject areas.

The seed list is the basis on which Scirus crawls the Internet. The Scirus seed list is created by a number of methods including an automatic URL extractor tool that identifies new scientific seeds based on a link analysis of the most popular sites in specific subject areas. The seed list only contains URLs that have been manually checked for scientific content allowing to crawl the Internet in an efficient, focused way ensuring deeper and fuller coverage of scientific web sites.

Scirus uses a spiders or crawlers to "read" the text on the sites found on the seed list. This type of focused crawling ensures that only scientific content is indexed to find new documents and update existing documents. The process of the robot follows is relatively simple.

Scirus loads data from science-specific sources. Scirus reads every word that appears on the site and examines where the word appears on the site (title, URL, text). Once the seed list has been crawled and the database has been loaded Scirus is ready to classify the data. The classification process improves the retrieval of science-specific pages and allows the user to perform searches that are targeted towards specific scientific domains or document types. Scirus performs document classification following two different schemes.

Document meta information, such as the URL of the page and anchor text pointing to the document is also used to refine and improve the subject classification. The algorithm for subject classification allows the assignment of multiple categories to a single document, because of the considerable overlap between neighbouring scientific disciplines (such as Neuroscience and Medicine or Psychology and Social Sciences).

Scirus uses custom software to analyze the profile of a page and classify the information type. Types that are recognized include scientific abstracts, full text scientific articles, scientist home pages, conference announcements and other page types that are relevant to the scientific domain. The classification algorithm analyses the structure and the vocabulary of a page to assign one of the categories. The structural analysis also allows the extraction of certain information chunks from the analysed pages. In the case of a scientist homepage the module will attempt to extract information like the name and affiliation of the owner of the page and add it to the document attributes.

Scirus uses an algorithm to rank the documents resulting from a query. Algorithms are procedures, or formulas, used to solve a problem. Ranking is based on two basic values: term and links.

For term value, the location and frequency of occurrence of the terms within the document are measured. The global frequency of the term within the whole index is also taken into consideration.

To ensure that full-text articles are not ranked higher than title/abstract pages Scirus counts the number of keywords and then divides them by the total number of terms in the document. Scirus also examines the length of the URL. Short URLs (such as www.microsoft.com) are more relevant than longer URLs (such as www.microsoft.com/help). Scirus does not use meta tags because they are subjective to ranking tweaking by users. When the terms in a query occur near to each other within a document it is more likely that the document is relevant to the query than if the terms occur at a greater distance. Therefore the proximity of the search terms influence the Scirus ranking.

Scirus uses link analysis as part of its relevancy ranking system. For link value, the number of links to a page is analysed. The cardinality or importance of a page is determined by calculating the number of links to a page. The more links to the page, the higher the ranking. Scirus also analyses the anchor text – the text of a link or hyperlink – to determine the relevance of a site. Because pages that are indexed via database loading are not crawled and are usually less interlinked, it is not possible to conduct a proper link analysis. These pages are assigned a static score. Every time a new Scirus Index is created the static score is examined for relevance. Scirus uses a special general terms dictionary with “select” scientific terms to identify which pages deserve a science flag.

3.3 Carrot2

Carrot2 is an Open Source Search Results Clustering Engine to automatically organize small collections of documents into thematic categories. Carrot2 is a library and a set of supporting applications to build a search results clustering engine. Carrot2 contains two document clustering algorighms designed specifically for search results clustering: Suffix Tree Clustering and Lingo.

Currently, Carrot2 offers two specialized search results clustering algorithms: Lingo and STC as well as an implementation of the bisecting k-means clustering. The algorithms differ in terms of the main clustering principle and hence have different quality and performance characteristics.

The key characteristic of the Lingo algorithm is that it reverses the traditional clustering pipeline: it first identifies cluster labels and only then assigns documents to the labels to form final clusters. To find the labels, Lingo builds a document-term matrix, a mathematical matrix that describes the frequency of terms that occur in a collection of documents for all input documents, and decomposes the matrix to obtain a number of base vectors that well approximate the matrix in a low-dimensional space. Each such vector gives rise to one cluster label. To complete the clustering process, each label is assigned documents that contain the label's words.

The key data structure used in the Suffix Tree Clustering (STC) algorithm is a Generalized Suffix Tree (GST) built for all input documents. The algorithm traverses the GST to identify words and phrases that occurred more than once in the input documents. Each such word or phrase gives rise to one base cluster. The last stage of the clustering process is merging base clusters to form the final clusters.

The two algorithms have two features in common. They both create overlapping clustering, in which one document can be assigned to more than one cluster. Also, in case of both algorithms a certain number of documents can remain unclustered and fall in them.

Bisecting k-means is a generic clustering algorithm that can also be applied to clustering textual data. As opposed to Lingo and STC, bisecting k-means creates non-overlapping clusters and does not produce the Other Topics group. Its current limitation is that it labels clusters using individual words and not all cluster's documents may correspond to the words included in the cluster label. Table 3-1 compares the characteristics of Lingo, STC and k-means under their default settings.

Table 3-1: characteristics of Lingo and STC clustering algorithms

Feature	Lingo	STC	k-means
Cluster diversity	High, many small (outlier) clusters highlighted	Low, small (outlier) clusters rarely highlighted	Low, small (outlier) clusters rarely highlighted
Cluster labels	Longer, often more descriptive	Shorter, but still appropriate	One-word only, may not always describe all documents in the cluster
Scalability	Low. For more than about 1000 documents, Lingo clustering will take a long time and large memory[a].	High	Low, based on similar data structures as Lingo.

3.4 Delphion

3.4.1 Citation Link

Citation Link reveals all of a patent's citations — both backward and forward — in a graphical map, using multiple visualization techniques. For example Figure 3-1 shows a graphical map of backward and forward first level of citation link of the US patent N. 07304034.

3.4.2 Text Clustering

Text Clustering shows textual information into useful knowledge by the relationships of clusters of similar documents based on extracted keywords. Clustering works with both original patent data and Derwent data. Text Clustering is a linguistic and relational technology used to analyze the patent documents. Documents are assigned uniquely to one defined cluster; clusters of similar documents are clearly displayed along with the extracted keywords that characterize each cluster. Results can be visualized graphically with a map that provides an overview of the clusters and an indication of the relationship among them. For example: Table 3-2 contains a collection of 112 patents of year 1972, responding to the boolean algorithm *"(((d03d OR b65h) <in> IC) AND ((gripp*) <in> (TITLE,ABSTRACT,CLAIMS)))";* five clusters contain groups of patents with similar terms; Figure 3-2 shows the graphical relationship of the clusters.

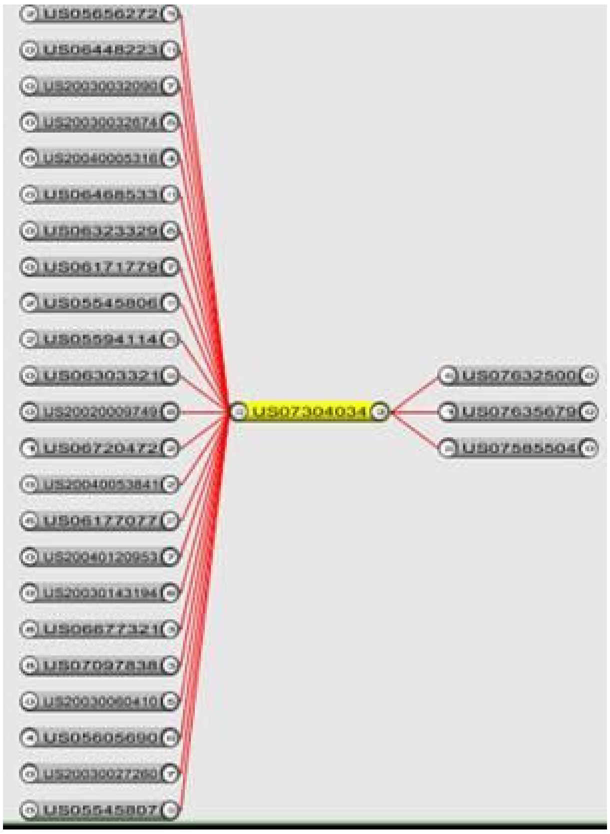


Figure 3-1: graphical map of backward and forward first level citation link of the patent N. US 730,403,4.

Table 3-2: National Collections - Data Coverage (Update:2012-01-11)

Cluster	Descriptive words
1	comprise, loom, roller, provide, apparatus, mean, move, device, control, include
2	sheet, mechanism, gripper, mount, press, transfer, conveyor, include, movement, printing
3	form, engage, surface, end, material, drive, provide, apparatus, lower, length
4	mean, member, parallel, relative, grip, pair, include, release, pass, groove
5	release, side, arrange, adjacent, movement, locate, operation, hold, first, time

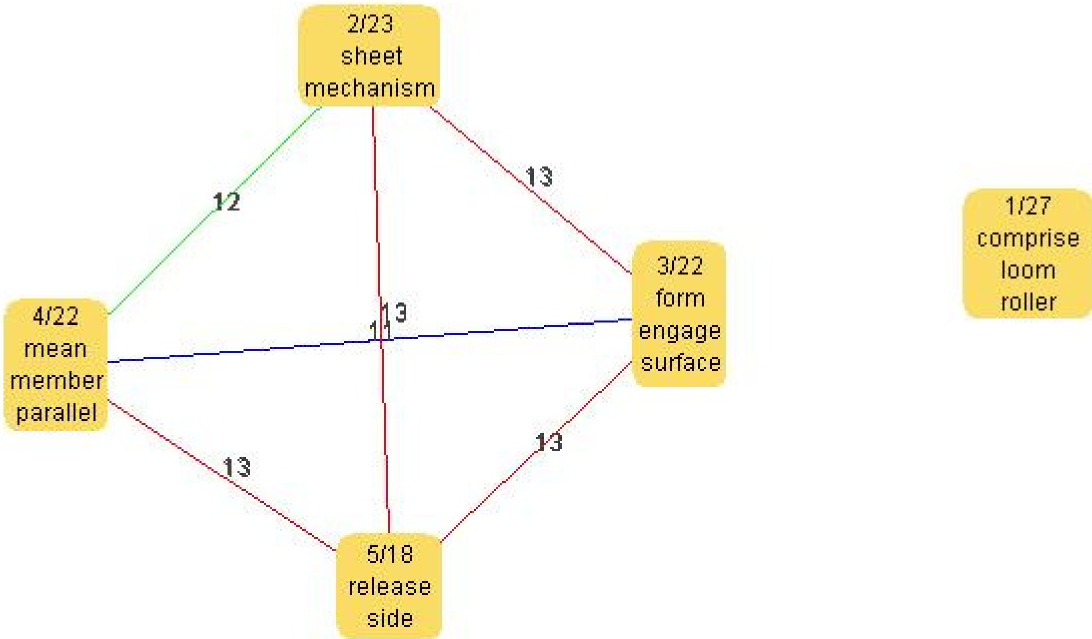


Figure 3-2: graphical relationship of the clusters of Table 3-2.

3.5 Prior-ip

PriorIP is a research website that organizes the world's IP. PriorIP's advanced algorithms organize the world's patents into related categories or clusters. These clusters are calculated ahead of time and are based on citation analysis, not textual analysis. This web tool allows to view the matched patents within their clusters and also view the clusters in a dynamically-generated set of cluster maps that contain all the clusters with matched patents. These maps present an overview of the technical areas containing search results, allowing to contextualize the results before viewing their details and to find related patents.

On the search results page following a search, for example: *("speed redcuer" AND "planetary gears" AND valve),* exact phrase match in ABSTRACT. A first output result is represented by a "Search Cluster Landscape" of Figure 3-3 and Figure 3-4 which contain a collection of four cluster maps, each containing all related patents.

Start by choosing the cluster *"electronic throttle valve"* and viewing the patent detail page by selecting the link from the US Patent Number: 5,777,412 detail page under 'Visually Browse Related IP'. The Cluster Neighborhood Map is presented on Figure 3-5.

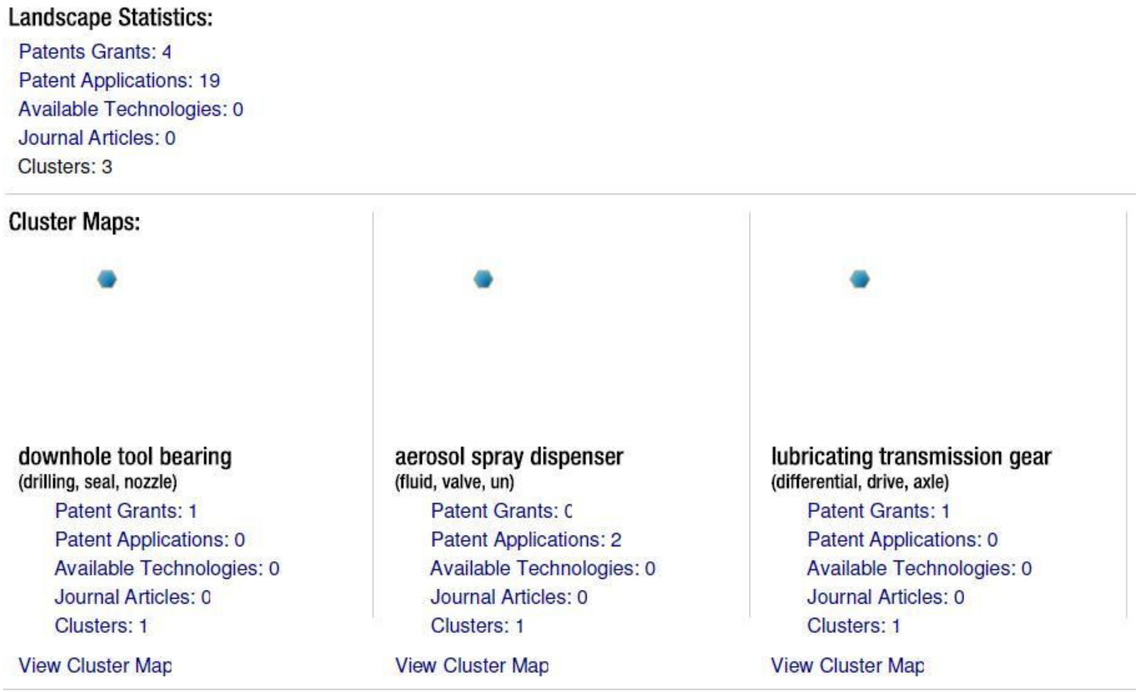


Figure 3-3: Search Cluster Landscape of ("speed redcuer" AND "planetary gears" AND valve).

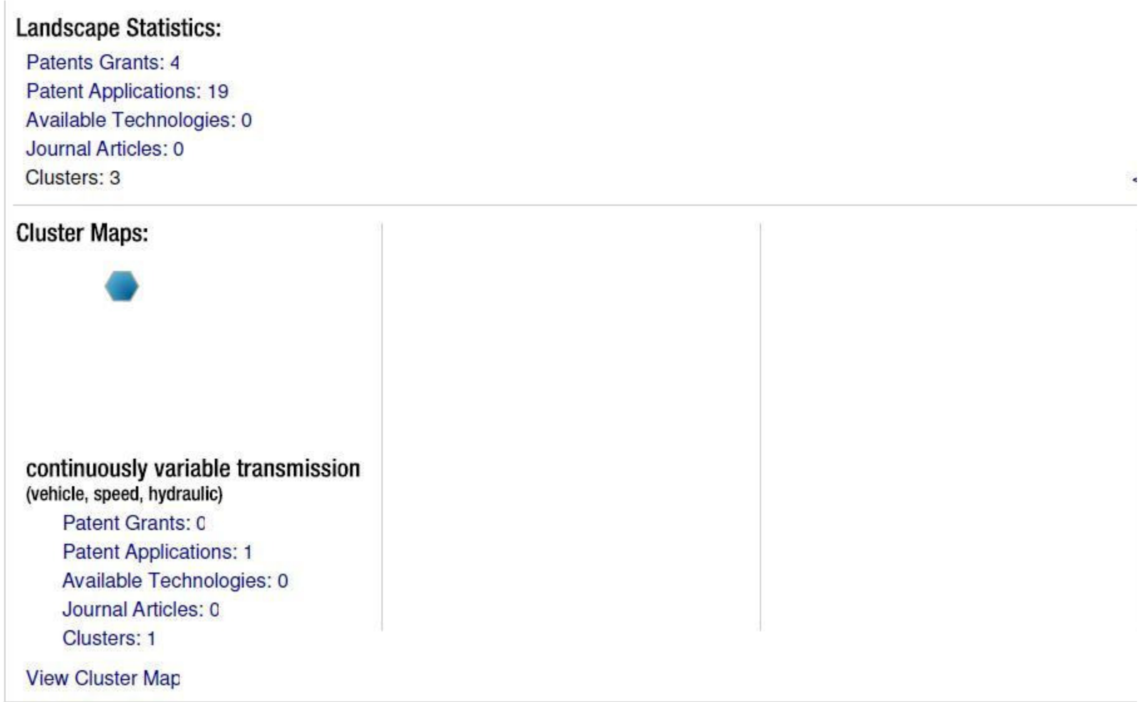


Figure 3-4: Search Cluster Landscape of ("speed reducer" AND "planetary gears" AND valve).

To research related clusters displayed in the map, continue by choosing the cluster *"throttle return spring"* and viewing the map on this cluster. The Cluster Neighborhood Map is presented on Figure 3-6.

Prior-IP is a research website that utilizes the algorithm related to (2008)'s System And Methods For Clustering Large Database of Documents (US Patent Application No. 2009/0043797) reported on chapter 2 of this dissertation, 2.3 Non-Patent review.

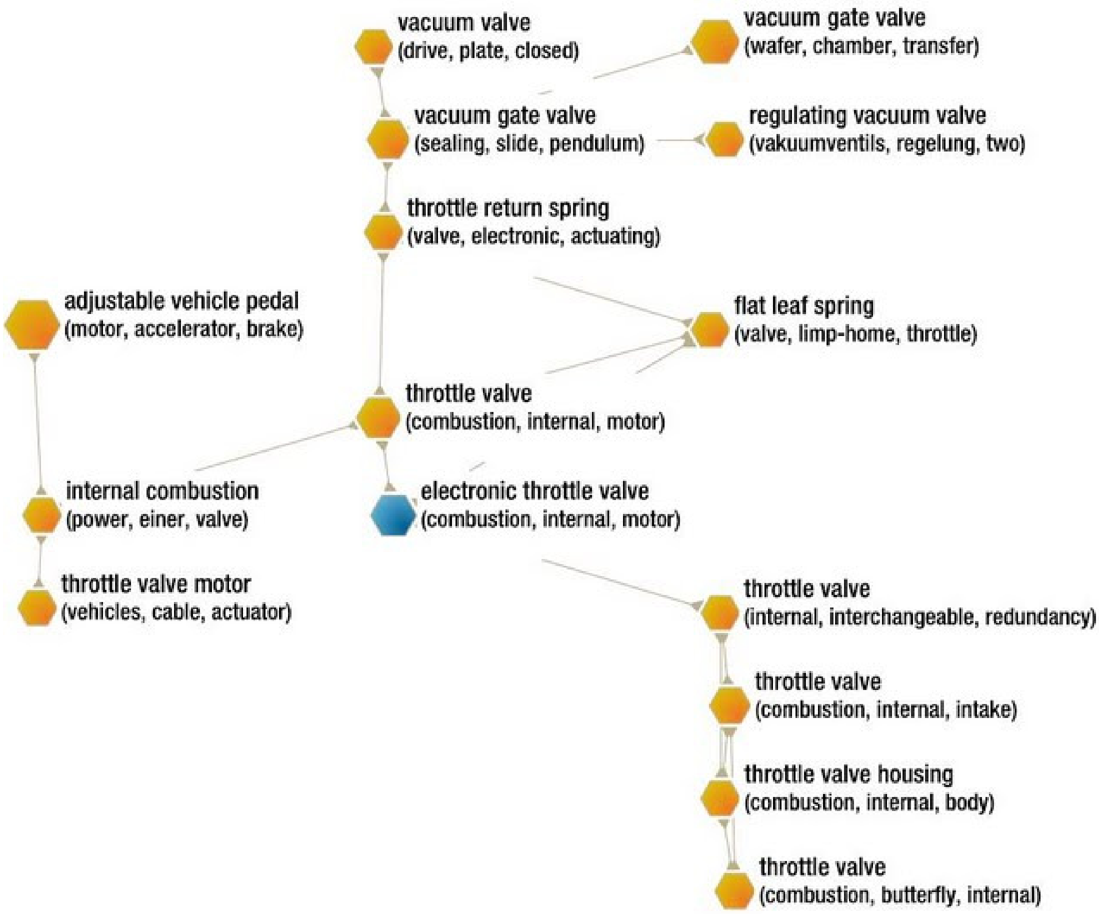


Figure 3-5: Cluster Neighborhood Map of US Patent Number: 5,777,412.

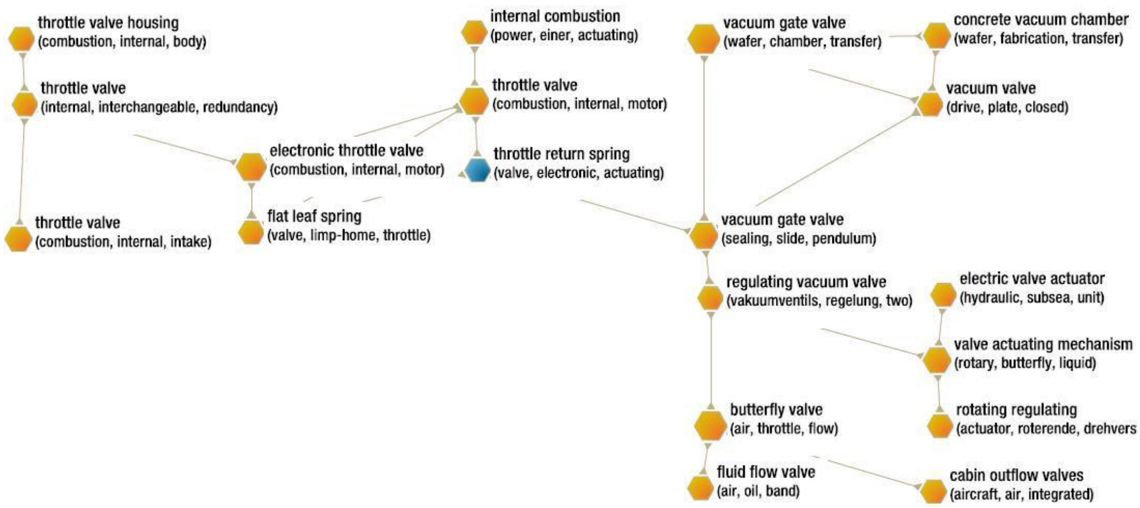


Figure 3-6: Cluster Neighborhood Map of cluster "throttle return spring".

3.6 Consideration

As a first consideration about the four clustering-based engines analysed in this chapter is that only Scirus engine offers an opportunity to analyse both patent-collections and scientific publications, while investigations can be diversified within specific temporal ranges. This latter feature is widely used in the project illustrated in this dissertation. Therefore great enphasis is laid upon this search engine.

Carrot2 offers some potentialities - apart the excellent rendering – which would be worth invastigating, but which are not subject of the present study.

Carrot2 is anyway employed in parallel with Scirus in the following chapter. This aimed at ranking the implementation of two search engines and consequently at checking if a prospective sinergy between the two, could target appraising the technical value of the analysed technological system.

Delphion’s applications are not pertinent to the present work, therefore this search engine is not included in the investigation. Moreover, Delphion is not for free, while this is a distinctive feature to discriminate search engines to be included in this study.

Prior-ip analysis patent data-base only, nevertheless it bases upon a powerful and effective mathematical algorithm.

Therefore, that being stated, Chapter 4 will analyze a case by means of Scirus and the prospective synergic potentiality will be tested matching the same analysis with Carrot 2 and Piror-ip.

CHAPTER 4

Common Technical Value of Patents and Scientific-Publications

4.1 Introduction

This chapter describes one query-based method for classifying documents, where the query depends upon a Common Technical Value of Patents and Scientific-Publications (Figure 4-1).

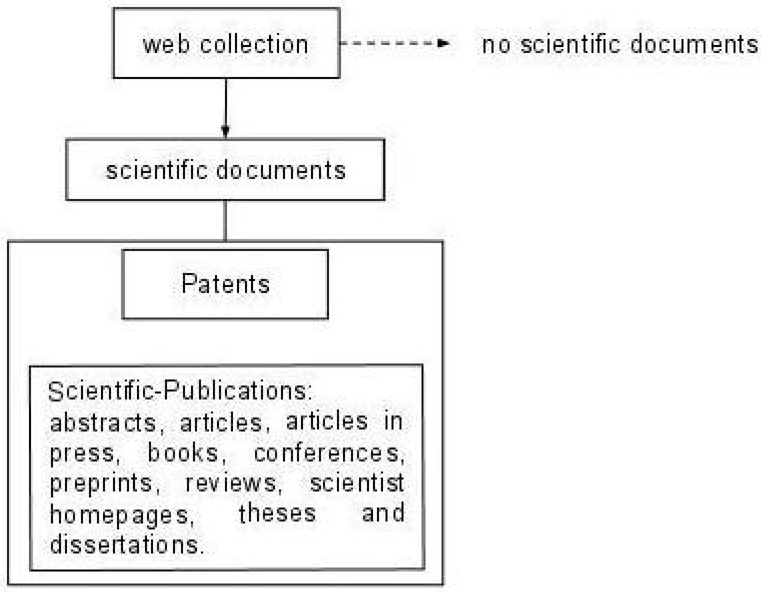


Figure 4-1: scheme of organization of scientific documents.

Said method employs Scirus and allows to contextualize a technological system by means of a sequence of queries which are built through a horizontally-structured comparison of clusters within a scientific web-collection, which has been previously split in two sets of documents: patent documents and scientific publications. At the same time the comparison is also vertically structured according to different temporal ranges, so that we get a 4-field table (Figure 4-2): F1+F2 above, F3+F4 under, where F1+F3 contain patents, F2+F4 contains publications. F1+F2 are horizontally compared by key-words, as well as F3+F4. F1+F3 as well as F2+F4 are vertically compared according to their timeline.

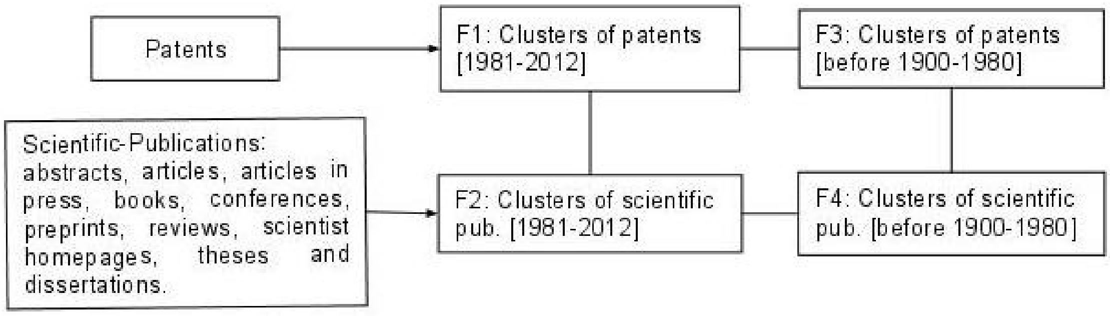


Figure 4-2: horizontally-vertically structured comparison of clusters within a scientific web-collection.

This method can define a technological system which can be contextualized in a different environment such as the market.

Paragraph 4.2 shows the case of a technological system, specifically a Process for injection of a unsaturated polyester resin.

The horizontal structure of a scientific web-collection is formed by separate clusters of scientific publications and of patents. The vertical structure of a scientific web-collection is formed by separate clusters from separate documents in different temporal ranges, which are here identified as evolutionary steps: *technological pionerism* and t*echnological diffusion*. A rating parameter R states the dissemination of the key-words, according to which those keywords referring to a certain cluster occupy both the horizontal and the vertical structures at the same time. The key-words belonging to high R-rating clusters set up the queries needed to define a technological system.

Paragraph 4.3 and paragraph 4.4 describe the technological system as depicted in paragraph 4.2 and analysed respectively by means of Carrot2 and Prior-ip, the latter being limited to a patent data-base.

Paragraph 4.5 summarizes the results obtained.

4.2 Case study 1 - Scirus

A technological system regarding the injection process of unsaturated polyester resin is analyzed by means of Scirus.

4.2.1 First Level Query

The following items:

"unsaturated polyester resin" injection (4.1)

set up a **first level query** which can be entered in the search area of the search engine (see Figure 4-3).

In the section Advanced Search (see Figure 4-4) a complete set of scientific documents is ticked off. Said documents are discriminated between:

- Abstracts, Articles, Articles in Press, Books, Conferences, Preprints, Reviews, Scientist homepages, Theses and Dissertations (any information type excluded patents);
- Patents.

The temporal range, split between:

- before 1900-2012;
- before 1900-1980.

is to be ticked off in the same section.

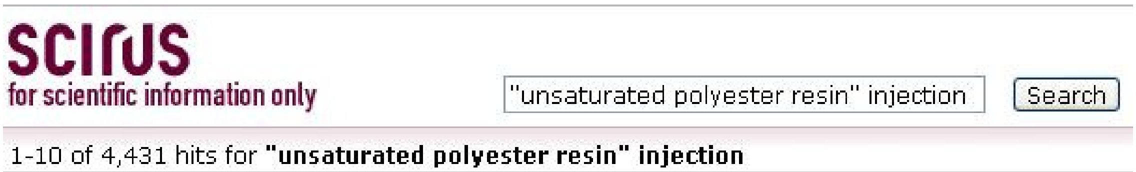


Figure 4-3: Scirus input items.

Figure 4-4: Scirus advanced search, information types.

Table 4-1 shows a structure of clusters relating to key-words (4.1) split in Patents and Scientific Publications and set in the temporal range [before 1900–2011]. Table 4-2 shows a structure of clusters relating to the key-words (4.1) split in Patents and Publications and set in the temporal range [before 1900–1980].

Table 4-1: "unsaturated polyester resin" injection: before 1900 – 2011

Any information type	Patents	Any information type - Patents
4,007 hits for **"unsaturated polyester resin" injection**	3,652 hits for **"unsaturated polyester resin" injection**	355 hits for **"unsaturated polyester resin" injection**
molding	molding	composites
glycol	**gel time**	tensile
molded	vinyl ester	nanocomposites
gel time	glycol	reinforced
vinyl ester	peroxide	molding
monomer	molded	flexural strength
peroxide	monomer	natural fibre
dibasic acid	reactive diluent	b. mechanical properties
unsaturated polyester resins	peroxides	nanocomposite
polyester resins	unsaturated polyester resins	reinforcement
injection molding	dibasic acid	dielectric
thermoplastic resin	polyester resins	resin flow
styrene monomer	injection molding	**gel time**
copolymer	acid value	transfer molding
isophthalic acid	styrene monomer	cellulose
peroxides	isophthalic acid	mold filling
polymerization	copolymer	flame retardant
acid value	thermoplastic resin	polymerization
composites	block copolymer	injection gate
transfer molding	glass fibers	impregnation
thermoplastic	thermosetting	thermoplastic
copper compound	thermoplastic	layered silicate
maleic anhydride	maleic anhydride	injection molding
block copolymer	anhydride	nanoparticles
anhydride	resinous	pe polyethylene
reactive diluent	copper compound	montmorillonite
resinous	surface smoothness	pp polypropylene
surface smoothness	thermosetting resin	mechanical properties
thermosetting	neopentyl glycol	ps polystyrene
neopentyl glycol	manganese compound	fibre composites
glass fibers	manganese	mandelic acid
manganese	cobalt	b. fibre/matrix bond
manganese compound	propylene	**cure kinetics**
melamine resin	electrode	e. resin transfer moulding (rtm)
number-average molecular weight	organic peroxide	resin transfer
glass transition temperature	silicone	glass fiber
tensile	chopped	polypropylene

organic peroxide	transfer molding	carbon nanotubes
silicone	number-average molecular weight	nanotubes
compression molding	carbonate	polymer composite
propylene	melamine resin	a. polymer matrix composites
terephthalic acid	itaconic acid	sem scanning electron microscopy
carbonate	conjugated	tga thermogravimetric analysis
dielectric	conjugated diene	polyester composite
itaconic acid	iron compound	filling time
iron compound	thickening agent	dicumyl peroxide
nanocomposites	terephthalic acid	pu polyurethane
twitter	compression molding	life cycle assessment
polybasic acid	isosorbide	alkali
benzoyl peroxide	dipropylene glycol	composite
dipropylene glycol	average molecular weight	vitrification
polyvalent alcohol	10274969	d. mechanical testing
linkage group	palatal	epoxy resin
10274969	polyvalent alcohol	heat release
usb274969	urethane resin	impact strength
usa274969	linkage group	polymer
thickening agent	sizing agent	laminate
specific surface area	10274914	impact energy
weight-average molecular weight	acid number	void content
curing agent	usb274969	injection pressure
thermosetting resin	usb274914	vinyl ester
electrode	metal compound	relative viscosity
reinforced	weight-average molecular weight	dielectric properties
metering	usa274914	compressive
injection moulding	injection moulding	rtm process
diluent	metering	dsc differential scanning calorimetry
trimellitic anhydride	usa274969	a. polymer–matrix composites (pmcs)
powder coating	glass transition temperature	hemp fibre
polymer science	organic base	flexural modulus
dielectric properties	melamine	untreated
embedded capacitors	thermoplastic material	isothermal
relative dielectric constant	elastomeric	carbon nanofibers
conjugated diene	powder coating	**gel point**
dielectric loss	diluent	rheology
mesh sieve	reflux condenser	reinforced composite

conjugated	aromatic compound	polymer science
dibasic acids	styrene-butadiene block copolymer	a. fibres
reflux condenser	dibasic acids	transfer moulding
methacrylate	methacrylic acid	flammability
methacrylic acid	vicinal	benzilic acid

Table 4-2: "unsaturated polyester resin" injection: before 1900 – 1980

Any information type	Patents	Any information type - Patents
347 hits for **"unsaturated polyester resin" injection**	331 hits for **"unsaturated polyester resin" injection**	16 hits for **"unsaturated polyester resin" injection**
molding	molding	composites
polyester resins	polyester resins	reinforced
glycol	glycol	glass fibres
monomer	monomer	fibrous
reinforced	molded	carbon fibres
glass fibres	glass fibers	plastics
composites	acid number	thermoplastic
molded	thermoplastic resin	fibrous material
glass fibers	unsaturated polyester resins	reinforcement
thermoplastic	resin solution	impregnated
thermoplastic resin	glass fibres	graphite
carbon fibres	resinous	carbide
unsaturated polyester resins	thickening agent	graphite fibre
acid number	peroxide	aluminium
plastics	blowing agent	fibre reinforced plastics
thickening agent	injection molding	conveyor
injection molding	dibasic acids	corrosion
epoxy resin	epoxy resin	driving power
zinc stearate	benzoyl peroxide	adhesive
benzoyl peroxide	isophthalic acid	rubber compound
fibrous	zinc stearate	conveyor belts
dibasic acids	free flowing	strength retention
resin solution	carbonate	polyamide
isophthalic acid	vinyl chloride resin	polyamide resin
crystalline	plasticizer	synthetic resin
free flowing	silicate	carbon filaments
silicate	non-reactive	secretary of state
carbonate	synthetic resin	fibrous cement
resinous	diisocyanate	thermoplastics
blowing agent	crystalline	amino resin
fibrous material	thermosetting	nominal weight

vinyl chloride resin	surface smoothness	armour
plasticizer	thermoplastic	graphite materials
adhesive	annular space	graphite intercalation
non-reactive	ethylene	mesophase formation
synthetic resin	aqueous alkali	petroleum pitch
titanium	hydrated alumina	adsorption
diisocyanate	free-flowing	carbonization
dicumyl peroxide	polycarboxylic acid	intercalation
silica	borehole	intercalation compound
graphite	mesh sieve	mesophase
peroxide	magnesium	reinforced composite
styrene monomer	silica	resin impregnated
impregnated	coloring agent	heated
reinforcement	reinforced	conductive
mesh sieve	dicumyl peroxide	bundles
magnesium	inner surfaces	failure mechanism
curing agent	**curing agent**	titanium
surface smoothness	styrene monomer	kevlar
polycarboxylic acid	**uncured**	impact damage
free-flowing	titanium	pilot boat
thermoplastic material	adhesive	modular construction
uncured	acid value	marine applications
coloring agent	thermoplastic material	alizarine
maleic anhydride	maleic anhydride	age levels
acid value	absorbent	parietal
sheet material	battery cell	inner table
aqueous alkali	tartrate	outer table
hydrated alumina	liquid system	apposition
sodium silicate	neopentyl glycol	parietal bone
absorbent	polystyrene	coated
liquid system	hydrazide	sheet material
carbon filaments	blowing agents	mandrel
thickening	accelerator	conductivity
aluminum oxide trihydrate	anhydride	hydroxyl ions
fibre reinforced plastics	polyesters	piston pump
graphite fibre	antimony oxide	ion radius
colouring agent	mould release agent	electrolyte
polyisocyanate	polyvinyl	electrode
catalyst	benzoin	injecting electrode
aluminium	reduced scale	diffusion velocity
polyesters	valeronitrile	ion mobility
fire retardant	isocyanate	chopped strand mat
banbury mixer	resin matrix	fatigue mechanisms

polyvinyl	polymerization	resin composite
shrinkage control	catalyst	chemical resistance
battery cell	magnesium oxide	fire retardant
reinforced plastic	phosphorus trichloride	epoxy resin
fibrous glass	shrinkage control	epoxides
alkali	thickening	fracture surfaces

4.2.2 Second level Query

Queries following first level queries depend on a common Technical Value of Patents and Publications. Each secondary query is in fact generated comparing clusters belonging to the structures of a previous query. A rating parameter R considers the frequency according to which the key-words of similar clusters occupy the horizontal and the vertical structure of the previous query.

A second level query includes key-words with a rating R calculated while analyzing the structure shown in Table 4-1 and Table 4-2 of the first level. A rating R represent the average value of a horizontal rating R_H and of a vertical rating R_V (Figure 4-5).

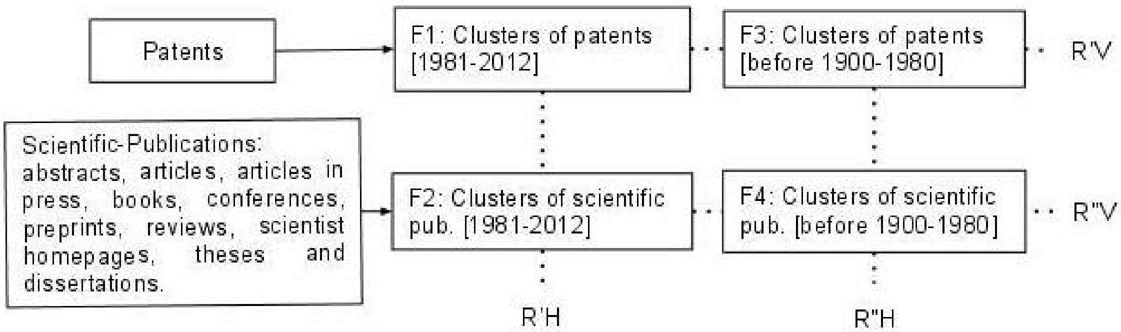


Figure 4-5: horizontal rating R_H and vertical rating R_V.

The horizontal rating R_H establishes the frequency according to which similar key-words simultaneously occupy both the patents and the scientific publication classes, e.g.:

- R_H takes a maximum horizontal value if similar key-words of the same structure belong to two patent clusters and to two scientific publication clusters at the same time;
- R_H takes a zero value if similar key-words of the same structure belong to one or none patent clusters and to one or none scientific publication clusters at the same time.

The vertical rating R_V establishes the frequency according to which similar key-words occupy the structure in the temporal range [before 1900-2012] and the structure in the temporal range [before 1900-1980]:

- R_V takes a maximum vertical value if similar key-words in the same patent structure or in the scientific publications structure belong to structures respectively located in the temporal ranges [before 1900-2012] and [before 1900-1980] at the same time;
- R_V takes zero or no vertical value if similar key-words in the same patent structure or in the scientific publications structure belong to one or none structures respectively located in the temporal ranges [before 1900-2012] and [before 1900-1980] at the same time.

The average value R is given by the expression (4.2):

$$R = (R'_H+R''_H+R'_V+R''_V) /4 \qquad (4.2)$$

where R'_H refers to the range [before 1900-2012]; R''_H refers to the range [before 1900-1980], R'_V refers to the patents structure, R''_V refers to the scientific publications structure.

In this specific case and aiming at defining a second level query, attention concentrates on those key-words, which at a first analysis prove being mostly repetitive in both structures of Table 4-1 e Table 4-2. Specifically the key-words mostly repetitive are bold written in Table 4-1 and Table 4-2:

- *"gel time";*
- *"curing agent".*

In table 4-3 the R rating referring to the key-word *"gel time"* has a value of 25 (%), while rating R referring to the key-word *"curing agent"* has no value at all.

At this stage the second level query is defined by the following key-words:

"unsaturated polyester resin" injection "gel time" (4.3).

The key-words (4.3) form the **second level query**, which is entered in the search area of the search engine.

Table 4-3: rating R calculated referring to key-words “gel time” and “curing agent”.

	Items	Items
Structure	**gel time**	**curing agent**
R'_H (before 1900-2012)	100	0
R''_H (before 1900-1980)	0	0
R'_V (patents)	0	0
R''_V (publications)	0	0
R	**25**	**0**

A first feedback about the reliability of the above described method has come from the contractor of the investigation, in the field of manufacturing concrete conglomerate slabs casted with polyester resin. Actually, both key-words with the definition of the second level query *“gel time”* and “*curing agent”*, are in line with the expectations of the expertee of the technological sector, who decides to continue investigating the key-words *“curing agent”,* even if the R rating which defines it is zero.

Therefore, as a second level query (4.4) we assume:

"unsaturated polyester resin" injection “curing agent” *(4.4)*

of which we report the following clustering analysis in the structures of Table 4-4 and Table 4-5.

Table 4-4: "unsaturated polyester resin" injection ("curing agent"): before 1900 – 2011

Any information type	Patents	Any information type - Patents
798 hits for **"unsaturated polyester resin" injection ("curing agent")**	746 hits for **"unsaturated polyester resin" injection ("curing agent")**	52 hits for **"unsaturated polyester resin" injection ("curing agent")**
vinyl ester	vinyl ester	composites
gel time	gel time	reinforced
molding	molding	molding
peroxide	peroxide	thermoplastic
peroxides	thermosetting resin	polymerization
thermosetting resin	molded	epoxy resin
monomer	monomer	nanocomposites
reactive diluent	peroxides	plastics
epoxy resin	reactive diluent	glass fibres
molded	thermosetting	nanocomposite
glycol	thermoplastic resin	vinyl ester

curable	epoxy resin	tensile
acrylate	curable	shrinkage control
thermoplastic resin	acrylate	reinforcement
thermosetting	glycol	flexural strength
cobalt	adhesive	unsaturated polyester resins
composites	fibrous	polymerization shrinkage
polymerization	reinforcement	polymer
unsaturated polyester resins	thermoplastic	photoresist
nanocomposites	cobalt	polyurethane
copolymer	copolymer	thermosetting
nanocomposite	acid value	microchannels
copper compound	copper compound	flame retardant
reinforcement	catalyst	impregnated
wind turbine	unsaturated polyester resins	laminate
laminate	methacrylate	substrates
resin matrix	reinforced	polymeric
fibrous	preferable	thermosetting resin
acid value	base material	gel time
substrate surface	injection molding	dielectric
acrylic	acrylic	thermoset
air removal	resin matrix	electrophoresis
tensile	accelerator	toughness
adhesive	polymerization	dimethacrylate
neopentyl glycol	substrate surface	release system
thermoplastic	air removal	measuring pressure
accelerator	monomers	satin finish
block copolymer	neopentyl glycol	high cooling
styrene monomer	iron compound	physical laboratory
flexural strength	wind turbine	national physical laboratory
preferable	laminate	release agent
reinforced	manganese compound	phthalic anhydride
polymer particles	polymer particles	anhydride
transfer molding	coated	methacrylate
melt viscosity	conductive	oligomer
injection molding	elastomer	crosslink density
methacrylate	reinforced plastic	oligomers
dispersed	dispersed	vinyl esters
manganese	manganese	bond conversion
iron compound	styrene monomer	monomer
manganese compound	block copolymer	adhesives
turbine blade	hydroxyl	isocyanate
usa274969	vicinal	acrylic
polyhydric	adhesives	epoxide

branched hydrocarbon	polyisocyanate	tonnage
conjugated	stress at failure	crystalline
aromatic compound	dihydric	polymeric substrate
conjugated diene	styrene-butadiene block copolymer	inorganic material
styrene-butadiene block copolymer	conjugated diene	peptide
dihydric	aromatic compound	protein
layered silicate	branched hydrocarbon	patterned
hydroxyl	polyhydric	microfabrication
polyisocyanate	fiber bundle	liquid crystalline polymer
diisocyanate	bundles	glycol
reinforced plastic	transfer molding	separation
vicinal	dibasic acid	mechanical properties
mechanical properties	anhydride	graphite
epoxy group	base composition	glass fiber
polymer	single molecule	modification
coated	dioctyl tin	low profile additives
bisphenol a	silicone	formaldehyde
unidirectional	reinforcing effect	polyols
straight chain	turbine blade	surface
interlaminar shear strength	dipropylene glycol	microfluidic
impact strength	polyvalent alcohol	ceramic
dielectric	linkage group	layered
trimer	10274969	capillary
clay nanocomposites	usb274969	layered silicate
cellulose	usa274969	durability
flame retardant	elongation	isocyanates

Table 4-5: "unsaturated polyester resin" injection ("curing agent"): before 1900 – 1980

Any information type	Patents	Any information type - Patents
43 hits for **"unsaturated polyester resin" injection ("curing agent")**	40 hits for **"unsaturated polyester resin" injection ("curing agent")**	3 hits for **"unsaturated polyester resin" injection ("curing agent")**
molding	molding	reinforced
glass fibers	glass fibers	composites
epoxy resin	epoxy resin	reinforcement
thermosetting resin	thermosetting resin	fibrous
molded	polyester resins	impregnated
polyester resins	molded	glass fibres
adhesive	adhesive	fibrous material
glycol	glycol	epoxides
reinforced	thermosetting	fracture surfaces

thermosetting	curable	epoxide
ceramic	ceramic	crosslinked polymer
glass fibres	sheet material	fracture surface
curable	emulsifying agent	fracture energy
sheet material	coupling agent	carbide
acrylate	laminate	graphite
emulsifying agent	blowing agent	thermoplastic
coupling agent	acrylate	carbon fibres
ceramic tile	peroxide	
peroxide	resinous	
impregnated	reinforced	
blowing agent	ceramic tile	
laminate	prominence	
resinous	polymerization	
silane	polyethylene	
material cost	refractive indices	
fire retardant	silane	
prefabricated	capillary action	
equivalent weight	polymerizable	
hydrazide	equivalent weight	
refractive	material cost	
capillary action	cross-linking agent	
refractive indices	blowing agents	
blowing agents	flame retardant	
thickened	prefabricated	
polymerization	fire retardant	
thermosetting resins	refractive	
hardener	thickened	
polyethylene	hardener	
polymerizable	resin matrix	
composites	chopped	
injection molding	glass fibres	
cross-linking agent	epoxide resin	
reinforcement	copolymer	
prepolymer	polyisocyanate	
fibrous	prepolymer	
prominence	dimethacrylate	
copolymer	hydrazide	
resin matrix	injection molding	
monomer	switching device	
chopped	thermosetting resins	
fibrous material	monomer	
flame retardant	polyvinyl	

dimethacrylate	adhesive layer	
thermoplastic	terephthalate	
switching device	trimethyl phosphite	
polyisocyanate	polyesters	
terephthalate	phosphite	
polyvinyl	diallyl phthalate	
adhesive layer	bromine	
epoxide	5618890	
epoxide resin	isocyanuric acid	
usb618890	flame retardancy	
5618890	liquid reaction	
bromine	us3800111	
us03651173	usb7042151	
us03800111	usa7042151	
us3800111	us03800111	
liquid reaction	us03651173	
phosphite	us3651173	
polyesters	circuit breaker	
trimethyl phosphite	usa7226048	
usa7226048	usb7226048	
flame retardancy	electric arcs	
usb7226048	triethylene glycol	
electric arcs	gba00025679	
us3651173	gb1124642	
circuit breaker	heat-curable	
triethylene glycol	aliphatic	
aliphatic	dicyandiamide	
dicyandiamide	tertiary	

4.3 Case study 1 - Carrot2

The technological system shown in the previous paragraph is analysed through Carrot2. This search engine does not allow any vertical or temporal discrimination. Therefore it does not help us in defining a query of a level next to the first. For this reason structures defined through Carrot2 refer to:

- First-level query identified in the key-words (4.1): *"unsaturated polyester resin" injection;*
- Second-level query defined by Scirus and identified in the Key-words (4.4): *"unsaturated polyester resin" injection "curing agent"*

Carrot2 offers two specialized search results clustering algorithms: Lingo and STC. Lingo reports a series of broadly described clusters and highlights peripheral clusters which the system considers of secondary importance. SRC reports a reduced number of clusters, formed by few key-words and drops the peripheral ones. Table 4-6 and Table 4-7 list the parameters which are inherent the application of Carrot2, and used to set up the clustering applied to query (4.1) and (4.4), respectively through algorithms Lingo and SRC.

Table 4-6: Characteristics of Lingo clustering algorithms

Source	ETools	
Algorithm	Lingo	
Query	**I° level query: "unsaturated polyester resin" injection**	**II° level query: '"unsaturated polyester resin" injection ("curing agent")'**
Cluster Count Base	30	
Cluster Merging threshold	0,70	
Minimum cluster size	2	
Maximum word document frequency	1,00	
Phrase Document Frequency threshold	1	
Phrase length penalty start	8	
Phrase length penalty stop	8	
Truncated label threshold	0,65	
Word document frequency threshold	1	

Table 4-7: Characteristics of STC clustering algorithms

Source	ETools	
Algorithm	STC	
Query	**I° level query: "unsaturated polyester resin" injection**	**II° level query: '"unsaturated polyester resin" injection ("curing agent")'**
Maximum final cluster	15	
Maximum phrases per label	3	

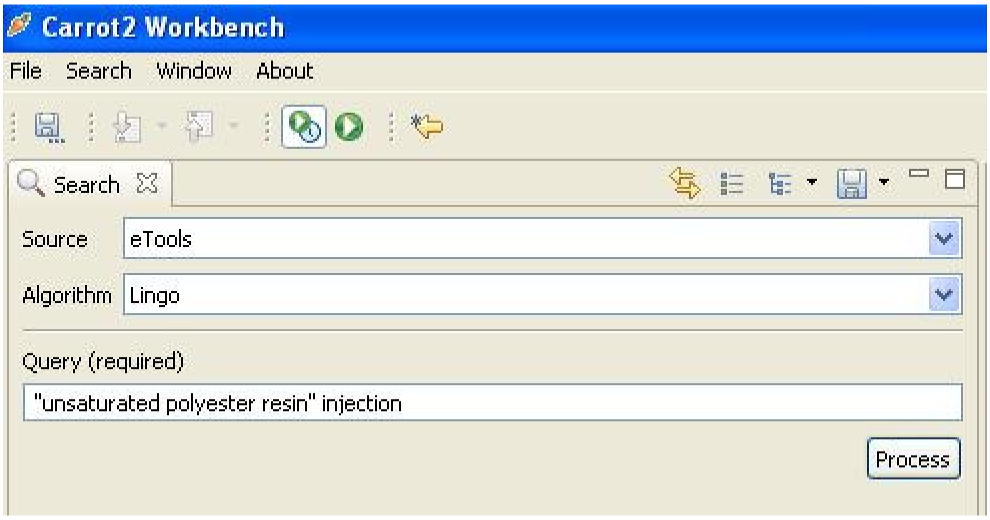
Maximum words per label	4
Optimal label length	3
Maximum word-document ratio	0,90
Minimum word-document recurrences	2
Phrase length tolerance	2
Base cluster merge threshold	0,60
Maximum base clusters count	300
Maximum cluster phrase overlap	0,60
Minimum base cluster score	2,00
Minimum documents per base cluster	2
Minimum general phrase coverage	0,50
Word document frequency threshold	1

4.3.1 First level query

The following keywords:

"unsaturated polyester resin" injection (4.1),

form a **first level query** non sensitive in the search area of the search engine Figure 4-6.



Figrue 4-6: Carrot2 input keywords.

The structures of the clusters based on the keywords (4.1) according to Lingo and STC, are shown in Table 4-8. The Figure 4-7 and the Figure 4-8 show a view of Tuning clustering of Lingo and STC clusters for the search results of *'"unsaturated polyester resin" injection'* .

Table 4-8: Lingo and STC clusters for the '"unsaturated polyester resin" injection' search results

Algorithm	Lingo	Cluster	STC	Cluster
Query	**I° level query: "unsaturated polyester resin" injection**			
	China	9	Flow, Hexion, Ball Indentation	10
	Compound	9	Injection Moulding	25
	Chemical	7	Injection	48
	Plastic Injection	7	Suppliers, Manufacturers	15
	Thermosetting	7	ISO 2039 P1, Ball Indentation Hardness	3
	Injection Moulding	6	Rtm Injection Machine	3
	Molding Compound	6	Molding Compound	6
	Technology	6	Quality, Surface	8
	Fiberglass	4	High Surface Quality	3
	Clycol	4	Used	11
	High Arc	4	Products	11
	Rtm	4	Pultrusion Process, Injection Pultrusion	4
	Systems	4	Plastic	8
	Buy	3	Composites	8
	Casting	3	Resins	8
	High Surface Quality	3	Other Topics	20
	Moulding Compounds	3		
	Polymer Science	3		
	Sheet	3		
	Affecting	2		
	Answers to Common Questions	2		

	Catalyst into the Reaction Vessel	2		
	Chinese Markets	2		
	GRP	2		
	Global-Leading Composites Portal	2		
	Related Suppliers	2		
	SMC	2		
	Technical Sessions	2		
	Other Topics	31		

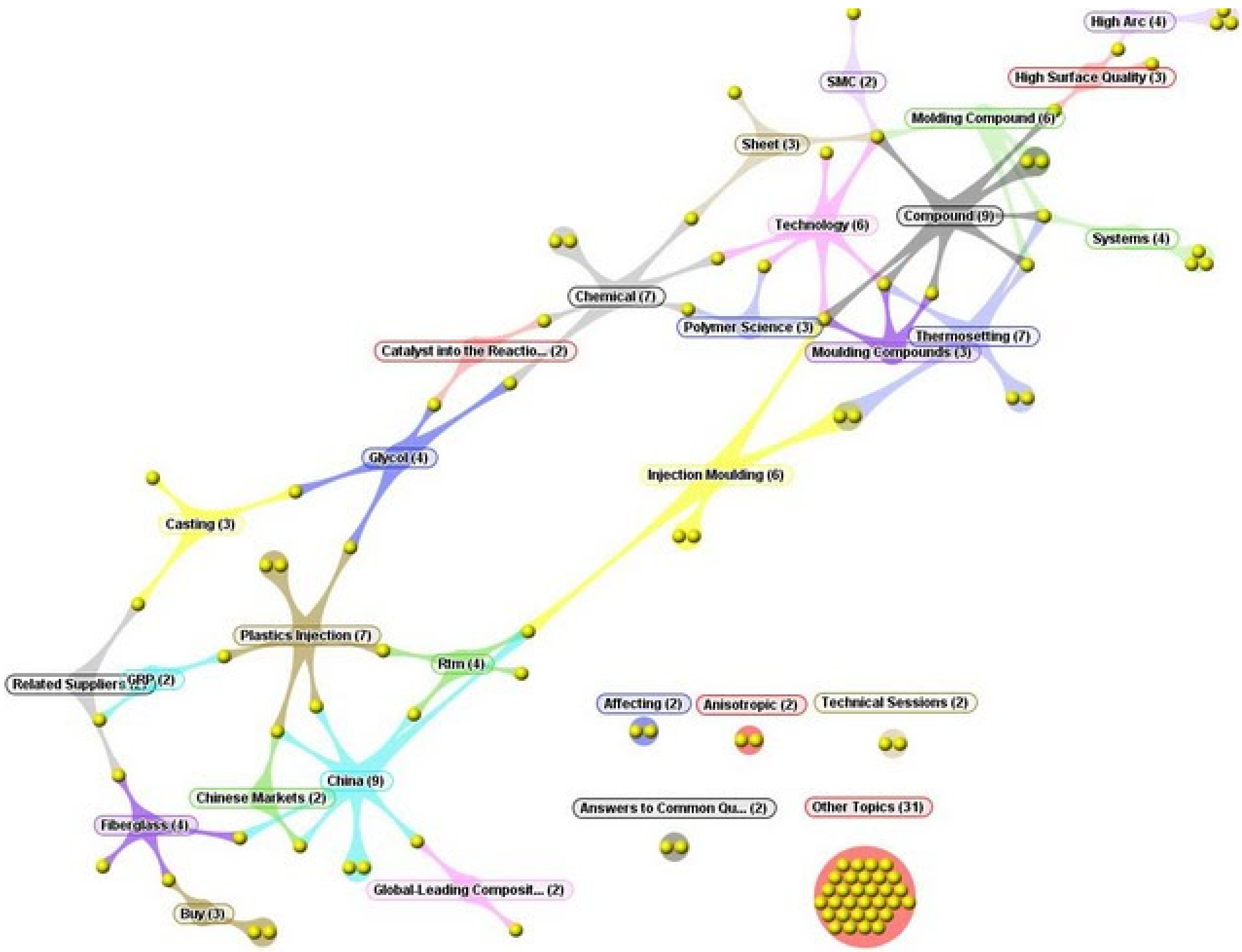


Figure 4-7: Tuning clustering of Lingo clusters for the '"unsaturated polyester resin" injection' search results.

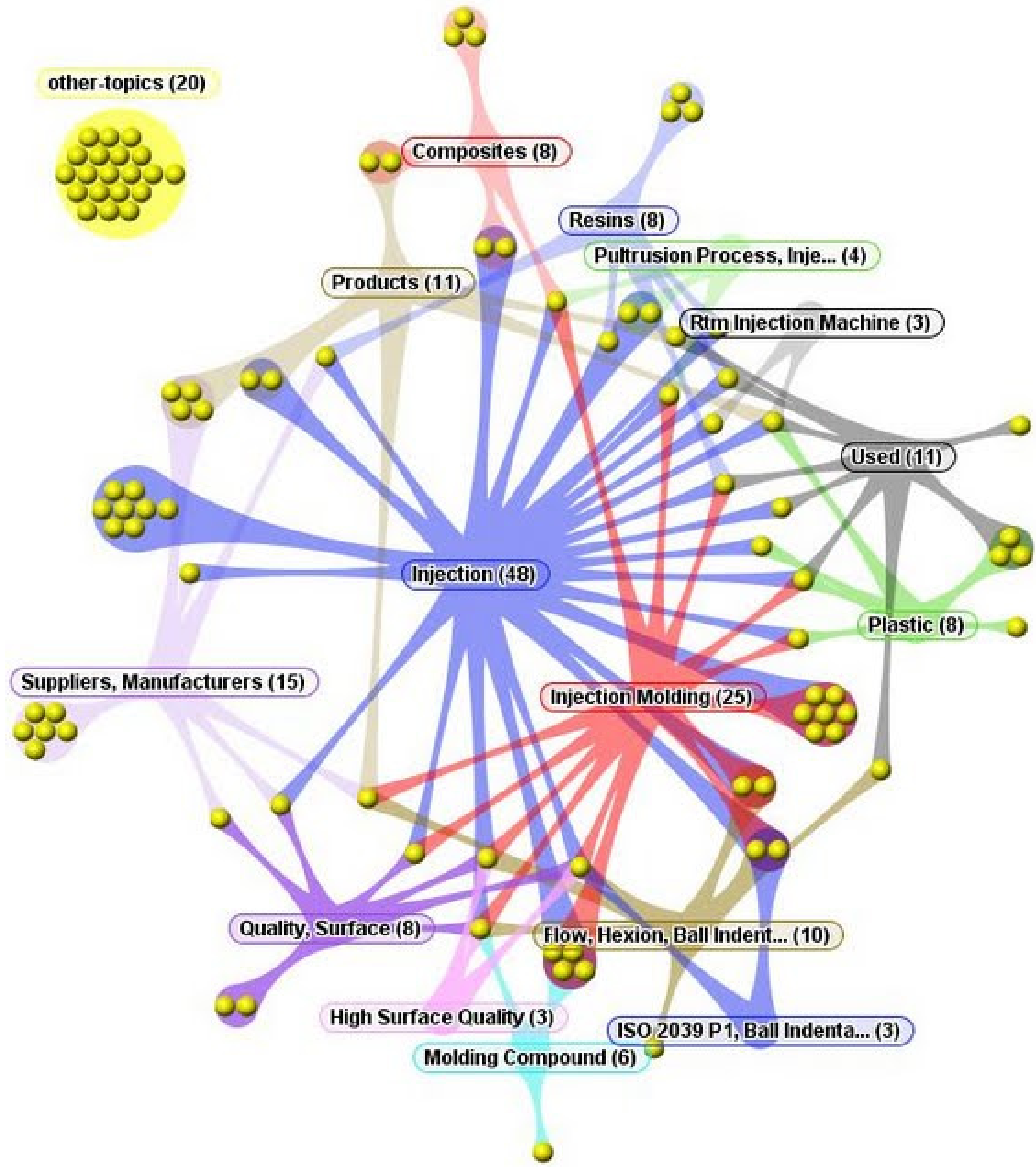


Figure 4-8: Tuning clustering of STC clusters for the '"unsaturated polyester resin" injection' search results.

4.3.2 Second level query

The following keywords:

"unsaturated polyester resin" injection "curing agent" (4.4),

build a **second level query** which can be entered in the search area of the search engine (see Figure 4-6). The structures of the clusters based on the keywords (4.4) according to Lingo and STC, are shown in Table 4-9. The Figures 4-9 and the Figure 4-10 show a view of Tuning clustering of Lingo and STC clusters for the search results of *'"unsaturated polyester resin" injection' ("curing agent").*

Table 4-9: Lingo and STC clusters for the '"unsaturated polyester resin" injection ("curing agent")' search results.

Algorithm	Lingo	Cluster	STC	Cluster
Query	**II° level query: '"unsaturated polyester resin" injection ("curing agent")'**			
	Manufactures	12	Curing, Injection	62
	Materials	11	Injection Molding	19
	Effect of Curing of Unsaturated Polyester Resin	9	Unsaturated Polyester Resin Composition	5
	Epoxy Resins	7	Curing Agent	6
	Moulding	7	Reaction Injection Molding	4
	Curing Agent	6	Mold	12
	Method	6	Suppliers, Manufacturers	8
	Reinforced	6	Polymer	10
	Heat	5	Materials	9
	Kinetics	5	Properties	9
	Polymer Science	4	Cure	9
	Study	4	Epoxy	8
	Catalyst	3	Effect	8
	Glass Fibers	3	Products	8
	Low Profile	3	Plastics	8
	Molding Compounds	3	other-topics	17
	Shrinkage	3		
	Thermal Properties	3		
	Ambient	2		
	Composites Consultants	2		
	Fiberglass	2		
	North America	2		

	Plastics and Rubber	2		
	Technical Sessions	2		
	Trade Platform for China	2		
	Vacuum Injection Techniques	2		
	Vinyl Ester	2		
	Other Topics	23		

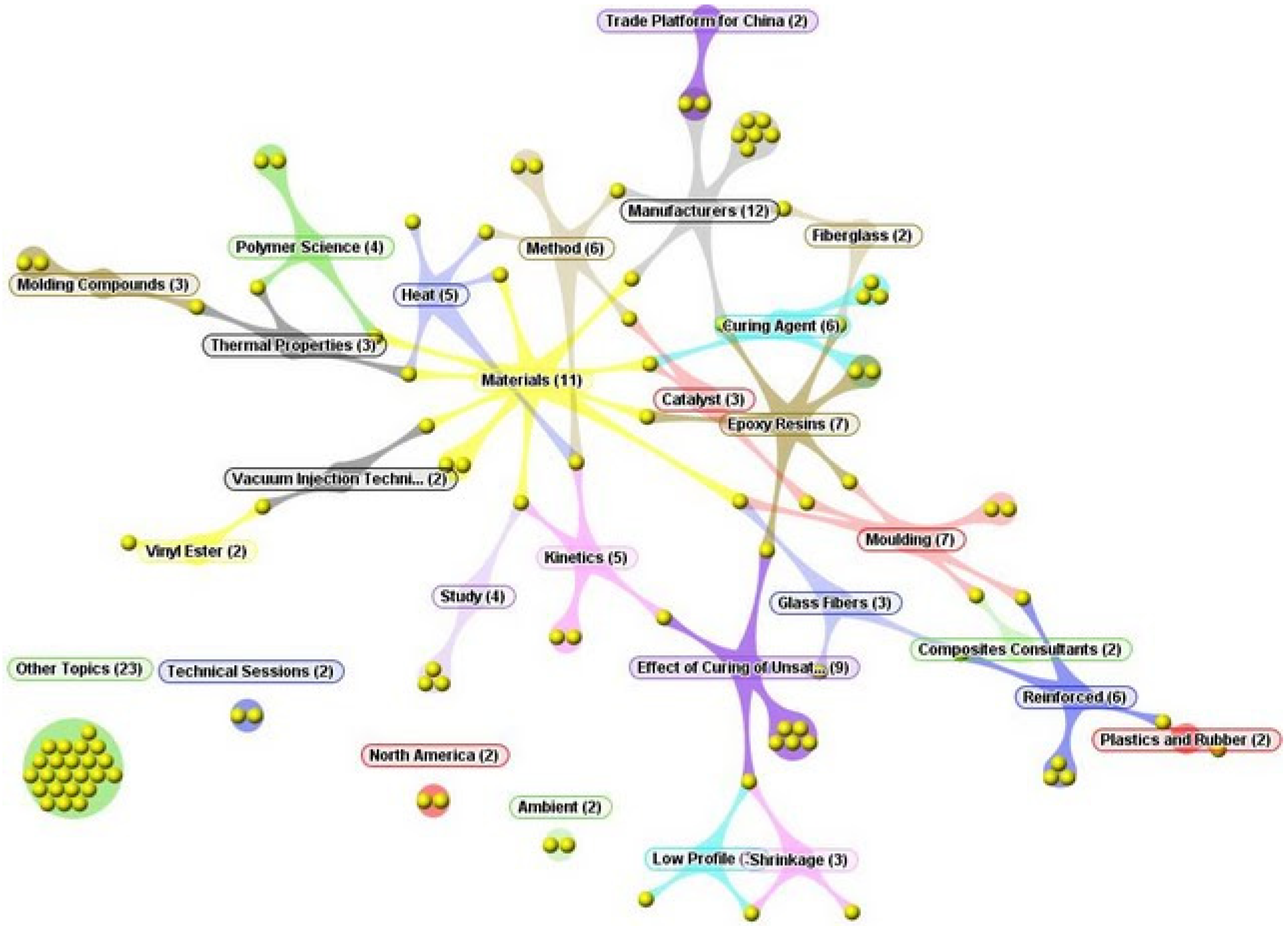


Figure 4-9: Tuning clustering of Lingo clusters for the '"unsaturated polyester resin" injection ("curing agent") search results.

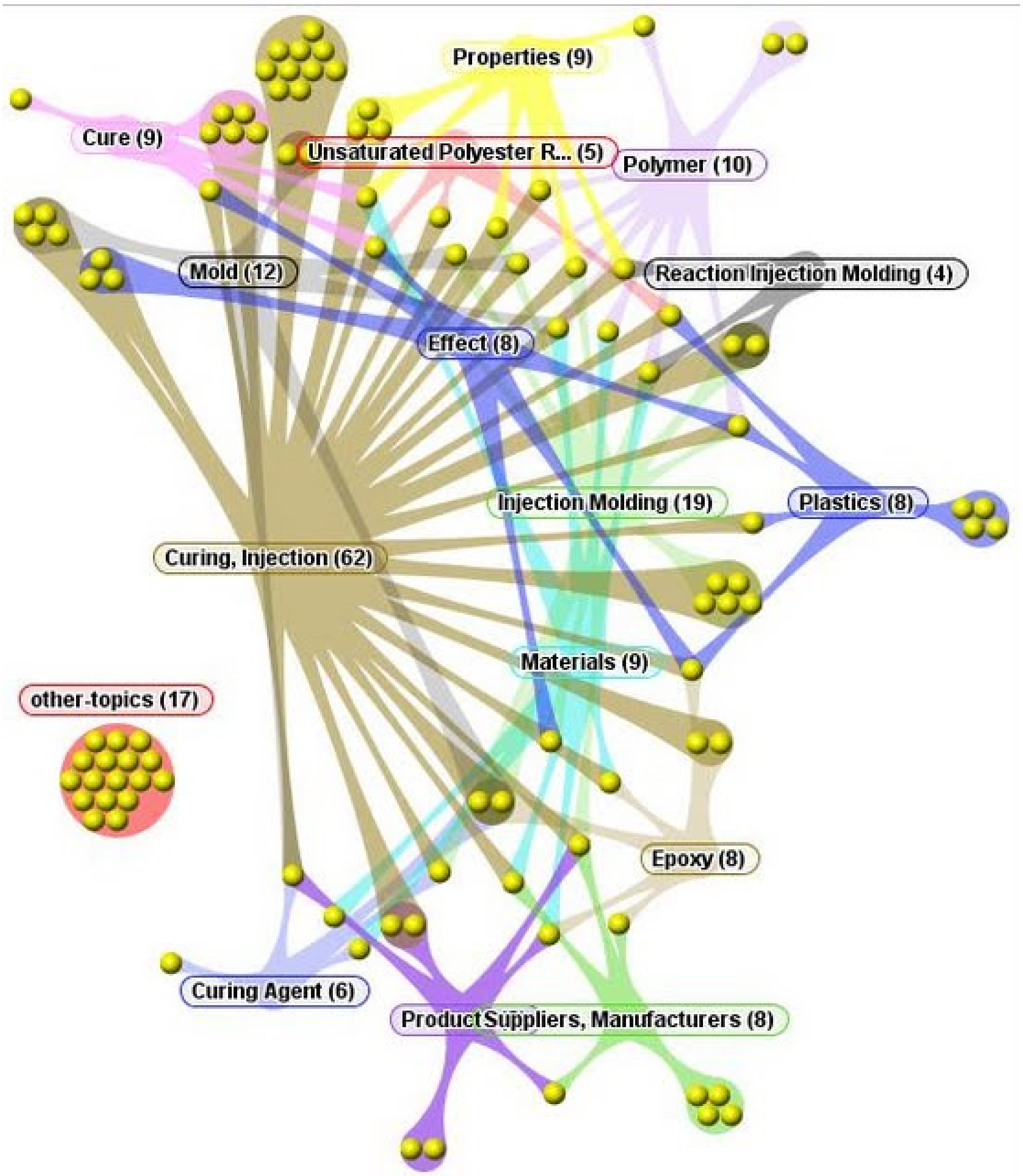


Figure 4-10: Tuning clustering of STC clusters for the '"unsaturated polyester resin" injection ("curing agent")' search results.

4.4 Case study 1 - Prior-ip

The technological system shown in the previous paragraphs is analysed through Prior-ip. Prior-ip is a research engine that organizes patent collections, managing exclusively the patents belonging a patent data-base.

4.4.1 First level query

The following keywords:

"unsaturated polyester resin" injection (4.1),

form a **first level query** non sensitive in the search area of the search engine Figure 4-11.

Figrue 4-11: Prior-ip input keywords.

The section Patent Results for Search lists 2907 patents. The section Visualize IP Search Results lists 298 Clusters overall.

At this point, the system allows to chose the most pertinent cluster compared to the key-words (4.1).

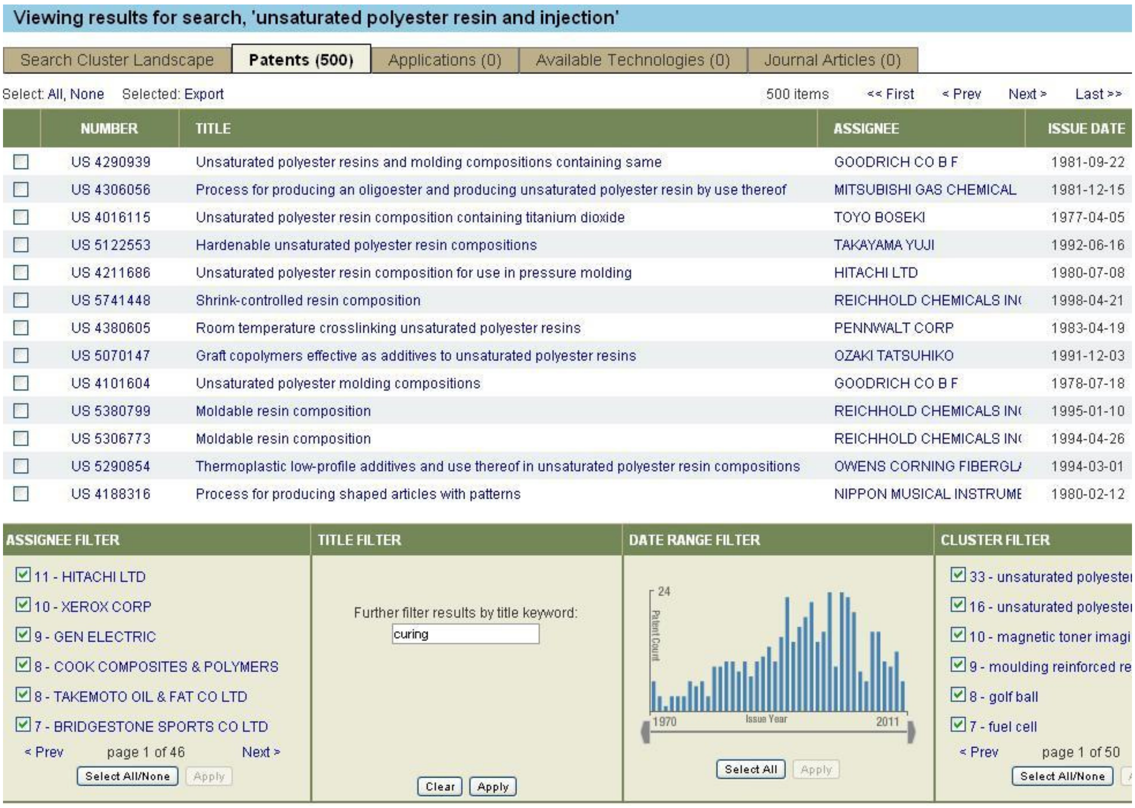
4.4.2 Second level query

Starting from the results of the first query shown in the former paragraph 4.4.1, the query of second level (4.4) built up by means of Scirus is analyzed:

"unsaturated polyester resin" “injection” “curing agent” (4.4).

If entering the key-word “C*uring”* in the TITLE FILTER area in Figure 4-12, we obtain five patents.

Otherwise we can choose a temporally separated analysis selecting one or more ranges in the area DATA RANGE FILTER.



Figrue 4-12: Refining and filtering area Prior-ip.

4.5 Consideration about the adopted methods

An analysis of a technological system by means of Scirus let us automatically recall subsequent clusters depending on structures of previous clusters. This makes Scirus apt to define a technological system objectively, applying subjective discriminations in high level queries, only (at least starting from the second level).

An analysis of a technological system run by means of Carrot2 does not allow an automatic recall of clusters subsequent the original ones. A limit is in fact the impossibility to recall clusters as a function of time in order to be able to distinguish and discriminate the clusters from a pioneer phase and those from a phase of technological diffuseness.

In the present chapter we have investigated the performances of Prior-ip in order to establish a comparision with the method which employes Scirus. Prior-ip is able to point out those clusters useful for a first lever query. Nevertheless, when still in a phase of first level query, Prior-ip compels operators to take subjective choices both by choosing clusters which are subjectively rated as interesting as well as by subjectively rating the temporal range.

The automatic definition of subsequent targets is therefore one of the main targets of this dissertation.

Prior–ip allows to choose clusters in a primitive phase of the analysis, i.e. when we lack the necessary elements to discriminate between different solutions at disposal. This makes Prior-ip a very interesting tool to approach an investigation, but anyway non-apt to fullfill the goals of this dissertation. However this search engine is a work in progress, worth monitoring for future potential applications.

Chapter 5 deepens the applications of Scirus in a new technological system (Case study 2).

CHAPTER 5

Technological diffusion and innovation

5.1 Introduction

Each key-word stated through a method as described in Chapter 4 is able to represent a technological system, The System, discriminating and splitting it from Environment, Social Needs and Market, i.e. the Supersystem, and the Common Components constituting the technological system, for example: an electrical motor, a filter, i.e. those components able to identify the System if considered by their own.i.e. those components which do not allow any identification of the System if considered singularly, i.e. The Subsystem.

Each key-word belonging to a cluster is able to state The System according to a rating R value ranging between 0 and 100. All key-words with a rating equal to zero can enter both The Supersystem and/or the Subsystem.

This Chapter shows the case of a technological system, specifically a speed reducer.

Paragraph 5.2 describes the process we have developed and applied in order to place temporally a pioneer evolutionary phase and a diffusion phase.

Paragraph 5.3 describes said technological system by means of Scirus, according to what stated in Chapter 4.

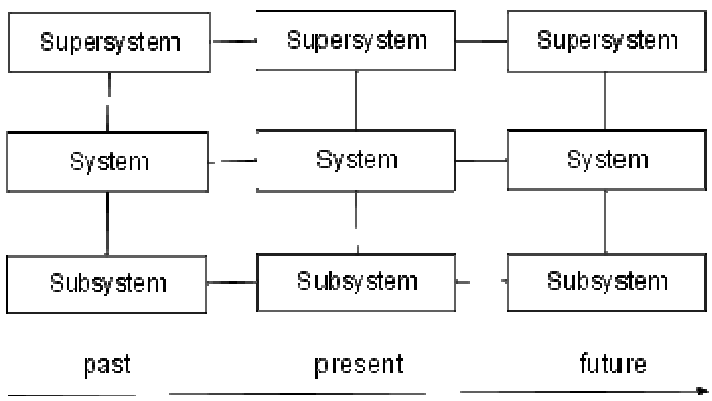


Figure 5-1: 9-screen system operator.

Paragraph 5.4 describes The System previously stated in paragraph 5.3, involving a number of Subsystems and Supersystems consequential on the clusters with zero rating emerging from the analysis of paragraph 5.3. This operation is developed manually with the support of a 9-screen-diagram, in which each level contains 3 screens which shows data in the past, in the present and in the future (Figure 5-1). The clusters belonging to the patent collection are the only information source used in this procedure.

5.2 Temporal setting of technological pionerism and technological diffusion.

The clusters ranking in the pioneer and in the diffusion evolutionary phases reflect a set of patent documents and scientific publications retrieved in the two ranges and characterized by: a reduced number of documents retrieved in the pioneer phase; an exponentially enlarged number of documents, particularly those patent related, retrieved in the diffusion evolutionary phase. Figure 5-2 shows the volume of documents regarding the injection process of the unsaturated polyester resin as analyzed on Chapter 4 by Scirus, discriminating between:

● Any information type = Abstracts, Articles, Articles in Press, Books, Conferences, Patents, Preprints, Reviews, Scientist homepages, Theses and Dissertations;

● Patents;

● Any information type excluded Patents = Abstracts, Articles, Articles in Press, Books, Conferences, Preprints, Reviews, Scientist homepages, Theses and Dissertations.

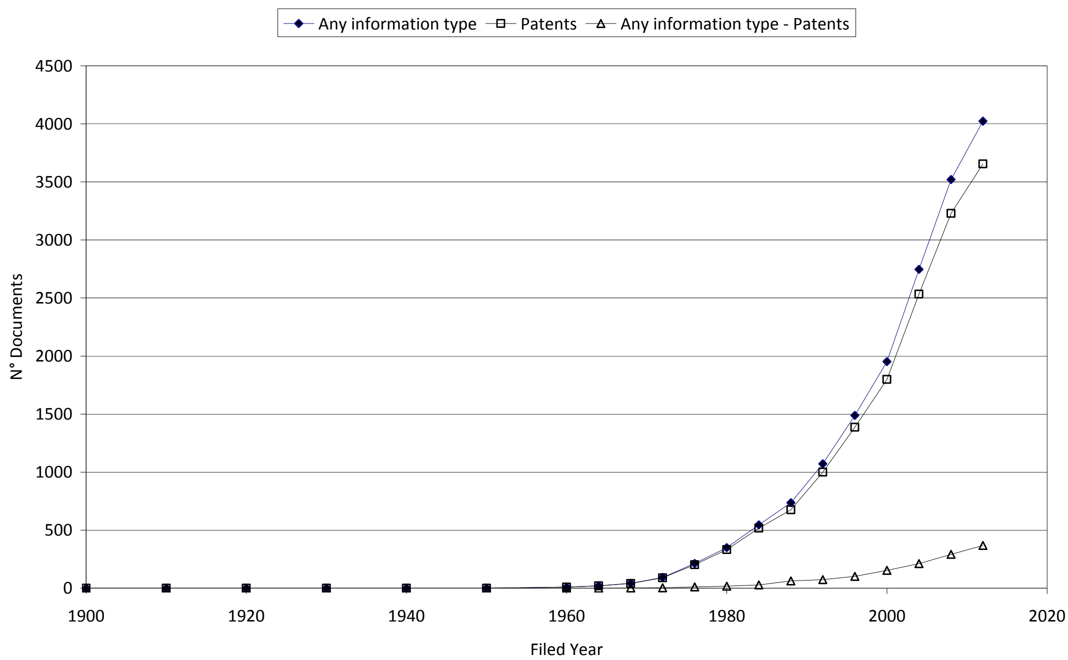


Figure 5-2: "unsaturated polyester resin", volume of the documents retrieved and discriminated between patents and scientific publications.

Chapter 4 shows how the horizontal structure of a scientific web-collection is formed by separate clusters of scientific publications and of patents. Particular enphasis has been put on the vertical structure of a scientific web-collection formed by separate clusters from separate documents in different temporal ranges, which are here identified as evolutionary steps: technological pionerism and technological diffusion, both located in two well-defined temporal range:

• before 1900-2012;

• before 1900-1980.

The definition of the above temporal range, referring to two different evolutionary phases, comes from a comparison between clusters placed in different time periods.

As to the key-words (4.1):

"unsaturated polyester resin" injection (4.1),

the temporal range selected determines different clusters, patents and scientific publications. The comparison of temporal custers, belonging to different temporal ranges is fundamental in order to state the exact moment, when an evolutionary phase ends in favour of a new one.

Coming back to the key-words (4.1), the clusters belonging to the following temporal structures have been compared:

• with one edge coincident with year [2012] (Table 5-1);

• with two edges respectively coincident with years [before 1900-2012] (Table 5-2).

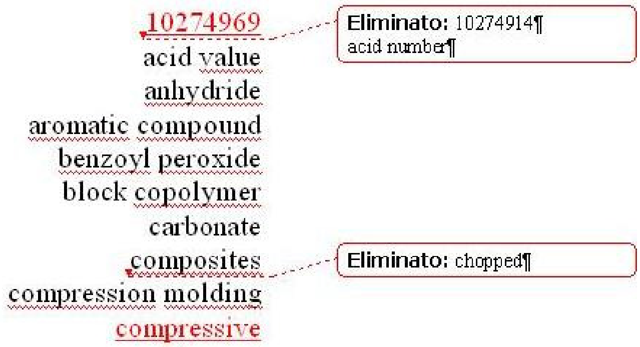
Table 5-1: number of documents discriminated by different temporal ranges, of which one edge is coincident with year [2012].

1971-2012	1981-2012	1991-2012	2001-2012
3,967 hits for **"unsaturated polyester resin" injection**	3,675 hits for **"unsaturated polyester resin" injection**	3,149 hits for **"unsaturated polyester resin" injection**	2,071 hits for **"unsaturated polyester resin" injection**

Table 5-2: Number of the documents discriminated by temporal ranges of which one edge is coincident with the period [before 1900].

before 1900-1980	before 1900-2012
348 hits for **"unsaturated polyester resin" injection**	4,024 hits for **"unsaturated polyester resin" injection**

The structures of clusters, Master Document, placed in a temporal range [before 1900-2012] have been compared - thanks to the option Compare documents supplied by the programs Office Microsoft - with those placed in a sequence in a temporal range with one edge [2012] (Slave Document) (Figure 5-3). Column “Difference” in Table 5-3 shows the number of clusters generated by the comparison; column “Percentage Difference” shows the percentage value of the number of clusters generated by the comparison related to a global number of clusters equal to 76.


10274969
acid value
anhydride
aromatic compound
benzoyl peroxide
block copolymer
carbonate
composites
compression molding
compressive

Eliminato: 10274914¶
acid number¶

Eliminato: chopped¶

Figure 5-3: Generated document containing a list of clusters, which are common to both structures in overlapping.

Table 5-3: Number of clusters generated from the comparison of Master and Slaves Documents in overlapping.

Master document	Slave document	Difference	Percentage Difference
before 1900-2012	1971-2012	6	7,6
4,024 hits for **"unsaturated polyester resin" injection**	3,967 hits for **"unsaturated polyester resin" injection**		
	1981-2012	14	17,7
	3,675 hits for **"unsaturated polyester resin" injection**		
	1991-2012	19	25,0
	3,149 hits for **"unsaturated polyester resin" injection**		
	2001-2012	21	26,6
	2,071 hits for **"unsaturated polyester resin" injection**		

What comes out from this analysis is fundamental to state the two temporal ranges exactly, where the two evolutionary phases are to be placed – pioneer evolutionary phase and diffusion technological phase. In this specific case *"unsaturated polyester resin" injection*, year 1966 is the exact moment in which an evolutionary phase hands over its place to a subsequent.

The method object of the present dissertation was tested in different technological systems. It came out that fixing in year 1980 the hand-over moment between two evolutionary phases we have been able to cover all tecnological cases, with a tollerance of 20% on the number of clusters (i.e. 76 ± 20%).

This analysys allows therefore to state exactly the extention and the very moment when a phase switches to the subsequent phase.

Due to this demonstrations, we can attribute a meaning and validate the followig comparison the followings expressions (5.1) and (5.2):

Clusters of patents [1981-2012]=Clusters of patents [before 1900-2012]   (5.1);

Clusters of scientific pub. [1981-2012] = Clusters of scientific pub. [before 1900-2012]   (5.2).

According to the above comprisons (5.1) and (5.2) the following evolutionary phases are individuated:

Pioneer evolutionary phase = [before 1900-1980]   (5.3)

Diffusion evolutionary phase (in this respect equivalent to diffusion technology) = [before 1900-2012]   (5.4).

5.3 Case study 2

A technological system regarding a speed reducer is analyzed by means of Scirus.

5.3.1 First Level Query

The following items:

speed reducer   (5.5),

set up a **first level query** which can be entered in the search area of the search engine see Figure 4-3.

In the section Advanced Search (see Figure 4-4) a complete set of scientific documents is ticked off. Said documents are discriminated between:

- Abstracts, Articles, Articles in Press, Books, Conferences, Preprints, Reviews, Scientist homepages, Theses and Dissertations (any information type excluded Patents);
- Patents.

The temporal range, split between:

- before 1900-2012;
- before 1900-1980;

is to be ticked off in the same section.

Figure 5-4 shows the volume of the documents regarding the key-words (5.5), for a total amount of about 43000 documents out of which 90% is formed by patents.

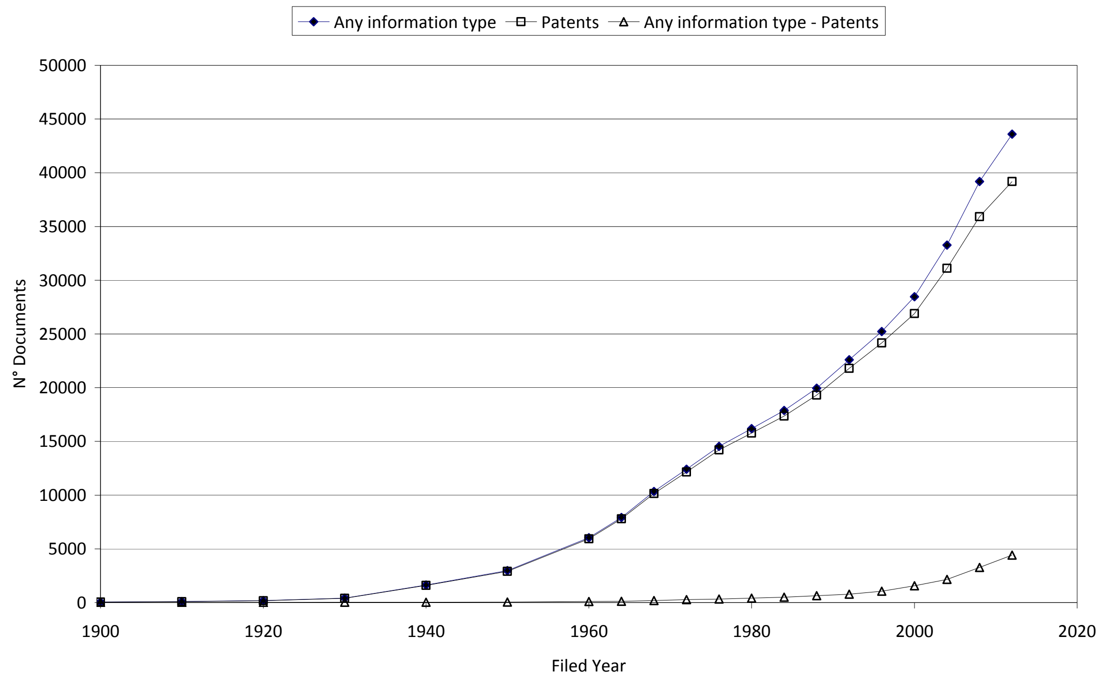


Figure 5-4: "speed reducer", volume of the documents retrieved and discriminated between patents and scientific publications.

Table 5-4 shows a structure of clusters relating to key-words (5.5) split in Patents and scientific Publications and set in the temporal range [before 1900–2012]. Table 5-5 shows a structure of clusters relating to the key-words (5.5) split in Patents and Publications and set in the temporal range [before 1900–1980].

Table 5-4: speed reducer: before 1900 – 2011.

Any information type	Patents	Any information type - Patents
43,419 hits for **speed reducer**	39,102 hits for **speed reducer**	4,317 hits for **speed reducer**
output shaft	**output shaft**	**output shaft**
reduction gear	reduction gear	roller
planetary gear	**planetary gear**	**input shaft**
input shaft	**input shaft**	actuator
eccentric	speed reduction	constrained optimization
speed reduction	eccentric	evolutionary algorithm
reduction ratio	reduction ratio	penalty function
axial direction	axial direction	reliability based design
meshing	rotary	actuators
industrial robot	external gear	multi objective optimization

external gear	industrial robot	probabilistic
rotary	meshing	pressure vessel
roller	sectional view	deterministic
sectional view	roller	welded
lubricating oil	perspective view	inequality constraints
lubricating	cylindrical	robustness
perspective view	lubricating oil	turbine
cylindrical	lubricating	inertia
rocking	rocking	kinematic
steering device	steering device	speed reduction
motor shaft	number of teeth	cycloid
number of teeth	actuator	**planetary gear**
actuator	deceleration	meshing
deceleration	motor shaft	wind turbine
annular	concave	feasible solution
gearing	protruding	helical
crankshaft	circular ring	control valve
eccentric shaft	intermediate bearing	syringe pump
intermediate bearing	crankshaft	syringe
circular ring	lubricant	uncontrollable
protruding	gearing	microfluidics
concave	durability	gear train
wave generator	**planetary gears**	trajectory
durability	wave generator	minimization
lubricant	eccentric shaft	compression spring
planetary gears	rotational	constraint handling
periphery	annular	rotational
gear case	multi stage	constrained optimization problems
crankshafts	pressure contact	cylindrical
spur gears	guide sleeve	lever arm
degree of freedom	rattling	tolerance region
bevel gear	publication number	gear system
multi stage	plan view	probabilistic constraints
oil reservoir	eccentricity	dimensionless
gear box	crank shaft	multiobjective optimization
gear teeth	size and weight	load case
publication number	bevel gear	misalignment
pressure contact	side elevation	droplets
gear unit	gear box	flow focusing
spur gear	oil reservoir	electrospray
compartment	periphery	differential evolution
pivoted	closing device	solenoid valve

size and weight	oil supply	waveform
rattling	annular space	drop formation
plan view	driving shaft	droplet
driving motor	camshaft	industrial electronics
hollow shaft	armature	performance function
eccentricity	miniaturization	ieee trans
annular space	hollow shaft	friction forces
guide sleeve	eccentric disc	grasping
oil supply	spur gears	preliminary design
driving shaft	epicyclic gear	electric motor
rotational	gear unit	due date
side elevation	spur gear	solution quality
armature	machining	shop scheduling
eccentric disc	compartment	starting time
crank shaft	degree of freedom	job shop scheduling
epicyclic gear	crankshafts	scheduling problem
miniaturization	gear case	vibration
machining	pivoted	workpiece
ball bearing	driving motor	kinematic chains
closing device	ball bearing	structural reliability
camshaft	pct8075666	conveyor belt
jpa2005344347	pctjp07074281	random parameter
jpa2005335913	wo08075666	optimization
rigidity	heated	helical gear
jp2007139128	ep1767815	conveyor
jp2007139038	wojp2007074281	biofouling
door opening	unit module	mode shape
jpa2005332338	cooled	gearbox

Table 5-5: speed reducer: before 1900 – 1980.

Any information type	Patents	Any information type - Patents
16,191 hits for **speed reducer**	15,773 hits for **speed reducer**	418 hits for **speed reducer**
output shaft	**output shaft**	tensile
input shaft	**input shaft**	roller
driven shaft	driven shaft	lubricant
drive shaft	drive shaft	gear teeth
speed reduction	speed reduction	turbine
gearing	gearing	filtration
motor shaft	motor shaft	sheet forming
annular	annular	dimensionless
intermediate shaft	intermediate shaft	chromatography
eccentric	eccentric	stress strain curve

number of teeth	number of teeth	ultimate elongation
sectional view	sectional view	drainage
gear teeth	gear teeth	strength of paper
driving shaft	driving shaft	wood fibers
reduced speed	reduced speed	inertia
gear train	gear train	silica
planetary gear	**planetary gear**	tensile creep
cover plate	cover plate	straining
projecting	projecting	lubricants
meshing	meshing	axis ratio
lubricant	lubricant	testing machine
toothed	toothed	lubrication
electric motor	electric motor	sliding speed
reduction ratio	reduction ratio	tribology
power input	power input	hysteresis
hollow shaft	hollow shaft	compressibility
pitch diameter	pitch diameter	rotating cylinder
gear trains	gear trains	rubber hose
shaft extension	shaft extension	feeding device
thrust bearing	thrust bearing	engine power
sheave	sheave	gasoline engine
fixed support	fixed support	raffinose
bearing support	bearing support	chromatographic
drive pulley	drive pulley	resistance
cylindrical	cylindrical	penetration
planetary gears	**planetary gears**	retention
speed gear	speed gear	reduction gear
tapered	tapered	paper making
lubrication	lubrication	capillary
bevel gear	bevel gear	institute of paper science and technology
letters patent	letters patent	solute
outer race	outer race	axial dispersion
lubrication system	lubrication system	helix angle
supporting frame	supporting frame	twisting
driving mechanism	driving mechanism	elution
reduced scale	reduced scale	sephadex
counterweight	counterweight	dextran
worm shaft	worm shaft	elution volume
v-belt drive	v-belt drive	polyethylene
speed change	speed change	liquids
teeth meshing	teeth meshing	insulation
spur gear	spur gear	rock wool
s stationery office	s stationery office	copper oxide photovoltaic cell
driven pulley	driven pulley	photo electric sensitivity
motor unit	motor unit	pneumatic conveyor
planetary gearing	**planetary gearing**	vane pump
oblique	oblique	shaft seal
removable	removable	vacuum pump

sprocket wheels	sprocket wheels	heat exchangers
resilient	resilient	reductor
gear ratio	gear ratio	high compression
dry well	dry well	fusion devices
cooling system	cooling system	isotope separation
securing	securing	mathematical optimization
vehicle speed	vehicle speed	colloid
usa740364	usa740364	cooling towers |x costs
bell crank	bell crank	cryostat
reduction gear	reduction gear	electric power-plants |x cooling
lead line	lead line	number of teeth
hand control	hand control	conveyor
gear unit	gear unit	bending stress
external gear	external gear	**planetary gear**
numeral	numeral	permissible
idler pulley	idler pulley	eddy diffusion
electronic switch	electronic switch	spherical
end piece	end piece	driving mechanism
dental drill	dental drill	viscoelastic
cap screws	cap screws	wire screen
change the speed	change the speed	hydraulic
driving motor	driving motor	adhesive

5.3.2 Second level Query

A **second level query** includes key-words with a rating R calculated while analyzing the structure shown in Table 5-4 and Table 5-5 of the first level.

In this specific case and aiming at defining a second level query, attention concentrates on those key-words, which at a first analysis prove being mostly repetitive in both structures of Table 5-4 and Table 5-5. Specifically the key-words mostly repetitive are bold written in Table 5-4 and Table 5-5: *"planetary gear"*; *"input shaft ", "output shaft "*.

Table 5-6 and Figure 5-5 show the rating R calculated. At this stage the second level query is defined by the following key-words with respective rating:

[R = 100%]: speed reducer ("planetary gear") (5.6);

[R = 66%]: speed reducer ("planetary gear") ("output shaft") (input shaft") (5.7).

Figure 5-6 shows the volume of the documents regarding the key-words (5.6) with a global rating R equal to 100%, for a total amount of little less than 1900 documents, out of which 96% is formed by patents.

Table 5-6: rating R calculated referring to key-words: planetary gear, output shaft, input shaft.

	Items		
Structure	**planetary gear**	**output shaft**	**input shaft**
R'_H (before 1900-2012)	100	100	100
R''_H (before 1900-1980)	100	0	0
R_V (patents)	100	100	100
R_V (publications)	100	0	0
R	**100**	**50**	**50**

Figure 5-7 shows the volume of the documents regarding the key-words (5.7), with a global rating R equal to 66%, for a total amount of little less than 600 documents about, out of which 96% is formed by patents.

The key-words (5.6), with a maximum rating R, form the **second level query**, of which we report the following clustering analysis in the structures of Table 5-7 and Table 5-8.

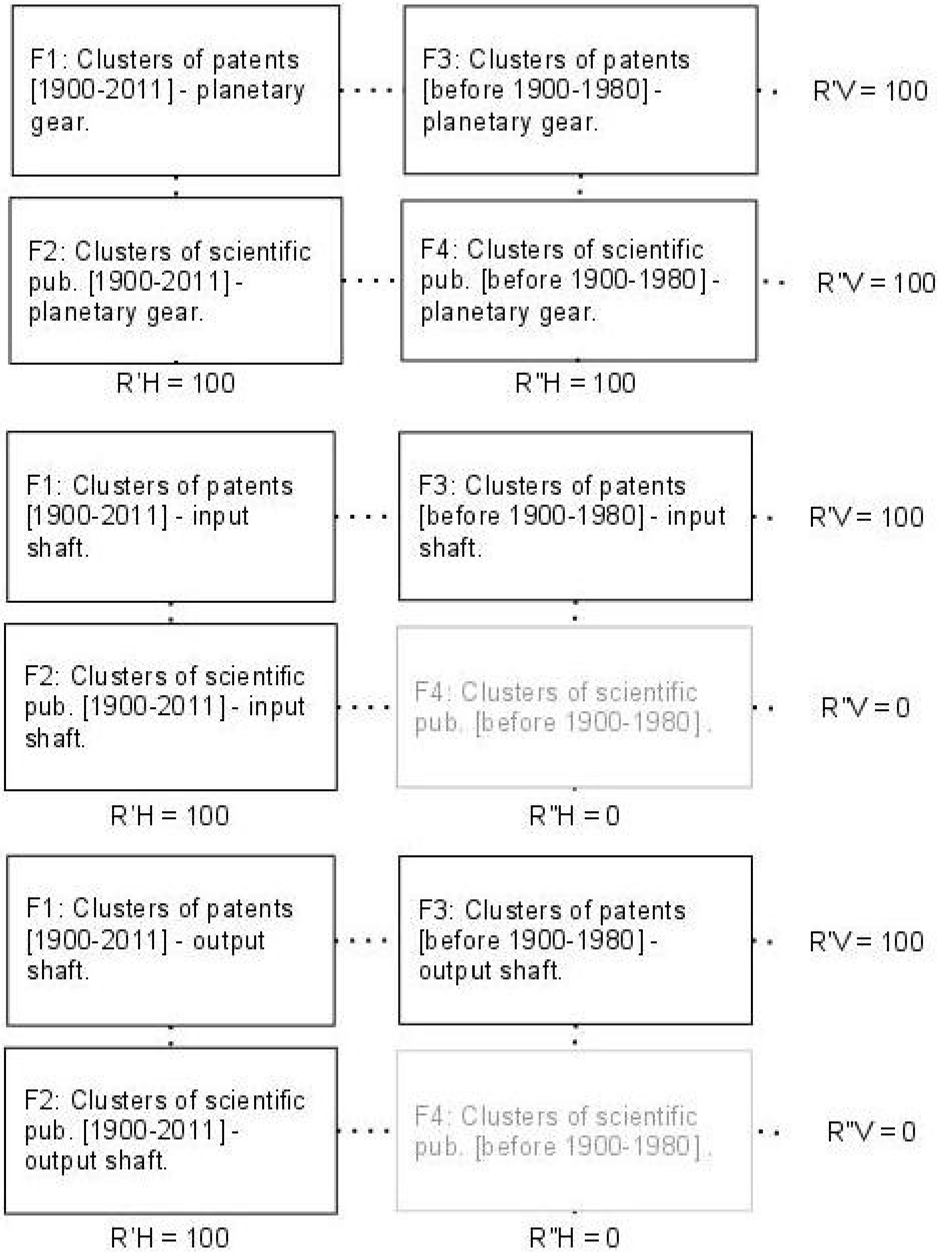


Figure 5-5: horizontal rating RH and vertical rating RV referring to key-words: planetary gear, output shaft, input shaft..

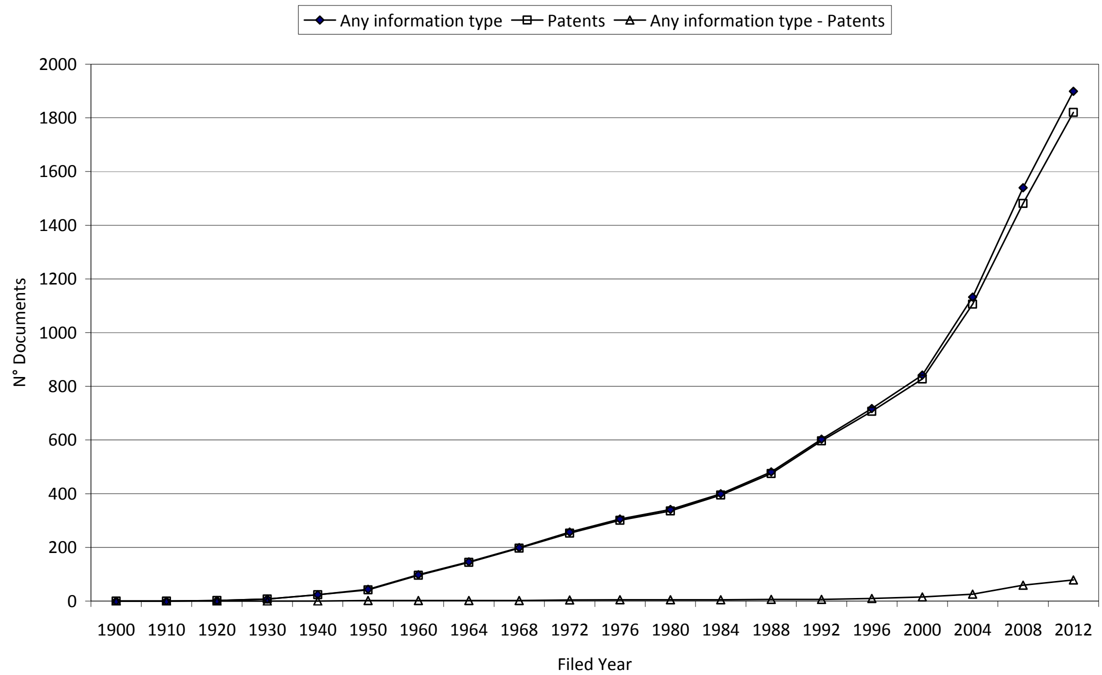


Figure 5-6: [R=100%] “speed reducer (“planetary gear”)”, volume of the documents retrieved and discriminated between patents and scientific publications.

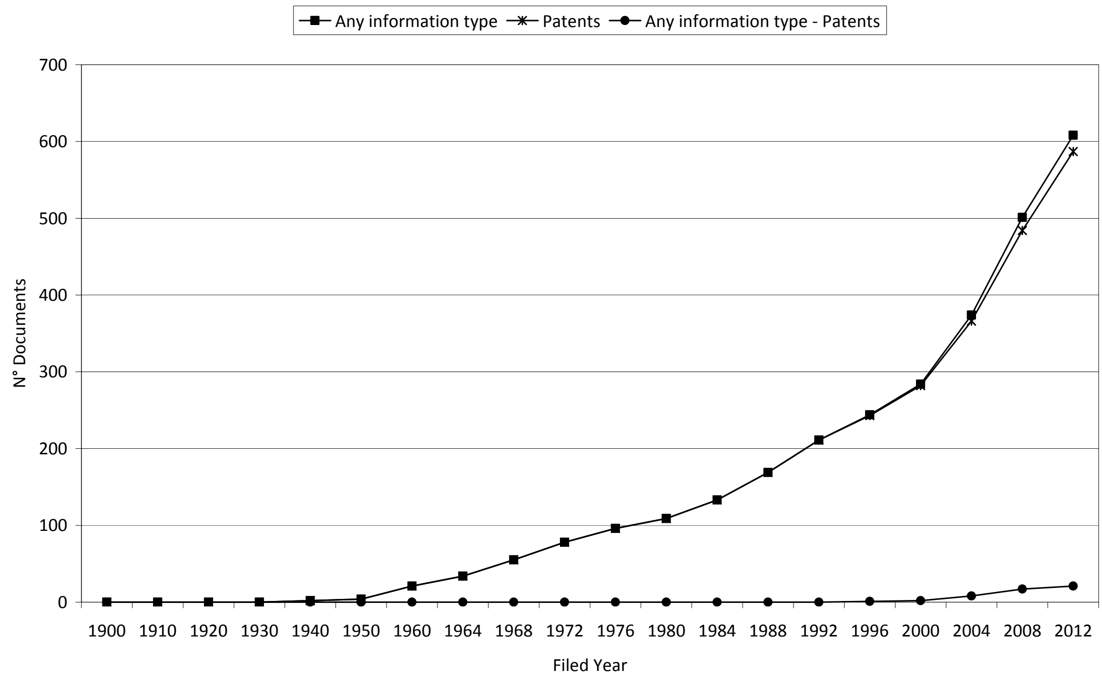


Figure 5-7: [R=66%] “speed reducer ("planetary gear") (“output shaft ”) (input shaft ”), volume of the documents retrieved and discriminated between patents and scientific publications.

Table 5-7: [R=100%] speed reducer ("planetary gear"): before 1900 – 2011.

Any information type	Patents	Any information type - Patents
1,883 hits for **speed reducer ("planetary gear")**	1,810 hits for **speed reducer ("planetary gear")**	73 hits for **speed reducer ("planetary gear")**
input shaft	input shaft	gear train
output shaft	output shaft	actuator
meshing	meshing	inertia
axial direction	axial direction	output shaft
speed reduction	speed reduction	planetary gear train
planetary gears	planetary gears	gearbox
reduction gear	reduction gear	input shaft
eccentric	eccentric	actuators
external gear	external gear	gear teeth
lubricating oil	lubricating oil	roller
gear ratio	fitted	kinematic
gear train	gear ratio	reduction ratio
lubricating	spur gear	speed reduction
spur gear	sectional view	meshing
drive shaft	drive shaft	gear ratio
fitted	reduction ratio	bending stress
planetary gear train	rotary	number of teeth
reduction ratio	lubricating	design example
number of teeth	number of teeth	kinematics
sectional view	spur gears	robotics and automation
spur gears	rotational	bevel gear
rotary	periphery	bevel gears
periphery	motor shaft	helical
workability	annular	turbine
roller	crankshaft	cycloid
rotational	lubrication	locomotion
lubrication	gear unit	heavy lift
motor shaft	oil reservoir	contact stress
oil reservoir	stopper	pitting resistance
crankshaft	workability	geometry factor
annular	roller	critical speed
stopper	gear train	sliding friction
gear teeth	planet wheel	wind turbine
recessed	hydraulic motor	trajectory
helical gear	hydraulic	manipulator
concave	axial motion	mechanical engineering
protruding	rocking	ring gears
oscillating	tilting	pitch diameter
circular ring	recessed	angular speed
intermediate shaft	helical gear	pressure angle
driving shaft	concave	external gear
tooth surface	protruding	blades
hydraulic	circular ring	cylindrical
intermediate bearing	gear teeth	planetary gear trains

hydraulic motor	assembling	tooth profile
electric motor	driving shaft	retaining ring
assembling	intermediate shaft	reduction gear
planet wheel	oscillating	cap screw
gear unit	perspective view	machine components
cylindrical	oil supply	kinematic chains
perspective view	intermediate bearing	machining
gear drive	usa628769	leg length
oil supply	usb628769	antagonistic
rocking	motor output	mechanical press
axial motion	absorbing	spring stiffness
tilting	ring gears	structural synthesis
lubrication system	conical	one half
oil lubrication	lubrication system	wind tunnels
11185895	oil lubrication	rotational inertia
geared motor	11730077	contact ratio
kinematic	usb730077	permissible
usb185895	usa730077	robot
usa185895	geared motor	armature
usa304764	peripheral speed	dynamic model
usb304764	rotation axis	simulation
11304764	friction surface	joint torque
thrust washer	pin hole	magnetic circuit
11730077	end frame	utk theses -- mechanical engineering
end frame	planetary gear train	torsion spring
ring gears	thrust washer	walking machine
usb730077	11304764	drive gear
conical	usb304764	set screw
planet wheels	usa304764	turnbuckle
support plate	motive power	gear box
contact ratio	electric motor	step height
absorbing	speed reduction gear	moment of inertia
center of rotation	contact ratio	drive shaft
speed reduction gear	screw shaft	discrete variable
screw shaft	screw pitch	rolling bearing
screw pitch	screw thread	flexible coupling

Table 5-8: [R=100%] speed reducer ("planetary gear"): before 1900 – 1980.

Any information type	Patents	Any information type - Patents
341 hits for **speed reducer ("planetary gear")**	336 hits for **speed reducer ("planetary gear")**	5 hits for **speed reducer ("planetary gear")**
output shaft	output shaft	number of teeth
input shaft	input shaft	forged alloy steel
drive shaft	drive shaft	drain tank
planetary gears	planetary gears	one half
driven shaft	driven shaft	gear box
speed reduction	speed reduction	drive shaft

gear train	gear train	bending stress
gearing	gearing	flexible coupling
meshing	eccentric	blades
eccentric	meshing	permissible
number of teeth	vehicle speed	gear teeth
ring gears	driving shaft	shaping machine
driving shaft	number of teeth	random point
vehicle speed	ring gears	base frame
brake band	brake band	drive power
gear teeth	pitch diameter	wind tunnels
pitch diameter	throttle valve	differential gear
throttle valve	exhaust port	pitch change
valve chamber	gear unit	temperature indicator
gear unit	rotary	synthesis problems
exhaust port	electric motor	inertia
electric motor	output member	moment of inertia
output member	valve chamber	adaptive optimization
annular	gear teeth	extremum point
rotary	annular	probability vector
hollow shaft	hollow shaft	extremum
line pressure	roller	gear trains
outer race	output speed	kinematic
roller	line pressure	tabular method
output speed	outer race	transmission gear
motor shaft	frame member	ring gears
sectional view	motor shaft	diametral
intermediate shaft	intermediate shaft	number of degrees
frame member	torque converter	automatic transmission
planetary gearing	sectional view	gear train
torque converter	planetary gearing	
gear trains	valve land	
set of teeth	brake drum	
gear wheel	rate of speed	
movable	conduit	
sun gears	spur gear	
gear system	sun gears	
countershaft	gear system	
reduced speed	cylindrical	
differential gear	reduced speed	
rate of speed	differential gear	
spur gear	countershaft	
pressure source	gear wheel	
conduit	movable	
drive gear	gear trains	
brake drum	toothed	
clutch plate	sheave	
valve land	rotary motion	
toothed	drive gear	
cylindrical	pressure source	

sheave	clutch plate	
brake shoe	set of teeth	
split ring	planetary gear train	
reducing gear	conveyor	
gear ratio	reducing gear	
adjustable	gear ratio	
numeral	brake shoe	
rotary motion	numeral	
axial alignment	split ring	
lubricant	adjustable	
cap screws	stub shaft	
epicyclic gear train	cap screws	
epicyclic gear	axial alignment	
stub shaft	ball bearing	
planetary gear train	speed gear	
reduced scale	epicyclic gear	
speed gear	epicyclic gear train	
ball bearing	differential speed	
minute hand	reduced scale	
hour hand	lubricant	
follower	circular pitch	
fixed frame	power input	
cam follower	valve piston	
teeth meshing	pressure build-up	
hydrostatic	axis of rotation	

5.4 9-screen-diagram

The definition in Subsystem-System-Supersystem triplets owing a temporal issue distributed in the evolutionary phases: pioneer and diffusion, represent a resource in order to forecast a Technological Change.

A Technological Change, as used hereafter, involves the systematic application of organized knowledge to practical activities, especially productive ones. It will occasionally be useful to emphasize the distinction (at least once) between *invention, innovation, transfer, and penetration* or *diffusion*. The first refers to the birth of an idea for a product, a process, or a procedure, with some claims to novelty and priority. The whole technological change rests upon invention - not necessarily discovery - but only a small fraction of inventions which actually have any application in technology. When such an application is formulated, resulting in new products, approaches or ways of doing or making things, an *innovation* has taken place [Ayres, 1969].

An innovation, as expression of application technology, depends from a structure of clusters of a patent collection resulting from a group of queries from a technological system (Figure 5-8).

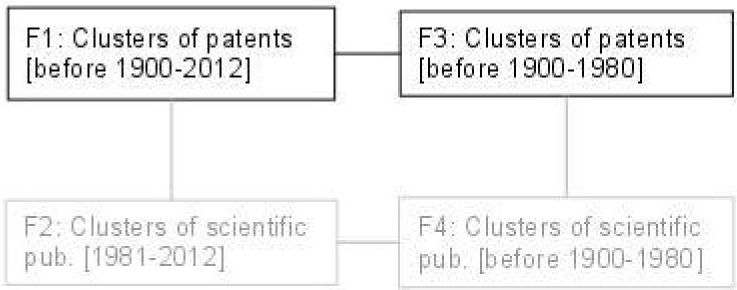


Figure 5-8: structure of clusters of a patent collection resulting from a series of queries in technological system.

Key-words belonging to patent-clusters [before 1900-2012] and [before 1900-1980] set up Subsystem-System-Supersystem triplets by means of a manual procedure, in case developed under the supervision of an expertee from the technological branch we are referring to.

Each key-word is able to represent a technological system, called *The System*, discriminating and separating it from Social Needs and Market, from Sourronding, Environment, called *The Supersystem*, as well as from Common Components constituent of a Technological System, i.e. those components able to identify the System if considered by their own. These set up *The Subsystem* [Seredinski, 2002].

Figure 5-9 and Table 5-9 show the results when setting patent-clusters from **a second level query,** only in a PRESENT triplet Subsystem-System-Supersystem, in the structure of Table 5-7.

Figure 5-10 and Table 5-10 show the result of setting patent-clusters from a **second-level query,** only in a PAST triplet Subsystem-System-Supersystem, in the structure of Table 5-8.

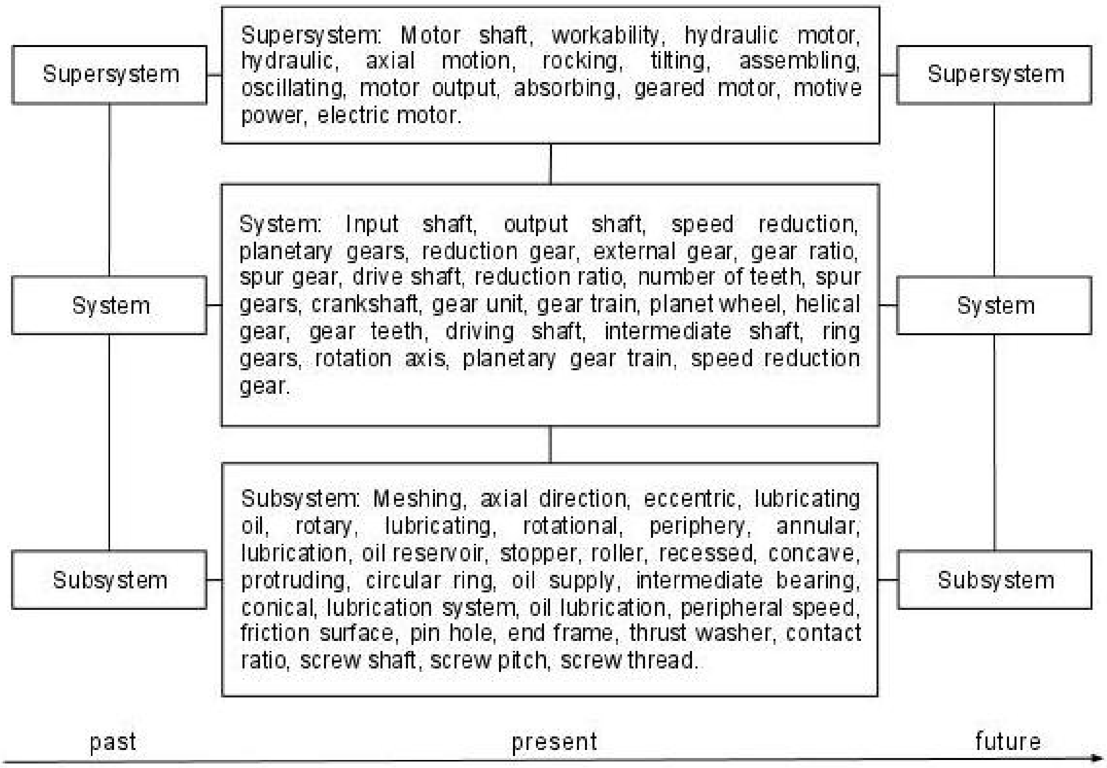


Figure 5-9: Subsystem-System-Supersystem's speed reducer ("planetary gear"): PATENTS, [before 1900 – 2011].

Table 5-9: Subsystem-System-Supersystem's speed reducer ("planetary gear"): PATENTS, [before 1900 – 2011].

subsystem	system	supersystem
meshing	input shaft	motor shaft
axial direction	output shaft	workability
eccentric	speed reduction	hydraulic motor
lubricating oil	planetary gears	hydraulic
rotary	reduction gear	axial motion
lubricating	external gear	rocking
rotational	gear ratio	tilting
periphery	spur gear	assembling
annular	drive shaft	oscillating
lubrication	reduction ratio	motor output

oil reservoir	number of teeth	absorbing
stopper	spur gears	geared motor
roller	crankshaft	motive power
recessed	gear unit	electric motor
concave	gear train	
protruding	planet wheel	
circular ring	helical gear	
oil supply	gear teeth	
intermediate bearing	driving shaft	
conical	intermediate shaft	
lubrication system	ring gears	
oil lubrication	rotation axis	
peripheral speed	planetary gear train	
friction surface	speed reduction gear	
pin hole		
end frame		
thrust washer		
contact ratio		
screw shaft		
screw pitch		
screw thread		

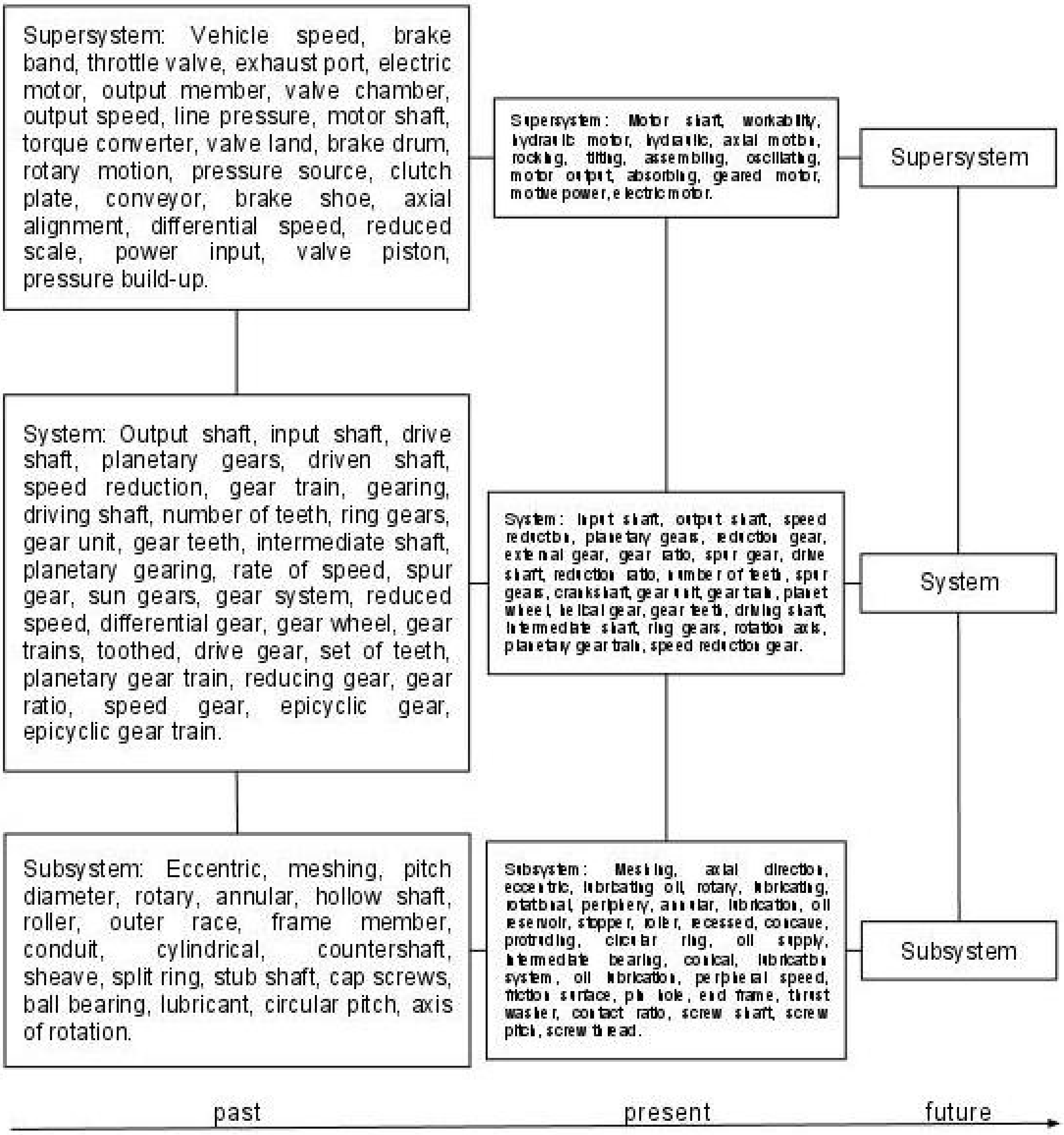


Figure 5-10: Subsystem-System-Supersystem's speed reducer ("planetary gear"): PATENTS, before 1900 – 1980.

Table 5-10: Subsystem-System-Supersystem's speed reducer ("planetary gear"): PATENTS, before 1900 – 2011.

subsystem	system	supersystem
eccentric	output shaft	vehicle speed
meshing	input shaft	brake band
pitch diameter	drive shaft	throttle valve
rotary	planetary gears	exhaust port

annular	driven shaft	electric motor
hollow shaft	speed reduction	output member
roller	gear train	valve chamber
outer race	gearing	output speed
frame member	driving shaft	line pressure
conduit	number of teeth	motor shaft
cylindrical	ring gears	torque converter
countershaft	gear unit	valve land
sheave	gear teeth	brake drum
split ring	intermediate shaft	rotary motion
stub shaft	planetary gearing	pressure source
cap screws	rate of speed	clutch plate
ball bearing	spur gear	conveyor
lubricant	sun gears	brake shoe
circular pitch	gear system	axial alignment
axis of rotation	reduced speed	differential speed
	differential gear	reduced scale
	gear wheel	power input
	gear trains	valve piston
	toothed	pressure build-up
	drive gear	
	set of teeth	
	planetary gear train	
	reducing gear	
	gear ratio	
	speed gear	
	epicyclic gear	
	epicyclic gear train	

CHAPTER 6

Forecasting

6.1 Introduction

Heteronomous areas such as marketing information, knowledge of expertees, etc. generate the criteria according to which some and not other key-words are made migrate. Among the methods for defining questions from the market and forecasting, Delphi is probably the best known process [Turoff, 2002]. Delphi process today exists in two distinct forms. The paper-and-pencil version is the commonest, and it is usually referred to as a "Delphi Exercise". In this situation a small monitor-team designs a questionnaire which is sent to a larger respondent group. After the questionnaire is returned the monitor-team summarizes the results and, based upon these ones, develops a new questionnaire for the respondent group. The respondent group is generally given at least one opportunity to reevaluate its original answers based upon examination of the group response. A newer form, sometimes called a "Delphi Conference", replaces the monitor team to a large degree by a computer which has been programmed to carry out the compilation of the group results. This latter approach offers the advantage of eliminating the delay caused in summarizing each round of Delphi, thereby turning the process into a real-time communications system.

In this specific case, key-words have simply been chosen according to their projection in the future according to the values often mentioned in the energetic, automotive branches and so on. According to this, the three most spread key-words are: *Diffusion evolutionary phase* Paragraph 6.2 shows a Subsystem-System-Supersystem triplet in the future, bound to Case study 2, Chapter 5.

Paragraph 6.3 introduces a “Loglet analysis” theory regarding the decomposition of growth and diffusion into S-shaped logistic components, roughly analogous to wavelet analysis, popular for signal processing and compression.

Paragraph 6.4 depicts mathematically the technological system referring to Case study 2, Chapter 5, and Case study 1, Chapter 4, by means of the logistic S-curves as described in paragraph 6.3, evaluating the rate of speed according to which the technology system evolves.

6.2 Case study 2 - Subsystem-System-Supersystem triplet in the future

The 9-screen diagram in paragraph 5.4, Chapter 5, is re-written and the sole key-words complying with the criteria: miniaturization, efficiency, downsizing (Figure 6-1) are translated into “Future”.

Figure 6-2 depicts the result of the so called PAST > FUTURE Migration.

Figure 6-3 depicts the result of the so called PRESENT > FUTURE Migration

Figure 6-4 depicts a complete 9-screen diagram PAST > PRESENT > FUTURE.

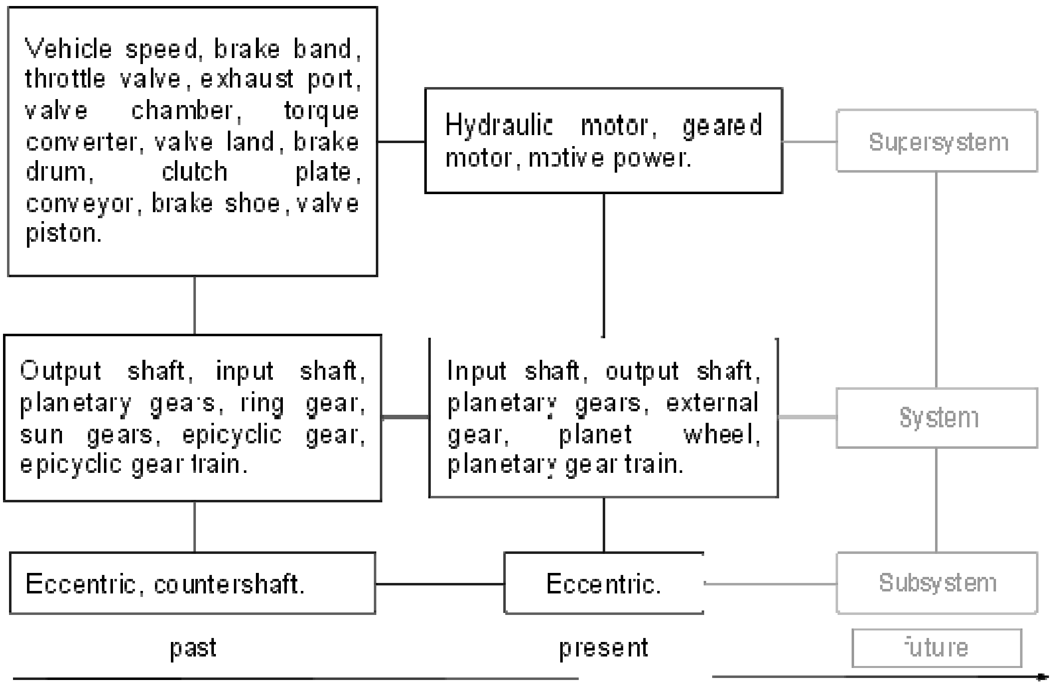


Figure 6-1: PAST/PRESENT 9-screen diagram’s speed reducer ("planetary gear"): PATENTS.

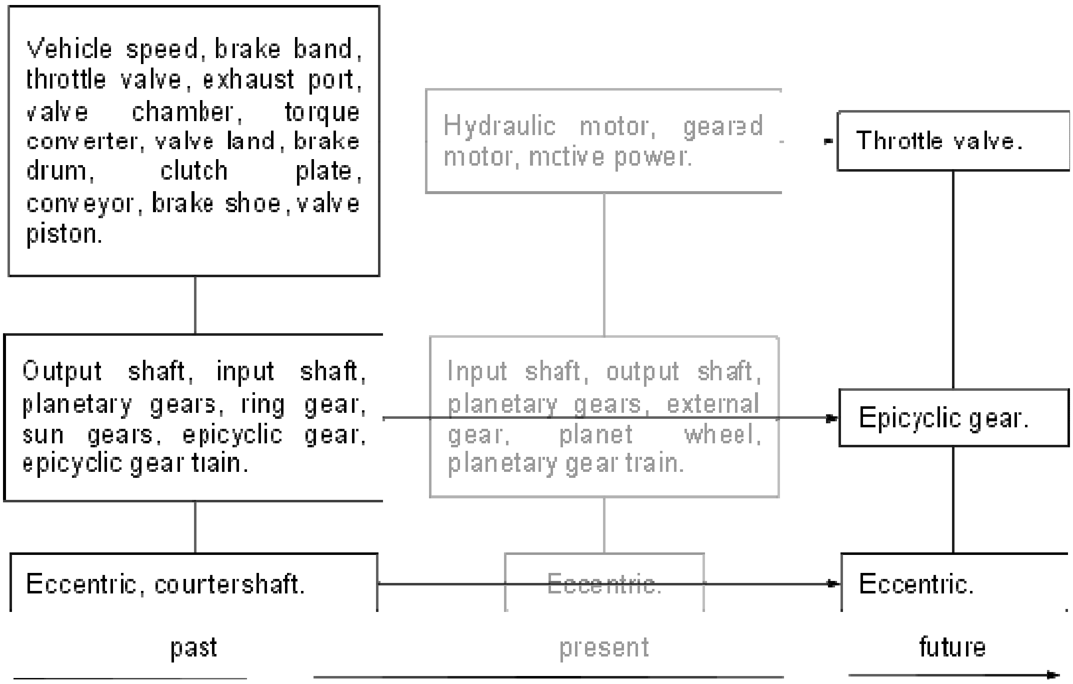


Figure 6-2: migration PAST > FUTURE. 9-screen diagram's speed reducer ("planetary gear"): PATENTS.

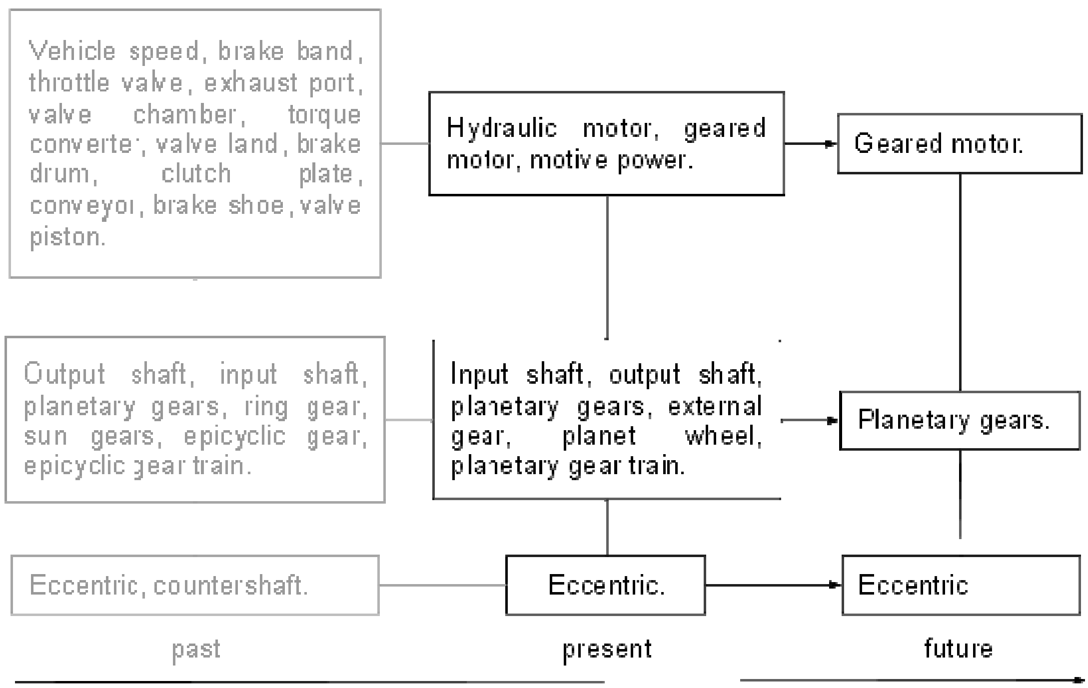


Figure 6-3: migration PRESENT > FUTURE. 9-screen diagram's speed reducer ("planetary gear"): PATENTS.

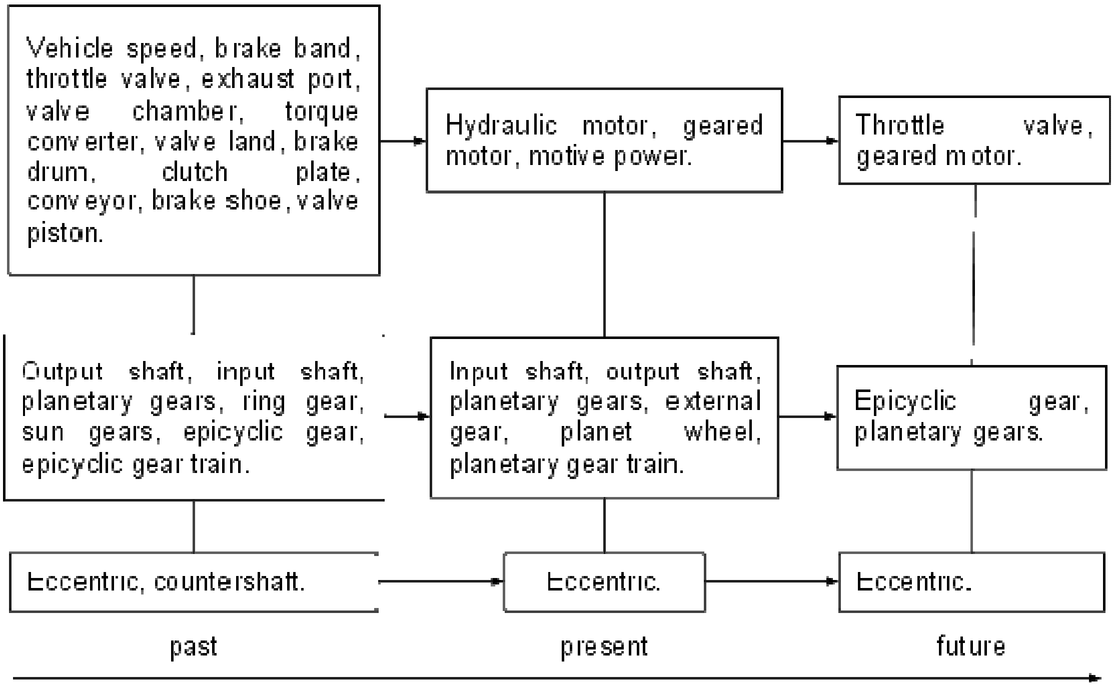


Figure 6-4: PAST > PRESENT > FUTURE. 9-screen diagram's speed reducer ("planetary gear"): PATENTS.

6.3 Logistic S-curves

A systematic approach to determine the technological route between discovery, pioneering, radical creation and qualitative or quantitative improvement, as the two extremities of a line of evolution regarding a certain inventive theme, is represented by the Logistic S-curves.

"Loglet analysis" refers to the decomposition of growth and diffusion into S-shaped logistic components, roughly analogous to wavelet analysis, popular for signal processing and compression. The term "loglet" joins "logistic" and "wavelet". Loglet analysis comprises two models: the first is the component logistic model, in which autonomous systems exhibit logistic growth. The second is the logistic substitution model, which models the effects of competitions within a market [Perrin, 1999].

The development of loglet analysis for the the analysis, decomposition, and prediction of complex growth processes allows to analyze existing time-series growth data sets in order:

- to decompose the growth process into sub-processes and to elucidate information on carrying capacities and other aspects ("top-down" approach);

- to analyze individual sub-processes in order to determine macro or envelope system behavior ("bottom-up" approach).

At the heart of loglet analysis is the three-parameter S-shaped logistic growth model. The logistic is attractive for modeling S-shaped growth because it is a parsimonious model where the three parameters have clear, physical interpretations.

6.3.1 Simple Growth Models

The exponential growth of multiplying organisms is represented by a simple and widely used model that increases without bounds or limits as Figure 6-5 illustrates. In mathematical terminology, the growth rate of a population P(t) is proportional to the population:

$$\frac{dP(t)}{dt} = \alpha P(t) \qquad \textit{(6.1).}$$

The Exponential Growth Model (6.1) can be solved as:

$$P(t) = \beta e^{\alpha t} \qquad \textit{(6.2),}$$

where α is the growth rate constant and β is the initial population P(0). An α with a value of 0.02 is equivalent to the statement " the population was growing continuously at 2% per year".

Because few, if any, systems are permanently unbounded and sustain exponential growth, equation (6.1) must be modified with a limit or carrying capacity that gives it the more realistic sigmoidal shape of the lower curve in Figure 6-5. The most widely used modification of the exponential growth model is the logistic.

The logistic equation begins with the P(t) and α of the exponential but adds a "negative feedback" term $(1-\frac{P(t)}{K})$ that slows the growth rate of a population as the limit K is approached:

$$\frac{dP(t)}{dt} = \alpha P(t)\,(1-\frac{P(t)}{K}) \qquad \textit{(6.3).}$$

feedback term

Notice that the feedback term $(1-\frac{P(t)}{K})$ is close to 1 when $P(t) \ll K$ and approaches zero as $P(t) \rightarrow K$. Thus, the growth rate begins exponentially but then decreases to zero as the population P(t) approaches the limit κ, producing an S-shaped (sigmoidal) growth trajectory.

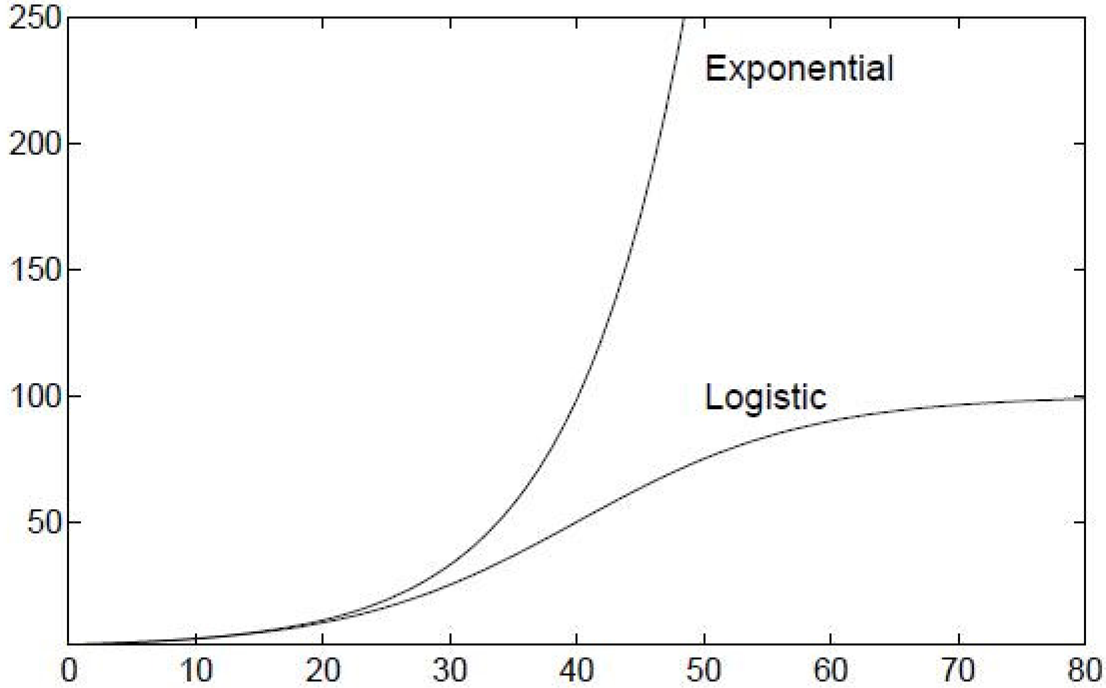


Figure 6-5: comparision of exponential and logistic growth.

The solution to the logistic differential equation (6.3) is:

$$P(t) = \frac{K}{1 + exp(-\alpha(t - \beta))} \quad (6.4).$$

Equation (6.4) produces the familiar S-shaped curve. Note that <u>three parameters are needed to fully specify the curve, α, β, and κ.</u>

The three parameters κ,Δt, and t_m define the parameterization of the logistic model used as the basic building block for Loglet analysis:

$$N(t) = \frac{K}{1 + exp\left[-\frac{ln(81)}{\Delta t}(t - t_m)\right]} \quad (6.5).$$

The simple logistic model is useful in part because the parameters obtained by fitting the model to data can be easily compared across many different systems. These parameters also help in formulating complex models, for which they provide a frame of reference and first-order guesses for the possible time-scales and magnitudes of component variables.

6.3.2 Taxonomy of bi-logistic curves.

Wavelets often overlap in time. Depending on the order and magnitude of the overlap, the aggregate curve can take on a wide range of appearances. Figure 6-6 shows a taxonomy of bi-logistic processes, with the Fisher-Pry transform of the two component logistics on the right.

Panel A is an example of a "**sequential**" bi-logistic; the second pulse does not start growing until the first pulse has nearly reached its saturation level κ_1. This shape bi-logistic characterizes a system which pauses between growth phases.

Panel B is an example of a "**superposed**" bi-logistic, where the second pulse begins growing when the first pulse has reached about 50% of saturation. This bi-logistic growth model characterizes systems that contain two processes of a similar nature growing concurrently except for a displacement in the midpoints of the curves.

Panel C shows a "**converging**" bi-logistic, where a first wavelet is joined by a second faster, steeper wavelet; the two pulses culminate at about the same time. Often a late adopter of a technology, having learned from the experiences of an early adopter, will advance faster, resulting in a smaller Δt.

Panel D shows a "**diverging**" bi-logistic, where two logistic growth processes begin at the same time but grow with different rates and carrying capacities defined from the start.

The panels show the merits of Loglet analysis. While curve A looks logistic, curve B hardly appears S-shaped. Curves C and D are S-shaped, but asymmetric, so they do not appear to be logistic. Yet all four curves are made up of logistic components.

6.3.3 Growth rates and the "bell" view

Just as the differential equation (6.3) reveals the mechanism propelling its integral equation (6.4), the rates of change of the component logistics provide clues to the mechanisms propelling the composite logistic. Analyzing the rates of change is often useful when yearly or percent per year tabulations are applicable, as in the case of economic data.

The instantaneous rate of growth of the logistic function is given by the derivative with respect to time of expression (6.5). Plotting the derivative respect to time of expression (6.5) produces a bell-shaped curve similar, but not identical, to the normal distribution function.

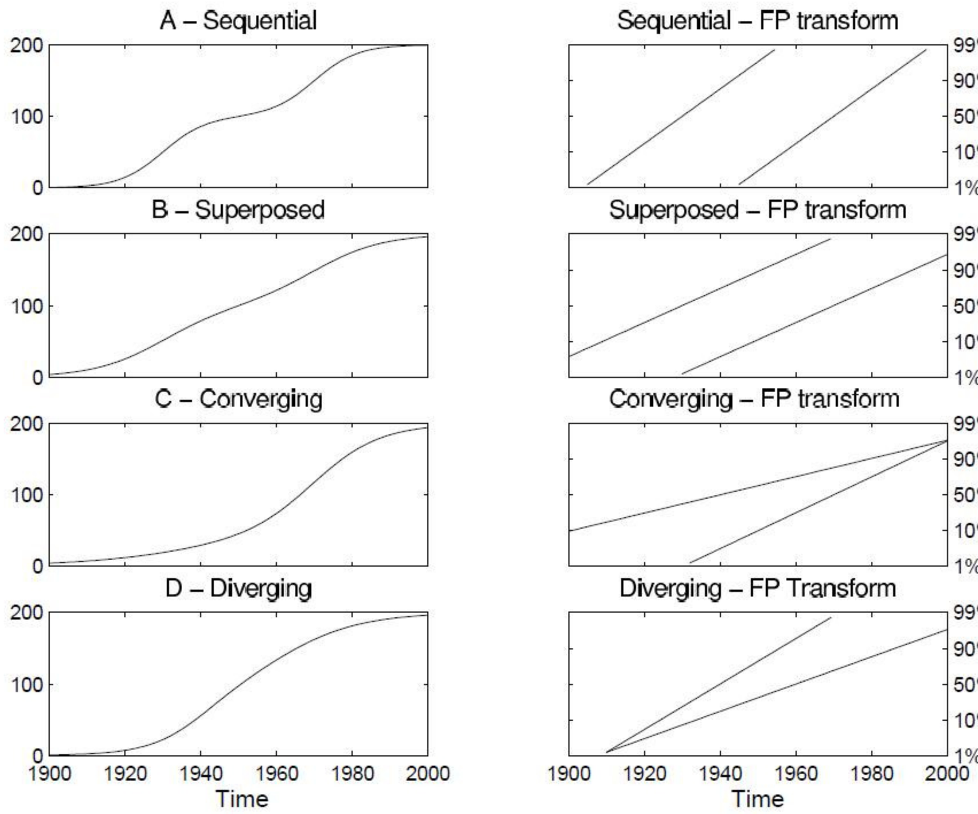


Figure 6-6: A taxonomy of bi-logistic processes growing through time to a notional limit of 200 units. Fisher-Pry decompositions are shown in the right column.

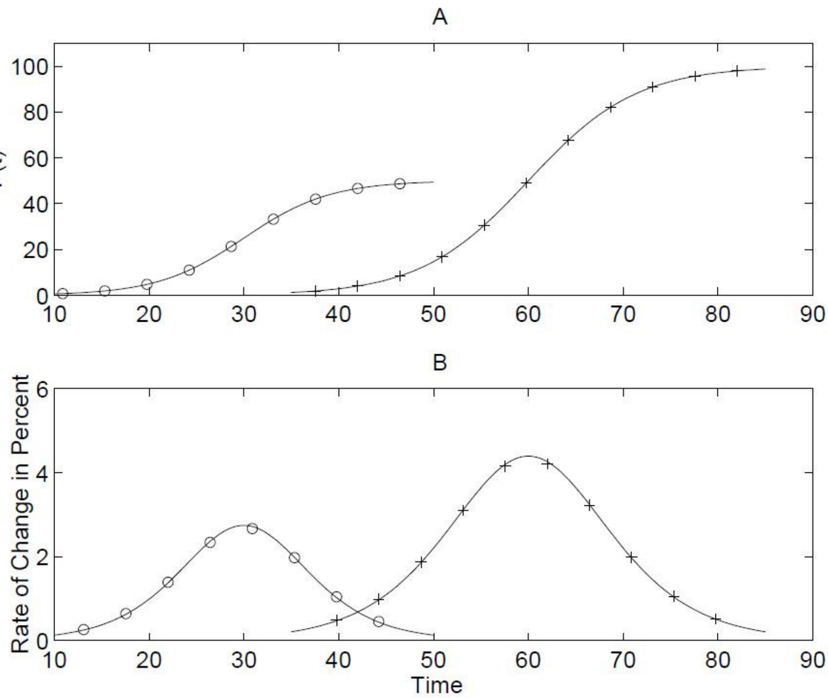


Figure 6-7: Rates of change of the two component logistic (The "Bell View").

6.4 Case study 2 – Logistic S-curves

Coming back to the key-words (5.6),

[R = 100%]: speed reducer ("planetary gear") *(5.6)*

The clusters – forming the Master Document - placed in a temporal range [before 1900-2012] have been compared with those placed in a sequence in a temporal range with one edge [2012]- forming the Slave Document. This according to the comparison procedure as described in paragrapf 5.2 - Temporal Setting of Technological Pionerism and technological diffusion – i.e.:

• Master Document [before 1900-2012] owes 21 new clusters non-stated in Slave Document [2001-2012];

• Master Document [before 1900-2012] owes 15 new clusters non-stated in Slave Document [1991-2012];

• Master Document [before 1900-2012] owes 14 new clusters non-stated in Slave Document [1981-2012];

• Master Document [before 1900-2012] owes 2 new clusters non-stated in Slave Document [1971-2012].

The clusters placed in a temporal range [before 1900-1970] and at the same time contained in a Master Document are compadered – according to the procedure - with those clusters placed in a sequence in a temporal range with one edge [1970] - Slave Document -, thus obtaining year 1920 as the moment in which the pionerism phase starts., i.e.:

• Master Document [before 1900-1970] owes 22 new clusters non-stated in Slave Document [1961-1970];

• Master Document [before 1900-1970] owes 8 new clusters non-stated in Slave Document [1950-1970];

• Master Document [before 1900-1970] owes 7 new clusters non-stated in Slave Document [1940-1970];

• Master Document [before 1900-1970] owes 5 new clusters non-stated in Slave Document [1930-1970];

• Master Document [before 1900-1970] coincides with Slave Document [1920-1970].

The results od the comparison procedure between Master Documents and slave documents in each of the two evolutionary phases respectively is summarized in Table 6-1 and Figure 6-8, where: Δ Cluster indicates new clusters and Cumulative Δ Cluster indicates the cumulated number of new clusters. Both sets of clusters are associated to the key-words: speed reducer ("planetary gear").

Table 6-1: Δ Cluster and Cumulative Δ Cluster associated to the key-words: speed reducer ("planetary gear").

Filed year	Cumulative patents+scientific documents	Δ Cluster	Cumulative Δ Cluster
before 1900-2012	1899	0	94
2001-2012	1057	21	94
1991-2012	1360	15	73
1981-2012	1558	14	58
1971-2012	1674	2	44
before 1900-1970	225	0	42
1961-1970	127	22	42
1950-1970	182	8	20
1940-1970	202	7	12
1930-1970	218	5	5
1920-1970	223	0	0
before 1900-1920	2	0	0

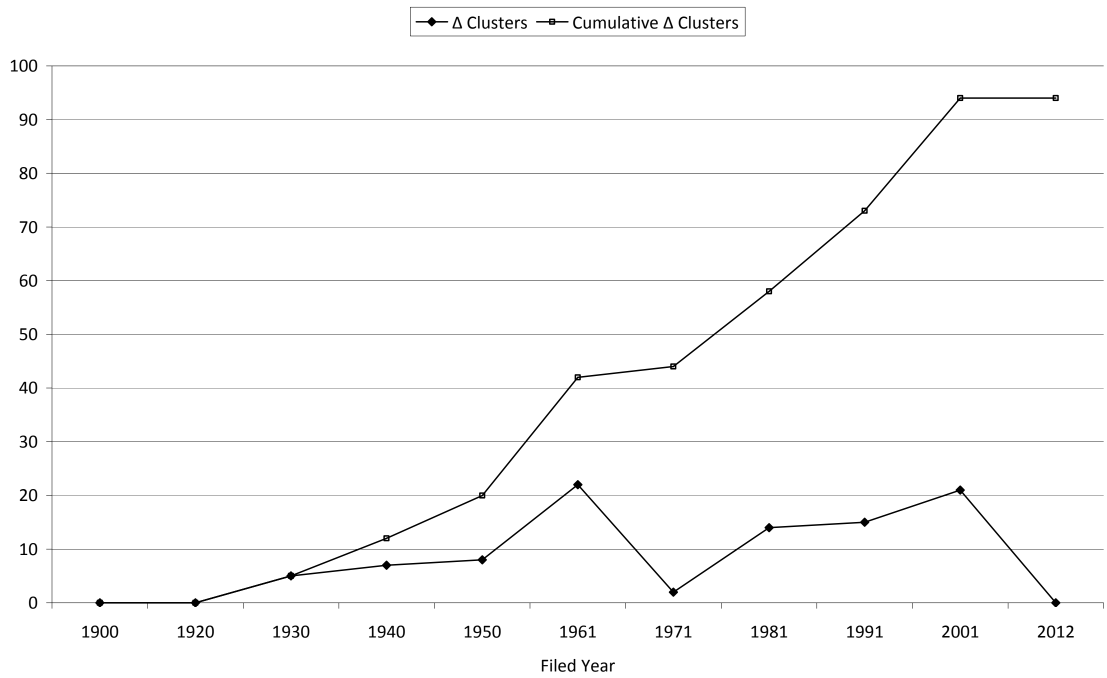


Figure 6-8: Δ Cluster and Cumulative Δ Cluster associated to the key-words: speed reducer ("planetary gear").

The performance of the Δ Cluster shown in Figure 6-8 is typical of a competitive system which develops according to the scheme: *birth, growth, apeness* and *decay* [Kucharavy, 2009].

Actually, Δ Cluster represents an increase of clusters throughout the development of the technological system over time. Therefore the algorith ruling Logistic S-curves as described in para 6.3, can analyse the Δ Cluster mathematically.

How new clusters - Δ Cluster - are to be interpretated is the topic of a work in progress which constituetes the follow-up of the work updated for the time being and described in this dissertation. In the present study phase, Δ Cluster have been considered cumulatively thus obtaining a growing curve.

In order to performe this analyses, the cumulative performance of Δ Cluster- Cumulative Δ Cluster- has been apraised by means of a software package for analyzing logistic behaviour developed and shared by the University of Rockefeller (NY) called Loglet Lab. Loglet Lab allows to discern and analyze S-shaped curve or a succession of many S-shaped curves even if overlapped in time. If the Δ Clusters set obtained and its relative ID trend results to be logistic, one or more curves can be found with minimal residuals. Each quantitative S-curve describes a generation of device or technology, giving precious data on mean and saturation times.

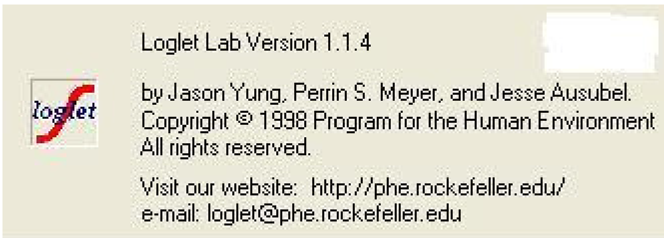


Figure 6-9: presentation of software to analyse Logistic S-curves.

The following Figures 6-10, 6-11, 6-12 and 6-13 report the result of analysis by Loglet with reference to the technological system "speed reducer ("planetary gear")".

In particular following informations have been obtained:

• wavelets often overlap in time;

• "converging" bi-logistic, where a first wavelet is joined by a second faster, steeper wavelet:

- First pulse: Midpoint = 1953; Growth Time = 40,3;
- Second pulse: Midpoint = 1991; Growth Time = 18,4.

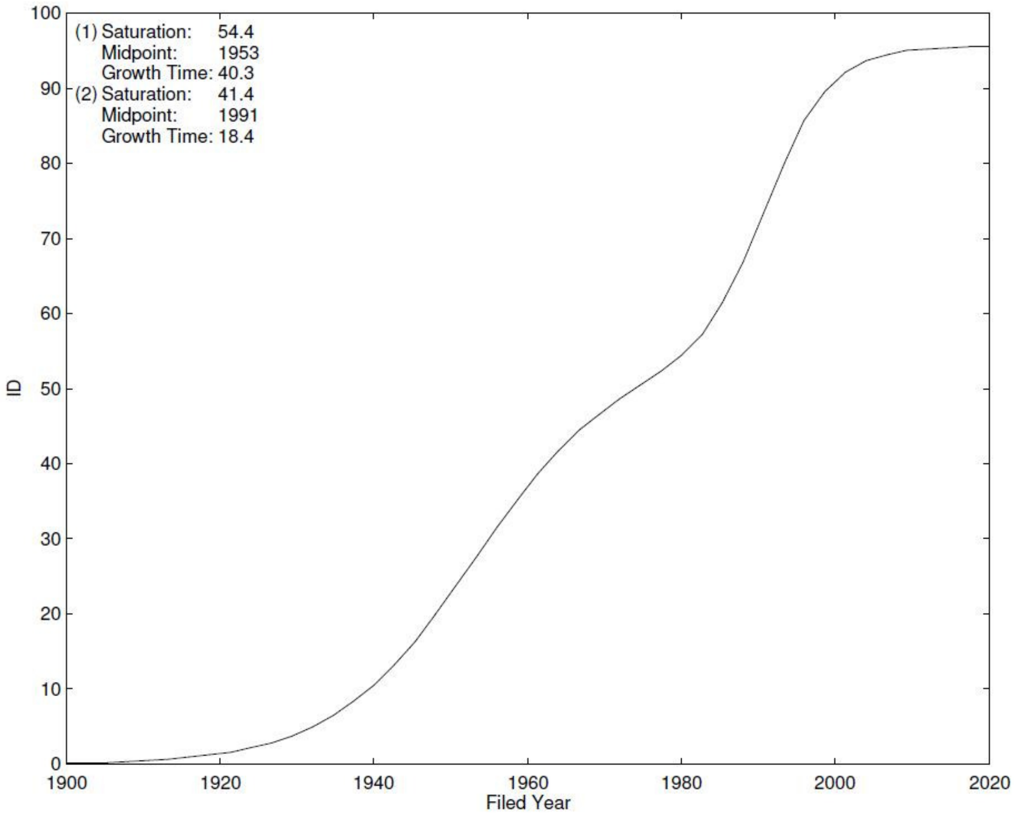


Figure 6-10: relative Δ Cluster's ID trend of "speed reducer ("planetary gear")".

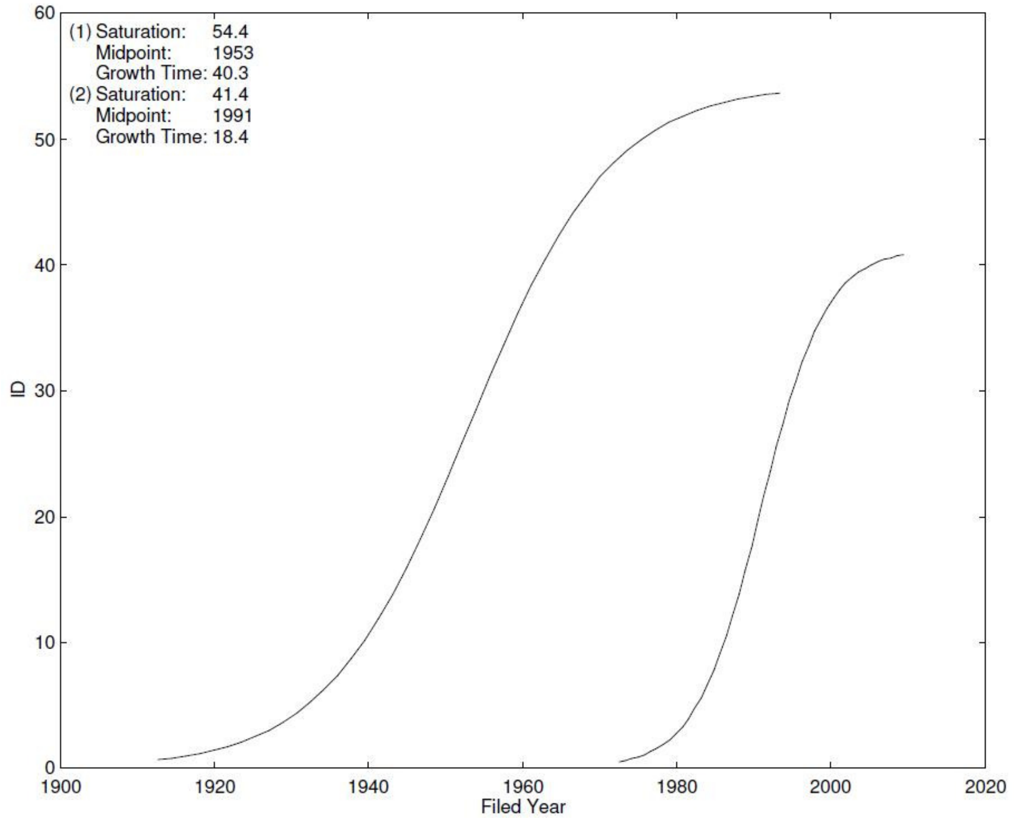


Figure 6-11: S-shaped curves fitting ID trend of "speed reducer ("planetary gear")".

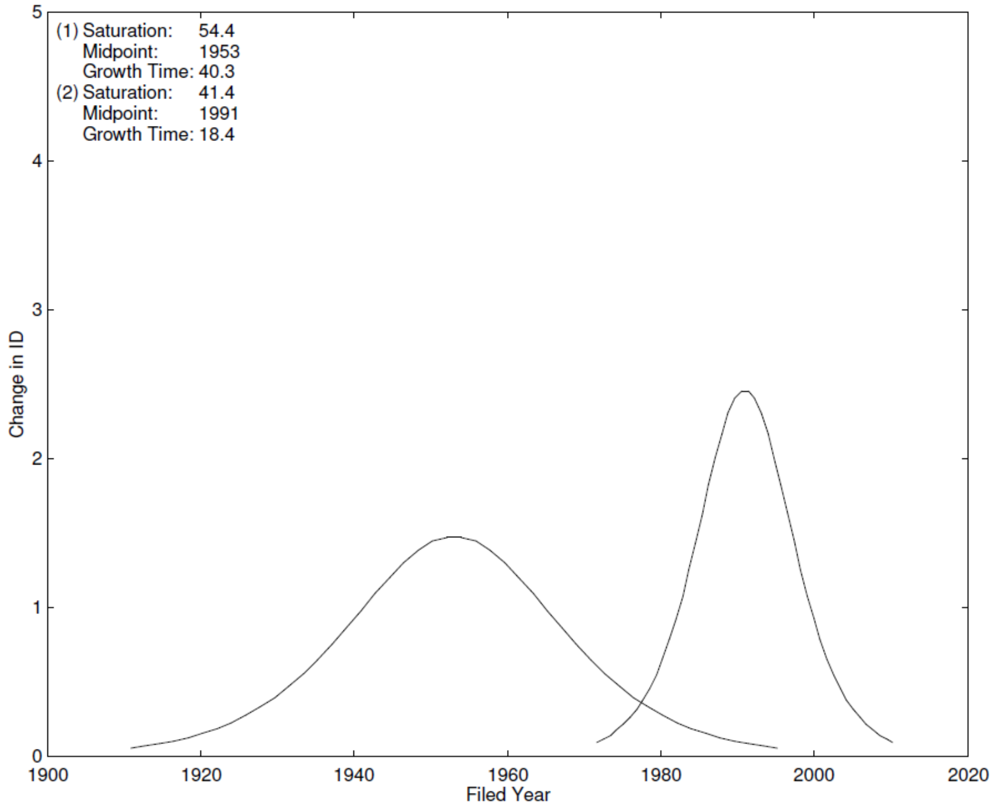


Figure 6-12: Bell-shaped curves fitting ID trend of "speed reducer ("planetary gear")".

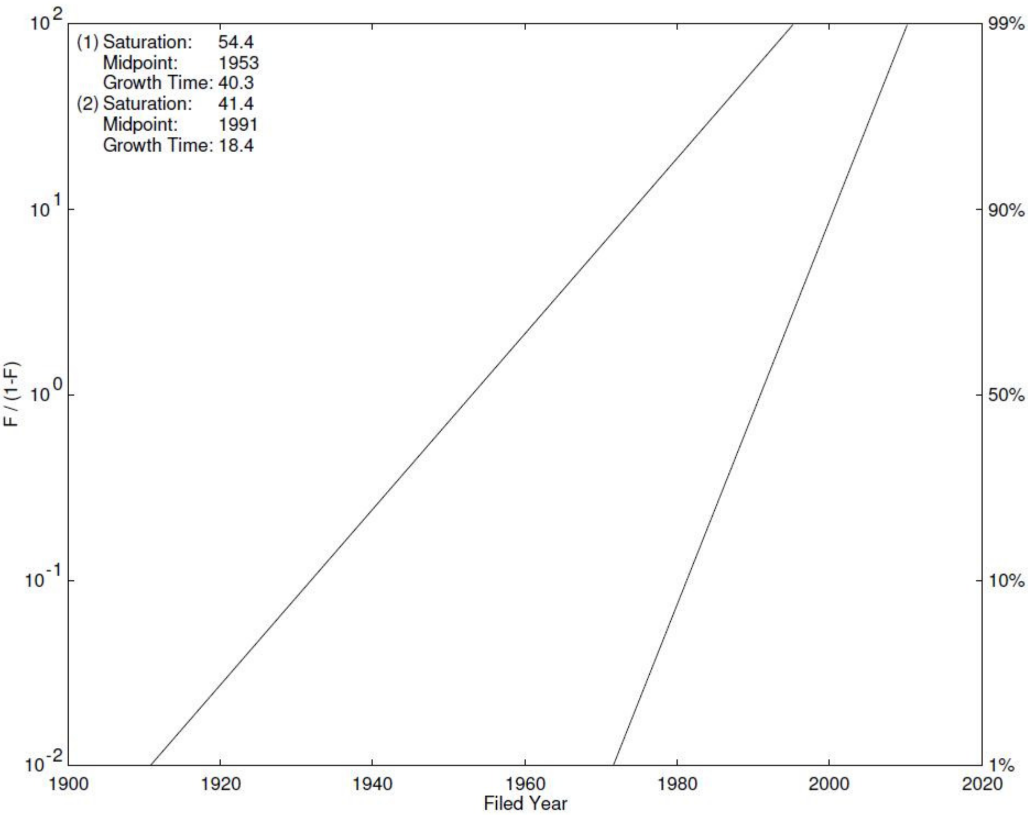


Figure 6-13: Fisher-Pry transform curves fitting ID trend of "speed reducer ("planetary gear")".

6.5 Case study 1 – Logistic S-curves

The same procedure as described in the previous paragraph has been applied also to the key-words (4.1), relative to Case study 1:

"unsaturated polyester resin" injection (4.1).

Thus obtaining the results reported in Table 6.2.

Table 6-2: Δ Cluster and Cumulative Δ Cluster associated to the key-words "unsaturated polyester resin" injection".

Filed year	Cumulative patents+scientific documents	Δ Cluster	Cumulative Δ Cluster
before 1900-2012	4027	0	77
2001-2012	2072	22	77
1991-2012	3150	18	55
1981-2012	3676	13	37
1971-2012	3968	7	24
1965-2012	4004	5	17
before 1900-1965	29	0	12
1961-1965	21	12	12
1950-1965	29	0	0

The following Figures 6-14, 6-15, 6-16 and 6-17 report the result of analysis by Loglet with reference to the technological system: unsaturated polyester resin "injection".

In particular following information have been obtained:

• wavelets often overlap in time;

• "converging" bi-logistic, where a first wavelet is joined by a second faster, steeper wavelet:

- First pulse: Midpoint = 1972; Growth Time = 35,8;
- Second pulse: Midpoint = 1992; Growth Time = 7,7.

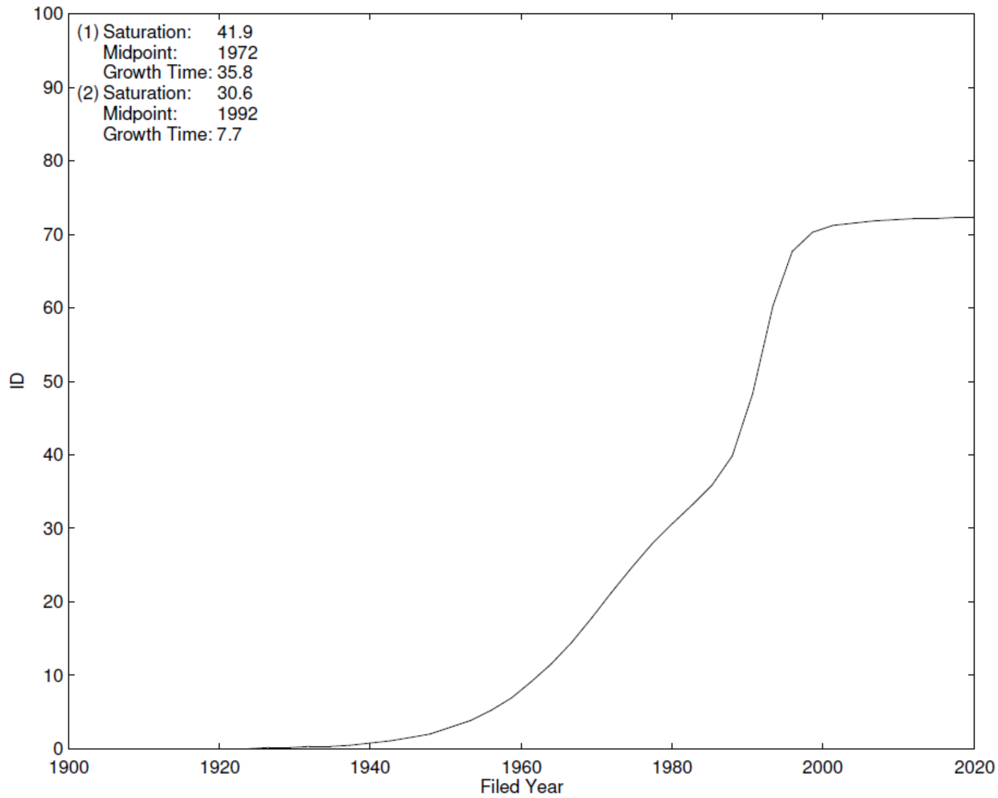


Figure 6-14: relative Δ Cluster's ID trend of "unsaturated polyester resin" injection ”.

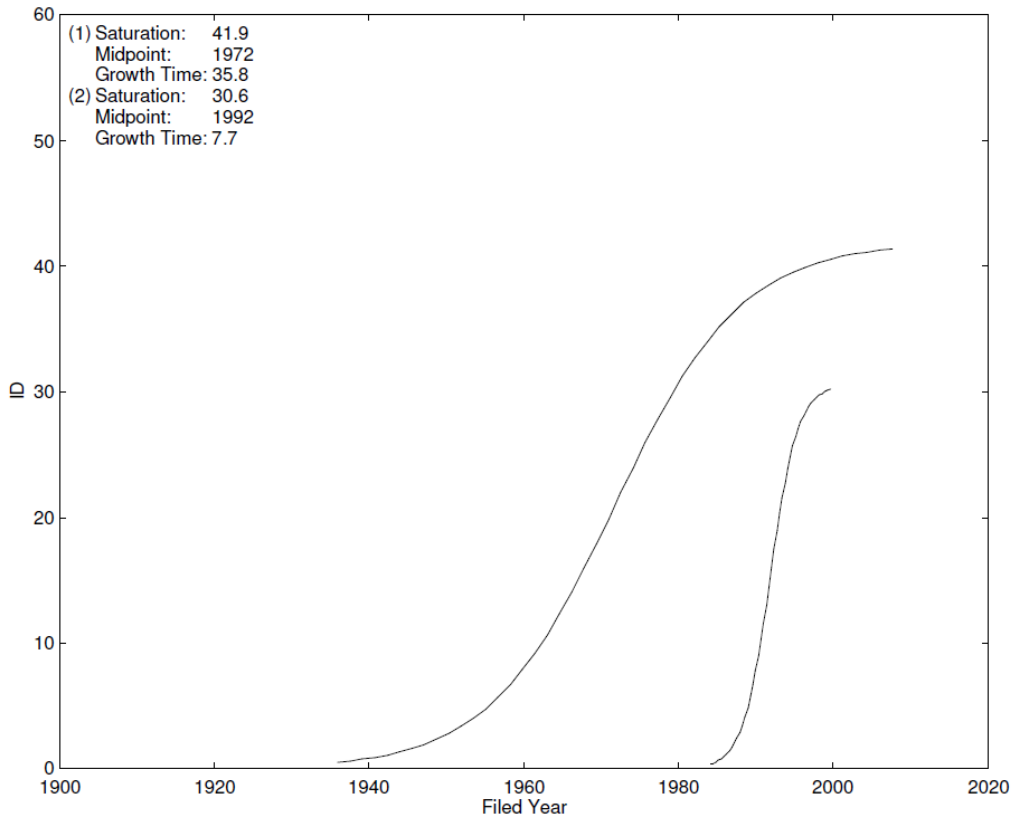


Figure 6-15: : S-shaped curves fitting ID trend of "unsaturated polyester resin" injection ”.

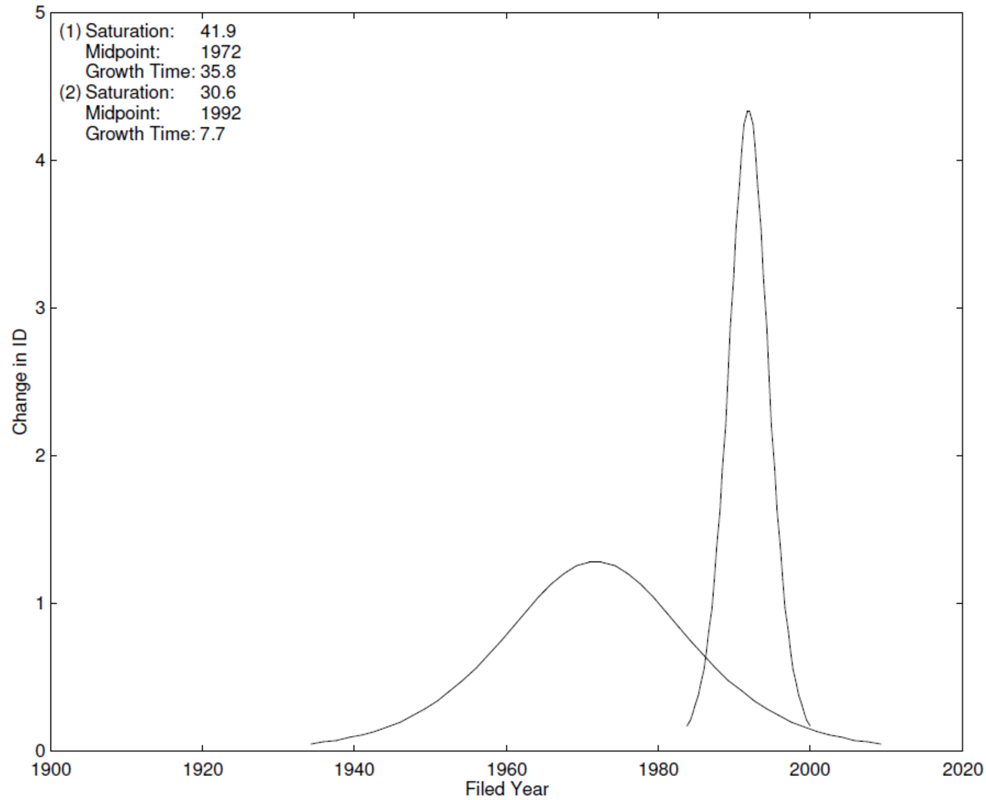


Figure 6-16: Bell-shaped curves fitting ID trend of "unsaturated polyester resin" injection ”.

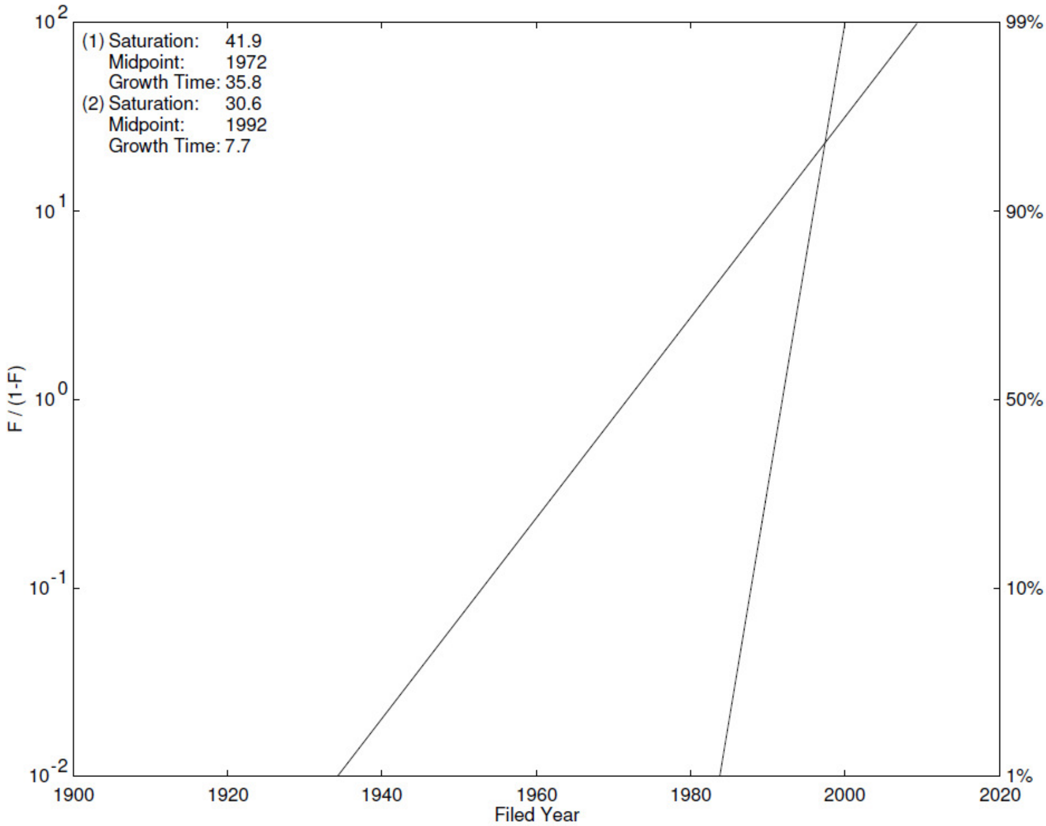


Figure 6-17: Fisher-Pry transform curves fitting ID trend of "unsaturated polyester resin" injection ”.

6.6 Conclusion

An analysis of the evolution trend of the technological system "speed reducer-planetary gear", evacuate according to let the opportunity of downsizing, miniaturizating and efficiency come up, enables defining a technical specification of an innovative FUTURE system (Figure 6-4), where the following key-words are present:

- *Epicyclic gear;*
- *Geared motor;*
- *Throttle valve.*

An actuator realized by means of the technology typical for an *Epicyclic gear* matches with the requirement of miniaturizating, as well as that of downsizing, thanks to a reduced number of components and to an output shaft ranging with an input shaft.

A Geared motor represents an actuator where the gearbox of the reducer is placed inside the housing of the motor or viceversa. The Gear Motor is ideally following the correct route which is bringing us to the *"direct drive"* conceipt, where the gearbox as well as any intermediate key-word disappears to leave place to a direct junction [Energizing source – end users].

A Throttle valve suggest a technological branch or a market segment, where the invention can place.

Two patents are examples of the above depicted evolutionary trend. One of them regards an example of direct drive; the other regards an hypocycloidal gear system.

BORNMANN GERD [DE]; SAUERSCHELL WOLFGANG [DE]; SCHOLTEN LUTZ [DE]; WIESE PETER [DE] (2002)'s patent relates about a direct drive for a throttle valve shaft in a throttle valve manifold comprising a coil and a rotor arranged directly adjacent to the coil. The rotor is made from a steel ring inside which a first inner magnetic shell and a second inner magnetic shell lie opposite each other. The steel ring has a first outer magnetic shell and a second outer magnetic shell lying opposite each other on the outside thereof. The steel ring is connected to the throttle valve shaft on the end thereof facing the throttle valve. A sensor for position recognition of the throttle valve is arranged in the middle of that region of the end of the steel ring facing away from the throttle valve.

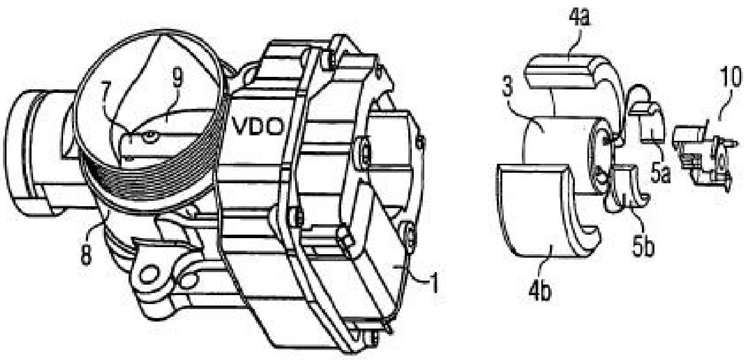


Figure 6-18: BORNMANN GERD [DE]; SAUERSCHELL WOLFGANG [DE]; SCHOLTEN LUTZ [DE]; WIESE PETER [DE] (2002)'s direct electromagnetic drive for a throttle valve shaft in a throttle valve connector (US Patent No. 7,100,568).

SCHMIDT WILLI [DE]; MOENCH JOCHEN [DE]; CETTIER DANIEL [DE] (2005)'s patent relates about a a gear mechanism (10), in particular for adjusting moveable parts in a motor vehicle, comprising a spur wheel (14) which is provided with external teeth (16) and meshes with an internal gear (18) that is provided with internal teeth (20), wherein the number of internal teeth (20) to generate a certain gear step-up ratio is greater by at least one than the number of external teeth (16) and the spur wheel (14) and the internal gear (18) perform an eccentric movement relative to one another, wherein the eccentric movement is directed exclusively by means of the matching tooth geometry of the internal and external teeth (20, 16).

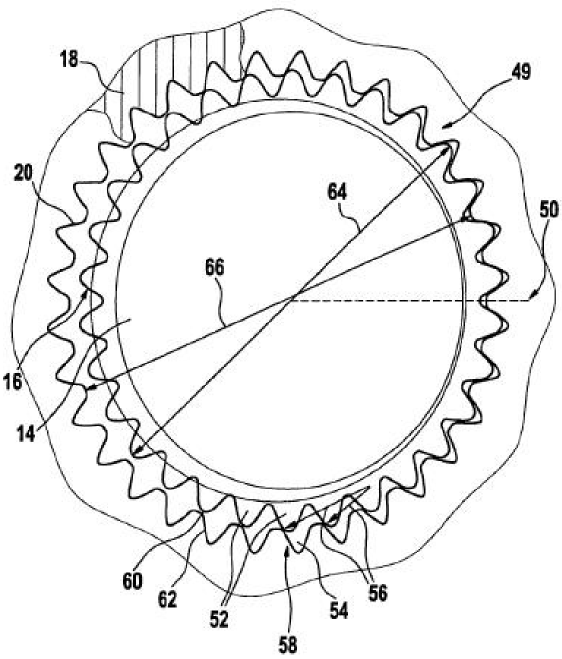


Figure 6-19: SCHMIDT WILLI [DE]; MOENCH JOCHEN [DE]; CETTIER DANIEL [DE] (2005)'s gear mechanism (US Patent No. 7,479,083).

The mathematical model referring to bi-logistic S-curves and deriving from the parameters which have been extrapolated from a set of Cumulative Δ Cluster shows a "converging" overlap of Wavelets in time (Figure 6-10 and Figure 6-13), where a first, traditional, technology is joined by a second faster, new technology, that is adopter of a technology, having learned from the experiences of an early adopter, will advance faster, resulting in a smaller Δt.

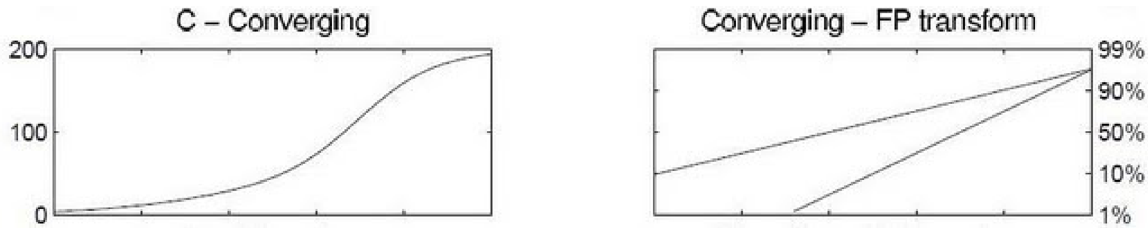


Figure 6-20: "converging" overlap of Wavelets in time.

The technical specification of the Throttle valve actuator complies with the requirements Downsizing and efficiency as defined in Chapter 7.

CHAPTER 7

Marketing of Technology

7.1 Introduction

This chapter reports the technical specification of a hypocycloidal gear transmission defined basing on the results of an investigation about the state of the art and the trend evolution of a product as developed in the previous chapter.

Topics of the investigation is a hypocycloidal gear trasnsmission specifically apt to running a butterfly or a throttle valve in the energetic branch as well as for gates or windows in the domotic branch.

The information mutuated from the state of the art as described in patents and in the academic documents allows to assimilate the typical questions of a hypocycloidal gear transmission and to focus the analysis upon new questions introduced by the new requirements: downsizing, miniaturization and efficiency.

Paragraph 7.2, paragraph 7.3 and paragraph 7.4 describe the system underlining the technical performances according to design criteria.

Paragraph 7.5 outlines a problem regarding the lateral sliding – off of the toothed wheels due to the bending moment driven by the load on the foothold teeth. We have omitted the solution of such an inventiveness problem, reached among others by means of a model developed according to the method of solution of contradictions ARIZ 85. This without diminishing the meaning of the present chapter.

A patent application regarding a solution for the lateral sliding-off of the toothed wheels is completing the necessary steps for introducing a new range of hypocycloidal gear transmission.

Paragraph 7.6 regards the realization of two prototypes.

7.2 Development of a Hypocycloidal Gear Transmission

A device called the *Hypocycloidal Gear Transmission (HGT)* is proposed. The HGT can be regarded as a epicyclic drive train; instead of 'arm or carrier" the HGT employs a kinematically equivalent *eccentric shaft* [Park, 2005]. Also, instead of having multiple planet gears, the HGT employs a single, dual stage planet gear that has a small tooth number difference with a stationary internal gear and a rotating output internal ring gear respectively.

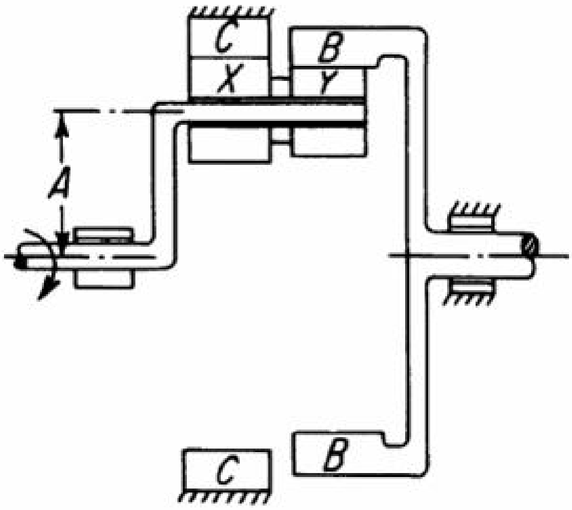


Figure 7-1: Simple four-gear differential gear transmission [Park, 2005].

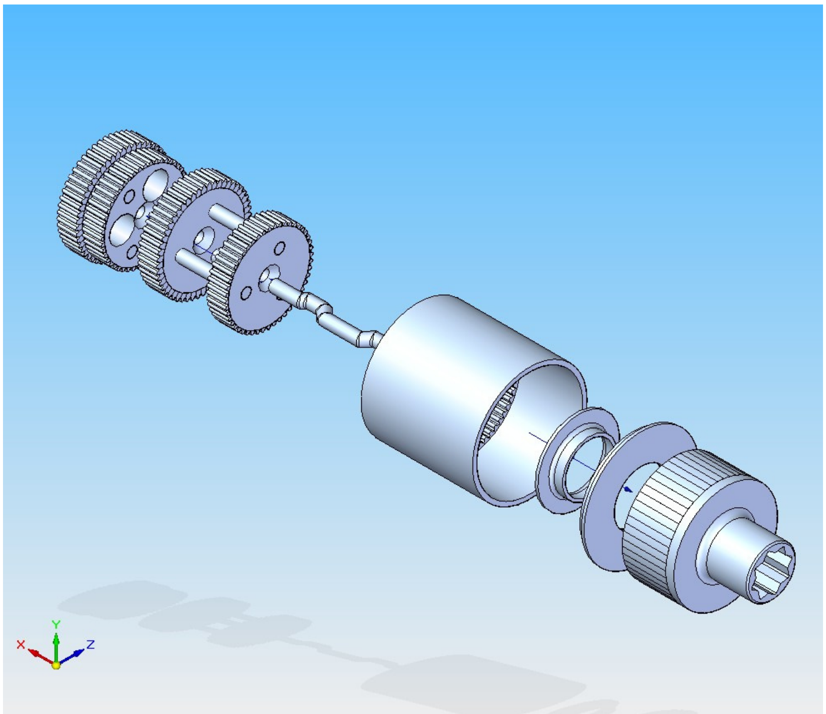


Figure 7-2: Expanded view of the HGT.

Figure 7-2 shows an expanded view of a typical HGT assembly. It is basically composed of an eccentric shaft with eventually balancing mass, wobble gear, stationary internal gear (shown as fixed ring gear), and output internal gear (shown as output ring gear). The operating principle is as follows. The eccentric shaft is connected to the motor input and drives the wobble gear against the stationary internal gear. The small eccentricity of the shaft makes the wobble gear generate the hypocycloidal motion; the wobble gear rotates not only about its own axis but also about the axis of the gear train inside the two internal gears. This motion causes tooth number differencing between the two internal gears and thus relative motion.

The simplicity in design and minimal number of parts make the HGT easy to assemble and reduces the negative effects on gear contact due to the stack up of manufacturing errors. The configuration of the HGT inherently allows for the widest range of reduction ratio, i.e., from 50:1 to 5,000:1, and exceptional torque density (torque to weight/volume ratio). In combination with carefully designed tooth profiles, the HGT is designed to provide high stiffness, low power loss, nearly zero backlash and lost motion, and smooth and quiet operation.

7.3 Actuator Prototypes Utilizing the HGT

7.3.1 Quarter-turn actuators HGT

The concept of the EM actuators using the HGT can be used on fluid valves switching applications.

Table 7-1 summarizes the primary requirements for a quarter-turn actuator model. This set of requirements derives by same purchasers of valves industry.

Table 7-1: Requirements for the ¼-turn Actuator prototype

Output Torque	Nominal 25,00 Nm
time 1/4 giro	6 sec
Input Speed	2800 rpm
Operating Temperature	-40°C to +40°C
Available Power	320 VAC, 3 Phase, 50 Hz,
	no limit on current
Life	3 Years
Efficiency	Maximized
Component Operating Stress	< 35% Yield Strength

Component Stall Stress	< 70% Yield Strength
Component Shock Stress	< 100 % Ultimate Strength

7.3.2 *Gates automation HGT*

Another actuator prototype has been fabricated and set up for tests. A domotics actuator prototype is designed for use in the gates, windows and curtains automation, domotics in general etc.

Table 7-2: Key requirements for the Domotics prototype.

Output Torque	Peak 37,50 Nm
	Nominal 25,00 Nm
Output Speed	17 rpm
Input Speed	2800 rpm
Operating Temperature	-40°C to +40°C
Available Power	320 VAC, 3 Phase, 50 Hz,
	no limit on current
Life	5 Years
Efficiency	Maximized
Component Operating Stress	< 35% Yield Strength
Component Stall Stress	< 70% Yield Strength
Component Shock Stress	< 100 % Ultimate Strength

The pressure angle is minimized (0º at the pitch point) in the boths actuators. This amount of reduction in the pressure angle means a reduction of the normal bearing load for the same tangential load on the gear. Reduction in bearing load is very important especially in this kind of eccentricity-driven system.

The size of the eccentricity is minimized. The ratio of the eccentricity to the wobble gear pitch diameter, reduced to 4.08 % (¼-turn) to 5,80 % (Domotics), is an effort to reduce the weight and inertia of the HGT.

The use of circular-arc tooth profiles reduces the sliding velocities and surface stresses, and would lead to substantial cost savings as compared to conventional gear teeth.

The proposed design regards a dual-stage gear reducer that permitts an extremely high torque capacity due to unusually high tooth contact ratios. It also features favorable zero-degree pressure angle at the pitch point by generating circular tooth profiles.

7.4 Design Criteria

7.4.1 Reduction Ratio

The reduction ratio equation of the HGT can be derived by a velocity vector analysis as normally done for a general epicyclic gear train.

$$TR = \frac{N1' N2}{N2' N1 - N1' N2} \qquad (7.1)$$

where: N1 = number of teeth of the first stage internal gear;

N1' = number of teeth of the first stage wobble gear;

N2 = number of teeth of the second stage output ring gear;

N2 ' = number of teeth of the second stage wobble gear.

If a TR calculated from Equation (7.1) is positive, the direction of the input and output rotation is opposite to each other. If it is negative, the direction of the input and output rotation is the same. For example, the ¼-Turn Actuator HGT has an output rotational velocity opposite to the rotational velocity of the input, while the Domotics Actuator HGT has the same rotational direction for both input and output velocities (Table 7-3).

Table 7-3: Transmission ratio of the HGT prototypes.

Prototype	**¼-turn Actuator HGT**	**Domotics Actuator HGT**
N1	98	69
N1'	90	61
N2	99	66
N2'	91	58
TR	1113,75	-167,75
Input-Output Direction	Opposite	Same

7.5 Loaded lateral side contact analysis

The main objective of this paragraph is to perform loaded lateral sides contact analysis for evaluation of the actual contact ratio under load and the load sharing factor of the HGT.

The HGT has very small clearances between working profiles of the tooth pairs near the path of contact. When load is applied to the HGT, elastic deformations will occur at the contacting tooth pairs. Then, these deformations will cause further rotational displacement of the wobble gear, and thus close the small clearances of the tooth pairs when the deflections are larger than the clearances. As an increasing load is transmitted through closed contacts, another clearance at the next tooth contact will disappear and so on. Thus, in general, minimizing the clearances between mating tooth pairs increases the chance of having a higher contact ratio.

Under this circumstances a lateral sliding-off load is generated, which tends to warp the tooth in a non –homogenous way in its largeness and to stress the input shaft. The stress on the input shaft has been studied in order to find a suitable solution for reducing or nullifying the sliding-off load driven on the eccentric- or crankshaft.

A simulation of the stress driven on the input shaft has been carried out by means of a Finite Element Anlysis.

Finite Element Analysis (FEA) ha been performed using ALGOR/FEMPRO V23SP2 - Build 23.00.02.0005 21-JAN-2009, for the loaded lateral sides contact simulation of the HGT. A complete analysis consists of three main steps: preprocessing, simulation, and postprocessing. The preprocessing step defines the physical model and creates a ALGOR input file (*.fem). In this research models have been created using SolidEdge, and then imported to ALGOR. The simulation step solves the numerical problem defined in the preprocessing step. The post-processing step shows and evaluates the results of the simulation .

An analysis model requires the following information: material data (general, mechanical, thermal, etc.), mesh geometry (element type, shape, order, section property, density, and number of nodes and their coordinates), analysis steps and substeps (increments), loads and boundary conditions, analysis type (static, dynamic, etc.), and output request (data of interest).

Two configurations have been analyzed through a FEA model:

- In the absence of a distance ring (Figure 7-3);
- With a distance ring (Figure 7-4).

7.5.1 Static Stress with Linear Material Models

Acceleration Due To Body Force = 9814.56 mm/s²

Acceleration/Gravity X Multiplier	Acceleration/Gravity Y Multiplier	Acceleration/Gravity Z Multiplier
0	0	-1

Information material:

Brass

Material Model	Standard
Material Source	ALGOR Material Library
Material Source File	C:\Programmi\ALGOR\23.00\matlibs\algormat.mlb
Date Last Updated	2004/09/30-16:00:00
Material Description	Cold-rolled 85% Cu, 15% Zn
Mass Density	0.0000000087418 N·s²/mm/mm³
Modulo di elasticità	117210 N/mm²
Coefficiente di Poisson	0.33
Modulo di elasticità al taglio	44126 N/mm²
Coefficiente termico di espansione	0.00001872 1/°C

ASTM 897 Grade 1 (125-80-10), Austempered Ductile Iron -Solido 3D

Material Model	Standard
Material Source	ALGOR Material Library
Material Source File	C:\Programmi\ALGOR\23.00\matlibs\algormat.mlb
Date Last Updated	2004/10/28-16:02:00
Material Description	None
Mass Density	0.0000000070965 N·s²/mm/mm³

Modulo di elasticità	163000 N/mm²
Coefficiente di Poisson	0.25
Modulo di elasticità al taglio	65100 N/mm²
Coefficiente termico di espansione	1.460000E-005 1/°C

FEA Object Group 7: Nodal Forces

Nodal Force

Vertex ID	Node Number	Magnitude	Vx	Vy	Vz	Multiplier Table ID
1451	203	-3500,00	0,00	0,00	1,00	1

FEA Object Group 8: Nodal Forces

Nodal Force

Vertex ID	Node Number	Magnitude	Vx	Vy	Vz	Multiplier Table ID
1526	278	-3500,00	0,00	0,00	1,00	1

FEA Object Group 9: Nodal Forces

Nodal Force

Vertex ID	Node Number	Magnitude	Vx	Vy	Vz	Multiplier Table ID
1908	660	3500,00	0,00	0,00	1,00	1

FEA Object Group 10: Nodal Forces

Nodal Force

Vertex ID	Node Number	Magnitude	Vx	Vy	Vz	Multiplier Table ID
1837	589	3500,00	0,00	0,00	1,0	1

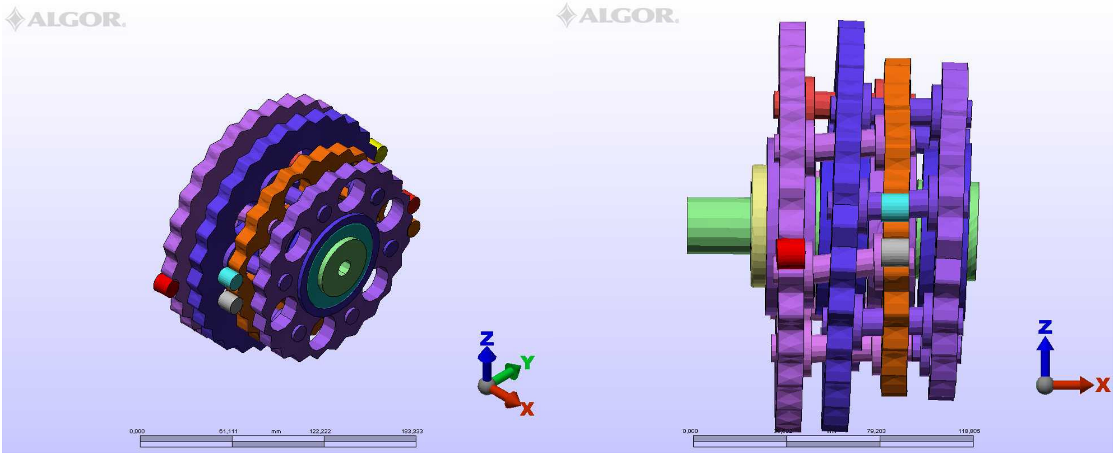


Figure 7-3: constrained model of first and second stage HGT without stabilizing ring.

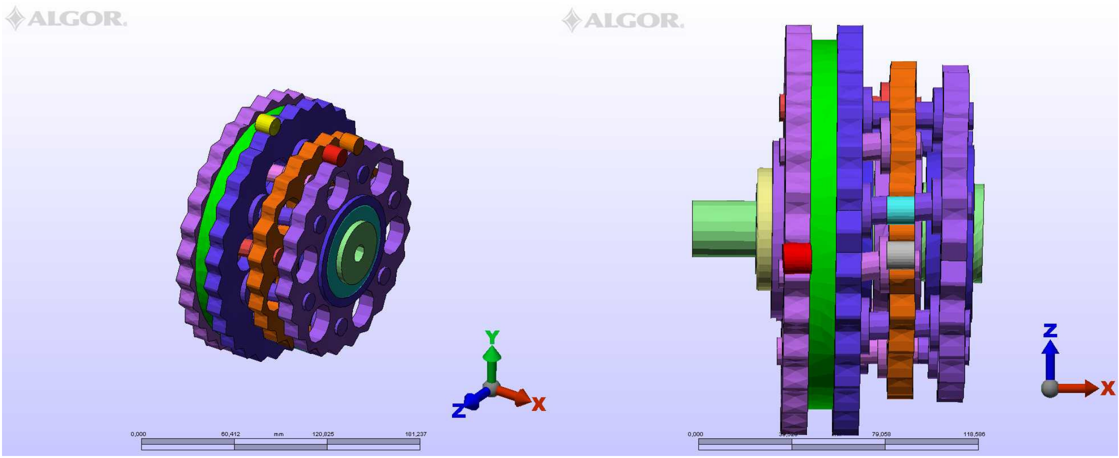
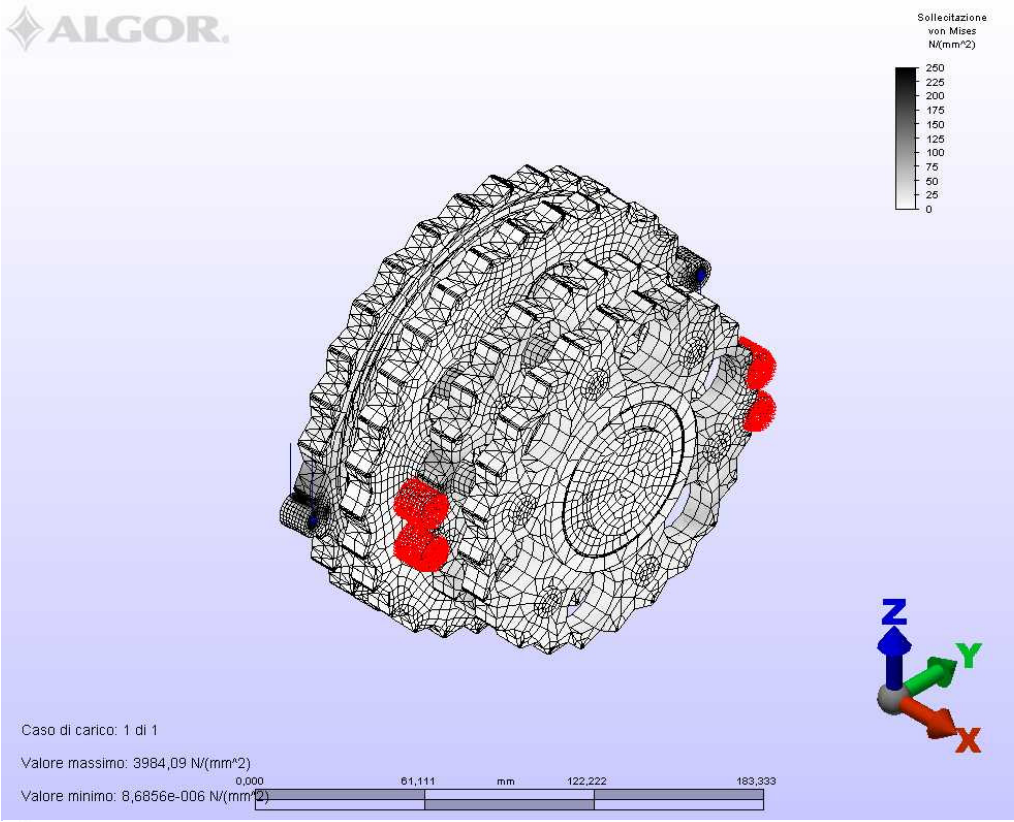


Figure 7-4: constrained model of first and second stage HGT with stabilizing ring.

Results

Figure 7-5 and following up to Figure 7-8 show the distribution of Von Mises stress and displacement of a constrained model of first and second stage HGT without stabilizing ring .

Figure 7-9 and following up to Figure 7-12 show the distribution of Von Mises stress and displacement of a constrained model of first and second stage HGT with stabilizing ring.



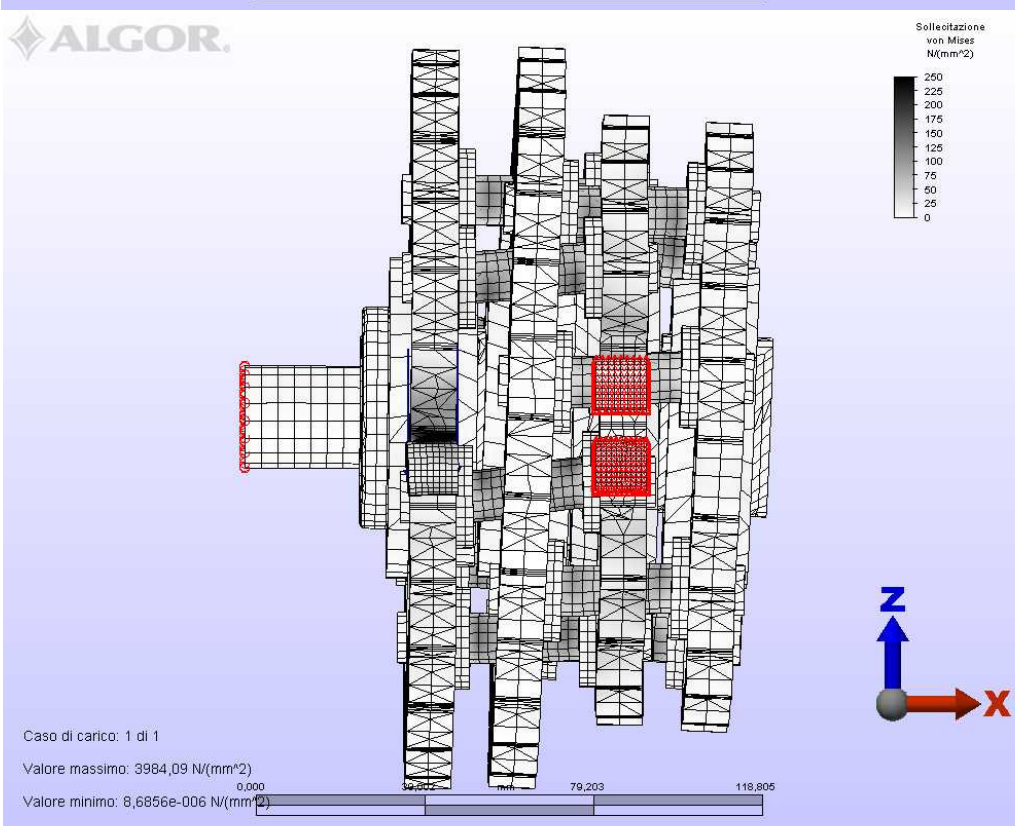


Figure 7-5, Figure 7-6: Von Mises stress distribution results of constrained model of first and second stage HGT without stabilizing ring.

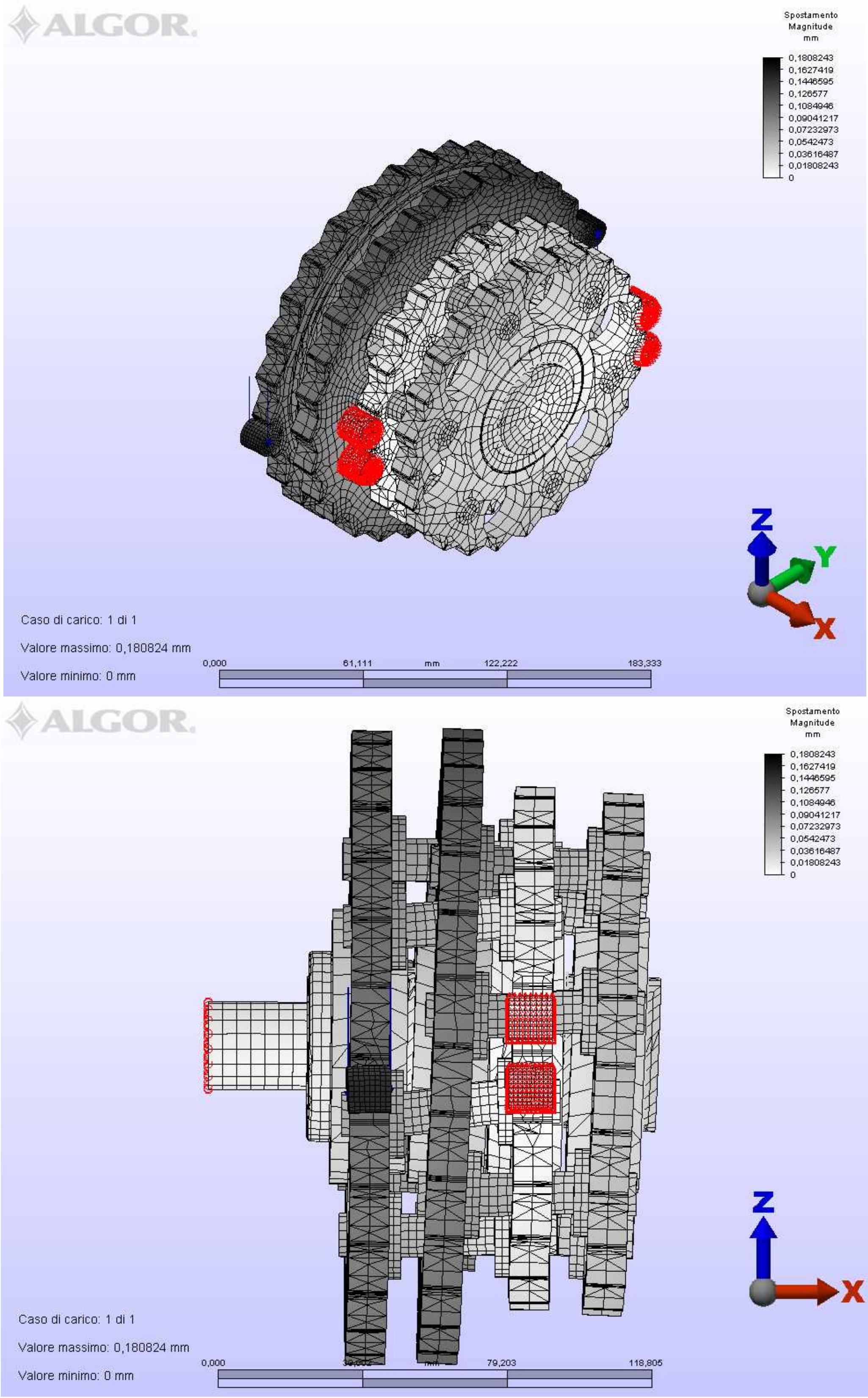


Figure 7-7, Figure 7-8: Displacement distribution results of constrained model of first and second stage HGT without stabilizing ring.

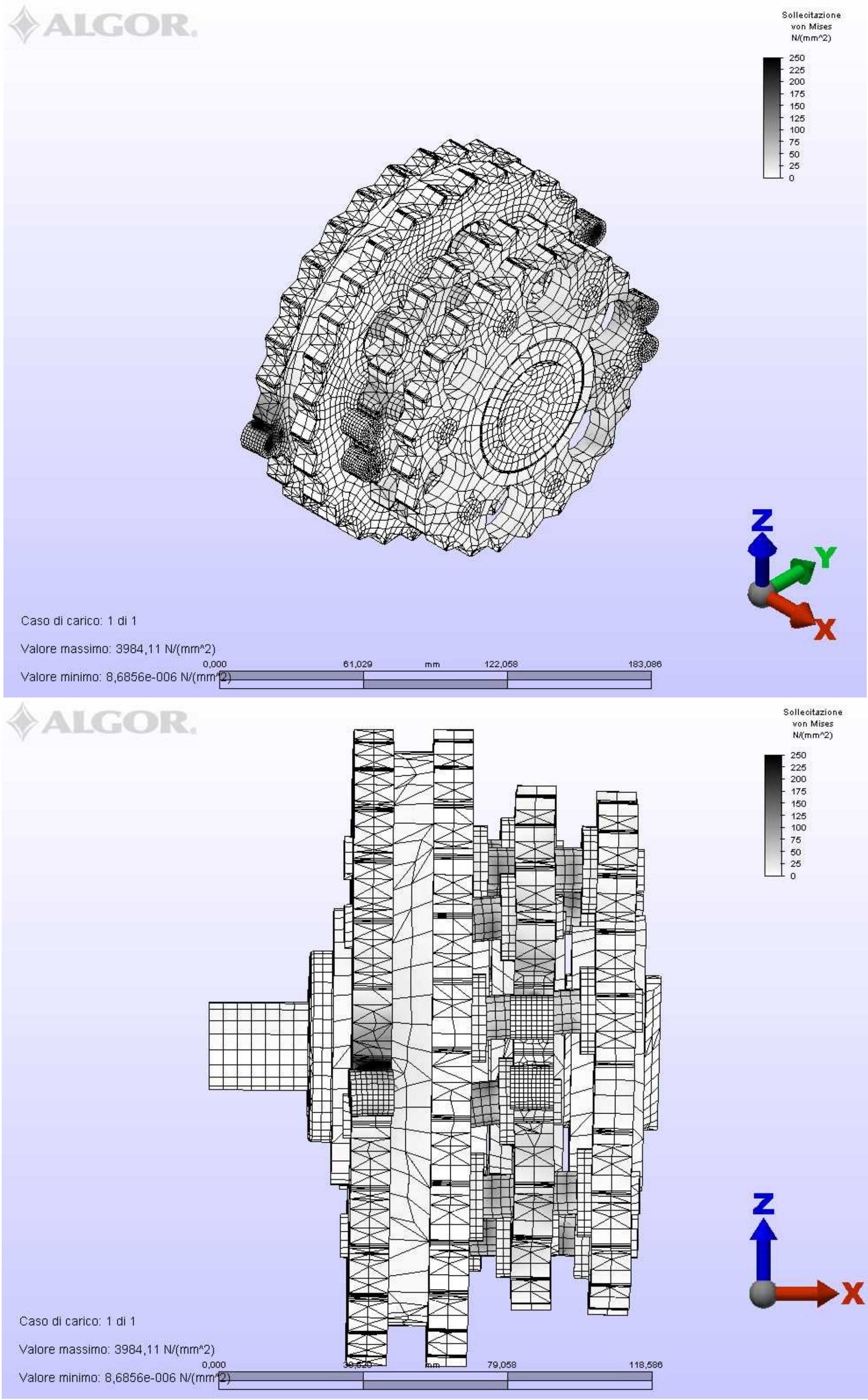
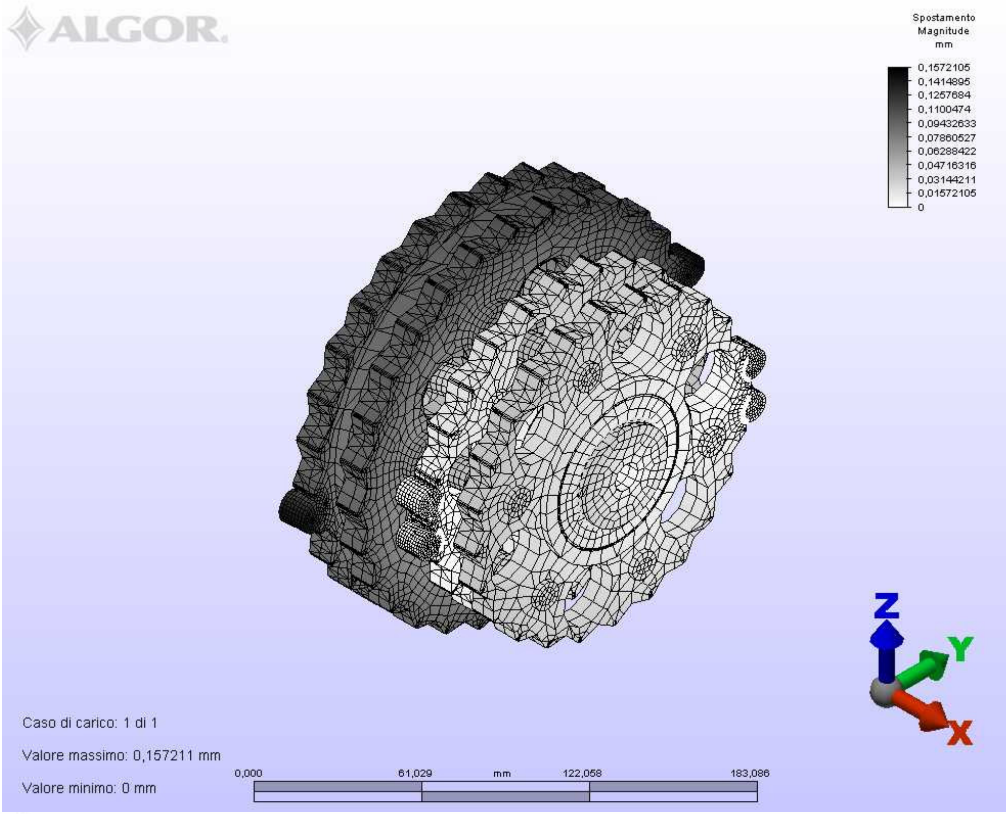


Figure 7-9, Figure 7-10: Von Mises stress distribution results of constrained model of first and second stage HGT with stabilizing ring.



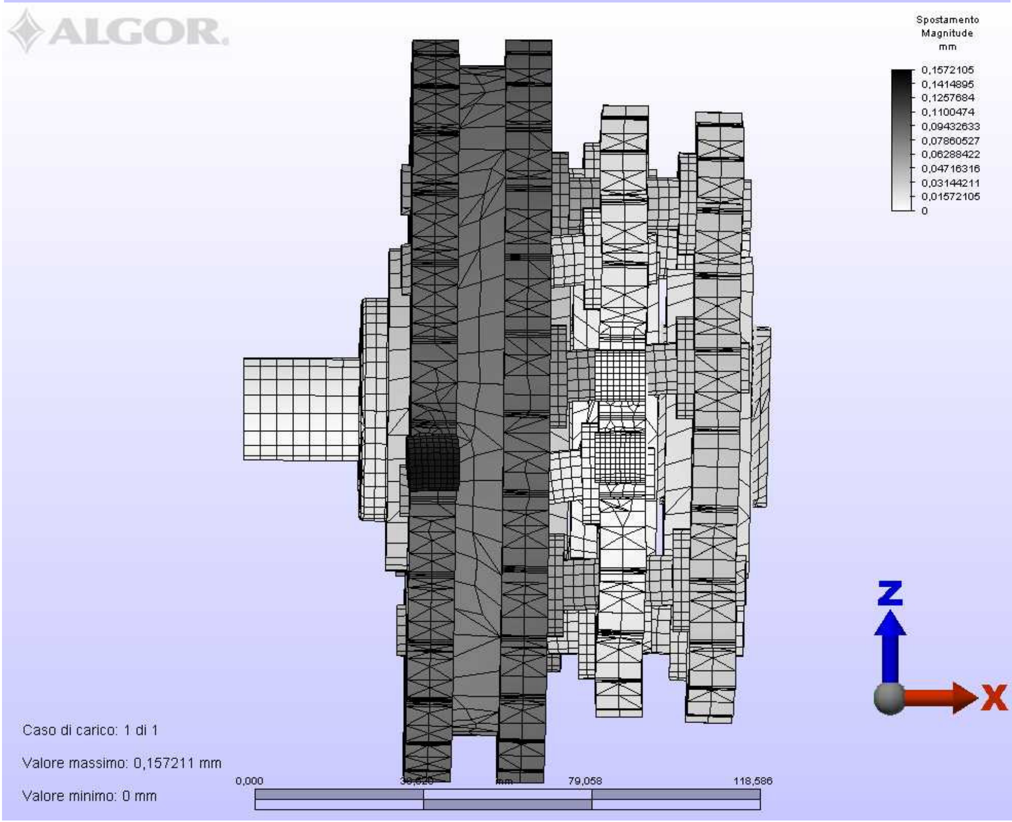


Figure 7-11, Figure 7-12: Displacement distribution results of constrained model of first and second stage HGT with stabilizing ring.

7.6 Fabrication of prototypes

7.6.1 Quarter-turn actuator HGT

This quarter-turn actuator for fluid valves application uses the HGT as a principal component. Figure 7-13 shows the expanded view of the ¼-turn Actuator. The stationary internal gear (attached to the inside actuator shell), eccentric shaft, wobble gears, output internal gears, and bearings (sliding bearings) compose the HGT assembly. The ¼-turn Actuator HGT is designed to be effectively backdrivable.

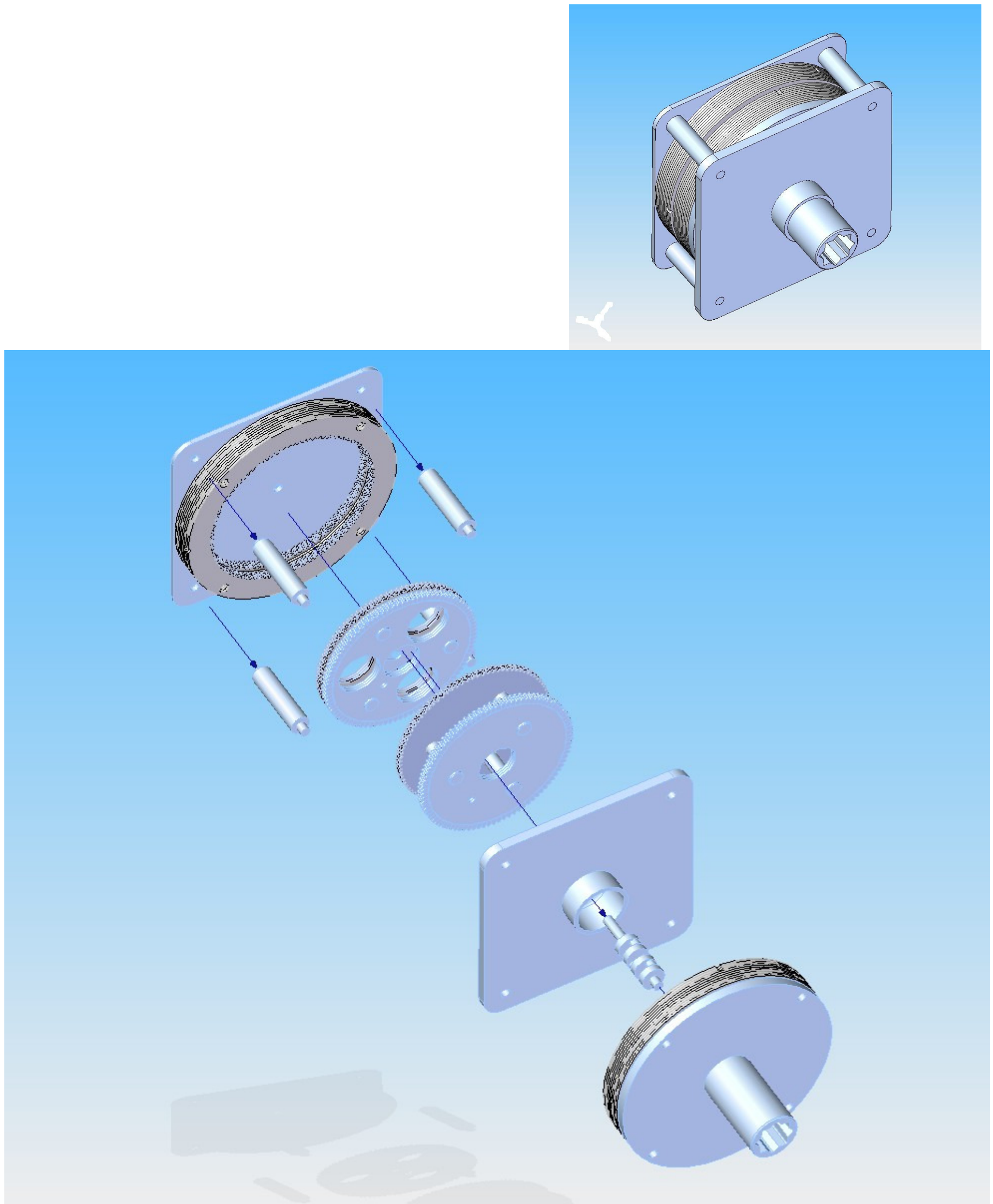


Figure 7-13: Expanded view of the ¼-turn Actuator.

Since the gears in the HGT use circular-arc profiles that require non-standard manufacturing methods, the processing of the gear teeth represents one of the challenging aspects of the fabrication. The gear blanks were not manufactured out of AISI 8620 H bearing grade steel. The circular-arc teeth of the all three gears were generated by CO2 Laser Cutting, and not carburized and not hardened. The CO2 Laser Cutting not only exhibits very high accuracy level but also can cut very small radius contours whose diameters are as low as a few tenth of a millimeter (which is desirable for cutting root fillets of fine teeth).

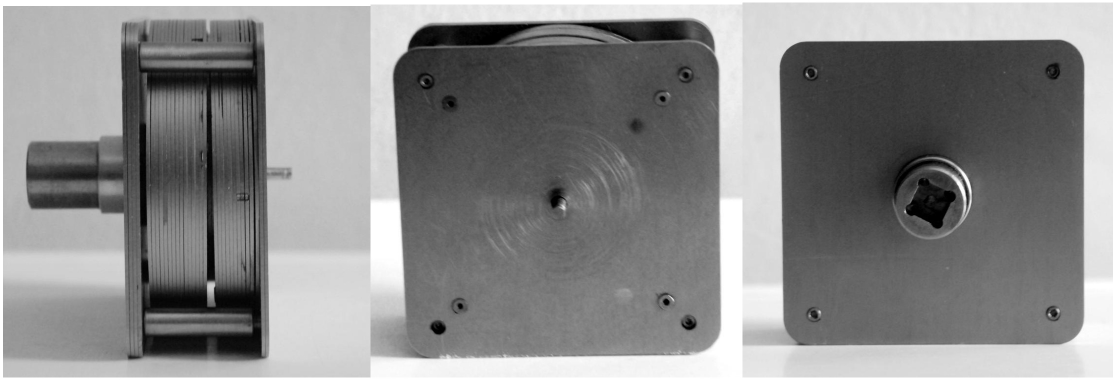


Figure 7-14: Whole assembly of the ¼-turn Actuator.

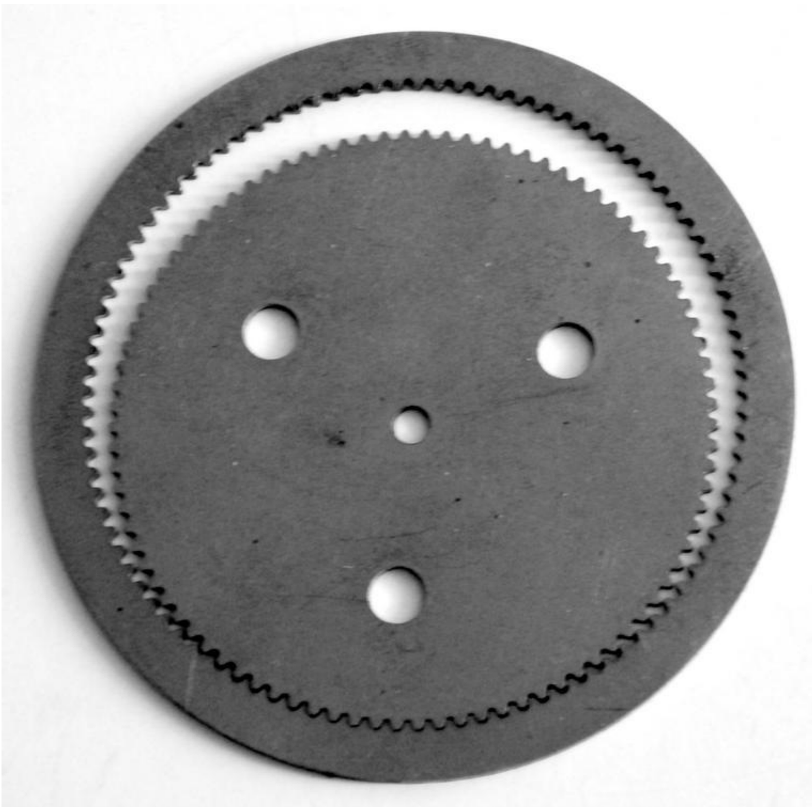


Figure 7-15: Assembly of wobble gear/output internal gear for the ¼-turn Actuator.

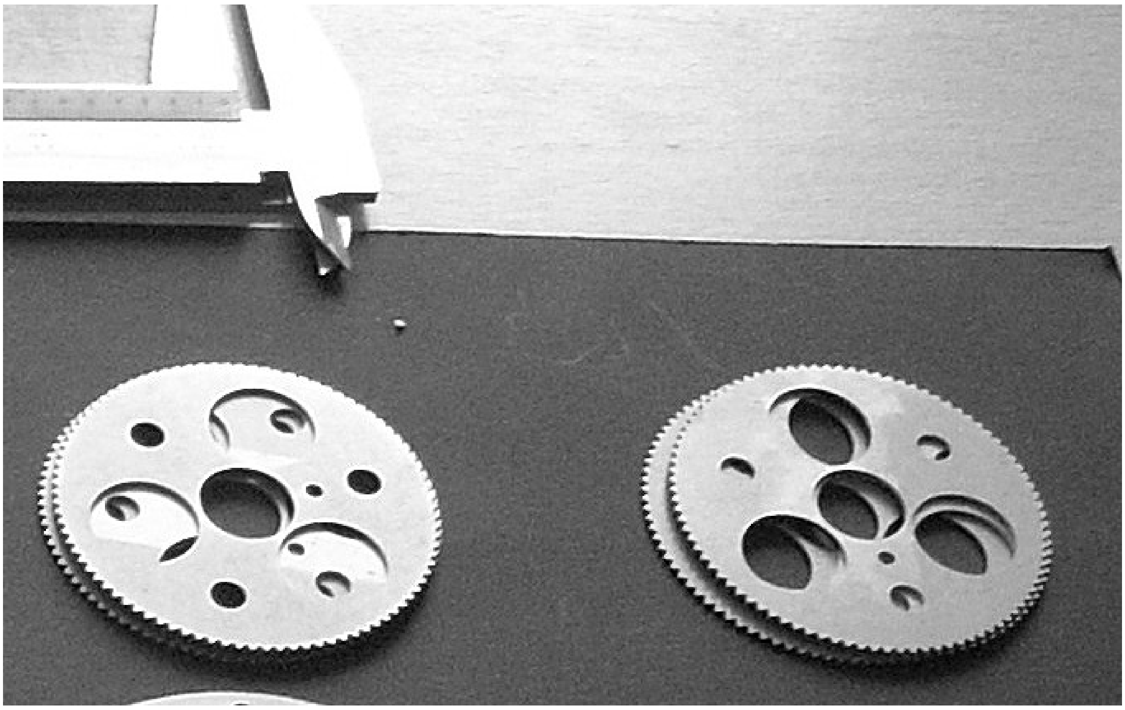


Figure 7-16: Cut components of a set of input and output wobble gears for the ¼-turn Actuator.

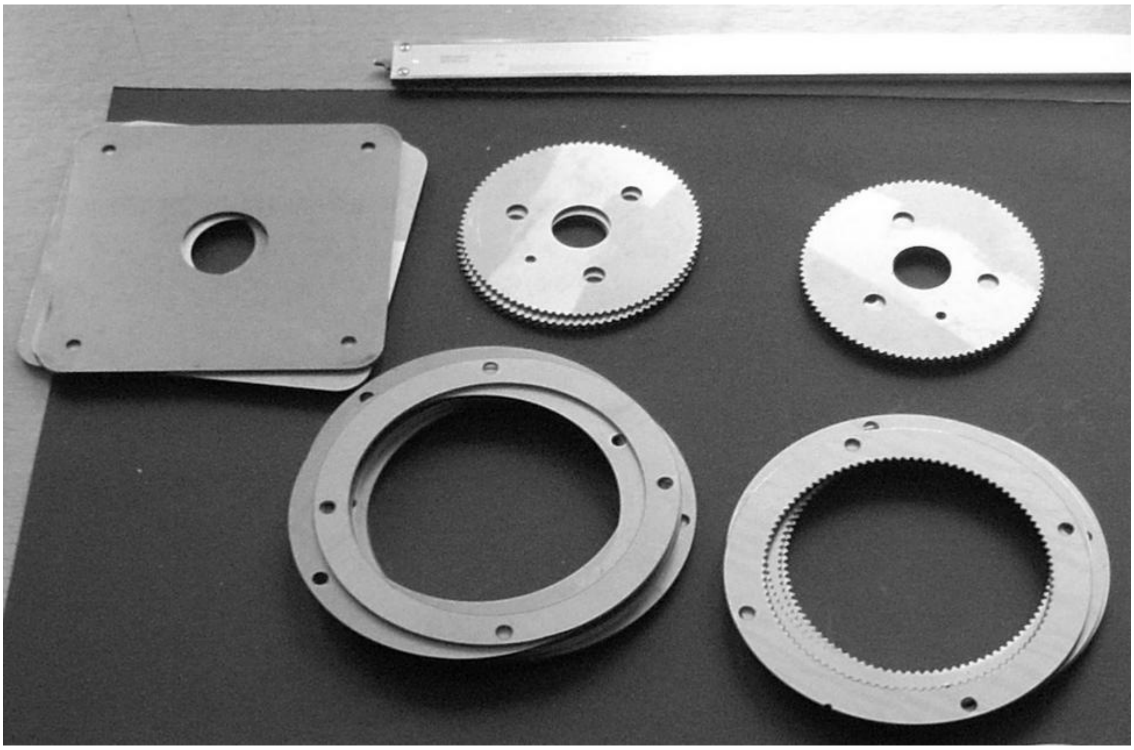


Figure 7-17: Cut components of another set of input and output wobble gears, internal gears and spacers for the ¼-turn Actuator.

7.6.2 Domotics actuator HGT

This Domotics actuator for moving of windows, gates and curtains application used the HGT as a principal component. Figure 7-18 shows the expanded view of the Domotics Actuator. The stationary internal gear (attached to the inside actuator shell), eccentric shaft, wobble gears, output internal gears, and bearings (sliding bearings) compose the HGT assembly. The Domotics Actuator HGT has been designed to be effectively back-drivable. A stereolithography prototype has been realized.

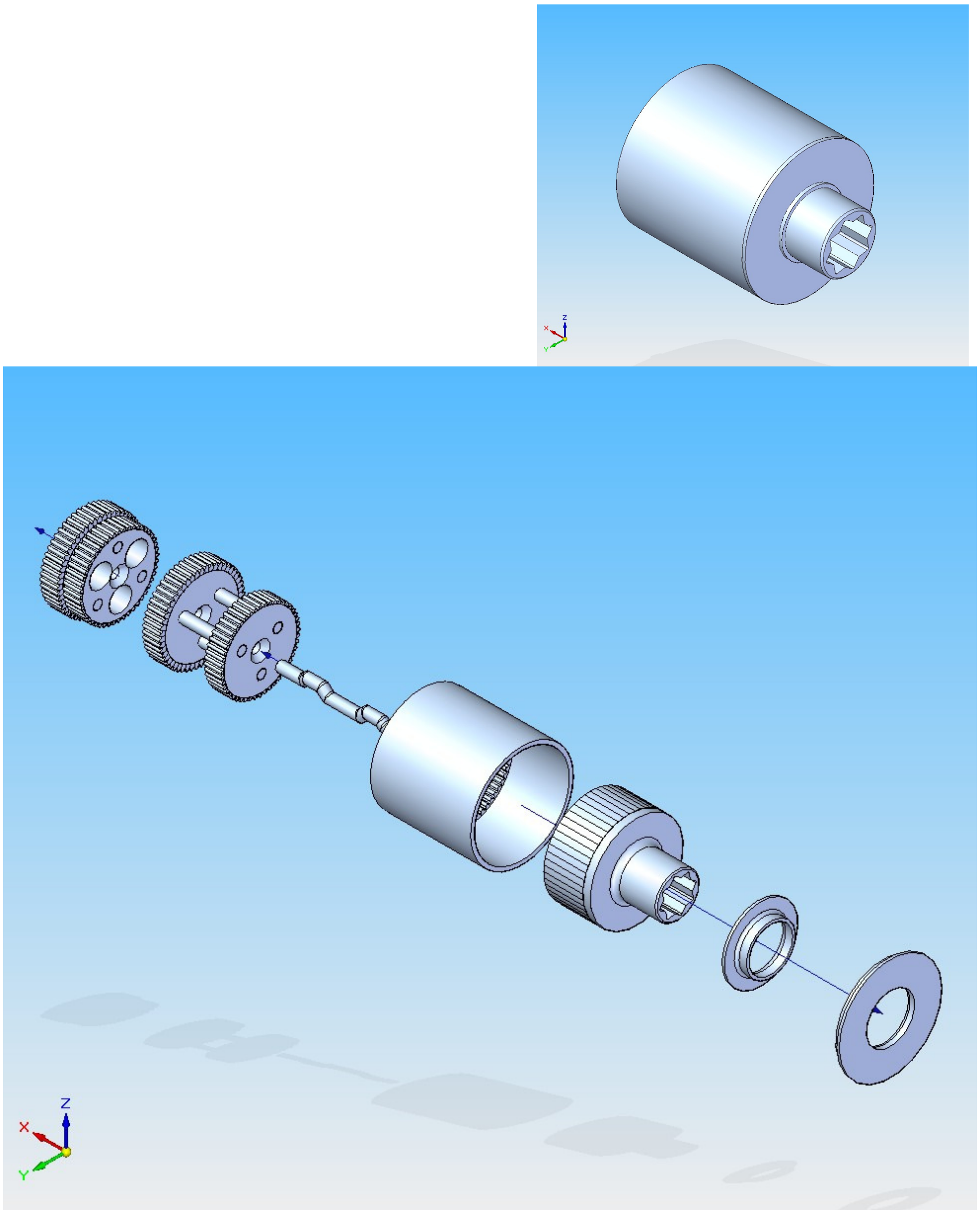


Figure 7-18: Expanded view of the Domotics Actuator.

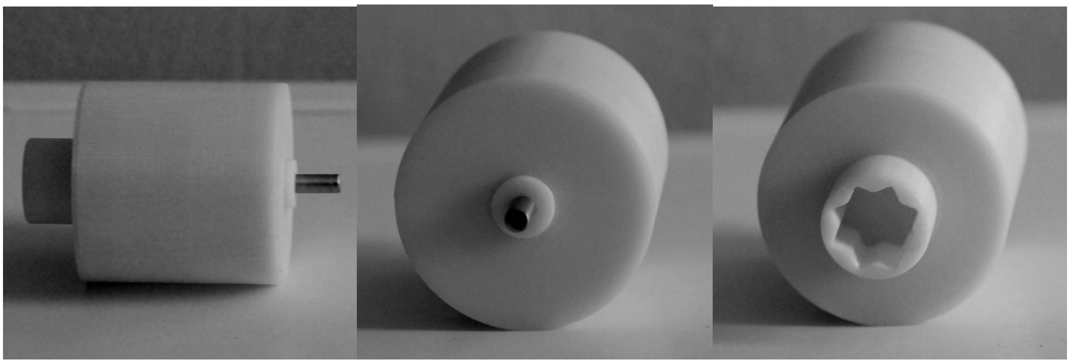


Figure 7-19: Whole assembly of the Domotics Actuator.

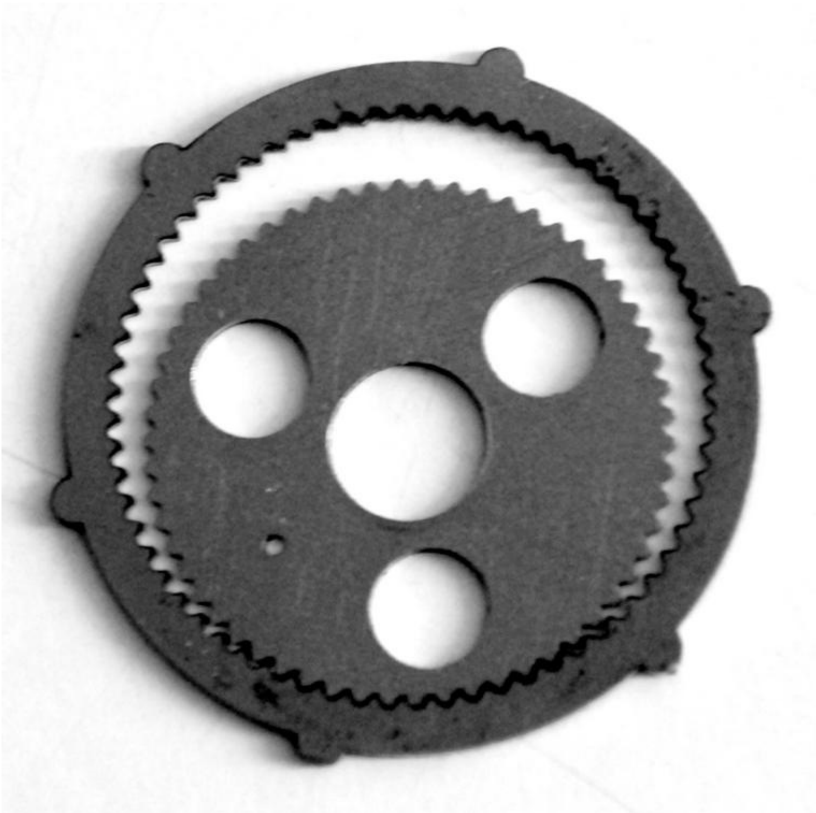


Figure 7-20: Assembly of wobble gear/output internal gear for the Domotics Actuator.

CHAPTER 8

Conclusion

8.1 Introduction

This dissertation has been generated out of a deep passion towards technological evolution and approaching solutions to inventive problems. Seminars given at the Museo Leonardo da Vinci, planned by Apeiron-Triz Association, have been of a fundamental importance in this respect:

- TOP-TRIZ Seminar. June 26-30, 2009. Lecturer: Zinovy Royzen.
- Technology Forecasting Seminar. June 26-29, 2008. Lecturer: Dmitry Kucharavy.
- OTSM-TRIZ Seminar. Mars 24-28, 2007. Lecturer: Nikolai Khomenko.

While introducing my paper, Technological Route between Pionerism and Improvement, 2008 TRZI-Future Conference - planned by The European TRZI Association, University of Twente, Enschede, (NL), Dr.– Eng., Ph.D., P.E. Sergei Ikovenko considered as limited if not really wrong a forecasting technological analysis purely based on a patent classification according to the International Patent Classification (IPC).

The same year, Prof. Davide Russo of the University of Bergamo, suggested I could develop a study regarding clustering.

Thanks to the spurs from the TRIZ Community as well as from the academic Community we have been able to develop and apply a new set of tools aiming at product innovation. The features described in the present dissertation are summed up.

8.2 Targets

In the most recent years the market has requested an increasig number of search engines more and more specialized in comparing different set of documents which are not in a sintagmatic relationship but in a paradigmatic one in order to discriminate those elements which clearly define the state of evolution of a product, which is actually contained in the state of the art as described by patents, but is not explicitated in the patents themselves.

In other words the market has been asking for methods apt to classify documents and based on the definition of a common Technical Value of Patents and Scientific-Publications in order to test the opportunity of defining technologies, which even if originated in a Branch A could be translated in a Branch B or C etc., this offering market available solutions.

8.3 Development

First step has been investigating the state of the art of the search engines able to organize and classify both types of documents, patents and scientific documents, by discirminating them temporarely.

The state of the art showed an easy applyable search engine, available for free in the web: Scirus.

Scirus has proved to be the only search engine able to offer an opportunity to analyse both patent-collections and scientific publications, while investigations can be diversified within specific temporal ranges. This latter feature is widely used in the project illustrated in this dissertation. Therefore great enphasis is laid upon this search engine.

Said method employs Scirus and allows to contextualize a technological system by means of a sequence of queries which are built through a horizontally-structured comparison of clusters within a scientific web-collection, which has been previously split in two sets of documents: patent documents and scientific publications. At the same time the comparison is also vertically structured according to different temporal ranges, so that we get a 4-field table (Figure 4-2): F1+F2 above, F3+F4 under, where F1+F3 contain patents, F2+F4 contains publications. F1+F2 are horizontally compared by key-words, as well as F3+F4. F1+F3 as well as F2+F4 are vertically compared according to their timeline. This method can define a technological system which can be contextualized in a different environment such as the market.

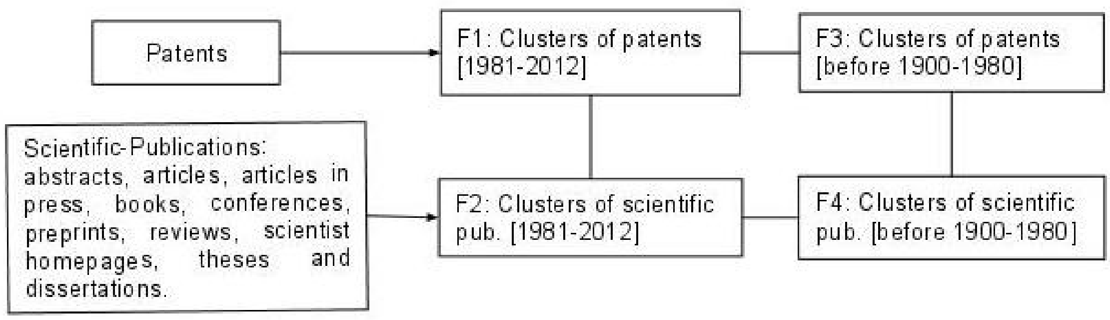


Figure 4-2: horizontally-vertically structured comparison of clusters within a scientific web-collection.

We can define this method as Non–expertee oriented. In fact, operators are not supposed to be expertee in the field key words and clusters refer to, because these are sorted automatically. Actually, the first query is nothing but the title of the topic we want to investigate and the definition of at least one subsequent query does not imply any subjective choice but is performed automatically.

A second level query includes key-words with a rating R calculated while analyzing the structure of clusters. A rating R represents the involvement level of each of the four cluster structures containing all major data necessary to describe a technological system.

Specifically, an analysis of a technological system by means of Scirus let us automatically recall subsequent clusters depending on structures of previous clusters. This makes Scirus apt to define a technological system objectively, applying subjective discriminations in high level queries, only (at least starting from the second level).

At the end of the last query, new clusters have been retrieved by the search engine. They can now be entered in a 9-screen-diagram, which is a tool for performing forecasting analysis and define innovation and technological diffusion.

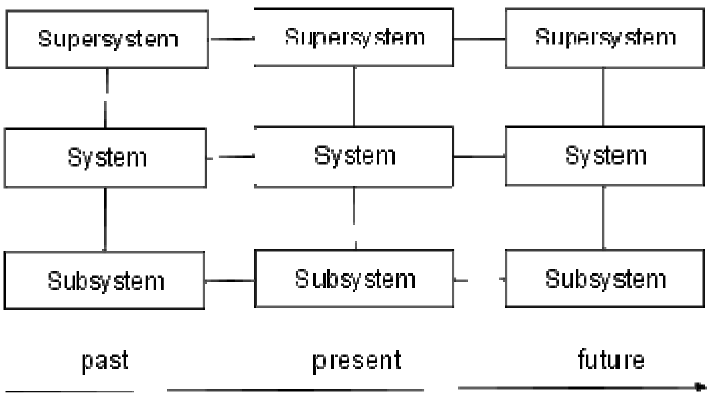


Figure 5-1: 9-screen system operator.

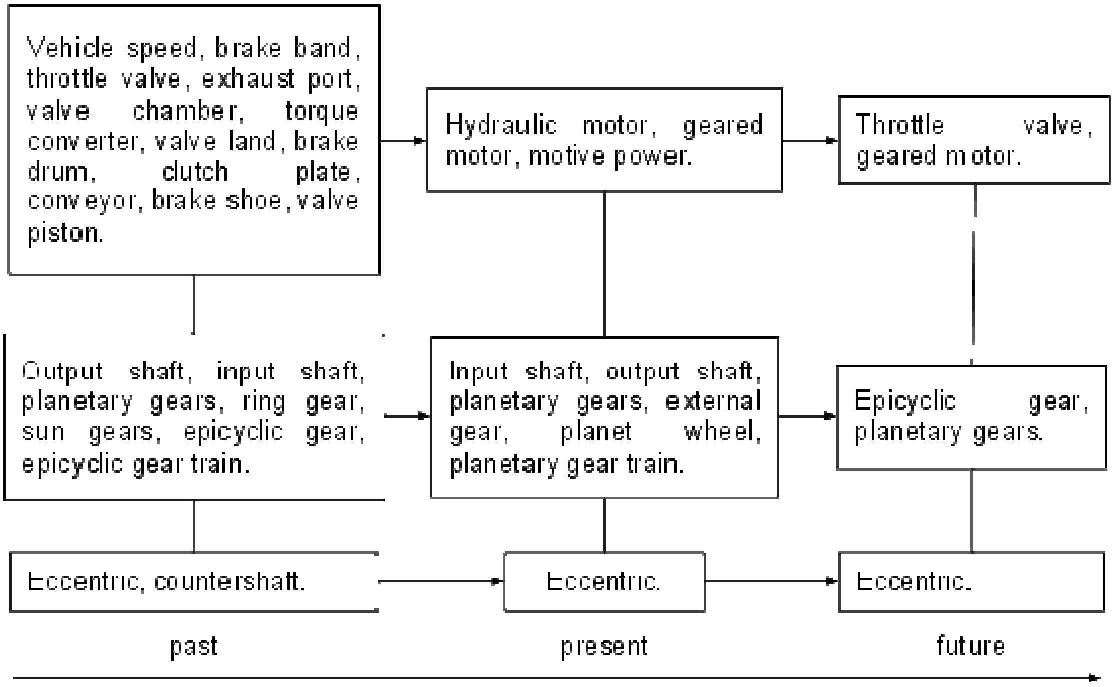


Figure 6-4: PAST > PRESENT > FUTURE. 9-screen diagram's speed reducer ("planetary gear"): PATENTS.

As mentioned before, clusters undergo a temporal discrimination, too. This discrimination is not arbitrary, on the contrary this dissertation demonstrates that it is objective. Moreover the dissertation shows that when clusters come to the hand-over moment the Δ cluster comes to 0.

The theoretical behavior of clusters and therefore the method developed for forecasting the life-cycle of industrial products is illustrated by an industrial case study.

8.4 Future developments

The residual clusters are the body of documents, on which the follow-up of this research will focus.

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D. REGAZZONI, C. RIZZI, R. NANI (2011). *A TRIZ-based approach to manage innovation and intellectual property*. In: Int. J. Technology Management, Vol. 55, Nos. 3/4, 2011Table 1-1: Five Levels of Solutions in Technology.

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