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EARLY WARNING SYSTEM FRAMEWORKS FOR PREDICTING TECHNOLOGICAL CHANGE

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Prof. Dr. Türkay Dereli

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Alptekin DURMUŞOĞLU
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Prof. Dr. Ramazan KOÇ
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy.

Prof. Dr. Türkay DERELİ
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Doctor of Philosophy.

Prof. Dr. Türkay DERELİ
Supervisor

Examining Committee Members	signature
Title and Name-surname	
Prof. Dr. Türkay DERELİ	
Prof. Dr. Adil BAYKASOĞLU	
Prof. Dr. Hadi GÖKÇEN	
Prof. Dr. Rızvan EROL	
Prof. Dr. Lale Canan DÜLGER	

ABSTRACT

EARLY WARNING SYSTEM FRAMEWORKS FOR PREDICTING TECHNOLOGICAL CHANGE

DURMUŞOĞLU, Alptekin
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Technology management has been an increasingly important research area with the uninterrupted rapid changes in the technology. In this respect, "technology watching", as being one of the fundamental functions of technology management, has also been essential for all organizations to select, implement or develop technologies that best suit their business needs. As a consequence, demand for technology watching methodologies has increased and many novel methodologies have been introduced in the literature. In most of these methodologies, subjective expert opinions constituted the base for forecasts and evaluations. Hence, they have been incapable to detect meaningful and critical relations within the huge technological and scientific data. Even more, some of these methodologies failed to produce outputs that are formerly highlighting unpredictable changes. Thereby, objective of this thesis has been presenting analytical frameworks that are providing roadmaps for predicting emerging technologies and their impacts at the earliest convenience.

The thesis covers four proposed frameworks that can be summarized as follows: The first framework is on an extended version of previously developed "Patent Alert System" (PAS) which is an early warning system for technology watchers. Patent counts are retrieved from the publicized databases and subsequently a recently developed fuzzy-based alert triggering mechanism is used to search for trend changes within the associated data. In the second framework, technologies are attempted to be classified via density of patenting activities. Significant clusters, that are minimizing the heterogeneity of members, are searched via Grand Deluge Algorithm (GDA) from numerous alternatives. The third one presents an extension of a well-known forecasting method: "Technology Forecasting using Data Envelopment Analysis" (TFDEA) to produce forecasts with smaller bias. The last framework employs belief triangles and "Rogersian Characteristics of Innovation Perception" for measuring the level of perceived innovativeness for a certain product. All of the proposed frameworks described above are all accompanied with real cases for verification and demonstration purposes.

It is well worth pointing out that, the frameworks proposed and exemplified through this thesis are expected to provide practical and useful solutions for technology watching activities.

Key Words: technology management, technology watching, patent alert system, technology classification, innovation measurement

ÖZET

TEKNOLOJİK DEĞİŞİMİN ÖNGÖRÜLMESİ İÇİN ERKEN UYARI SİSTEMİ ÇERÇEVE MODELLERİ

DURMUŞOĞLU, Alptekin
Doktora Tezi, Endüstri Müh. Bölümü
Tez Yöneticisi: Prof. Dr. Türkay DERELİ
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Teknoloji yönetimi, teknolojideki kesintisiz ve hızlı değişimle birlikte, önemi hızla artan bir araştırma alanı olmuştur. Bu bağlamda, teknoloji yönetiminin önemli fonksiyonlarından biri olan, “teknoloji izleme” de; iş modellerine uygun teknolojilerin; seçilmesinde, kullanılmasında ve geliştirmesinde, temel bir gereksinim halini almıştır. Böylelikle, teknoloji izleme yöntemlerine talep artmış ve birçok yeni yöntem bilimsel yazında yer almaya başlamıştır. Bu yöntemlerin birçoğunda, tahminler ve değerlendirmeler, uzmanların öznel görüşleri üzerine inşa edilmiştir. Dolayısıyla, bu yöntemler, çok miktarda teknolojik ve bilimsel verinin içerisinde yer alan kritik öneme sahip ilişkilerin tespiti konusunda yetersiz kalmıştır. Dahası, bu yöntemlerin bir kısmı öngörülmesi zor değişikleri önceden tahmin edecek çıktılar üretmede başarısız olmuştur. Bu sebeple, ele alınan tez ile teknolojilerdeki değişikleri öngörebilen yol haritalarını sağlayabilecek analitik çerçeve (çatı) modellerin sunulması amaçlamaktadır.

Bu tez kapsamında önerilen dört çerçeve (çatı) model şu şekilde özetlenebilir: Birinci çerçeve model, daha önce geliştirilmiş bir erken uyarı sistemi olan Patent Alarm Sistemi’nin (PAS) geliştirilmiş sürümüdür. Patent sayıları, kamuya sunulan patent veritabanlarından çekilerek, yeni geliştirilmiş olan bulanık mantık tabanlı bir eğilim arama mekanizmasıyla taranmakta ve ilgili eğilim değişiklikleri tespit edilmektedir. İkinci çatı modelde, teknolojiler, patent faaliyetlerinin yoğunluğu dikkate alınarak sınıflandırılmaktadır. Teknolojilerin eğilim sınıflarına aitliği Grand Deluge Algoritması (GDA) uygulanarak bulunmuştur. Üçüncü model ise, bilinen bir teknoloji tahminleme yöntemi olan “Veri Zarflama kullanarak Teknoloji Tahminleme Analizi” nin (VZTTA) daha az hataya sahip tahminler üretecek şekilde genişletilmesine yöneliktir. Son çerçeve model de, belirli bir ürünün algılanan yenileşiminin, inanç fonksiyonları ve “Roger’in İnovasyon Algısı Özellikleri” kullanılarak ölçümlenmesini kapsamaktadır. Tez kapsamında önerilen tüm çerçeve modeller, kontrol ve gösterim amacıyla gerçek vakalarla birlikte sunulmuştur.

Bu tezde önerilen ve uygulamaları sunulan tüm çerçeve modellerin, teknoloji izleme faaliyetleri için pratik ve faydalı çözümler sağlayacağı öngörülmektedir.

Anahtar Kelimeler: teknoloji yönetimi, teknoloji izleme, patent alarm sistemi, teknoloji sınıflandırma, inovasyon ölçümü.

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CONTENTS

LIST OF FIGURES

page

LIST OF TABLES

page

LIST OF SYMBOLS / ABBREVIATIONS

CDMA	Code-Division Multiple Access
EWS	Early Warning System
EPO	European Patent Office
GDA	Great Deluge Algorithm
ICT	Information and Communication Technology
IP	Intellectual Property
IPC	International Patent Classification
MAPE	Mean Absolute Percentage Error
MCD	Master Classification Database
OBI	Greek Patent Office
PAS	Patent Alert System
RCIP	Rogersian Characteristics of Innovation Perception
R&D	Research and Development
RoC	Rate of Change
SOA	State of the Art
S&T	Science and Technology
TPO	Turkish Patent Institute
TFDEA	Technology Forecasting using Data Envelopment Analysis
TF	Technology Forecasting
TW	Technology Watching
USPTO	United States Patent and Trademark Office
VLRoC	Varying Level of Rate of Change
WIPO	World Intellectual Property Organization
WPI	World Patent Information
XML	Extended Mark-Up Language

CHAPTER 1

INTRODUCTION

1.1. General Remarks

A new era has been initialized with the globalization of the world. As a consequence of this era, economical, political and geographical borders have disappeared all over the world. Everything has started to change much faster than ever. Changes have all affected each other mutually. Individual understandings like ethics, environmental considerations like sensitivity on global warming, technical changes like discovery of internet and many others have all influenced each other. However, it has not been easy to recognize which one is the reason and which one is the result.

In parallel to these changes, it has been certain that enterprises need capabilities to find appropriate, adaptable and urgent solutions against this storm of changes. Many companies and governments have been obligated to reorganize their management styles and philosophies accordingly. Unfortunately, some firms failed to do so and they closed down their businesses.

On the other hand, results of this era have not been negative for all companies. Each change has accompanied by several novel situations each with different cons & pros. Enterprises which are able to turn those situations into brilliant opportunities have had much more chance to extend their businesses or set up new businesses.

In parallel to those paradigm shifts and above defined changes, the world has also witnessed an unprecedented change in technology. It is also claimed that, the big change has started with the change in technology. But this philosophic dilemma is too complex and it is not intended to be replied in this thesis. This thesis focuses on the characteristics of those uninterrupted rapid changes in the technology which exist in any given time.

Both scientists and people from industry have attempted to develop systematic approaches against to those unpredictable technological changes. Following capabilities have emerged as the fundamental requirements to deal with technological changes: gaining insight about the technological change, predicting and adapting and further managing and leading technological change. In this regard, many companies and research establishments have made efforts to be aware of the latest developments in relevant technology areas. Thereby, a necessity of introducing systematic “technology watching frameworks” has appeared. Underlying reasons of this need is explained with the following rationales.

• Need for feasibility: It is required to be known, if some other firm(s) is developing, commercializing the same or similar products. Thereby, it is required to check whether, there is a need for doing that certain business in the new technology. It can be succeeded through a proper “technology watching” scheme/framework.

• Need for benchmarking: The state of the competitors is required to be known to generate new competitive strategies. Technology watch can be employed as an active methodology to keep informing about the rivals.

• Need for value enhancement: Potential benefits of a novel technology are required to be known if it can really improve the efficiency of business systems and let the business to stay ahead of competition. Technology watch can easily detect such vital changes.

• Need for new product development: Some new technologies can be inspiring for other new technologies; thereby technology watch can be essential for new product development.

• Need for avoiding of illegal copying issues: With the technology watch, companies can detect illegal copies of their products and search for legal solutions to keep their intellectual property rights. Thereby, their loss of profit is prevented.

Thus, this PhD thesis is inspired by the above given requirements along with the perceived lack of an appropriate solutions to technology watch for early detection of changes. With all of these issues in mind, four proposed frameworks are presented through the thesis; which can properly supply solutions for the states defined above.

Before going into details about the proposed frameworks, in this introduction part, readers will be able to find more detailed information on the definition of the problems and statement of thesis against to those problems. Corresponding solution methodologies will also be briefly described and introduced.

In addition to all of those, a roadmap will be readily available to the readers for creating traceability for the rest of the thesis. With the use of presented roadmap, maximum benefit and efficiency is desired to be presented.

1.2 Thesis Statement and Summary of Frameworks

Since meaning of technology may range from just a piece of knowledge for a method or technique to a techno-complex system of machinery, it is remarkable to state that, in this PhD thesis, technology is considered as any materialized output of knowledge that can be commercialized.

As stated before, this PhD thesis is inspired by the perceived lack of appropriate solutions to the accurate technology watching. In this regard, this thesis proposes four different frameworks to qualify the technology selection process. A summary of stated problems, proposed frameworks against the problems and contributions of each proposed framework has been given in Table 1.1.

The first framework is on the extended version of previously developed "Patent Alert System" (PAS) which is an early warning system for technology watchers. Patent counts are retrieved from the publicized databases and subsequently a recently developed fuzzy-based alert triggering mechanism is used to search for trend changes within the associated data. With the addition of feature to detect possibilistic/fuzzied trend lines, users are now able to commend on the possibility of a trend change for a technical activity.

In the second framework, technologies are attempted to be classified via density of patenting activities. Significant clusters, that are minimizing the heterogeneity of members, are searched via Grand Deluge Algorithm (GDA) from numerous alternatives. As a result, promising clusters, for the time that the analysis was performed, are presented. With the defined framework, proposed approach can be continuously run to detect the shifts on the clusters of technologies.

The third one presents an extension of a well-known forecasting method which is named as: “Technology Forecasting using Data Envelopment Analysis” (TFDEA). An unrealistic assumption regarding constant rate of technological change is released from the existing method with some extra considerations. Proposed extension yields better forecasts with smaller bias which are statistically significant.

The final framework employs belief triangles and “Rogersian Characteristics of Innovation Perception” for measuring the level of perceived innovativeness of a certain product. Believes of several customers on the innovativeness of products are measured and added to each other using special mathematical operators to obtain the idea of a whole community.

For verification and demonstration purposes, all of the proposed frameworks described above are all accompanied with real cases.

Table 1.1 Summary of developed frameworks

Problem	Framework Title	Employed Methodologies	Case Study	Contribution
There is a certain need for a “watch system” which enables technology watchers to be aware of any trend changes at the earliest convenience.	Patent Alert System with Possibilistic Alerts	Fuzzy regression, trend detection, XML	An illustrative case, American wind technologies	This framework presents a visual and fast responding technology watch system.
Technologies require to be classified in terms of patenting density to see their market demand.	Clustering of Technologies Via Number of Patented Inventions	Great Deluge Algorithm (GDA), K-Means algorithm	Technologies developed in Turkey and issued by Turkish Patent Institute (TPI)	Technologies are grouped via high internal homogeneity with respect to their trendiness.
There is a need to detect unpredictable data delivery capabilities of future CDMA technologies.	Technology Forecasting Using an Extended Version of Data Envelopment Analysis	TFDEA, curve fitting, descriptive statistics	Code Division Multiple Access (CDMA) technologies	The forecast are expected to shed a light on the future of CDMA based technologies. Proposed considerations for TFDEA will also add value to the future implementations of TFDEA
There are methodological departures in innovation measurement. All existing ones ignore perception factor during the measurement.	Development of a Novel Measure for Perceived Innovativeness	Belief functions, belief triangles	Iphone 3GS phones	A collaboration framework among customers and business owners has been constructed using a systematic data analysis. An innovation measurement scheme has been developed which is capable of returning an objective measure by adding subjective opinions of individuals on innovativeness of certain product.

1.3 Roadmap for Readers

A roadmap was prepared to all of the readers of this thesis for providing the most possible benefits. The prepared roadmap is as presented in Figure 1.1. Thesis starts with the introduction part which is provided in this chapter. Following the introduction; Chapter 2, presents an overview on technology management concepts and the relevant literature. Chapter 2 also introduces technology forecasting concept and its latest methodologies along with the technology watching literature. It also focuses on the available data sources like patent information and journal publications that are used during technology watch processes. Therefore, this chapter is suggested for the readers who think that he/she is far away from technology management concepts and literature.

Chapter 3 introduces the initial version of Patent Alert System (PAS) and the requirements for the extended version. It discusses the need for searching fuzzified possibilistic trends within patent data and presents a framework for extracting possibilistic fuzzy lines. Finally, subsequent to a hypothetical example, an implementation from US wind energy technology is presented.

In Chapter 4, a clustering methodology for the technologies that are classified via International Patent System (IPC) is presented. Purpose of classification and need for such a classification is given first and it is followed by possible benefits of using Grand Deluge Algorithm (GDA) for such a search.

An extension of a recognized forecasting method: “Technology Forecasting using Data Envelopment Analysis” (TFDEA) to produce forecasts with smaller bias is provided in Chapter 5.

Belief triangles and “Rogersian Characteristics of Innovation Perception” for measuring the level of perceived innovativeness for a certain product are presented in Chapter 6. An implementation for measuring the perceived innovativeness of I-phone 3GS phones is also given in the same chapter.

Chapter 3, 4, 5 and 6 which are describing the proposed frameworks and their applications can be read separately, however it is advisable to be read in the given order to understand the linkages between them.

The outcomes of this research, associated conclusions and recommendations for further studies are summarized in Chapter 7. Other relevant information is then presented in the Appendices.

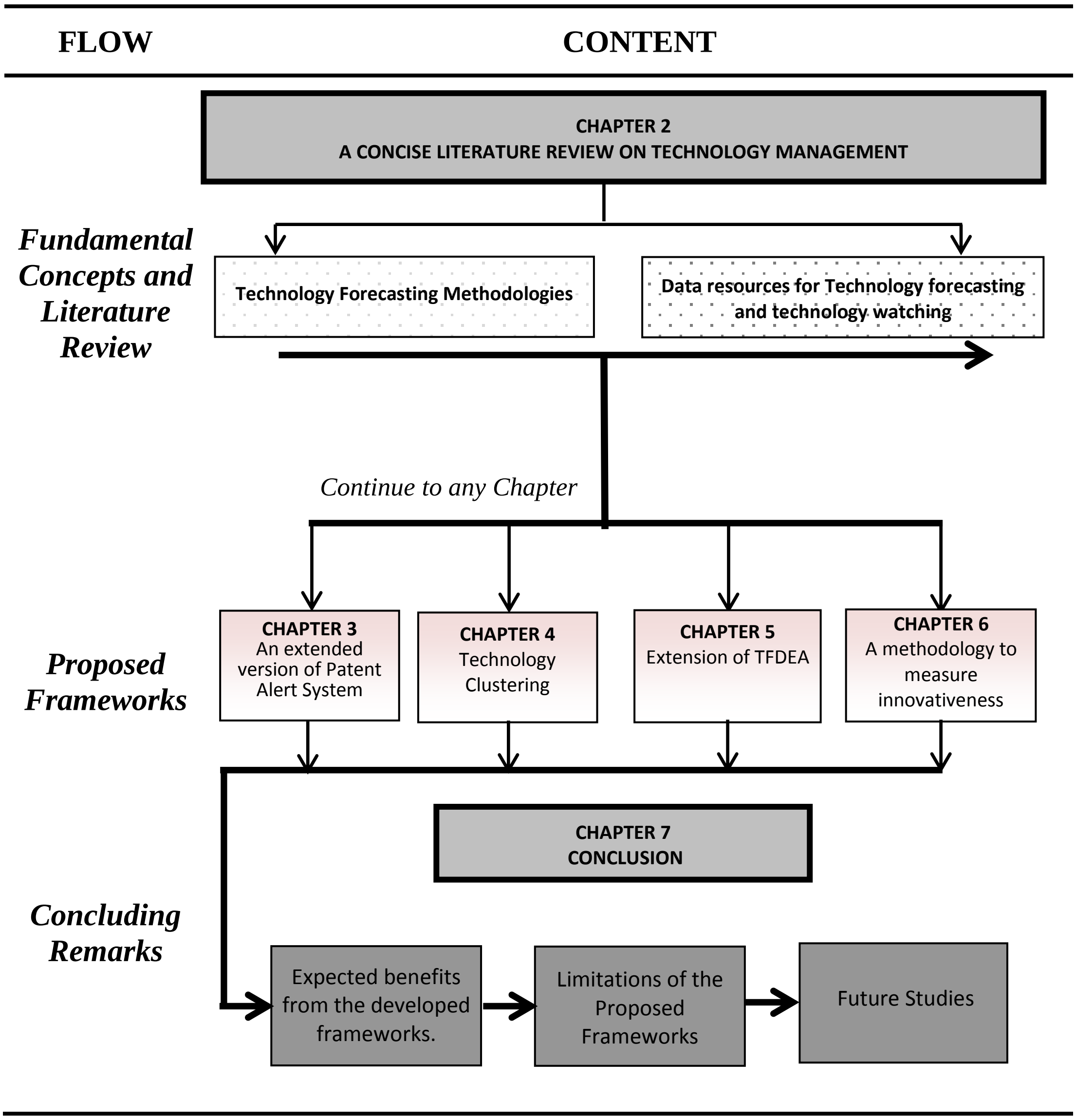

Figure 1.1 Roadmap of the thesis for the readers

1.4 Concluding Remarks

The proposed frameworks in this thesis are all novel to the literature. They have been presented in several conferences and published in several prestigious journals. They have been found valuable to be published and presented. These frameworks are also expected to be used in industries for supporting strategic decision-making and planning for new technology investments or technology development.

It is also anticipated that, some ideas and implementations presented in this thesis can create new research directions for other researchers.

The knowledge that can be discovered from this thesis is expected to be vital for all the parties reading it and it is wished that to be in service for humanity.

CHAPTER 2

LITERATURE REVIEW ON TECHNOLOGY MANAGEMENT

2.1 Introduction

Technology management is a process, which includes planning, directing, control and coordination of the development and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organization (Liao, 2005). It involves a broad range of knowledge and practice dealing with managing technology for different organizations. It has been conceptualized as an umbrella term which covers many different techniques, tools and activities. Tools and techniques employed through technology management have a wide range lying from quick simple tools to highly complicated mathematical analyses. Each of these techniques and analysis has its own specific focus with an intention to supply decision supports for anyone who is related to technology management. In this respect, different technology management paradigms, frameworks, conceptual models, propositions, perspectives, measurements, and impacts have been investigated.

There been also some studies concentrating on the functions and possible benefits of technology management (Lopes and Flavell, 1998; Haas and Kleingeld, 1999; Garshnek et al., 2000; Pretorius and Wet, 2000; Sharratt and Choong, 2002; Wu, 2002; and Hicks et al., 2002)

Through these efforts, technology management frameworks have been extensively preferred due to their structural and stepwise definitions. Some of these frameworks are listed at Table 2.1. These frameworks cover technology management formulations on computer integrated manufacturing, construction project management, business process reengineering, project appraisal, product design, space disaster management, technology assessment, process design, and engineering design.

Table 2.1 Some of the technology management frameworks from literature

Technology management frameworks	Related papers
Computer integrated manufacturing	Sarkis et al., (1995)
Construction project management	Dey et al., (1996)
Business process reengineering	Chan and Choi (1997); Wu (2002)
Project appraisal	Lopes and Flavell (1998)
Product design	Haas and Kleingeld (1999)
Space disaster management	Garshnek et al., (2000)
Technology assessment	Pretorius and Wet (2000)
Process design	Sharratt and Choong (2002)
Engineering design	Hicks et al. (2002)
Knowledge management	Liao (2003)

Since this thesis consists of technology management frameworks covering different technology forecasting methodologies, the remaining part of this chapter will be covering a concise literature on technology forecasting methodologies. It is also remarkable to state that each chapter has its own literature parts merely based on the related to the proposed frameworks.

2.2 Technology Forecasting

Technology, as being one of the most important instruments that adds value to the businesses, is required to be properly managed and planned to create competitive advantage. However, it has been a management dilemma to evaluate and integrate emerging technologies into new or existing investment/business plans successfully. In this respect, technology watching (TW) has covered all the tools to identify possible relevant technologies for the organization/country or a region.

Technology forecasting (TF), as being fundamental tool of TW, deals with specific characteristics of specific technologies, like speed or acceleration of an aircraft in near future, or first flight date of existing aircraft projects. If there are technological alternatives, TF is implemented to determine the best possible alternative among all which provides the most desirable outcome. Several different methodologies can be implemented to reach the above defined purposes of TF. However, all TF methodologies may not give the same result or even produce conflicting results. The robustness and suitability of the used method determines the quality of the forecasts. Existing TF methods are extensively based on the rational and explicit, or intuitive approaches. Indeed, a robust TF methodology is expected to meet the following specifications:

- Methods should be teachable: Therefore, an implicit or an instinctive model is not a preferable TF method,
- Methods should be descriptive and should have a background idea and theory which is scientifically defendable,
- Methods should provide a traceable procedure where the steps can be implemented by anyone who has necessary exercise.
- These methods should guarantee to produce the same forecast regardless of who uses them.
- The method should be explicit and thereby it should be verifiable and others reviewing the method or its implementation can check it for consistency.
- The forecasts of the methods should be traceable at any subsequent time.

There are two main categories for technology forecasting methods which are: exploratory forecasting methods and normative forecasting methods (e.g. Martino, 1993; Kahraman et al., 2004; Ghotb and Warren, 1995; Teng and Tzeng, 1996; Zhau, and Goving, 1991; Williams, 2003; Zadeh, 1965; Gabor, 1964). Exploratory forecasting methods covers forecasting of the future using past data based on present conditions, which includes Delphi method, growth curves and the case study method.

The Delphi method is an approach used in forecasting the likelihood and timing of future events (Shin, 1998; Halal et al., 1998). The Delphi method is a structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts. In the standard version, the experts answer questionnaires in two or more rounds. After each round, a facilitator provides an anonymous summary of the experts' forecasts from the previous round as well as the reasons they provided for their judgments. Thus, experts are encouraged to revise their earlier answers in light of the replies of other members of their panel. It is believed that during this process the range of the answers will decrease and the group will converge towards the "correct" answer. Finally, the process is stopped after a pre-defined stop criterion (e.g. number of rounds, achievement of consensus, and stability of results) and the mean or median scores of the final rounds determine the results. The method could be more adoptive in the situations, which are few historical data or more external factors (Chang, et al., 2002; Ronde, 2003). The most important prerequisite for using the method is that all participants should be experts in a given aspect of the proposed technology (Levary and Han, 1995).

A growth curve is an empirical model of the evolution of a quantity over time. Growth curves are widely used in biology for quantities such as population size, body height or biomass. Values for the measured property can be plotted on a graph as a function of time. Growth curves are employed in many disciplines besides biology, particularly in statistics, which has an extensive literature on growth curves. In mathematical statistics, growth curves are often modeled as being continuous stochastic processes, e.g. as being sample paths that almost surely solve stochastic differential equations. Forecasting by growth curves method is based on fitting a growth curve to a set of data on technological performance, then extrapolating the growth curve beyond the range of the data to obtain an estimate of future performance. The method is based on the parameter estimation of a technology's life cycle curve (Young, 1993; Ernst, 1997). It is helpful in estimating the upper limit of the level of technology growth or decline at each stage of the life cycle and in predicting when the technology will reach a particular stage (Bhargava, 1995; Watts and Porter, 1997; Meade and Islam, 1998; Frank, 2004). However, when using the growth curve method, the technology life cycle of the object must be known and if historical data are not sufficient for a long period of time, only limited information can be obtained from the data (Levary and Han, 1995).

A case study is a research methodology common in social science. It is based on an in-depth investigation of a single individual, group, or event. Case studies may be descriptive or explanatory. The latter type is used to explore causation in order to find underlying principles.

Rather than using samples and following a rigid protocol (strict set of rules) to examine limited number of variables, case study methods involve an in-depth, longitudinal (over a long period of time) examination of a single instance or event: a case. They provide a systematic way of looking at events, collecting data, analyzing information and reporting the results. As a result the researcher may gain a sharpened understanding of why the instance happened as it did, and what might become important to look at more extensively in future research. Case studies lend themselves to both generating and testing hypotheses. Another suggestion is that case study should be defined as a research strategy, an empirical inquiry that investigates a phenomenon within its real-life context. Case study research means single and multiple case studies, can include quantitative evidence, relies on multiple sources of evidence and benefits from the prior development of theoretical propositions. Case studies should not be confused with qualitative research and they can be based on any mix of quantitative and qualitative evidence. Single-subject research provides the statistical framework for making inferences from quantitative case-study data. The case study method relies on the study of technological developments that have already occurred in actual firms or organizations. The predictions regarding the development of future technologies are made based upon the analysis of past developments (Hirsch, 1986; Fuller et al., 2003). The method is more suitable in the complex technology with only a small number of organizations involved (Hjelkrem, 2001; Kohlbeck, 2005).

The other category of technology forecasting is normative forecasting. The normative forecasting means predicting the technological performance depended on future needs. In essence, it forecasts the capabilities that will be available on the assumption that necessitates will be met. Normative forecasting methods include the relevance trees and scenario writing method.

The relevance tree method essentially involves the drawing of one or more tree diagrams which structure the sequence of technological problems that must be solved in order to reach the objectives (Barbiroli, 1992). Therefore, prerequisites for using the method are that the hierarchical structure and related factors of technology development must be known (Martino, 1993; Levary and Han, 1995).

The scenario writing method proposes different conceptions of future technology and each alternative scenario is based on certain assumptions and conditions (Hirschhorn, 1980; Steven and Ziamou, 2001; Schwartz, 1992). The forecaster evaluates the validity of the assumptions. The results of the evaluation are used to determine the scenario most likely to occur by scenario developers. It is very crucial that scenario developers must be experts in all aspects of the proposed technology (Levary and Han, 1995; Schwartz, 1992). To sum up, Table 2.2 presents the illustrations and prerequisites of the technology forecasting methods.

Table 2.2 Interpretations of technology forecasting methods ***(Source: Adapted from Levary and Han)***

Method	Illustration	Prerequisite
Delphi method	The method combines expert opinions concerning the likelihood of realizing the proposed technology as well as expert opinions concerning the expected development time into a single position.	All participants should be experts in a given aspect of the proposed technology.
Growth curve	(1) The method was based on the parameter estimation of a technology's life cycle curve; (2) It is helpful in estimating the upper limit of the level of technology growth or decline at each stage of the life cycle.	(1) Available historical data that covers extended period of time. If historical data are not available from a long enough period, only limited information can be obtained from the data;
The case study method	The predictions regarding the development of future technologies are then made based upon the analysis of past developments.	
Relevance trees	(1) The method is a normative approach; (2) The goals and objectives of a proposed technology are broken down into lower level in a tree-like format.	The hierarchical structure of technology development must be known.
Scenario writing	(1) The method proposed different conceptions of future technology; (2) The each alternative scenario being based on certain assumptions and conditions.	Scenario developers must be experts in all aspects of the proposed technology.

In addition to the classical methods given above, there are also some emerging methods like “Technological Forecasting Data Envelopment Analysis-TFDEA” (Anderson et al., 2002; Inman et al., 2006), Evolutionary Theory (Bowonder et al., 1999), Technology Roadmaps (Phaal et al., 2004), Patent Analysis (Kayal, 1999), Bibliometric Analysis (Watts and Porter, 1997; Daim et al., 2006), and Back Propagation Network (Wang and Shih-Chien, 2006).

Linstone (1999), Ayres (1999), Martino (1999), Fildes (2006) and Porter (1999) have also previously reviewed the literature which provides examples of many approaches. It is also remarkable to state that all those methods briefly described above are extensively adopted methods where the first purpose of their use is not technology forecasting. Therefore, all these methods are derived from the existing forecasting methods.

2.3 Need for Combining Methods

This section of the thesis justifies the necessities for combining the methods. Previous studies on TF have proved that one of the most frequent reasons why a forecast fails to predict future accurately occurs due to ignoring of significant fields. A given technical approach/method may fail to achieve the level of capability forecast for it, because it is superseded by another technical approach which the forecaster ignored.

Another problem is that of confliction of the forecasts. Because of those problems, it is often necessary to combine forecasts of different technologies. Therefore rather than to try to select the one method which is most appropriate, it may be better to try to combine the forecasts obtained by different methods. If this is done, the strengths of one method may help compensate for the weaknesses of another.

Kumar et al. (2002) indicate the necessity of combining the forecasting model with the perceived future industry dynamics. He emphasizes that the quantitative forecasting methods such as time series and econometric modeling have become less accurate and cannot be relied upon because the industry no longer has the stable historical relationship that these models rely on. The literature suggests that including forecasts from different statistical methods generally improves accuracy when significant trends are involved. Useful information can be obtained using several sources of forecasts, adjusting for biases. Yoo and Moon (2006) suggest that instead of trying to choose the best single method, one should combine the results from different methods, which would help in reducing errors arising from faulty assumptions, biases, or mistakes in the data.

Consequently, primary reason for combining forecasts of the same technology is to attempt to counterbalance the weaknesses of one forecasting method with the strengths of another. In addition, the use of more than one forecasting method often gives the forecaster more insight into the processes at work which are responsible for the growth of the technology being forecast.

A frequently used combination is that of growth curves and a trend curve for some technology. The use of growth curves and a trend curve in combination allows the forecaster to draw some conclusions about the future growth of a technology which might not be possible, were either method used alone. With growth curves alone, the forecaster could not say anything about the time at which a given technical approach is likely to be supplanted by a successor approach. With the trend curve alone, the forecaster could not say anything about the ability of a specific technical approach to meet the projected trend, or about the need to look for a successor approach. Thus, there is a certain need for combining forecasts.

Another frequently used combination of forecasts is that of the trend curve and one or more analogies. It is customarily considered that the scatter of data points about a trend curve to be due to random influences which can neither be controlled nor even measured. However, consistent deviations may represent something other than just random influences. Where such consistent deviations are identified, there may be an opportunity to apply an analogy. Typical events which bring about deviations from a trend are wars and depressions. Thus the purpose of combining analogies with a trend forecast is to predict deviations from the trend deviations which are associated with or caused by external events or influences. As with other uses of analogy, it is important to determine the extent to which the analogy between the event used as the basis for the forecast, and the historical model event, satisfies the criteria for a valid analogy.

Combining forecasts of different technologies may be even more important than combining the forecasts of the same technology. One reason for this is the fact that technologies may interact or be interrelated in some way. Another rationale for this is that of consistency in an overall picture or scenario. One of the simplest examples of interacting trends is the projection to absurdity, i.e. simply projecting the given data indefinitely without getting any specific result. For instance, if one simply projects recent rates of growth of world population, one arrives at some fantastic conclusions about the density of population in a particular place by various dates in the next millennium. Some other trends which can confidently be expected to not continue indefinitely are:

- Annual production of scientific papers.
- Number of automobiles per capita.
- Kilowatt hours of electricity generated annually.

Another instance of interacting trends was in the case of the number of scientists in the U.S. growing faster than the overall population. Since 1940s through the 1960s, science as an activity in the United States grew exponentially. The number of dollars spent on R&D was growing faster than the GNP (in the 1960s).

If projected indefinitely, these two curves would give the result that eventually every person in the U.S. would be working as a scientist and the entire GNP would be devoted to R&D alone, which are however absurd conclusions. Thus, it is clear that the scientific discipline of technology forecasting is not mere trend extrapolation but also involves combining forecasts.

The Technology Futures Analysis Methods Working Group (Porter et al., 2004) provides a good review of integrating multiple methods and evolving new methods for technology forecasting.

2.4 Patent Information

In today's highly competitive environment, technology has become the most important weapon of enterprises. Acquiring competitive advantages can only be succeeded through management of innovation and technology. Different source of data and their processed form - information- can be employed to manage these important processes (Durmuşoğlu, 2008). Thus, intelligent selection of the information source along with valid framework is essential to reduce the failure risk of wrong technology selection. Using a valid framework is not easy and requires expertise in some fields of technology management like: technology identification, technology assessment, technology watch, technology forecasting and technology mapping. The gathered and processed data through a framework can be used to formulate a technology vision and strategy (Durmuşoğlu, 2008).

Patents are the documents which protect an inventor's invention by a particularly given monopoly, so that others can't duplicate and commercialize it. Patent documents enclose an archive with millions of papers. These papers witness the progress of technologies through the history. Therefore patent documents are one of the most valuable and rich technology information resources.

World Intellectual Property Organization (WIPO) defines patent information as the "all related information arose from a patent system" (www.wipo.int/edocs/mdocs/sme/en/wipo_ip_bis_ge_03/wipo_ip_bis_ge_03_13-main1.pdf). European Patent Office (EPO) defines it as the technical information which can be found in patent documents, plus any legal information about them (http://www.epo.org/patents/patent-information/about.html). The information included in a patent system has different extensions. In literature, there is also infancy on the classification of patent information. However patent information practically can be grouped as: direct and indirect information. Direct patent information is the information which can be easily accessed just by reading a patent. On the other hand indirect patent information is the information which is extracted from patent documents by the use of further analysis. Table 2.3 shows what type of data can be included in direct and indirect information.

Table 2.3 Examples of direct/indirect patent information

Direct Information	**Indirect Information**
Patent Title	Number of Patents Owned by the Same Country Citizens
Patent Number	Number of Patents Owned by the Same Applicant
Patent Filing	Number of Patents Owned in a Specific IPC Section
Patent Issue Dates	Number of Citations per Patent
Inventor Name	Number of Patents per Companies in a Specific Industry
Applicant Name	Number of Patent Applications per Innovation Expenses
Assignee Name	The Quality of a Patent
IPC Classification	The Number of Claims per Patent
Description of the Invention	The Number of Pages per Patent
Priority Date/ Country	The Number of a Specific Word Repeated in Patents
Patent Abstract	The Number of Patents Applied by the Same Applicant
Patent Citations / References	Research and Development Trends
Patent Claims	Industry Trends
Drawings	R&D Activity Cycle Times

These patent classes can be renamed using different phrases as the Gibbs (2007) does in his non-literature article. Gibbs classifies the patent information as: explicit and implicit data. Explicit information refers to indirect patent information and implicit does it for direct information (Durmuşoğlu, 2008).

Indirect patent information examples can be extended with many other statistical outputs. It should be noticed that indirect patent information can also take several forms like tables, graphs, charts and maps (Durmuşoğlu, 2008).

There are several good reasons which make the use of patent information such attractive. Direct patent information is structured information and does not have variability due to its formatted and unified content. It is also easy to obtain and can be collected via free online access (Durmuşoğlu, 2008). The unified and hierarchical classification of patents in accordance to industries also creates a serious advantage. The most important advantage of patent information can be obtained by the right use of data. Table 2.4 shows the list of possible benefits of the patent information prepared by WIPO.

Table 2.4 Possible benefits of patent information (source: WIPO)

	What can we get?	What can do with these?	Where we get?
Technological Information	• Technology development trend • Core technology • Basic Patent • Technology relation • Technology distribution status	• Selection of research theme • Decide R & D direction • Forecast new product	• Description • Abstracts • Classification
Administrative Information	• Business Technology Trend • Product development trend • Research management trend • Market share status • Company relationship • Estimate market size • Agency activity status	• R&D management benchmarking • Establish R&D strategy • Establish patent management strategy • Technology trade strategy • Human resource handling	• Assignee • Inventor • Period of patent rights • Patent family • Cited patents
Rights Information	• Patent Claims • Patent registration • Possibility of Infringement • Legal status • Licensing, buying, selling	• Decide whether a patent applies or not. • Handling claim	• Claims • Core technology contents of patent • File wrapper • Examination process

2.4.1 On the use of patent information

The rapid changes in the technology have transformed the structure of competition in business world. With the change in technology, more opportunities are created to invest. A deeper understanding of technological change has been an essential need to avoid unnecessary investment and beyond to find promising investments. Thus understanding technology, forecasting and tracking technology has become extremely important for managing technology.

Since patents are the documents which are one of the best economic instruments for inventors to keep control of their novelties (Mazzoleni and Nelson, 1998) patents have been treated as the most important output indicators of innovative activities (Frietsch and Grupp, 2006). They have become the focus of many tools and techniques to measure innovation and change (Belderbos, 2001; Pilkington, 2004; Hanel, 2006). Some certain advantages of patent data like: containing standardized and structured data relating to new technological developments as well as being freely available, made it a trendy source of information.

Many methods have been developed to recognize progresses of technologies, and one of them is to analyze patent information (Kim et. al, 2007). Patent data represents a valuable source of information that can be used to plot the evolution of technologies over time (Pilkington, et al., 2002). Therefore, patent information and patent statistical analysis have been widely used for examining present technological status and for forecasting future trends. Mogee (1991) applied his patent analysis results to the technology analysis and planning of a corporation. Berkowitz (1993) analyzed how to make proper patent strategies to achieve and maintain competitive advantages under the process of technology development, while Hufker and Alpert (1994) discussed the various situations for applications of patent strategy from a managerial perspective. Ernst (1997) used patent information for technological forecasting. Campbell (1983), Breitzman and Mogee (2002), Jung (2003) also analyzed the patents to show technological details and relations, reveal business trends, inspire novel industrial solutions, or help make investment policy.

Recently, Corrocher et al. (2007), show in their work that high opportunity in ICT (information and communication technology) applications, results high growth of patenting activities. Dou and Bai (2004) present how the recent “Avian Influenza” disease affected investments and patenting activities around the world. Scheu et al (2006) also indicate the expectation of increase in the number of nanotechnology patents as the consequence of large public and private investments in new technologies at the nanoscale. All these studies and many other similar ones (ie: Bengisu and Nekhili (2006), Waguespack (2005)), have proposed a correlation between patenting activities and technology.

On the contrary; there are some concerns about the ability of patent information to indicate current research and development (R&D) activities. Ashton and Sen (1988) claim that although patent information is the unique source on the determination of technology there are some limitations on the use of patent information. They categorize these limitations in two ways. First one is about time duration between application and granting process. They propose that during the granting process most of the novel product or process changes have been already implemented. Therefore the whole picture of technology cannot be taken for a certain time. Second reason is about the products or processes which can/did not patented for some reasons. There may be several reasons why an innovation was not patented. The innovations may not be technical, new or perhaps inventive to be patented or the patentable ones may not be patented for economic reasons (McQueen and Olsson, 2003). There are also some cases (Takalo and Kanniainen, 2000) where the companies are not sure about the concrete use of their innovation. Therefore, some companies may decide to keep their options open for the future and may ask for patent protection later. Also some companies prefer to keep innovations as trade secrets. Arundel and Kabla (1998) presents a supportive finding about low propensity rates (percentage of innovations for which a patent application is made). According to their findings, in Europe only 35.9% of the products and 24.8% of the processes is patented.

Although these debates continue to exist, it should be noticed that current researches have shown that the best way to measure innovations is to use patent application data. Several scholars rely on patent count data and use them as the measure of innovation and technology (i.e. Sorenson and Stuart 2001, Rosenkopf and Nerkar 2001, Acs, Anselin and Varga 2002, Katila 2002)

2.4.2 Patent classification

Literature searches show that there is numerous numbers of papers on patent activities. Each paper in literature has different scopes. Some of the studies are based on country statistics (Kronz and Grevink, 1980; Kronz and Grevink, 1986; Jialian, 1994; Rajeswari, 1996; Kutlaca, 1998; Marinova, 2001; Rezapour et al., 2007) and some others focus on industries or some certain technologies (Hemphill, 2007, Allred and Park, 2007, Levitas et al 2006, Storto, 2006, Reitzig, 2003). All of these researches benefit from several different patent classification schemes. Each classification scheme uniformly classifies the patents according to the technologies employed in the inventions. The classification schemes differ according to purpose of use or according to institution which grants the patent.

One of the well-known and most used classification schemes is “International Patent Classification” (IPC). IPC system is a hierarchical system in which the whole area of technology is divided into parts as sections, classes, subclasses and groups. Each of these parts corresponds to an industry and a technology in the relevant industry. IPC includes eight sections designated by one of the capital letters A–H. Eight sections are subdivided into 118 classes; the classes are subdivided into 624 subclasses, then subclasses are subdivided into over 67,000 groups. The full list of these sections, classes and subclasses is presented in APPENDIX A.

The first edition of the IPC was established pursuant to the provisions of the European Convention on the International Classification of Patents for Invention of 1954 (http://www.wipo.int/classifications/ipc/en/). IPC entered into force by the sign of the Strasbourg Agreement and then published on September 1, 1968. The Classification has been periodically revised in order to improve the system and to take account of technical development. The first two editions of the IPC were in force from September 1968 to June 1974 and July 1974 to December 1979, respectively. Thereafter, new editions have entered into force at 5-yearly intervals; the third on 1 January 1980, the fourth on 1 January 1985 and so on (Adams, 2001).

On 1 January 2000 the seventh edition and most recently, in January 2006, the eight edition has been introduced. There have been some structural changes with the reform. Wongel, (2005) summarizes these changes as follows:

- Split into core and advanced level.
- Creation of a Master Classification Database (MCD).
- More frequent revision: every three months instead of every five years.
- Reclassification of the back file.

The IPC has now existed for 33 years and is the only truly worldwide classification system for technical information (Stembridge, 1999). Apart from the IPC, several major patent offices still use national classifications. Various attempts have been made to provide concordances between them, with (Adams, 2001) varying levels of success.

United States Patent Office (USPTO) implements a different classification system which organized very differently. The USPTO classification system is divided into two categories: a class and a subclass. Representation of the class and subclass varies by the type of patent. The US Classification System is also extraordinarily large consisting of some 400 classes, and 136.000 subclasses. USPTO also reclassifies patents regularly and continuously updates the classification system.

2.4.3 Patent data access

The increasing use of the Internet has also included the establishment of several Web Sites for patent information retrieval. The utilities created by these online databases made it available to access patent data at any time and at any anywhere. Anyone who can access to the Internet has been able to search for a patent and read the full text of published patent documents. The list and web addresses of these web sites are given in Table 2.5. Some of these web sites provide service just for a specific area like serving for chemistry patents or machinery patents. Some information providers also require payment for the service. Corporations such as IBM provide the site and generate profits for the supplier of patents that they promote. There are also other private companies that provide commercial databases. Derwent, Dialog, STN, Questel Orbit, Micropatent, WIPS, etc are some examples of these commercial services. Commercial services offer patent information with more details based on some particular analysis required by the end users.

Many national patent offices such as the TPO (Turkish Patent Institute), USPTO and the Canadian Patent Office provide information as a public service. The full-text and full-page image database of the United States Patent and Trademark Office (USPTO) is one of the earliest and free online patent information services. Another major on-line free patent database is esp@cenet, which has some 30 million patent documents. The free services work well for simple searches, based on key words, such as a known patent number, name of the inventor(s) or applicant(s), a key word in the title, etc., but are not a suitable tool for executing more complex investigations and legally motivated searches. As access to these kinds of databases is not restricted across national borders, so users worldwide can very easily access patent documents from a computer connected to the Internet.

Table 2.5 List of online patent databases

Name/ Properties of Database	**Web URL**
U.S. Patent Office	www.uspto.gov
Turkish Patent Office	http://online.tpe.gov.tr
Lexis-Nexis	www.lexis-nexis.com
Dialog Corp	www.dialog.com/info/products
FIZ Karlsruhe: This German corporation provides access to different databases in Europe and worldwide	www.fiz-karlsruhe.de
IBM Patent Server	www.patents.ibm.com
Chemical Abstracts: This will enable one to determine which databases are available for use in Chemical Searching.	www.cas.org
Corporate Intelligence: This database will also allow for Trademark Searching.	www.corporateintelligence.com
Derwent	www.derwent.co.uk
Micro Patent	www.micropat.com
Questel-Orbit	www.questel-orbit.com
RAPRA Abstracts: This database is prepared by the Rubber & Plastics Research Association, and is quite thorough and specific to this field.	abstracts.rapra.net

CHAPTER 3

PATENT ALERT SYSTEM WITH POSSIBILISTIC INTERVALS

3.1 Introduction

Identification and assessment of technological advances have been vital for companies to keep their competitive position or to gain new capabilities for the competition. In this content, Technology Watch Systems (TWS) have been tools of systematic analysis of technology developments that outputs regarding the technological opportunities and threats could be easily interpreted by an analyst. Among several TWS's, Patent Alert System (PAS) (As MsC Thesis of Durmuşoğlu (2008) and Dereli and Durmuşoğlu, 2009a) has been a recently developed one which enables users to set or configure alert(s) for the trend changes in a certain technology area of requested sector.

Data of associated patent counts is retrieved by extended markup language (XML) mechanism located in PAS, and then an internal alert triggering mechanism is used to search for trend changes on the associated data. This internal alert triggering mechanism is a kind of modified linear regression which sets a newer trend line once a certain amount of deviations (threshold) has risen. Although alerts, indicating the direction of technological changes, provide supportive information to the analysts, extracted trend lines have been narrowed by a strict line where possible deviations have not been reflected. However, deviations in techno-systems are known to occur as the consequence of the vagueness coming from the nature of the system. Therefore, in this work, alert triggering mechanism of PAS is reconsidered using "possibilistic linear fuzzy regression". Results yielded better and promising outcomes for the reconsidered algorithm.

3.2 Problem Statement

Research and development (R&D) is positioned at the center of modern economies of today's world to remain competitive. However the path to be followed has not been steady for R&D efforts. Each company has already its own definitions and methodologies for executing R&D which are occasionally structured based on cumulative knowledge and experience. However, it has been certain that a typical R&D work should have been focused on some certain matters (Australia to focus on four R&D topics, 2002; Regional focus on fuel cells, 2001; Hauser, 1984). This state has created a critical question about "what subject to focus". In the scientific literature, initial step of searching for "what subject to focus" has been called as identification process. Identification comprises those activities which capture information on new technologies and their likely business impact (Skilbeck and Cruickshank, 1997). Powerful information technologies have presented opportunities for identification of R&D topics where these technologies are capable of extracting the required information from different numerical/textual data efficiently.

Systems to trace technological developments around the world are known as Technology Watch Systems (TWS). TWSs are involved in processing of all information technology environments to extract knowledge, such as identifying trends and changes (Gomez-sanz, 2009). TWSs maintain awareness of all levels of global R&D through a systematic information retrieval and analysis. However the fact is that, TWSs have been usually the matter of commercial software. Therefore, ideas/algorithms behind these kinds of commercial software have been occasionally hidden due to the commercial realities.

Dereli and Durmuşoğlu (2007, 2009a) have also recently developed a TWS which is named as Patent Alert System (PAS). PAS uses trends in patenting activities as the indicators of the change in technology, and acts like an alert clock. The users, who want to keep track and monitor the trend changes in patenting activities, can set the alert. PAS makes use of the XML (Extended Markup Language) to capture and update the patent data from the publicly accessible patent databases. The captured data is searched for the trend changes in technologies requested in the alert. An internal alert triggering algorithm is used to search the potential trend changes on the associated data. The algorithm fits a constant line for the counts of patents and then calculates the deviation between the fitted and real value. If the cumulative deviation is much more then the predetermined threshold value, then a new line is searched by using the regression analysis. This loop is repeated immediately after each update. Trends found in the patent data expresses the time evolution of patents and technologies using the indicators like upward, downward and steady. These trend changes are used to generate “alerts” which are then forwarded on-line to the people who requests/sets the alerts.

Although the alerts (indicating the direction of technological changes) of PAS provide supportive information to the analysts, extracted lines have been rigid. As in case of linear regression; deviations (deviation of the observed value from the estimated value) is assumed to derive from relevant factors omitted explicitly from the model and random measurement errors in recording observations (Kim et al., 1996). However, deviations in techno-systems are known to occur as the consequence of the vagueness coming from the nature of the system. In modeling, it is important to fully capture the underlying nature of the data (Oha et. al, 1996). Therefore, it appeared to be worthwhile to reconsider alert triggering mechanism of a technology watch system -PAS- using “possibilistic fuzzy linear regression” where deviations are reflected as the fuzziness of the system.

3.3 Patent Alert System

A deeper understanding of technological change has been a vital to avoid redundant investment and develop promising businesses. In this sense, tracking of the technology systematically has become extremely important. Prediction of new engineering developments and scientific advances assumed to be independent of business activity is called “technical forecasting” (Kahraman, 2002). There have been numerous methods developed for technical forecasting. Different methods have utilized different type of data sources each with its own cons-pros. One of these data resources has been patents (Kim et al., 2008). If carefully analyzed, the patents can show technological details and relations, reveal business trends, inspire novel industrial solutions, or help make investment policy (Campbell, 1983; Jung, 2003). Patent data represent a valuable source of information that can be used to plot the evolution of technologies over time (Pilkington et. al., 2002). Together with the internet search, it can also be used for new product development (Khoo et al., 2002). Further from the all above mentioned benefits, patent data can indicate technological advances before the actual beginning of an innovation (Sen and Sharma, 2006). Therefore companies which are aware of technological advances by the use of patent data can stay updated and foresee future advances before the competitors do.

The rapid change in the number of patents (both applications and the granted ones) forces the use of fresh and updated data in any kind of patent analysis. Today, an enterprise often has to make real-time decisions about its operations in response to the fast changes happening all the time in the world (Dver, 2002). The recent availability of Internet-based abstract services and patent database, allowing easy access to documents in electronic form has made the application of bibliometric techniques for technology forecasting quite practical (Morris et al., 2002). These new web technologies have facilitated to access a patent data automatically, capture it and manipulate it as desired (Dereli and Durmuşoğlu, 2008). One of the most known of these technologies is XML (Extended Markup Language). XML has been a core technology which serves as a common language that facilitates data exchange and the rapid location of information (Shen et al., 2010).

Opportunities created by the advances in web technology and specifically in XML have created the idea of developing a trend-based Patent Alert System (PAS) for technology watch. PAS with XML integration provided fresh data through the patent search engines with its very high patent retrieval capacity.

PAS can be categorized as a technology watch system since it uses trends as the indicators of the change in technology, and acts like an alert system. The users, who want to keep track and monitor the trend changes in patenting activities, should set the alert. It makes use of the XML (Extended Markup Language) to capture and update the patent data from the publicly accessible patent databases. The captured data is tested for the trend changes in technologies requested in the alert.

The overall information flow of the PAS has been illustrated in Figure 3.1. The first step in the flow of the alert system is the configuration (setting) of alert by the user. The relevant IPC section, class and the subclass of the patents to be watched are selected by the alert initiator (the user) through the use of interface (Figure 3.1-A). The requested alert is then transmitted to PAS engine (Figure 3.1-B). PAS retrieves the relevant database by using XML (Figure 3.1-C) and the patent count data for the selected IPC section, class and the subclass is captured (Figure 3.1-D) correspondingly. The next step is the recording of the captured data to the own database of the PAS (Figure 3.1-E). An online trend-extraction algorithm is employed to search and find the trend changes in the captured patent data (Figure 3.1-F). If a trend change is found, the user is immediately alerted by following indicators (Figure 3.1-H); "stabilized (steady)" "positive (upward)" or "negative (downward)". If there is no trend extracted, then the loop is repeated in each update (Figure 3.1-G) (Dereli and Durmuşoğlu, 2007).

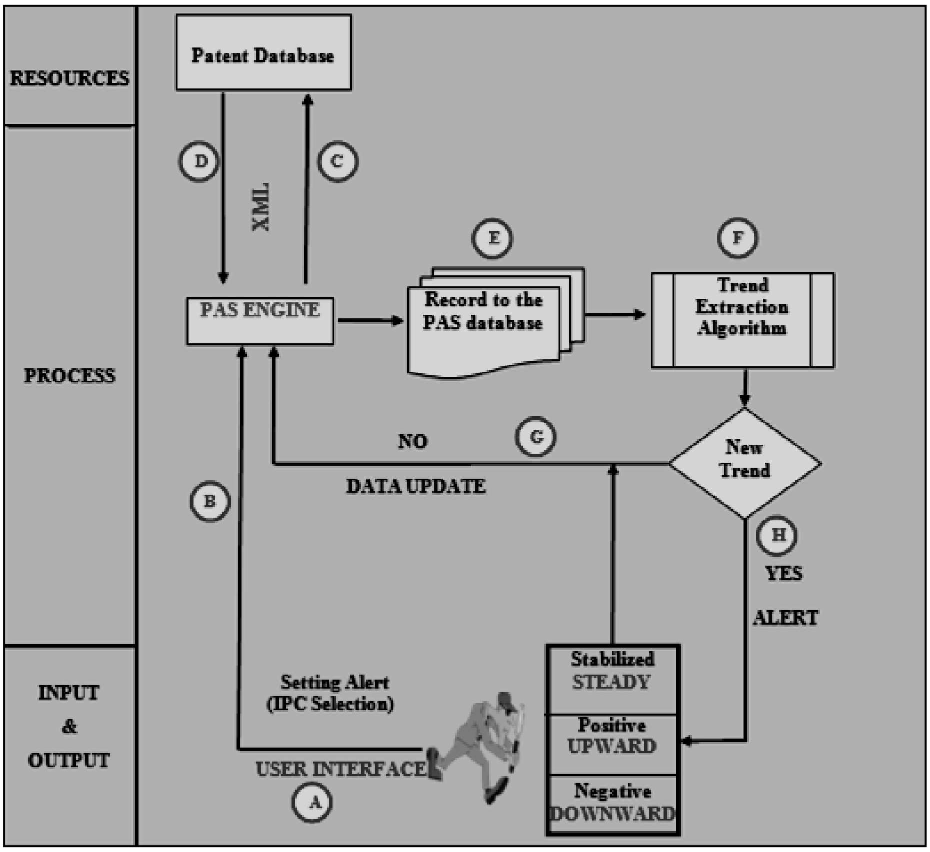

Figure 3.1 Overall flow of information in PAS (Dereli and Durmuşoğlu, 2007)

The patent studies may benefit from existing classification scheme of World Intellectual Organization (WIPO). WIPO introduced the "International Patent Classification" (IPC) system by Strasbourg Agreement in 1971. IPC system is a hierarchical system in which the whole area of technology is divided into a range of sections, classes, subclasses and groups the patents according to their scopes (WIPO). Since publicly accessible databases cluster the patents by using IPC codes, PAS has also designed in such a way that the alerts are configured and the patents are analyzed based on IPC codes (APPENDIX A).

A trend extraction algorithm has also been developed for PAS to search the trend changes within the monitored technology. The algorithm initially fits a constant line for the counts of patents and then calculates the deviation between the fitted and real value (of patent counts). If the cumulative deviation is more than the predetermined threshold value (a responsiveness parameter discussed in the following section), then a new line is searched by using the regression analysis. If no trend change is found, the algorithm halts until the database is updated. As soon as a new data captured by the system, the trend-search restarts.

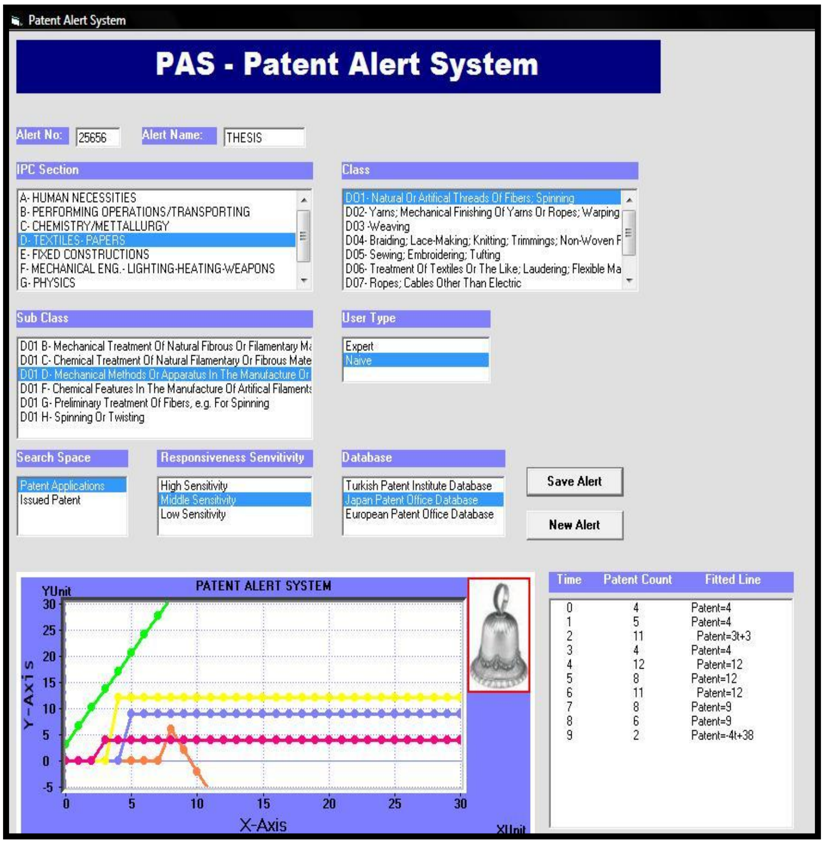

Figure 3.2 Interface of PAS for alert configuration (Dereli and Durmuşoğlu, 2008)

The trends found in the patent data express the time evolution of patent and technology with the symbols; upward (+), downward (-) and steady (stabilized) as illustrated in Figure 3.1. They are used to generate "alerts" which are then forwarded on-line to the people who requests/sets the alerts. A step by step explanation of the methodology developed for extracting the trend changes from counts of patents/applications is given below (Dereli and Durmuşoğlu, 2008).

The trends found in the patent data express the time evolution of patent and technology with the symbols; upward (+), downward (-) and steady (stabilized) as illustrated in Figure 3.1. They are used to generate "alerts" which are then forwarded on-line to the people who requests/sets the alerts. A step by step explanation of the methodology developed for extracting the trend changes from counts of patents/applications is given below (Dereli and Durmuşoğlu, 2008).

STEP 1- *Initialization of trend change extraction algorithm: The first value of the patent count captured for the "alert" configured by the user is assigned as the initial hypothetic line*

P(t) = R(t=0) (As initial step);
where;
t: Indicates the period number (it depends on the update frequency of the patent databases requested by the users) and starts with zero and increments one in each update.
P(t): Hypothetic line which sets the patent count.
R(t): Real patent count captured in time t

STEP 2- *In each data update, the deviation (dev(t)) and is cumulative deviation (cumdev) calculated between the hypothetic line and the real value (captured) obtained.*
dev(t) = P(t) – R(t)
Else cumdev(t)= cumdev(t-1)+ dev (t)

STEP 3- *If the cumdev(t) is more than the previously determined threshold value (th), then a new linear model is fitted by using "linear regression".*

Else; update the patent data under consideration and go to STEP 2.
If absolute cumdev(t)>th then linear regression is run and a new line is fitted as and cumdev(t)is set to zero.
P(t)= a(t)± b

STEP 4- *If there is a change in the model, this trend change is forwarded to user as an alert using one of the following indicators:*

Downward Trend	: If a < 0 ➔ negative (-)
Upward Trend	: If a > 0 ➔ positive (+)
Steady Trend	: If a = 0 ➔ stabilized

As discussed above, the trend extraction algorithm uses a *threshold value* (denoted by "*th*" in the trend extraction algorithm) for initializing the trend search within the patent counts being considered. Threshold value is actually a *responsiveness parameter* of the trend extraction algorithm which is one of the central parts of the Patent Alert System (PAS). The searching of new linear models is started when *the deviation between the fitted and real value of patent counts* exceeds the threshold value.

The responsiveness level (sensitivity) of the system is determined or adjusted by the users configuring the alerts through the use of user interface shown in Figure 3.2. Three options for the responsiveness sensitivity are provided/suggested by the system; high, middle and low sensitivity. If *"high sensitivity"* option is selected by the user; "1" has been assigned to the threshold value. This means that any deviation in patent count will lead a new trend search. If *"middle sensitivity"* or *"low sensitivity"* options are selected by the users; the threshold parameters are assigned based on *"average number of patents issued in the indicated patent section/class or sub-class"*. The average number of patents issued in the indicated patent section has been explored by the query created particularly for the Patent Alert System (PAS). The query discovers the average number of issued patents in previous week (one week prior to the alert configuration) and assigns it as the threshold value if *"low sensitivity"* option is preferred by the user. Half of the *"average number of patents issued in the indicated patent section"* is assigned as the threshold value in case of the *"middle sensitivity"* option. As the value of threshold parameter (*th*) decreases, the sensitivity of the PAS has been improved and therefore frequency of the alerts generated and forwarded to the users has increased correspondingly. However, it should be underlined here that the *"high sensitivity"* option sometimes may generate repeating alerts and this might not be desirable for the ones who just want to be informed about *significant trend changes*. Therefore, the selection of the best possible threshold value for the trend extraction algorithm is vital for drawing robust conclusions from the PAS. Alternatively, the adjustment of the threshold parameter might be left to the users, certainly, if they have the required experience and professionalism.

3.4 Fuzzy Regression

If underlying phenomenon or variable include some amount of "impreciseness", "vagueness" or "fuzziness" then a more realistic modeling is usually required instead of deterministic models. Statistical regression has been a practical method in explaining the relationships between the variation of the independent variable y and dependent variable x. However, there are some assumptions yet to be satisfied, for example, the randomness of the observed data (Wang and Lin, 2008). The deviations between observed and estimated values in "conventional regression analysis" are assumed to be due to random errors. However in fuzzy regression modeling deviations between observed values and estimated values are assumed to be due to system fuzziness (Kahraman et. al., 2006). Fuzzy regression is in many aspects more versatile than conventional linear regression because functional relationships can be obtained when independent variables, dependent variables, or both, are not only crisp values but intervals (Sanchez and Gomez, 2004).

The possibilistic regression model was first proposed by Tanaka and Guo (1999) to reflect the fuzzy relationship between the dependent and independent variables. It aims to build a model so that it could contain all observed data in the estimated possibilistic numbers resulted from the model (Imoto et. al., 2008). The basic idea, often referred to as the possibilistic regression approach, is to minimize the fuzziness of the model by minimizing the total support of the fuzzy coefficients, subject to including the data points of each sample within a specified α-cut (Shapiro, 2004).

For establishing possibilistic linear regression models, a linear model has been initially set, that learns a fuzzy regression function from crisp inputs and crisp or interval-valued outputs (Tanaka, 1987). In the first step, a linear regression function that produces an interval from crisp data is learned by solving a linear programming problem. Then, an interval-valued linear regression function is deduced. This function associates an interval to a crisp input.

The upper and the lower regression boundaries are used in the possibilistic regression to reflect the possibilistic distribution of the output values. By solving the linear programming (LP) problem, the coefficients of the possibilistic regression can easily be obtained. The general form of a possibilistic regression can be expressed as:

$$Y=A_1x_1+\ldots+A_nx_n=A^tx \qquad (3.1)$$

where x_i is an input variable, A_i is an interval denoted as $A_i=(a_i, c_i)$ with center a_i and spread c_i, Y is an estimated interval, $x=[x_1,\ldots,x_n]^t$ is an input vector and $A=[A_1,\ldots,A_n]^t$ is an interval coefficient vector (Tanaka and Guo, 1999).

In possibilistic regression, the given outputs are intervals where the given inputs are crisp; then two regression models are considered, specifically, an upper regression model and a lower regression model, where the estimated interval outputs approximate to the given outputs from upper and lower directions as shown below. These two regression models are called dual possibilistic models. The given data are denoted as:

$$(Y_j,x_{j1},\ldots, x_{jn})=(Y_j, x^t_j) \qquad (3.2)$$

where Y_j is an interval output denoted as (y_j,e_j). The dual possibilistic models are denoted respectively as follows:

$$Y_j^*= A_1^*x_{j1}+\ldots+A_n^*x_{jn} \text{ (upper regression model)} \qquad (3.3)$$

$$Y_{*j}= A_{*1}x_{j1}+\ldots+A_{n*}x_{jn} \text{ (lower regression model)} \qquad (3.4)$$

To obtain the upper and lower regression models simultaneously in Tanaka's fuzzy linear regression model (Tanaka et. al, 1989), an LP given in (Equations 3.5 through 3.7) should be solved. The objective function of the given LP covers the summation of residual values. The objective is to minimize total value of residuals which equally indicates the minimization of the total fuzziness of predicted output variables. In this LP model, predicted intervals include the observed intervals at "h-level degree of fit", which is satisfied by the constraints given in (3.6) and (3.7). "h-level" is also called as the target degree of belief. This target value is determined by the users, and it is also a measure of goodness of fit for the fuzzy linear regression method, which shows the compatibility between the model and the data (Chang and Ayyub, 2001). Since it is determined by the user, a proper selection of "h-level" is important for a fuzzy regression model. It is suggested that the "h value" be determined in accordance with the sufficiency of data at hand (Wang and Tsaur, 2000). If it is sufficiently large, then H-level should be taken as zero, and it should be increased with the decreasing volume of the data set.

$$\text{Minimize } J = \sum_{j=0}^{j=k} \left(c_j \sum_{i=1}^{n} |x_{ij}| \right) \tag{3.5}$$

Subject to

$$\sum_{j=0}^{j=k} \propto_i \; x_{ij} + (1-h) \sum_{j=0}^{j=k} c_j \; |x_{ij}| \geq y_i \tag{3.6}$$

$$\sum_{j=0}^{j=k} \propto_i \; x_{ij} + (1-h) \sum_{j=0}^{j=k} c_j \; |x_{ij}| \leq y_i \tag{3.7}$$

$c_{j \geq} 0, \qquad \propto_j \varepsilon \, R, \;\; j = 0, 1, 2, 3, \dots., k$

$x_{i0} = 1, \;\; i = 1,2, \dots \dots n, \;\; 0 \leq h \leq 1$

k: total number of independent variables
n: total number of observed dependent variable

In this regard, taking into account the above-given formulas, trend lines of PAS are extracted again in the illustrative example given in Section 3.5.

3.5 Reconsideration of Trend Mechanism

Patent Alert System (PAS) is used to identify technological changes and trends. In many situations, these directional change and thus their projections about future are imprecise to some degree, due to partial/imperfect knowledge and vagueness of systems. Thereby, conventional regression models are reconsidered to model these imprecise natures and induced imprecise functional relationships.

In PAS, alerts may arise in small time intervals depending on the threshold value. In these cases where small amount of data is available to run "modified linear regression", fundamental assumptions of statistical regression analysis lost its validity. It is well-known that that statistical linear regression is superior to fuzzy linear regression in terms of predictive capability, whereas their comparative descriptive performance depends on various factors associated with the data set (size, quality) and proper specificity of the model (aptness of the model, heteroscedasticity, autocorrelation, nonrandomness of error terms) (Kim et.al, 1996). For that reason, it is meaningful to reconsider alert triggering mechanism of PAS using "linear fuzzy regression". As a consequence the reconsidered algorithm is modified as follows (Section 3.2 presents for the previous version).

STEP 1- *Initialization of trend change extraction algorithm: The first value of the patent count captured for the "alert" configured by the user is assigned as the initial hypothetic line*

$P^*(t)=R(t=0)$ (upper regression model) and $P_*(t)=R(t=0)$ (lower regression model)
t: the period number (it depends on the update frequency of the patent databases requested by the users) and starts with zero and increments one in each update.
$P^*(t)$: Hypothetic upper line which sets the patent count
$P_*(t)$: Hypothetic lower line which sets the patent count
R (t): Real patent count captured in time t

STEP 2- *In each data update, the deviation (dev(t)) and is cumulative deviation (cumdev) calculated between the hypothetic lines and the real value (captured) obtained.*
$dev^*(t) = P^*(t)–R(t)$ (upper regression model's deviation)
$dev_*(t) = P_*(t)–R(t)$ (lower regression model's deviation)
Else
$cumdev(t)^*=cumdev^*(t-1)+dev^*(t)$ (upper regression model's cumulative deviation)
$cumdev(t)_*=cumdev_*(t-1)+dev_*(t)$ (lower regression model's cumulative deviation)

STEP 3– *If the $cumdev^*(t)+cumdev_*(t)$ is more than the previously determined threshold value (th), then a new linear model is fitted by using "linear regression".*

Else; update the patent data under consideration and go to STEP 2.
If absolute $cumdev^*(t)+cumdev_*(t)>th$ then possibilistic linear regression is rerun using the following linear programming and a new line is fitted as and $cumdev^*(t)$ and $cumdev_*(t)$ and is set to zero.

$$\text{Minimize } J = \sum_{j=0}^{j=1}\left(c_j \sum_{i=1}^{n} |x_{ij}|\right)$$

subject t*o*

$$\sum_{j=0}^{j=k} \propto_i \; x_{ij} + (1-h)\sum_{j=0}^{j=k} c_j \; |x_{ij}| \geq y_i$$

$$\sum_{j=0}^{j=k} \propto_i \; x_{ij} + (1-h)\sum_{j=0}^{j=k} c_j \; |x_{ij}| \leq y_i$$

$c_{j\geq}0,$
$\propto_j \, \varepsilon \, R, \;\; j = 0, 1, 2, 3, \ldots, k$
$x_{i0} = 1, \qquad i = 1,2, \ldots \ldots n,$
$0 \leq h \leq 1$

$P^*(t)=(p_1+\acute{\alpha}_1)(t)+(p_0+\acute{\alpha}_0)$ (upper regression model's deviation)
$P_*(t)=(p_1-\acute{\alpha}_1)(t)+(p_0-\acute{\alpha}_0)$ (lower regression model's deviation)

STEP 4- *If there is a change in the model, this trend change is forwarded to user as an alert using one of the following indicators:*
For any a (a_1 or a_2);

Downward Trend	: If a < 0 ➔ negative (-)
Upward Trend	: If a > 0 ➔ positive (+)
Steady Trend	: If a = 0 ➔ stabilized

3.6 An Illustrative Example

A real-life example was formerly presented (Dereli and Durmuşoğlu, 2009a) for demonstrating the execution of the trend extraction algorithm for the older version of PAS. Patents of "textile technologies" (laundering, drying, ironing, pressing or folding textile articles) were in use for the exemplification. In this reconsidered version "the novel mechanism for PAS" is employed for the same example.

Input data for this example is "time" and the output data is "patent applications for the given IPC" which is presented in Table 3.1.

Table 3.1 Number of granted patents for IPC-D06F (Dereli and Durmuşoğlu, 2009)

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
# of Patents	1	5	7	10	9	6	6	6	5	18	24	29	31	45	42	29	21	16	11	22

Several methods could be utilized to adjust threshold value. One of the most convenient methods is finding an average of the historical data. For this example; alerts which are generated after year 2000 are investigated. Therefore the average number of patents which were granted between 1987 and 2000 are used as threshold value (14.42) (Dereli and Durmuşoğlu, 2009).

The first unexpected deviation (where deviation is more than the threshold value) occurs in year 2003. A "Linear Programming" (LP) model is written to solve the possibilistic regression problem as follows;

$$
\begin{aligned}
&\text{Min } J= (c_0*(x_{10}+x_{20}+x_{30}+x_{40}))+(c_1*(x_{11}+x_{21}+x_{31}+x_{41})),\\
&a_0*x_{10}+a_1*x_{11}+(1-h)*(c_0*x_{10}+c_1*x_{11})>=45,\\
&a_0*x_{20}+a_1*x_{21}+(1-h)*(c_0*x_{20}+c_1*x_{21})>=42,\\
&a_0*x_{30}+a_1*x_{31}+(1-h)*(c_0*x_{30}+c_1*x_{31})>=29,\\
&a_0*x_{40}+a_1*x_{41}+(1-h)*(c_0*x_{40}+c_1*x_{41})>=21,\\
&a_0*x_{10}+a_1*x_{11}-(1-h)*(c_0*x_{10}+c_1*x_{11})<=45,\\
&a_0*x_{20}+a_1*x_{21}-(1-h)*(c_0*x_{20}+c_1*x_{21})<=42,\\
&a_0*x_{30}+a_1*x_{31}-(1-h)*(c_0*x_{30}+c_1*x_{31})<=29,\\
&a_0*x_{40}+a_1*x_{41}-(1-h)*(c_0*x_{40}+c_1*x_{41})<=21,\\
&c_0>=0,\ c_1>=0,\\
&x_{10}=1,\ x_{20}=1,\ x_{30}=1,\ x_{40}=1,\\
&x_{11}=2000,\ x_{21}=2001,\ x_{31}=2002,\ x_{41}=2003,\\
&h<=1,\ h>=0
\end{aligned}
$$

Using the software Matlab, the solution set is found as:

a_0= (16407.50), a_1= (-8),

c_0= (2.5), c_1=(0)

Thus, the optimal possibilistic regression can be obtained as follows:

y^U=-8x+16050 (upper regression line)

y^L=-8x+16045 (lower regression line)

Second unexpected deviation occurs in year 2003. As a consequence the new lines are detected using LP model given below.

$\text{Min } J= (c_0*(x_{10}+x_{20}+x_{30}+x_{40}))+(c_1*(x_{11}+x_{21}+x_{31}+x_{41})),$
$a_0*x_{10}+a_1*x_{11}+(1-h)*(c_0*x_{10}+c_1*x_{11})>=21,$
$a_0*x_{20}+a_1*x_{21}+(1-h)*(c_0*x_{20}+c_1*x_{21})>=16,$
$a_0*x_{30}+a_1*x_{31}+(1-h)*(c_0*x_{30}+c_1*x_{31})>=11,$
$a_0*x_{40}+a_1*x_{41}+(1-h)*(c_0*x_{40}+c_1*x_{41})>=22,$
$a_0*x_{10}+a_1*x_{11}-(1-h)*(c_0*x_{10}+c_1*x_{11})<=21,$
$a_0*x_{20}+a_1*x_{21}-(1-h)*(c_0*x_{20}+c_1*x_{21})<=16,$
$a_0*x_{30}+a_1*x_{31}-(1-h)*(c_0*x_{30}+c_1*x_{31})<=11,$
$a_0*x_{40}+a_1*x_{41}-(1-h)*(c_0*x_{40}+c_1*x_{41})<=22,$
$c_0>=0, c_1>=0,$
$x_{10}=1, x_{20}=1, x_{30}=1, x_{40}=1,$
$x_{11}=2003, x_{21}=2004, x_{31}=2005, x_{41}=2006,$
$h<=1, h>=0$

Thus, the optimal possibilistic regression can be obtained as follows:

y^U=0.334x-646.667 (upper regression line)

y^L=0.328x-646.667 (lower regression line)

The LP models given above has been solved using the “Matlab’s Optimization Tool” (Figure 3.3), All detected possibilistic lines are as presented in Figure 3.4.

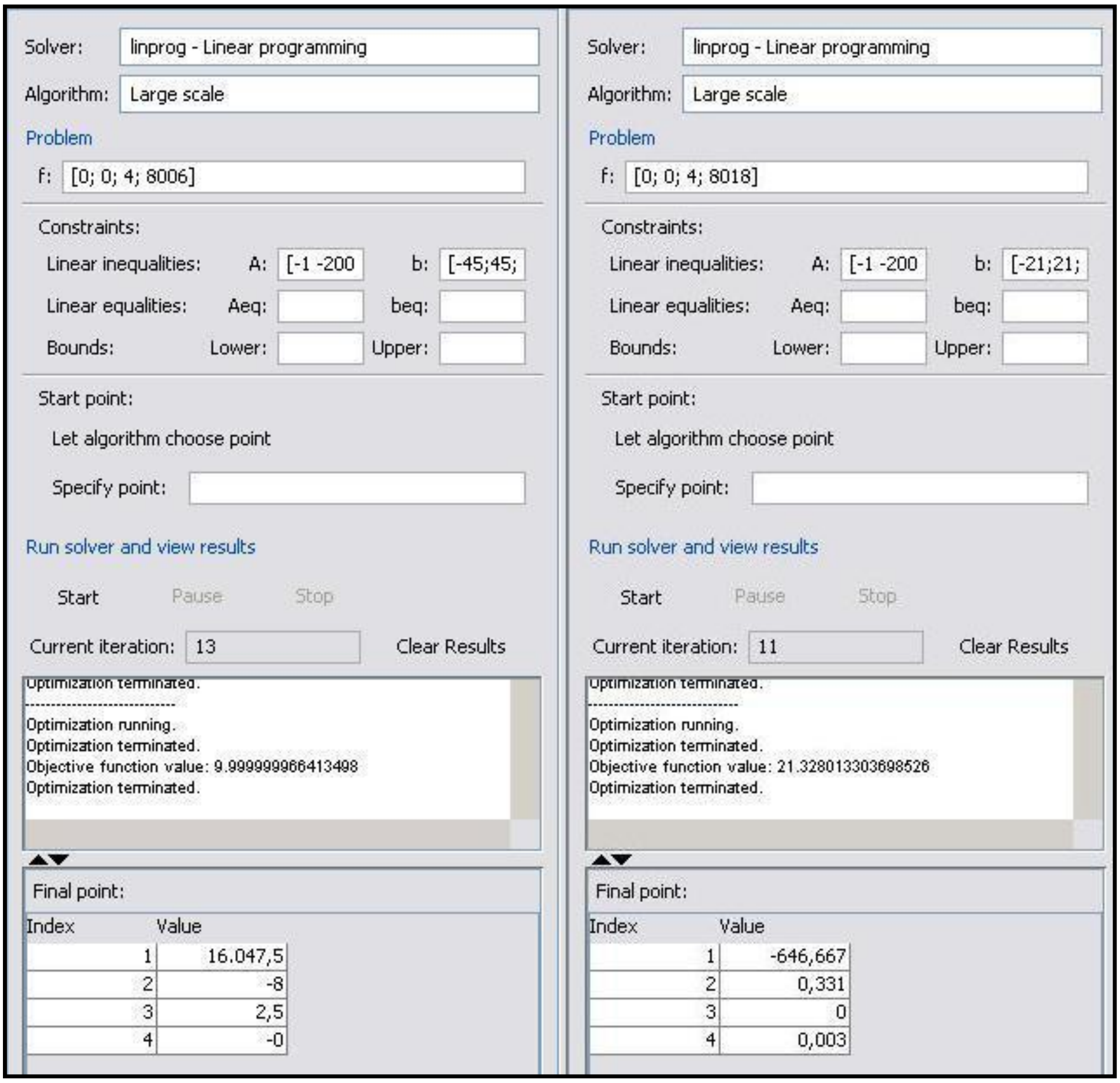

Figure 3.3 Snapshot for the solution of LP from Matlab's optimization toolbox

In the Matlab's optimization toolbox given in Figure 3.3, left pane shows the inputs and outputs (final point) of the points for the first unexpected deviation and the right pane shows the second. 13 iterations have been performed to obtain the upper and lower regression lines for the first deviation and 11 iterations for the second deviations.

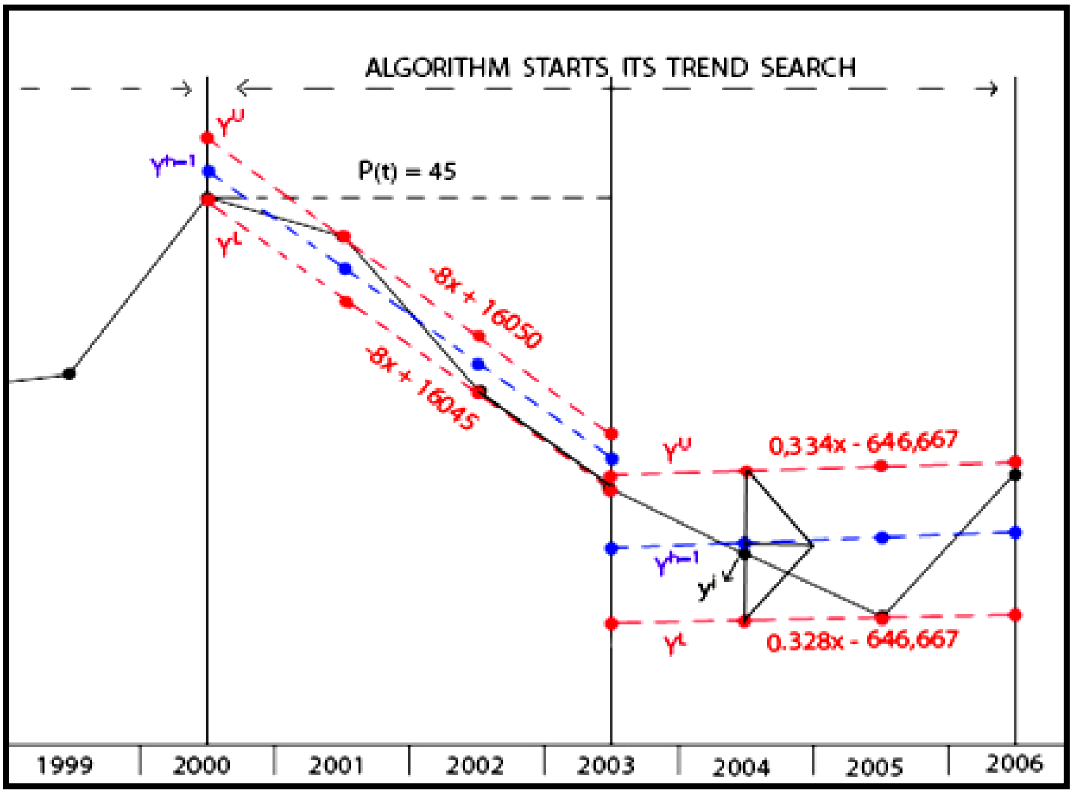

Figure 3.4 Graphical representation of trend extraction algorithm

The performance of the proposed reconsiderations can be evaluated using different error estimates, for this particular example "*Mean Absolute Percentage Error*" (MAPE) has been implemented.

3.7 Performance of the Proposed Reconsideration

Mean absolute percentage error (MAPE) is a measure of accuracy in fitted equations in statistics, specifically for trending. It usually expresses accuracy as a percentage and it is defined as:

$$M = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \tag{3.8}$$

where A_t is the actual value and F_t is the forecast value.

The difference between A_t and F_t is divided by the actual value A_t again. The absolute value of this calculation is summed for every fitted or forecast point in time and divided again by the number of fitted points n. This makes it a percentage error so one can compare the error of fitted time series that differ in level. MAPE has been considered as the performance indicator of the PAS with linear regression and PAS with possibilistic fuzzy regression. Table 3.2 presents the results.

Table 3.2 MAPE performances of the PAS

	PAS with linear regression	**PAS with possibilistic fuzzy regression**
MAPE	56,8 %	38,05 %

It should be stated that the MAPE values could be extremely lower with smaller threshold values. Threshold value determines the sensitivity level of the predictions and lower thresholds would yield more frequent updates of the models. The main idea for this comparison is to present relative improvement obtained by the use of possibilistic regression. Other then the exemplified data set given above, several other examples, including data from several different technologies, have been applied to the proposed technique and results demonstrated its effective solutions as in the given case.

The reconsideration of the trend triggering mechanism of PAS, enables users to predict the dependent variable (time) via an interval by using the predictor variable for issued patents more accurately. The coefficients of the model used for the regression are now also intervals. Each coefficient is expressed via its center (denoted as “a”) and its radius (denoted as “c”). Therefore, future projections are not narrowed anymore which is facilitated by the modification of existing trend extraction algorithm. As a consequence, more accurate forecasts are produced.

3.8 A Case Study for Wind Energy Technologies in USA

Wind energy is known as one of the utility generation technologies. The development of wind energy technology has been triggered by the oil crises and the concerns about the environmental effects of acknowledged energy sources. CO^2 gases emitted by fossil fueled electricity generation are one of the largest contributions to greenhouse gases and it builds 1/3 of the emitted CO^2 in US. The concern about the climate change caused by greenhouse gases have driven governments to limit the emission of the CO^2 and to look for more green alternatives for electricity generation. Wind energy seems to be the least expensive energy source among the renewable energy alternatives.

Wind power has been used for at least three thousand years. Before the end of the 19th century it was only used to produce mechanical power. The first wind turbines to generate electricity were introduced at the beginning of the 20th century. After that, wind power technology has been used and improved as an electricity generation source but it gained the real momentum at the 70s as mentioned above. Financial support for research and development of wind energy became available. This increased interest and available financial resources accelerated the improvement of wind energy technology. According to ABS 2010 Wind Power Report, 1.5% of the electricity generated globally in the year of 2009 was harvested from wind and compared to other renewable energy sources wind energy capacity added in 2009 was the largest. Worldwide capacity growth of wind energy was 31%. As a result of the step by step improvement in the wind turbine technology, also the size, depending on it the capacity, of the wind turbines increased over time. Most of the wind turbines installed in 90s had a capacity of 50-150 kW, today wind turbines with a capacity of up to 5 MW are commercially available.

Wind turbines generate power by converting the momentum in the wind into mechanical power and converting the rotating mechanical power into a.c. power via standard a.c. generation techniques.

The main two types of wind turbines regarding the rotating mechanical part, rotor, are horizontal axis and vertical axis wind turbines. Horizontal axis wind turbine is the most common type with propeller type, usually two or three blades rotating around a horizontal axis on top of a tower. In case of vertical axis wind turbines "slightly curved symmetrical airfoils" rotate vertically, which make it seem like an eggbeater. Vertical axis wind turbines have the advantage to operate independent of the wind direction and the mechanical parts which link the rotating part to generating part and also generating part are located at the ground level, which is on top of a tower in case of horizontal axis wind turbines. Horizontal axis wind turbines use different type of mechanisms to turn the axis into wind direction. Some disadvantages of vertical axis turbines are no "self starting capability" and "limited speed regulation options”. Today most of the commercially available wind turbines are horizontal axis wind turbines.

By using the fuzzied version of Patent Alert System, this section will analyze two different technologies based on wind energy. In order to connect the results with real world events, trend changes are evaluated against global events which should have an impact on technological development in this area.

3.8.1 Facts for implementation

Similar to linear regression based PAS procedure mentioned above the patent count data belonging to the years between 1974 and 1979 have been used for creating the first fuzzy regression. Initially, it is attempted to integrate threshold value by taking the average number of patent count data between 1974 and 1979. However it is experienced that if fuzzy regression based PAS procedure was applied there was a trend change alert in pretty much every year or two years. Mathematical reason behind this has been observed to be the fact that threshold value of fuzzy regression based PAS was a product of derivations from the actual data and both upper and linear regression lines. Thus, taking average of previous years’ patent counts for determining a threshold value was creating relatively smaller values.

As an implication, since the procedure requires any latter regression model to be created with the data that is between the previous trend change point and the given current point, in some cases newly created fuzzy regression models required upper and linear regression lines to be very close to each other so that they appear to be collapsing on top of each other. Reason behind this situation has been observed to be the fact that due to high frequency of trend alerts, newly created fuzzy regression models were fed only by data that belongs to only a few years back. This problem could be addressed by making use of more robust methods for predicting a threshold value such as making use of expert judgment however due to lack of expertise in the technology specific development this option was not viable. Although it is known that an established threshold value can still be applicable in case of mature technology areas where technological developments are rather saturated however they may not always be applicable in case of relatively rapidly developing technology areas.

Due to dropping threshold value method, need for determining a new way to identify trend change points has emerged. Since fuzzy regression methods create both an upper and a lower regression line the range between these lines has been accepted as the expected range of possibilities and in case any observed data went out of the expected range that time point has been regarded as the beginning of a new trend. In order to address the issue of selecting range of data fed into the fuzzy regression model moving average method, that makes use of previous 10 years at the time a trend change alert has been encountered, has been adopted. As technology application involves in energy related development range of moving average can depend on multiple perspectives which might be social, political, environmental and technological developments. In this case range has been determined as 10 years, but could better be improved with an expert help. It is understood that use of moving average can be more applicable to relatively rapidly developing technology areas in order to make the regression models more adapting to the significant changes.

3.8.2 Horizontal windmills

Results of fuzzy regression based PAS method for horizontal and vertical motor control data can be observed in Figure 3.5 and Figure 3.6 below. Red lines represent actual patent data counts observed throughout the years whereas dotted lines are regression lines representing expected range of possibilities created between trend changes. As realized, range of possibilities has been varying for different years. The reason behind this occurrence is the fact that expected range of possibilities determined by upper and lower regression lines are created by using 10 years of previous data points and these years might have relatively high and low patent counts. In some cases such as years after 2003 expected ranges of possibilities are relatively wide due to the fact that there have been major changes in patent counts and PAS model tends to take all those into consideration while predicting the upcoming years. An implication that can be drawn from this situation is that due to rapid changes relative to previous years, expectations for the latter years are uncertain and might actually require organizations to better focus on the technological development.

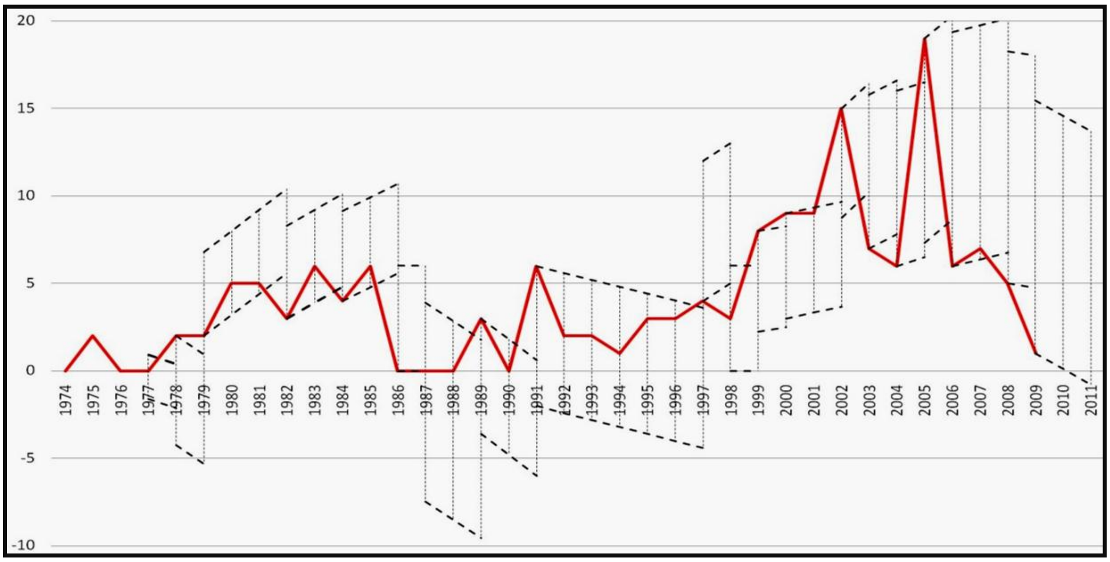

Figure 3.5 Horizontal axis motor control with fuzzy regression based PAS

3.8.3 Vertical windmills

As mentioned before, in the previous section there was a need for modifying range of range of moving average. In the Figures 3.6 and 3.7 below you can see the results in the case where moving average was always product of previous 10 years. As encountered, fuzzy regression model producing Figure 3.6 (expected range of possibilities from 1989-2009) has been modified by only using previous 7 years where as fuzzy regression model producing Figure 3.7 (expected range of possibilities from 2002-2004) has been modified by using previous 9 years. As can be observed the reason for modifying fuzzy regression model for horizontal motor control case, the expected range of possibilities appeared to be too wide that it did not really give any significant information about what might actually happen in the upcoming years where as in the case of vertical motor control we observed the trend to go down a little unexpected since the previous years' data seemed to create stable forecast expectation. It is believed that these results are product of local optimum points that may not have been caught by the algorithm of the software package we are using.

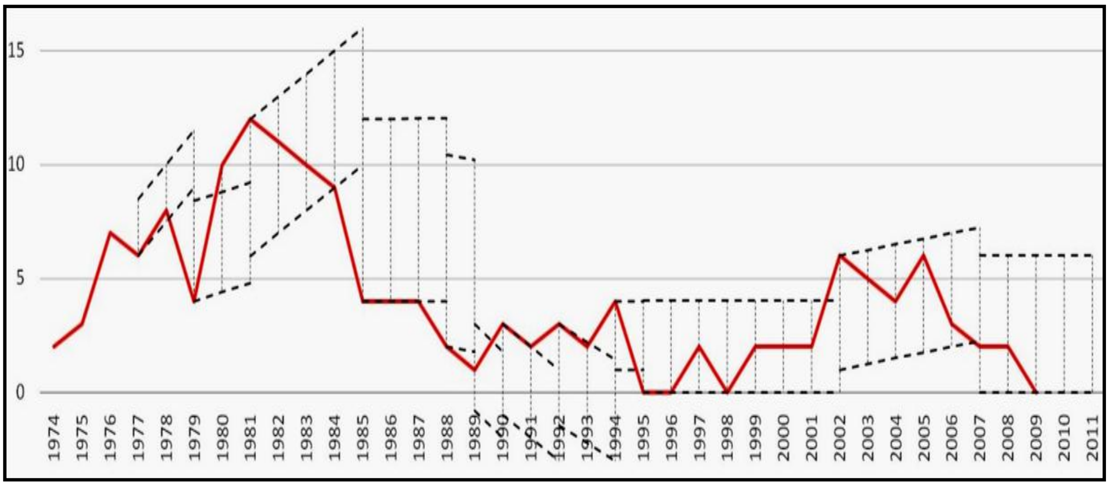

Figure 3.6 Vertical axis motor control with fuzzy regression based PAS

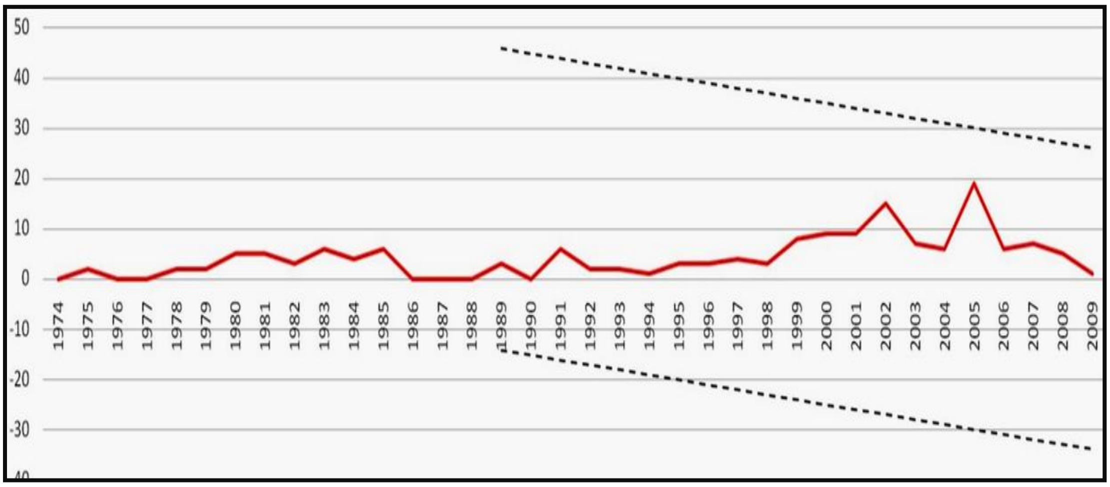

Figure 3.7 Horizontal axis motor control without moving average modification

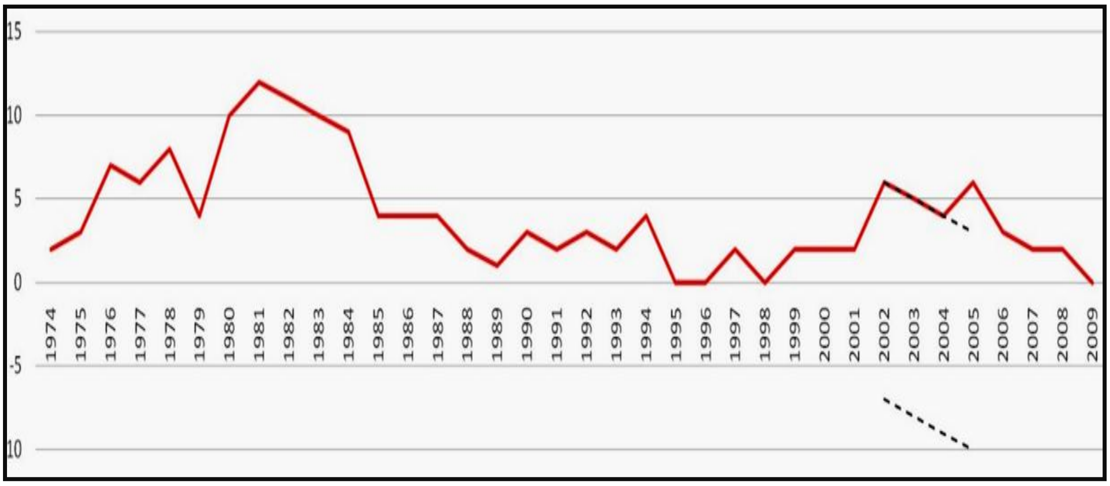

Figure 3.8 Vertical axis motor control without moving average modification

3.9 Conclusion

Deviations in techno-systems are known to occur as the consequence of the vagueness coming from the nature of the system. Therefore, models which reflect deviations as the randomness of the system have lost their validity. It is very well known that fuzzy logic is of valuable help in modeling mathematically complex or ill-defined systems (Acosta and Todorovich, 2003). In this regard, there has been a certain need to reconsider alert triggering mechanism of a previously developed TWS -PAS- using "linear fuzzy regression" where deviations can be presented in form of the fuzziness. The reconsideration of triggering mechanism of PAS mentioned in this chapter enabled potential users to predict the patent counts via an interval by using the predictor variable, time.

In this chapter, the possibilistic regression model is employed to derive the possibilistic area of the future technology by the use PAS. The proposed trend mechanism for PAS, is an appropriate method and appeared to be useful in searching the change-points of technology trends. All considered sample data yielded strictly positive outcomes when compared to the existing trend extraction mechanism located in PAS. With the reconsidered model, future projections are not narrowed anymore where the intervals present possibilistic ranges for the future occurrences. Hence, more precise and accurate forecasts are produced. One other benefit of the possibilistic regression method has been its efficiency in terms of computation time and its ability to handle noise to some extent.

PAS has the potential to serve as a cornerstone for credible technology forecasting and help predict the technology directions of industries. Future research in this regard can be carried out by a more advanced and sophisticated fuzzy-based genetic model which may be required to clarify the variation in patenting activities/technology changes.

CHAPTER 4

CLUSTERING OF TECHNOLOGIES VIA NUMBER OF INVENTIONS

4.1 Introduction

International Patent Classification (IPC) system is a hierarchical classification structure used essentially to classify and explore patents along with the technical fields which they are concerned with. Therefore; corresponding number of patents for a certain IPC, can serve as an indicator of technical developments in the relevant area. These numbers can also form a basis for investigating state of the art for a particular field of technology.

In this section of the thesis an approach for clustering of patents is proposed for those of the technologies listed by IPC via the number of patent counts. A set of n real numbers indicating the patent counts for different technologies is partitioned into k clusters such that the sum of the squared deviations from the mean-value within each cluster is minimized. With this purpose in mind, two different heuristics have been considered for clustering since complete enumeration would take considerable solution time.

The first heuristic is specifically proposed for this thesis and the second one is *G*reat *D*eluge *A*lgorithm (GDA) which has been extensively used for solving complicated problems. The proposed heuristics are coded in visual basic (VB) 6.0 and a user interface is developed for the program. The developed program attempts to find the appropriate k value in order to make the best possible clustering (Dereli et. al, 2011b).

As an application of the proposed clustering approach, patent data that is retrieved from web site of Turkish Patent Institute (TPI) has been used for clustering technologies.

4.2 Statement of Purpose

Technology/Technical Intelligence (TI) is business-sensitive information on technical events, trends, activities or issues (Ashton & Stacey, 1995). It aims to capture and disseminate the technological information needed for strategic planning and decision making. Many methods have been developed to recognize progresses of technologies, and one of them is to analyze patent information (Kim et al., 2007). Patents are known as one of the best instruments for businesses to keep control of technological innovativeness (Shih et al., 2009). Through the analysis and organization of large amounts of patent data, the technical development of specific industries can be exhibited (Chen, 2009). These existing analyses have extensive range from time series analysis to citation analysis. However, to the best of our knowledge only one of these studies (Dereli and Durmuşoğlu, 2009b) considered clustering technologies via the volume created by the patents which has provided essential motivation to perform this framework. In their preceding study (Dereli and Durmuşoğlu, 2009b) they employ "K-means clustering" method to classify technologies through the patent counts which they are assumed to be a member of a fuzzy cluster (trendy, classical and dated). As they and we focus on, clustering patents using the patent counts is expected to support technology developers and trackers by providing a stature about the subsets of technologies via the demand for patenting technologies.

Number of patent counts is also utilized excessively; to determine which technologies can be grouped on the same cluster in means of the volume they have. A clustering approach is proposed for patents for those of the technologies listed by IPC through considering the total number of patents. A set of n real numbers indicating the patent counts for different technologies is partitioned into k clusters such that the sum of the squared deviations from the mean-value within each cluster is minimized. With this purpose in mind, two different heuristics have been considered for clustering since complete enumeration would take considerable solution time. The first heuristic is specifically proposed for executing the proposed clustering approach and the second one is a well-known and relatively novel heuristic named as *G*reat *D*eluge *A*lgorithm (GDA).

In accordance with the proposed heuristic (PH), technologies are classified randomly into desired/preferred number of clusters (which the value for k is allowed to be entered by the user through the interface) and sum of standard deviations for each of cluster is used as the measure of fitness for the proposed heuristic. Novel clusters are re-formed by using the predetermined neighborhood strategy and the new fitness is calculated at the each iteration. Better fitness values (is expected to be as small as possible) which have smaller deviations are accepted without any reservation. On the other hand, worse ones are only accepted with a certain probability to avoid stacking in local optimum.

During the implementation of Great Deluge Algorithm (GDA), a different neighborhood generating strategy is used which is previously employed by Gonçalves and Resende (2004). A solution set representing a candidate solution to the problem is encoded as a vector of random keys and each solution set is made of T+1 genes. Using the given neighborhood generation strategy the worse solutions are accepted if only its fitness is less than or equal to some given upper limit. If the novel solution is worse than tolerance/upper limit, a different neighbor is selected and the process repeated. If all of the visited neighbors of produce approximate solutions beyond tolerance, then the algorithm is terminated and *the best solution at hand* is put forward as the best approximate solution obtained.

Consequently, the proposed heuristic and the GDA has been coded in visual basic (VB) 6.0 and a user interface/friendly program has been developed. As an application of the proposed scheme, patent statistics of Turkish Patent Institute (TPI) has been used and the most appropriate number of clusters has also been found.

The rest of this chapter of the thesis is structured as follows. Section 4.2 is a brief discussion of literature including “technology classification” and “classifying methodologies” are given in. The data retrieval for gathering patent information is presented in Section 4.3. The basics of the proposed heuristic and GDA are briefly overviewed in Section 4.4. The developed interface and an implementation from Turkey have been illustrated in Section 4.6 and Section 4.7, respectively. Concluding remarks and potential benefits of the proposed classification scheme are discussed in Section 4.8.

4.3 Literature

The domain literature related to this section can be divided into two parts: Technology classification and classification and clustering methods.

4.3.1 Technology classification

Technologies can be classified in terms of several dimensions such as the functions they perform, the structures they have, energy usage intensity, required know-how to operate them and etc. However; these classifications consider technical aspects and they do not include market value or future opportunities into account. It is possible to find several different examples for such technical classification. One of the known studies on the *"technology classification"* was performed by Steele (1989). Steele has roughly classified the technologies as: product technologies, production technologies and information technologies.

Muller (2004) preferred to classify technologies in terms of the *"require know-how"* to operate technologies. He named these classes as: *"hard technology" and "soft technology"*. Jin et al. (2008) divide technologies into two main groups as: *"physical technologies"* and *"information technologies"*. They call all physical assets and operational technologies under the group of physical technologies. Subsequently they employ Kotha and Swamidass's (2001) technology classification and they group technologies as advanced manufacturing technologies, physical assets and operational technologies under the title of three clusters which are *"Product Design Assets and Technologies"*, *"Process Assets and Technologies"*, and *"Logistics/Planning Assets and Technologies"*. Dissimilar to existing classification efforts, Dereli and Durmuşoğlu (2009b) classified technologies, in terms of their popularity and trendiness. They classified technologies into three types- trendy, classic, and dated- that are identified by using K-means clustering approach. They have tested their approach by using textile patents retrieved from the on-line database of the Turkish Patent Institute.

4.3.2 Classification and clustering methodologies

Classification is known as the arrangement of objects into groups on the basis of their relationship (Bieniawski, 1989) and similarity. It has been an intensively applied method for gaining insight about different phenomena. Scientists from several different areas employ their own ways of solving the classification. Therefore; it is possible to find, a wide range of techniques in the literature to handle classification and clustering problems as a special type of classification imposed on a finite set of objects, whose relationship to each other is presented by a predefined proximity.

There are two main categories of classification which is unsupervised and supervised classification. Supervised classification means that the classifier is induced from a set of data containing information about individuals for which the class value is known (Nielsen et al., 2009). On the other hand, unsupervised classification refers to the process of defining classes of objects. It is sometimes called "cluster analysis" (Stille and Palmström, 2003). Clustering analysis methods can be listed as: nearest neighbor methods, hierarchical methods, and mixture model methods. The nearest-neighbour methods are one of the most popular methods used in clustering analysis. Objective of these algorithms is to determine where the new data belongs among "k distinct classes". This classification is based on a historic data set of examples. In hierarchical clustering, a hierarchy of clusters is established to represent clusters in the form of a tree structure. All observations are initially listed on the root of the tree within a single cluster and subsequent leaves correspond to clusters under that hierarchical level. It must be noted here that, the previous work of Dereli and Durmuşoğlu (2009) which classified technologies into three classes (trendy, dated and classical) was a "supervised classification" which k=3 was given as a priori. The proposed classification presented in this part of the thesis, does the similar by letting users to enter the value of k, however it succeeds further by searching the best value of *"k"* by employing a heuristic algorithm.

Even it is supervised or unsupervised classification; similarity of members in a group/class in terms of the measured attributes indicates the success of the classification. Therefore, similarity functions are important for measuring performance of the classification. A similarity function defines the form to compare the descriptions of the objects (Martínez-Trinidad and Guzmán-Arenas, 2001). There is a wide range of similarity functions, from very simple string matching functions to very challenging ones. Similarity functions are imperfect and the quality of their results will depend on the specific data set being matched (Silva et al., 2007). The most known similarity measures are based on distances, such as Euclidean distance, Manhattan distance and classical standard deviation. Some similarity measures may not be applicable for some data sets, like nominal data which illustrates state of qualifications (ie: defective or not). Thus, there is no unique similarity function that works best on all given problems. Defining the appropriate similarity function does not end the process of classification. Similarity functions should be maximized or dissimilarity functions should be minimized in order to obtain a solution set. Minimizing or maximizing these functions may not be as easy as expected. If the complexity increases, data clustering is converted into an NP-complete problem (Garey et. al, 1982), which may not be solved optimally by employing classical search procedures. At that time, heuristics are used to obtain the best possible minimum or maximum (ie: Güngör and Ünler, 2007; Güngör and Ünler, 2008).

4.4 Data Retrieving

Numerous sites have been developed to provide access to patent information over the Internet (ie: http://ep.espacenet.com, http://online.tpe.gov.tr). These web sites are extensively prepared by the patent offices. However it would not be easy to retrieve patent information from these sites systematically if the patents had not been structural documents. Behind these considerations, the studies which have been issuing patent information should necessarily involve structured and classified information with the purpose of distinguishing one technology from the others. International Patent Classification (IPC) system developed by World International Property Organization (WIPO) has been one of the widely used classifications to achieve the anticipated decomposition (Wu et. al., 2010; Dereli and Durmuşoğlu, 2009; Kang et. al., 2007; Alencar et. al. 2007; Trappey et. al., 2006; Richter and MacFarlane, 2005). The IPC covers all areas of technology and is currently used by the industrial property offices of more than 90 countries. The expert system is designed to handle raw natural-language text input and to avoid using any humanly-selected keywords for classification (Fall et. al., 2004).

A full listing of the IPC can be found at APPENDIX A. By means of IPC system, patent documents can be retrieved from several free accessible patent databases for a certain section, class or subclasses. The collected data based on these retrievals can be used to represent several statistics such as; number of patent applications, number of granted patents, number of claims listed per patents and number of cited patents and etc. In trend analysis regarding the technological activities, number of patent applications or granted patents has been repeatedly used to determine time evolution of technological activities (ie: Shih et al., 2009; Dereli and Durmuşoğlu, 2009; Yoon and Park, 2004; Lee et. al, 2009; Choi and Park, 2009; Choi et al. 2007, Suh and Park, 2009; Guellec and Potterie, 2001 etc.).

4.5 Description of the Proposed Heuristic

Clustering has been an important examination in information and data analysis. Many of its applications can be found in the literature of marketing, medical sciences, archaeology, or pattern recognition. However, as stated before, technologies have not been clustered in terms of their trendiness before. Thus, the problem of clustering technologies can be defined as follows: Given ***n;*** number of patent applications or granted patents for ***T*** **technologies**, the objective is to classify all the elements into ***k*** **clusters** (Figure 4.1)**,** such that the sum of square of the distances of each element to the center of its belonging cluster is minimized. Since it is proposed to add up the distances, it is appropriate to employ “standard deviation” as the similarity function to avoid neutralizing effect of negative distances on the positive distances. It is known that smaller standard deviations reflect more bundled data. More bundled data means less extreme values. A data set with less extreme values has a more reliable mean at that hand.

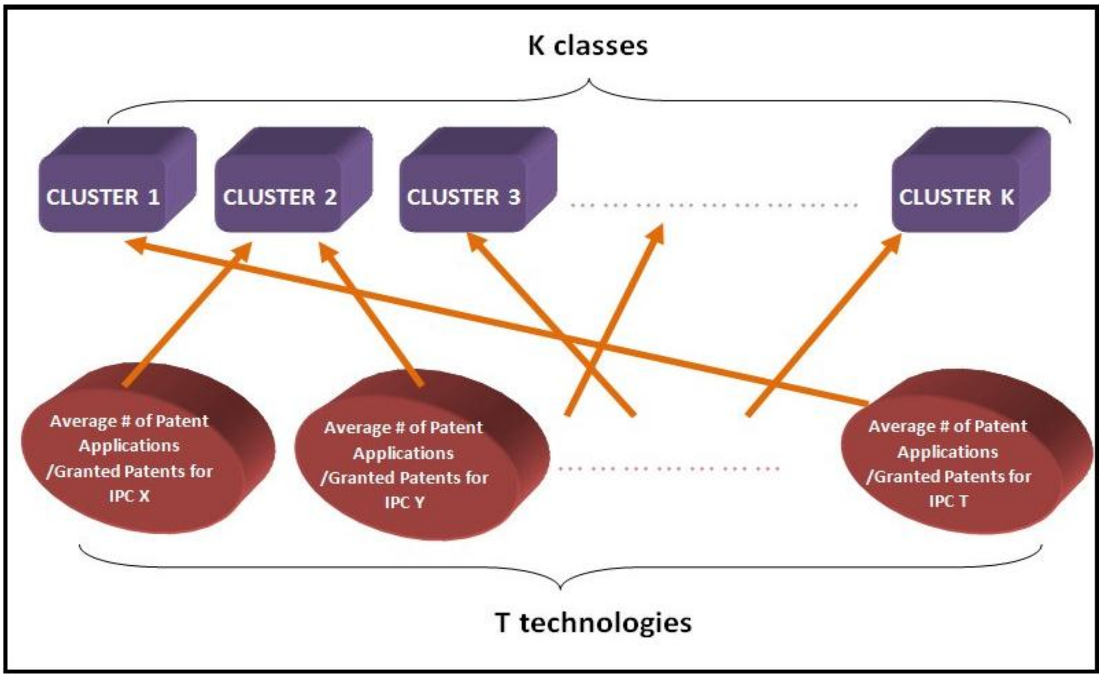

Figure 4.1 The general scheme for clustering

The steps of the proposed heuristic are as illustrated in Figure 2. An initial solution is created randomly. For this purpose number of technologies (T) to be clustered in cluster (K) in determined using the Equation (4.1) and Equation (4.2).

Number of Members (KM) in the first cluster:

$$KM_1 = \text{int}\left(\frac{T}{K}\right) \tag{4.1}$$

Number of Members (KM) in i^{th} clusters other than the 1^{st} one

$$KM_i = \text{int}\left(\frac{T - \sum_{i=1}^{i=i-1} KM_i}{K - \sum_{i=1}^{i=i-1} K_i}\right) \tag{4.2}$$

Subsequent to initial solution generation, fitness value is calculated by using the standard deviation since it is accepted as the similarity function through the clustering given in the proposed algorithm. The calculated fitness value is saved as the “best at hand” and “at hand”. Value of “at hand” changes for each acceptable solution; however value of “best at hand” changes if only a better result than the existing one is found.

After the initial solution is saved, a move to a novel solution is performed through 3 different neighborhood search strategies. In the first strategy, a cluster is selected randomly to assign one member of the most populated cluster. During this random number generation and for all other random number generation processes, existing ranges are uniformly and dynamically updated by using the Equation (4.3) and Equation (4.4).

<u>For Random Cluster Selection</u>

If P(0<=rnm<1/K) then Select cluster “1"

If P((k-1)/k<=rnm<=i/K) then Select cluster “i" (4.3)

<u>For Random Cluster Selection</u>

If P(0<=rnm<1/KM)< then Select member“1"

If P((KM-1)/KM<=rnm<i/KM) then Select cluster “i" (4.4)

In the second strategy, a randomly selected member of randomly selected cluster is added to randomly selected cluster. Finally, in the third strategy, one member from each of two randomly selected clusters is interchanged. Subsequently, fitness value is calculated again as stated before. Better solutions are accepted, however worse solutions are only accepted if a randomly generated number (rnm) is smaller than $1/(\text{iteration})^2$ just not to stack in a local optima. It is worthy to state here, why $1/(\text{iteration})^2$ is used as an acceptance measure. Remember that, from a mathematical point of view, Simulated Annealing (SA) can be viewed as a randomization device that allows wrong-way movements during the search for the optimum through an adaptive acceptance/rejection criterion (Wei-zhong and Xi-Gang, 2009). Heat intermediates this randomization. Heat is decreased by the time and thereby probability of acceptance for worse solutions gets smaller. Therefore, 1/(iteration)^2 is employed as it is the decreasing heat. In each iteration 1/(iteration)^2 gets smaller but not as fast as it would be in 1/(iteration).

The above described procedure goes ahead until a certain number of iterations do not contribute to fitness value or certain number of iterations is completed.

Objective Function Z= Minimize (Standard Deviation of Clusters)

```
Initial Solution          Determine the number of members to be assigned to each clusters
                          Assign each technology to a cluster randomly
                          Calculate the STD for each cluster
                          Sum STDs up
                              save it as At Hand
                              save Best At Hand
                      while  stopping criterion is not true  do;
Neighborhood Generation       Produce a random number for neighborhood generation strategy
                          If strategy 1 is selected
                              Randomly select a cluster
                              Select a member from the most populated cluster other than selected one
                              Add that randomly selected member to the selected cluster
                          If strategy 2 is selected ,
                              Randomly select  a cluster
                              Randomly select a member from that cluster
                              Add that member to a randomly selected cluster
                          If strategy 3 is selected
                              Randomly select  two clusters
                              Randomly select one member from each of that clusters
                              Interchange members' clusters
Calculate Fitness               Calculate the STD for each cluster
                          Sum STDs up and compare it with Previous At Hand
                                If summed up STD < Previous At Hand
                                Save summed up as At Hand
                                If At Hand< Best At Hand
                                Save At Hand as Best At Hand
                                    Else
                                    Accepting Criteria= 1/(iteration)^2
                                    Produce a random number as RDN
                                        If RDN< Accepting Criteria
                                    Accept Conditionally
                                             Save summed up as At Hand
                                        Else Reject
```

Figure 4.2 The steps of the proposed heuristic

4.6 Great Deluge Algorithm (GDA)

A local search procedure called "*G*reat *D*eluge *A*lgorithm**"** (GDA) was introduced by Dueck in 1993. It has been relatively a novel algorithm applied to optimization problems. It has also several similarities with the simulated annealing algorithm (SA). As in case of SA; GDA may accept worse candidate solutions (than the current one) during its run (Burke et al., 2010).

The pseudo-code of a variant of GDA employed for this work is given in Fig. 3. In implementation of the GDA, the algorithm is initialized with a random solution *s*. A numerical value of *initial cost/badness* is computed for *s* and thereby it is undesirability is measured. The higher the value of *cost/badness ((f(s))* the more undesirable is the initial random solution. Another numerical value called the *tolerance (B)* is included as being equal to the initial cost.

```
Set the initial solution s
Calculation initial cost function f(s)
Initial level B=f(s)
Specify input parameter ΔB=(B0- f(s*))/Nnow
While further improvements is impossible
        Define neighborhood N(s)
        Randomly select the candidate solution s* ε N(s)
        Calculate f(s*)
         If  f(s*) ≤ f(s)
         Then accept s*
Else if  f(s*) ≤ B
    Then accept s*
Lower the level  B = B - ΔB
```

Figure 4.3 The pseudo code for the implemented GDA

The worse solutions are accepted if its fitness is less than or equal to some given upper limit *B* (in the paper by Dueck it was called a "level") (Burke et al., 2004). If *s** is worse than tolerance/upper limit *B*, a different neighbor *s** of *S* is chosen and the process repeated. If all the neighbors of *s* produce approximate solutions beyond *tolerance (B)*, then the algorithm is terminated and *s** is put forward as the best approximate solution obtained.

In this algorithm the decay rate B actually defines the speed of the "level" reduction. For the desired number of moves N_{mov} and its value can be calculated by Equation (4.4)

$$\Delta \boldsymbol{B}=(B_0-f(s^*))/N_{now} \tag{4.4}$$

where B_0 is the initial value of the level and the $f(s^*)$ is the cost function of the final result.

4.6.1 Neighborhood structure

During the implementation of GDA, a different neighborhood generating strategy is used which is previously employed by Gonçalves and Resende (2004). A solution set represents a candidate solution to the problem and is encoded as a vector of random keys (random numbers). Each solution set is made of T+1 genes where T is the number of technologies to be clustered. The T+1st gene is used to determine the number clusters and the uses the Equation (4.5).

$$\text{Number of Clusters} = \text{Smallest Integer} > [gene_{M+1} * T] \quad (4.5)$$

Genes 1 through T are used to determine the assignment of technologies to the clusters using the Equation 6. Figure 4.4 presents an example of the decoding of a solution set.

$$Cluster_i = \text{Smallest Integer} > [gene_{i*}\text{Number of Clusters}] \text{ where } i = 1,., T \quad (4.6)$$

Number of technologies to be clustered = 8
Randomly Generated Data Genes = (0.70, 0.89, 0.12, 0.54, 0.37, 0.78, 0 41, 0.19, 0.29)

0.70 0.89 0.12 0.54 0.37 0.78 0.41 0.19 0.29

Number of clusters [0.29*8]=3
H goes to cluster [0.19*3]=1
G goes to cluster [0.41*3]=2
F goes to cluster [0.78*3]=3
E goes to cluster [0.37*3]=2
D goes to cluster [0.54*3]=2
C goes to cluster [0.12*3]=1
B goes to cluster [0.89*3]=3
A goes to cluster [0.70*3]=3

Cluster 1= {C, H}
Cluster 2= {D, E, G}
Cluster 3= {A, B, F}

Figure 4.4 An example of decoding a solution set

4.7 Development of the Computer Program

The proposed heuristics are coded in visual basic (VB) 6.0 and a user interface/friendly program is developed. This program can be run either using the k value taken from the user or trying to find the best k value in order to make the best clustering for the proposed heuristic and for GDA it only searches for the best k value. Figure 4.5 illustrates the interface of the program. Microsoft Excel is employed for data uploading to the program. Therefore, the number of data entrance is limited with the capabilities of Excel. Besides, the data should is expected to be consistent with the existing structure entrance where the first row includes data titles and the second row includes the number of patent applications and the number of granted patents.

Two types of reporting function is prepared. The first one reports only the best results obtained. In the second type of reporting, details about the selected options, rejected/accepted results are given.

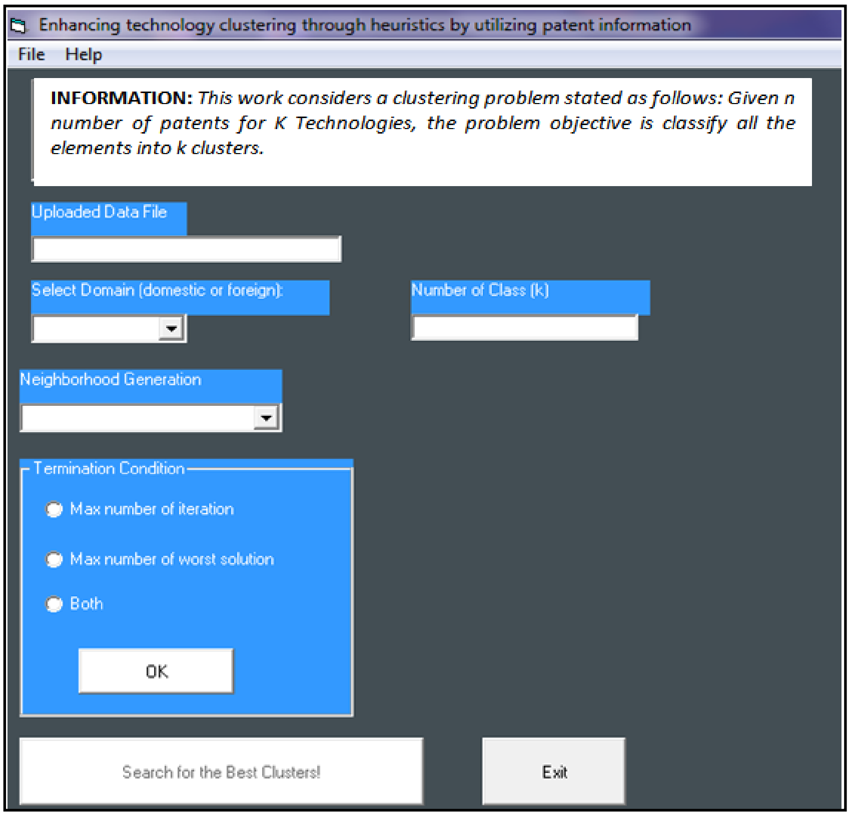

Figure 4.5 A snapshot from the interface

4.8 An Application of the Proposed Methodology

The proposed clustering approach has been tested with patenting activity statistic taken from the Turkish Patent Institute (TPI) (http://www.turkpatent.gov.tr/portal/default2.jsp?sayfa=136). Patents from eight main IPC sections from A to H and from1998 to 2008 are included. Both number of applications and granted patents are comprised for these technologies. The corresponding data is as illustrated in Table 4.1. The proposed heuristic has been run through the visual basic interface by considering the averages for these 11 years.

Table 4.1 Number of granted patents and patent applications between 1998 and 2008

IPC Section	Domestic 1998	Foreign 1998	Domestic 1999	Foreign 1999	Domestic 2000	Foreign 2000	Domestic 2001	Foreign 2001	Domestic 2002	Foreign 2002	Domestic 2003	Foreign 2003	Domestic 2004	Foreign 2004	Domestic 2005	Foreign 2005	Domestic 2006	Foreign 2006	Domestic 2007	Foreign 2007	Domestic 2008	Foreign 2008
A	8	165	7	298	4	224	15	440	6	363	33	255	6	449	14	193	34	1029	95	1634	80	1150
B	6	154	4	148	1	177	13	319	5	320	12	205	12	389	4	208	23	838	45	975	51	954
C	2	205	7	437	7	399	9	678	10	507	5	347	5	585	1	242	16	1095	21	658	29	1144
D	1	58	0	28	2	53	6	117	1	130	3	62	3	107	4	34	6	167	29	197	30	215
E	4	31	2	39	2	37	0	65	2	59	2	34	6	53	1	29	7	181	24	177	25	221
F	8	49	3	53	3	90	10	159	6	145	14	84	10	133	2	71	17	401	61	332	65	340
G	3	44	5	37	1	58	4	108	8	84	6	54	6	79	0	40	4	200	30	206	27	214
H	0	58	0	74	1	80	1	173	6	145	4	70	5	111	0	38	11	272	13	292	31	292

A	Human Necessities
B	Performing Operations; Transporting
C	Chemistry; Metallurgy
D	Textiles; Paper
E	Fixed Constructions
F	Mechanical Engineering, Lighting, Heating, Weapons and Blasting
G	Physics
H	Electricity

4.9 Results of the Proposed Heuristics

The developed program has been run for different values of k. For a given number of clusters; k=3 and 100 iterations as the stopping criteria, results given in Table 4.2 are obtained. The best fitness is obtained at iteration #54 and the observed clusters are as: Cluster 1= {A, C}; Cluster 2= {B}; Cluster 3= {D, E, H, F, G}. The related maps of these clusters are illustrated in Figure 4.6. In line with the findings, technologies for “Human Necessities and Chemistry/Metallurgy” have been the most active technologies. On the contrary, “Textile, Paper, Fixed Construction, Mechanical

Engineering, Lighting, Heating, Weapons, Blasting, Physics and Electricity" technologies have not been actively patented.

Table 4.2 Results for k=3; stopping criteria 100 iterations

Best fitness obtained at iteration **57** is 38.55					
Best clusters are:					
Cluster 1	A	C			
Cluster 2	B				
Cluster 3	D	E	H	F	G
Fitness of last accepted solution is iteration 95 is 187.30					
Clusters are:					
Cluster 1	C				
Cluster 2	E	A	G	F	B
Cluster 3	D				
Fitness of iteration 101 is 194.06					
Clusters are					
Cluster 1	C	G			
Cluster 2	E	A	H	F	B
Cluster 3	D				

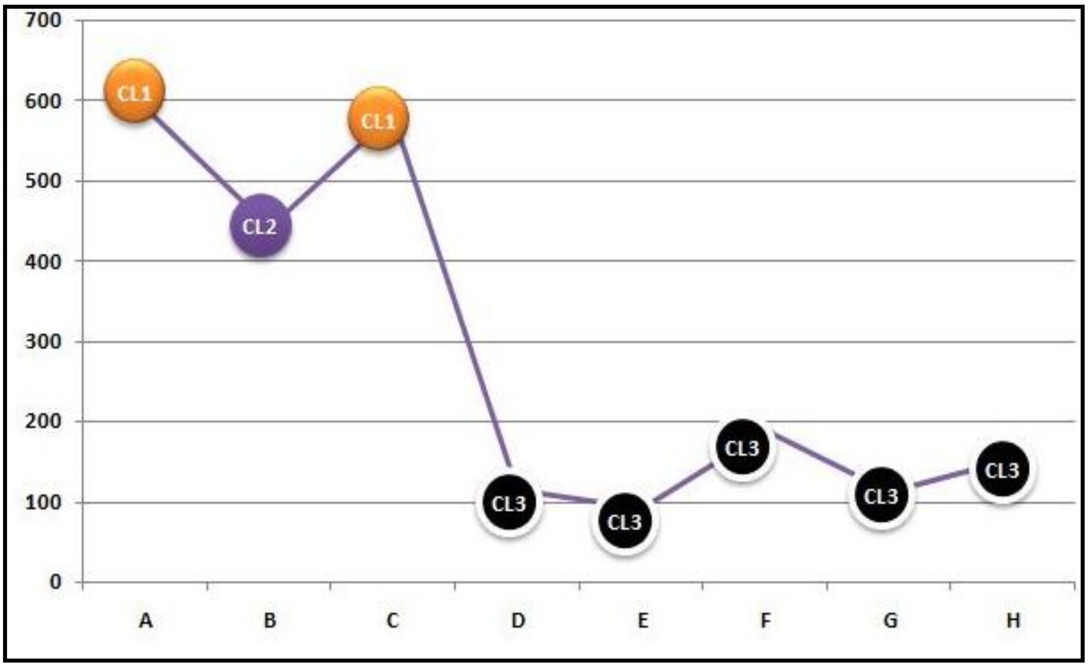

Figure 4.6 The relation map of clusters obtained for k=3

Another run has been performed without entering any "k" value, yielded the results given in Table 4.3. The number clusters where k=7 resulted with best fitness and thereby the best clustering. The corresponding clustering map is as illustrated in Figure 4.7.

Table 4.3 Results for the proposed algorithm for different k values

Best clusters for k= 2 is					
Members of Cluster 1	H	G	F	D	E
Members of Cluster 2	A	C	B		
Best clusters for k= 3 is					
Members of Cluster 1	B				
Members of Cluster 2	C	A			
Members of Cluster 3	E	F	H	G	D
Best clusters for k= 4 is					
Members of Cluster 1	D	G	E	F	H
Members of Cluster 2	B				
Members of Cluster 3	A				
Members of Cluster 4	C				
Best clusters for k= 5 is					
Members of Cluster 1	D	G	E		
Members of Cluster 2	C	A			
Members of Cluster 3	F				
Members of Cluster 4	B				
Members of Cluster 5	H				
Best clusters for k= 6 is					
Members of Cluster 1	F				
Members of Cluster 2	G	D			
Members of Cluster 3	H				
Members of Cluster 4	C	A			
Members of Cluster 5	B				
Members of Cluster 6	E				
Best clusters for k= 7 is					
Members of Cluster 1	A				
Members of Cluster 2	C				
Members of Cluster 3	F				
Members of Cluster 4	D	G			
Members of Cluster 5	B				
Members of Cluster 6	H				
Members of Cluster 7	E				
Best of the best clusters obtained at k= 7					
Members of Cluster 1	A				
Members of Cluster 2	C				
Members of Cluster 3	F				
Members of Cluster 4	D	G			
Members of Cluster 5	B				
Members of Cluster 6	H				
Members of Cluster 7	E				

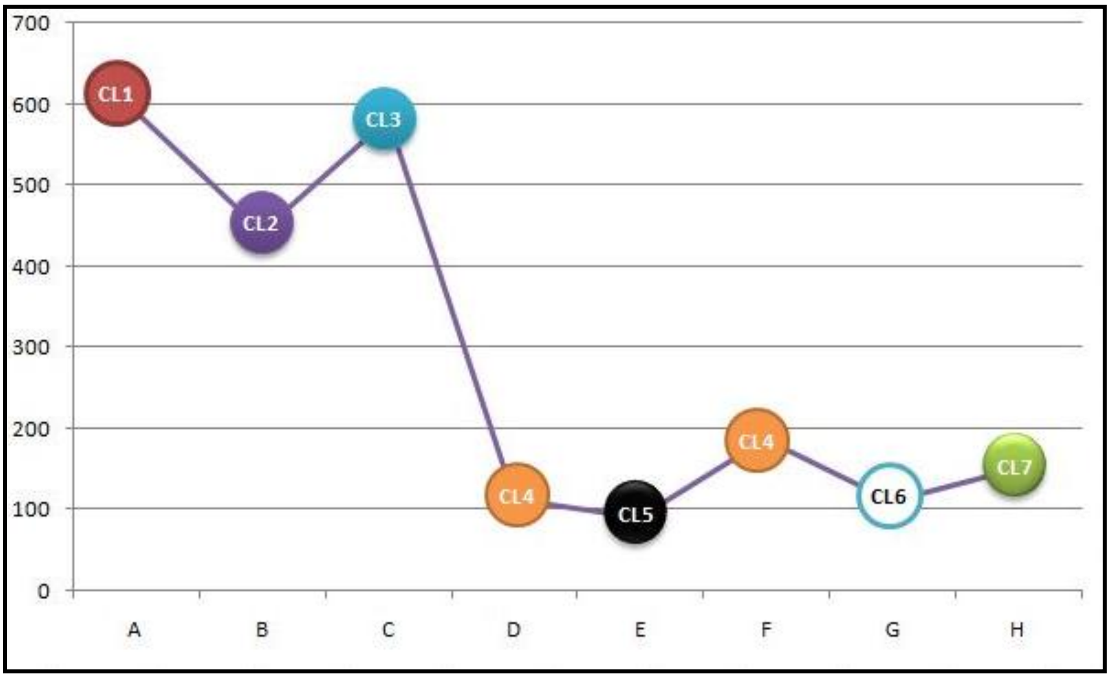

Figure 4.7 The relation map for the best possible solution

In search of the best value of k, 8 have not been considered, since there are already 8 IPC sections to be clustered. It is worthy to state here that, as the number of clusters increase, value of total fitness will naturally decrease. Therefore, in future studies a limiting value for fitness or number of clusters may be required to avoid unrealistic clustering.

4.10 Results of the GDA

The developed program has been also run for GDA. f (s^*) value is accepted as zero as the target badness for this work. By the use of GDA different values of k is tried and the best solution obtained is stored. 1000 iterations have been performed. Results are shown in Table 4.4 are obtained. The corresponding clustering map for the best solution is as illustrated in Figure 4.8.

Table 4.4 Results obtained with GDA

Best fitness obtained at iteration 724 is 11.45			
Best clusters are:			
Cluster 1	A		
Cluster 2	G		
Cluster 3	F		
Cluster 4	D	E	
Cluster 5	C		
Cluster 6	H		
Cluster 7	B		
Fitness of last accepted solution is iteration 724 is 11.45			
Best clusters are:			
Cluster 1	A		
Cluster 2	D	E	
Cluster 3	C		
Cluster 4	B		
Cluster 5	F		
Fitness of last iteration 1000 is 218.30			
Clusters are			
Cluster 1	D	G	
Cluster 2	B		
Cluster 3	C		
Cluster 4	A	E	F
Cluster 5	H		

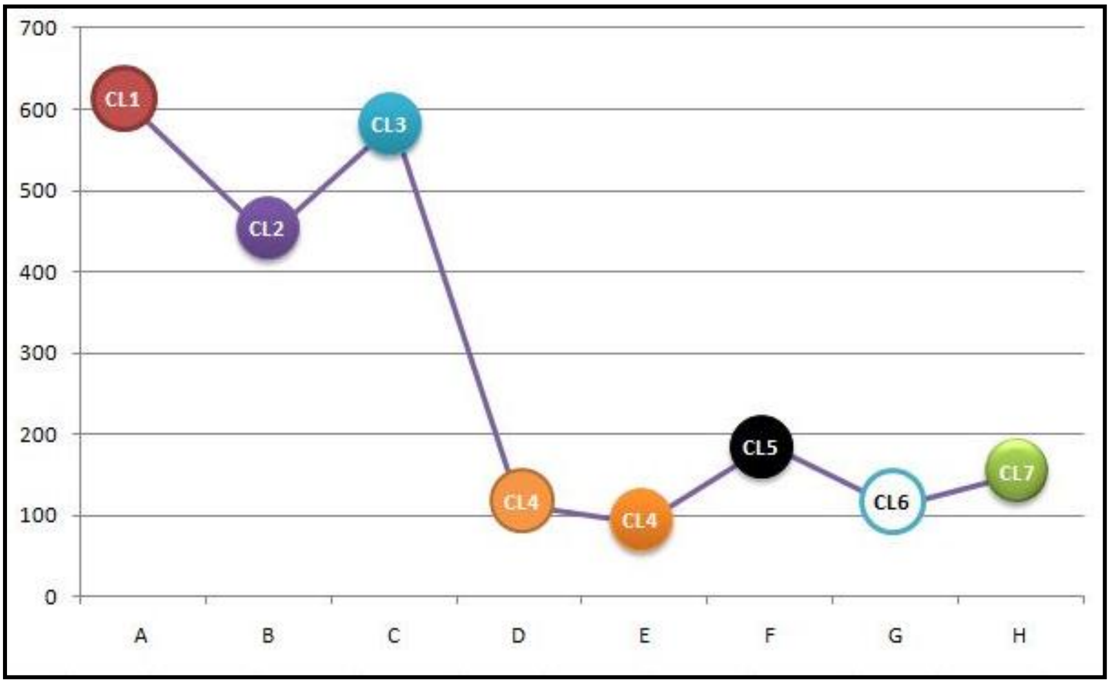

Figure 4.8 The relation map for the best possible solution obtained with GDA

The best possible solutions obtained by both of the heuristics where the k is equal seven (k=8 has not been considered again). However the proposed heuristic has yielded promising results when compared to GDA. The fitness value for GDA is 11.45 on the other hand the fitness obtained by the proposed algorithm is 1.59.

4.11 Concluding Remarks

Millions of patent documents can be used as a practical and useful source of watching technological changes and trends. Especially, in very complex and unstructured domains, they become very useful source of several tools and analysis for the technology watchers; owing to ease of accessibility and International Patent Classification (IPC) system which provides classified scopes for technologies.

On the other hand; increasing number of patents does not allow managing a quantity of information manually. As the technology makers grant patents or applies for patenting over time, the tracking of the relevant data gets harder. In this type of extending systems, clustering approaches provide very crucial benefits to gain insight about the data. Therefore, as it is intended in this part of the thesis, huge patent data regarding technologies can be used to cluster technologies in terms of the time evolutions which they are belong to. The clustering method which is proposed and implemented in this part along with GDA, attempts technologies to be grouped in such a way that each one is similar to the others, in means of the amount of the patenting activity. Thereby they exhibit high internal homogeneity with respect to their trendiness. The idea of clustering technologies in means of their patenting frequency has been initially introduced by Dereli and Durmuşoğlu (2009b); however the requirement for improving their model has been completed by this work. In the future; the validity of the proposed approaches which is introduced in this work could be further tested with much more amount of data which includes the technologies in IPC classes and subclasses. Unfortunately, there is no way of comparing the results expressed since it has been novel to the literature. However, it is obvious that some enhancements and improvements can be performed through the proposed clustering approaches.

“Patent counts” has been the unique dimension considered through this section. However, some other relevant/significant factors such as number of patents that is citing the relevant technology or similarly the number of patents cited by the relevant technologies could have been included. Moreover another factor indicating the trendiness of a technology could also be identified and included in the relevant clustering approach. The line indicating the patent counts versus years could be employed to calculate such trendiness with the calculation of the relevant fitted line.

Adding new dimensions to the existing data would certainly require a much more complex analysis most likely with more significant findings. However the idea behind this work has been tested within the current content and it has also provided encouragement for the future considerations.

In addition to all of these drawbacks, expert knowledge can be further included to the proposed clustering by letting them to decide on threshold value for the value of the fitness or number of clusters.

CHAPTER 5

TECHNOLOGY FORECASTING WITH EXTENDED VERSION OF TFDEA

5.1 Introduction

Code Division Multiple Access (CDMA) technologies are one of the exceptional wireless technologies presenting multiple allocations that can be occupied at the same time and frequency for a given band. Thereby, CDMA technologies have been one of the promising solutions provided against growing data demand. Advances in CDMA technologies (protocols) indicate that total data capabilities of CDMA are increasing and the limits for the next technology are always eagerly-anticipated. In this respect, technology forecasting using data envelopment analysis (TFDEA) has been one of the forecasting methodologies previously used by Anderson et al. (2008). It provided insightful forecasts for the future of wireless technologies where an average "rate of change (RoC)" for data capacity was put forward. In this section of the thesis, TFDEA results have been borrowed from the indicated study to predict the data capacity for CDMA technologies with a further consideration. This further consideration includes identification of a mathematical relation between "varying levels of rate of changes" (VLRoC) and "time". The investigation efforts resulted with a statistically significant curve that is capable of explaining the relation between the time and ROCs. The ascertained curve that has the highest goodness of fit is finally used to forecast the future of CDMA technologies.

5.2 Statement of Purpose

Number of worldwide wireless technology users have increased with the increasing popularization of mobile devices such as laptops, mobile phones and personal digital assistances (Yen et al., 2010) along with the growing Internet facilities adding value to the value chains of services (Sirbu et al., 2006). Therefore, system providers/telecommunication companies have been seeking for promising technologies (both protocols and hardware) to meet this increasing demand for the wireless technologies. As a consequence, focus on wireless communication has attempted to increase the capacity, data rate and performance of the systems (Vakil and Aghaeinia, 2009). There have been also searches for new and different technologies which are capable to utilize all of bandwidth and thereby deliver much more data for the customers.

In this respect, CDMA (Code-Division Multiple Access) has been accepted as standard multiple access policy for the wireless communication systems due to its capacity, ability to combat multi-path fading and flexibility to be modified for multi-media/multi-rate communications (Kucur and Atkin, 2005). CDMA also enable users to share the airwaves at the same time than do alternative technologies. It can also be used in both 2G and 3G networks. Thereby, CDMA technology has been a preferable one among many others.

Story for CDMA was started by 1988. It has also evolved by the time (Prasad and Ojanpera, 1998). In 1991, first large-scale CDMA capacity tests were performed using commercial-grade equipment. At the end of 1997, 7.8 million of subscribers were using CDMAOne worldwide after four months later to its introduction (http://www.cdg.org/technology/).

CDMA2000 has been another leading improvement for CDMA technologies. It was submitted to ITU to be an IMT-2000 global 3G standard on 1998. It has been also followed by several revisions which are summarized in Table 5.1. CDMA2000 1X standard was completed and approved by ITU for publication, just one year after the introduction of CDMA2000. In 2010, CDMA2000 1xEV-DO introduced to global marketplace by the CDG. First live demonstration of "CDMA2000 1xEV-DO Rev. A" was also performed in 2005. "EV-DO Rev. B" network has been the most recent technology which deployed in 2010.

Table 5.1 A summary on the evolution of CDMA 2000 (gathered from: http://www.cdg.org/technology/)

Technology	Brief Description	Year	High-Speed Data	Spectral Efficiency
CDMA2000 1X	CDMA2000 1X is a 3G technology designed to deliver high-quality voice and high-speed data. It is an efficient wireless technology for circuit-switched voice communications.	2000	Supports bi-directional peak data rates up to 153.6 kbps, delivering an average user data throughput of 80-100 kbps in commercial networks using a 1.25 MHz FDD channel.	Up to 0.180 bit/sec/MHz over a 5 MHz FDD channel.
CDMA2000 1xEV-DO Release 0	CDMA2000 1xEV-DO Release 0 is designed and optimized to deliver data-centric broadband network services.	2002	Supports a peak data rate of up to 2.4 Mbps in the forward link and 153 kbps in the reverse link within a single 1.25 MHz FDD channel. In commercial networks, Rel. 0 delivers an average data throughput of 300-700 kbps in the forward link and 70-90 kbps in the reverse link. It achieves an aggregate data throughput of up to 3,150 kbps in the downlink and 900 kbps in the uplink within a 5 MHz FDD channel.	0.630 bit/sec/MHz in downlink and 0.180 bit/sec/MHz uplink over a 5 MHz FDD channel
CDMA2000 1xEV-DO Revision A	CDMA2000 1xEV-DO Revision A is an evolution of 1xEV-DO Rel. 0 that increases the peak data rate on the reverse and forward links to support a wide-variety of symmetric, delay-sensitive, real-time, and concurrent voice over IP (VoIP) and advanced broadband data applications.	2006	Supports peak data rates of up to 3.1 Mbps in the forward link and 1.8 Mbps in the reverse link within a 1.25 MHz FDD radio channel. In commercial networks, Rev. A achieves an average data throughput of 600-1400 kbps in the forward link and 500-800 kbps in the reverse link. It achieves an aggregate data throughput of 3840 kbps in the downlink and 1500 kbps in the uplink over a 5 MHz FDD channel.	It supports achieving up to 0.768 bit/sec/MHz and 0.300 bit/sec/MHz in the forward and reverse links respectively over a 5 MHz channel.
Multicarrier EV-DO and EV-DO Revision B	Multicarrier EV-DO and EV-DO Revision B are evolutionary steps from CDMA2000 1xEV-DO Rev. A that further enhance the broadband user experience and increase network capacity through a software and hardware upgrade, respectively.	2010	The standard supports the aggregation of up to 15 channels in 20 MHz bandwidth, yet the most common configuration is an aggregation of three carriers within a 5 MHz channel. The Multicarrier EV-DO software upgrade delivers a peak data rate of **9.3 Mbps** in the downlink and **5.4 Mbps** in the uplink, and with a Rev. B hardware upgrade, the peak data rate in the downlink increases to **14.7 Mbps**.	In a 5 MHz channel and with a hardware upgrade, Rev. B achieves spectral efficiencies of 0.840 bit/sec/MHz and 0.486 bit/sec/MHz in the forward and reverse link respectively.

The evolution of the CDMA technology is obviously expected to be continued. Actors in the wireless technology market and the third parties using wireless technology for their businesses are interested in the direction and scale of this evolution. If some promising forecasts can be obtained, they can be essentially strategic to the firms for their future orientation. Thereby, the total data capacity of CDMA is expected to be foreseeable.

In this perspective, technology forecasting using data envelopment analysis (TFDEA) has been previously used by (Anderson et al., 2008) to provide practical and insightful forecasts for the future of wireless technologies where an average “rate of change (RoC)” for data capacity was put forward. In this section of the thesis, TFDEA results have been borrowed from the indicated previous study to predict the data capacity for CDMA technologies with a further consideration. This further consideration includes identification of a mathematical relation between the varying levels of RoCs (VLRoC) and the time. The investigation efforts resulted with a promising and statistically significant curve that is capable of explaining the relation between the time and the RoCs. As the final step, the fitted mathematical function is employed to forecast the future of CDMA technologies.

The rest of this chapter is structured as follows. Section 5.3 is a literature review on ‘‘technology forecasting using data envelopment analysis” (TFDEA). TFDEA methodology and the proposed enhancement to increase the forecast accuracy are presented in Section 5.4. In Section 5.5, the model fitting options for RoC are discussed. Statistical significance of fitted curves and the selection of one from the alternatives have been illustrated in Section 5.6. Section 5.7 presents the findings that are verifying the proposed model. The forecasts for data capacity of CDMA technologies are also provided in Section 5.8. Finally, concluding remarks and potential benefits of the proposed classification scheme are discussed in Section 5.9.

5.3 Literature Review on TFDEA

The rapid changes in the technology arena have also transformed the structure of competition in the business world. More investment opportunities are created along with the change in technology occurring so rapidly (Dereli and Durmuşoğlu, 2010).

In this perspective, technology, as being one of the most important instruments that adds value to the businesses, is required to be properly managed and planned to create competitive advantage. However, it has been a management dilemma to evaluate and integrate emerging technologies into new or existing investment/business plans successfully. In this respect, technology forecasting (TF) has been a concept covering all the tools to identify possible relevant technologies for the organization/country or a region.

Principally, TF deals with specific characteristics of specific technologies, like speed or acceleration of an aircraft in near future, or first flight date of existing aircraft projects. From this standpoint, there have been techniques introduced in the literature which are intended to be used for forecasting the future of the relevant specific characteristics. However the superiority of one technique to the other has not been certain. The problem of selecting the appropriate technique for a specific case was called as *"matching of technological forecasting technique to a technology"* by Mishra et al., (2002). They (Mishra et al., 2002) stated that "the quality of forecasts would greatly depend on proper selection and application of appropriate techniques". Therefore, the superiority of one technique on a specific case has not been preferable for another case. In that respect, the competition among the techniques has extensively focused for the same type of problems.

"Technology Forecasting Using Data Envelopment Analysis" (TFDEA) was introduced in 2001 (Anderson et al., 2001) to be employed for some certain set of technology forecasting problems and it was found to provide both a managerially and statistically significant improvement over the previously published technology forecasting results (Anderson et al., 2008).

There have been some mile-stone studies on TFDEA where is each is accompanied with some applications. The timeline demonstrating these articles are as presented in the Figure 1 (Durmuşoğlu and Dereli, 2011). The life of TFDEA technique was initialized with the efforts on measuring the rate of change in a product category (Anderson et al., 2001). It was believed that simple measures such as product life cycles were not capable to measure performance change over time and extrapolating a single performance criterion was not meaningful for design tradeoffs. Consequently, TFDEA was built by Anderson et al., (2001) to measure incremental innovation in technology by applying it to the online transaction processing market. A variable returns to scale data envelopment analysis (DEA) model was utilized to determine an annual rate of change in benchmarks based on data provided by the "Transaction Processing Performance Council" (TPC) (Anderson et al., 2001). The rate of change then was used to forecast possible future performance trendsetters of the TPC (Anderson et al., 2001).

In 2002, Anderson et al., (2002) have further extended the previously developed proxy which was defined to measure a certain technology's progress over time. In their revised model, the assumption of state of the art (SOA) on product release was dropped and technical progress was measured iteratively over time. The effective time elapsed between the SOA and a no longer SOA has been refined to include a weighted average, and a means of utilizing proxy Decision Making Unit (DMUs), was implemented to maintain the dataset over time (Anderson et al., 2002).

In 2004, TFDEA was published as the dissertation thesis of Inman (Inman, 2004). The steps of TFDEA were announced to public with more details in the mentioned dissertation thesis. Late coming papers have all cited this thesis (Inman, 2004) to show the detailed steps of TFDEA.

In 2005 (Inman et al., 2005) TFDEA was used to predict the first flight year of well-known 19 US aircrafts/jets which was previously performed by Martino, (1993). Both of the papers (Inman et al., 2005 and Martino, 1993) used the data for aircrafts introduced between 1944 and 1960 to predict the first flights of those fighters introduced between 1960 and 1982. They have had the chance to compare their forecasts with the actual values since they have already obtained the actual values for those fighters introduced between 1960 and 1982. In fact, Martino (Martino, 1993) was also comparing two different methods in terms of the forecast accuracy: linear regression and scoring model. (Inman et al., 2005) calculated the forecasts for first flights and compared the results with linear regression of Martino.

In another paper (Inman et al., 2006), authors used effective time (t_f) instead of the actual year and thereby they improved the quality of their forecasts. In 2008, TFDEA was used to predict the total data capacity of wireless technologies (Anderson et al., 2008). TFDEA was performed for wireless technologies however it was not possible to compare the forecasts with the actual values since they have not been realized yet.

Finally, an implementation of TFDEA was performed to forecast the first flight date of commercial aircrafts (Lamb et al., 2010). In the study, application of TFDEA to commercial airplane was used to aid in overcoming some of the difficulties in technology R&D target-setting.

In this section of the thesis, calculated rate of change (RoC) values is borrowed from Anderson et al., (2008). The borrowed values of RoCs are used to identify and seek for a mathematical relation between the varying levels of RoCs and the time. The investigation efforts resulted with a promising and statistically significant curve that is capable of explaining the relation between the time and the RoCs. As the final step, the mathematical function that is fitted is used to forecast the future of CDMA technologies. Thereby, instead of using a constant change rate, a function of RoC has been employed.

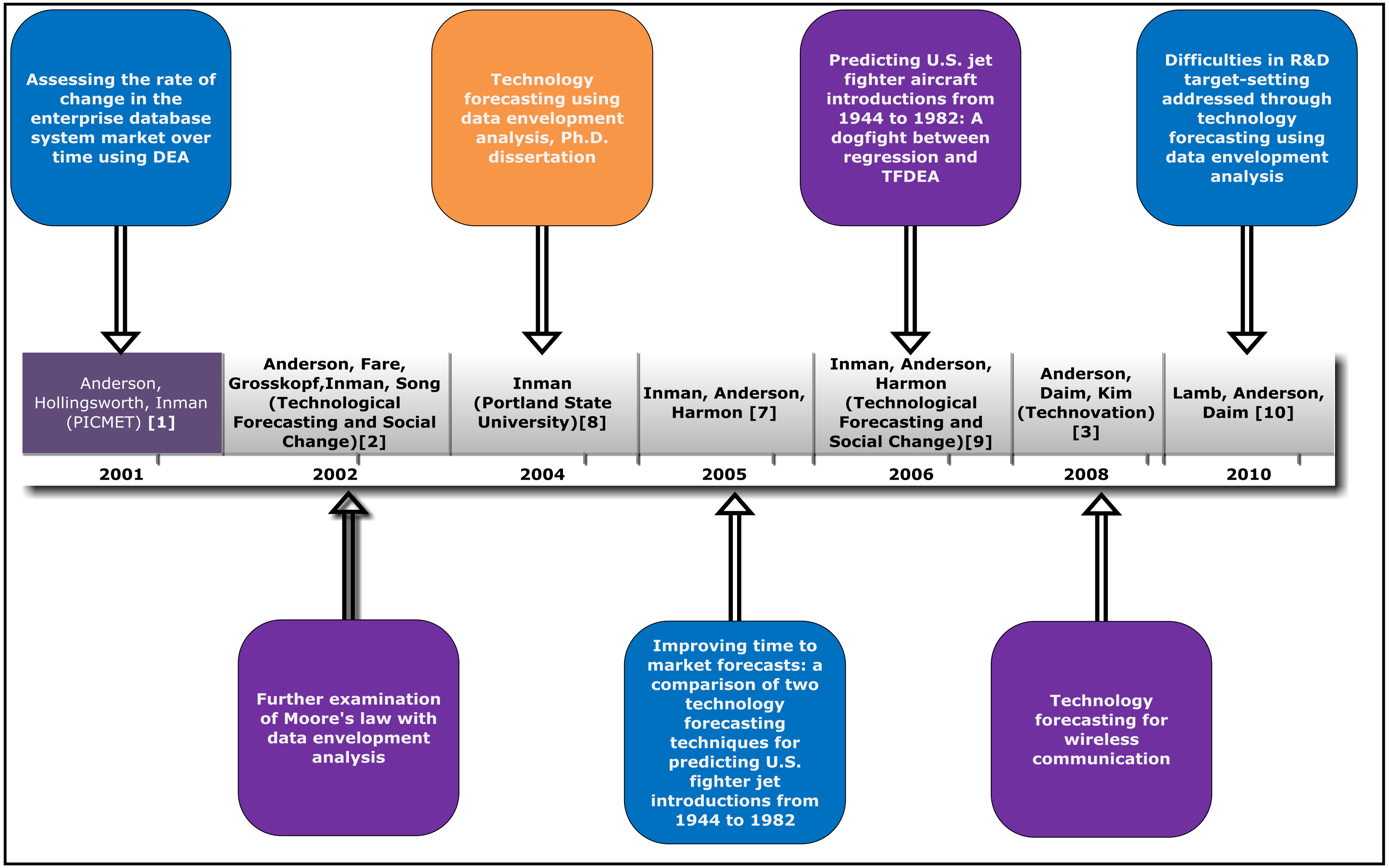

Figure 5.1 The milestone articles published on TFDEA (Durmuşoğlu and Dereli, 2011)

5.4 TFDEA Methodology and Increasing Forecast Accuracy

TFDEA is an extension of "Data Envelopment Analysis" (DEA) which is an operations research method introduced by (Charnes et al., 1978). DEA is based on relative efficiency, in order to detect efficiencies in the decision units. In a typical DEA application, it is assumed that the time periods are divided into equal intervals. However, DEA with itself can be incapable of forecasting technologies which are typically introduced at intermittent time periods (Lamb et al., 2010). Therefore some modifications can be proposed to develop TFDEA allowing DEA to be used for technology forecasting (Durmusoğlu and Dereli, 2011).

One fundamental concept for TFDEA is defined as "being state-of-the-art (SOA) technology" which indicates one technology's superiority over the others for the time being that the analysis is performed. If a technology is SOA, its efficiency score is assigned as 1, by considering the historical levels of performance. TFDEA assigns the subsequent efficiency scores for each of the remaining technologies based on the preceding SOA technology. The basic mathematical and operational summary of TFDEA is summarized by (Lamb et al., 2010) as in Equation (5.1)-(5.11) as illustrated in Figure 5.2.

1	For k=1,…,n	Each product k
2	For $t_f = t_k$ to T	From k's release to last time period
3	$\max_{\theta_k^{t_f},\lambda} \quad \theta_k^{t_f}$	Measure distance to SOA
4	s.t. $\quad \sum_{i=1}^{n} y_{r,j}\ \lambda_j \ \geq \theta_k^{t_f}\ y_{r,k}$	How much more output is possible
5	$\sum_{i=1}^{n} x_{i,j}\ \lambda_j \ \leq \ x_{i,k}$	Given no more input
6	$\sum_{i=1}^{n} \lambda_j \ = 1$	Compared to whole product
7	$\lambda_j \ = 0, \quad \forall\, j, \ \ such\ that\ t_j > \ t_f$	Don't compare against future products
8	$\lambda_j \ \geq \ 0$	
9	$\gamma_k^{t_f} = \left(\theta_k^{t_f}\right)^{\frac{1}{t_f - t_k}}$ $\forall\, k, such\ that\ \theta_k^{t_f} \ \leq 1, \theta_k^{t_f} > 1$	Calculate rate of change
10	Next t_f	Repeat for next time period
11	Next k	Repeat for next product

Figure 5.2 Flow of TFDEA and the relevant equations

In brief, in TFDEA methodology k denotes the "technology k", at each time period, t_f, against all commercialized technologies. The variables $\lambda_{j,k}$ and $\theta_k^{t_f}$ are determined by the underlying DEA linear program. The objective function of maximizing $\theta_k^{t_f}$ describes the additional output needed to be achieved by technology k at time period t_f , if it were SoA at that time. On the other hand, $\lambda_{j,k}$ describes the quantity of technology j which is used in setting a performance target for technology k. The data consists of $x_{i,k}$ as the i'th input and $y_{r,k}$ as the r'th output for technology k (Lamb et al., 2010).

After computing $\theta_k^{t_f}$ values, the following steps are employed to forecast the future value of the interested technical performance:

STEP 1: Today's efficiency (last analyzed year) of the products which are SOA at time release are calculated
STEP 2: The value of effective time is calculated as in Equation (5.12)

$$t'_f = \sum_{j=1}^{n} t_j \lambda_j \qquad (5.12)$$

STEP 3: Rate of change (RoC) is calculated using the Equation (5.9)
STEP 4: An average value of RoC is calculated
STEP 5: The last best value of the performance criteria is multiplied by RoC to calculate the next year's value; similarly the other year's forecasts are found using the Equation (13)

$$\text{Value of Performance (Year)}=(\text{The last best value})^{\text{Year-Last Analyzed Year}} \qquad (5.13)$$

Specific to this work, a modification is considered for the value of RoC. Current form of Equation (13) assumes RoC as constant it is simply equal to the average of "RoC values" calculated from the change rate of previous state art technologies. This assumption may not be released unless a significant and promising mathematical model can be found explaining RoCs as the function of time (Equation (5.14)). In this respect, years can be accepted as the independent variable and the RoCs can be formulated as dependent variable. In case a significant relation is extracted, variable levels of rate of change (VLRoC) can be obtained and more precise forecasts can be produced.

By the release of the assumption that the RoCs are constant, forecasts can gradually increase or sometimes decrease by the effect of time. Thereby, "time variable" is being included through the TFDEA's rate of change. The appropriate form of this function and the trials to fit the model will be discussed in next section.

$$F(RoC)= f(year) \tag{5.14}$$

5.5 Modeling Rate of Technological Change

In this section, the search for fitting a curve explaining relation between RoCs and the years is presented. Since different types of innovations can lead to different growth patterns, (Michalakelis et al., 2008), some well-known fitting options which are frequently used in technology forecasting (like: linear, quadratic and cubic models) are all attempted for fitting alternatives. Keramidas and Lee, (1990) has also analyzed some data sets and concluded that it is quite evident that the power transformations can be very useful in forecasting technological substitutions for concurrent short time series with a similar dependent structure.

The RoC values that are borrowed from (Anderson et al., 2008) are used to find an appropriate model. The fitting results for the each alternative (linear, quadratic and cubic models) over the whole dataset are presented in Figure 5.3, Figure 5.4 and Figure 5.5 respectively. The statistics used for the description of the results is the mean absolute percentage error (MAPE) and Sum of Squares of Error (SSE). Curve fitting utilities of Minitab was used to provide these statistics. Corresponding statistical measures are presented in Table 5.2.

Table 5.2 Fitness of the proposed models for the data available in literature

Statistics/Model	**Linear Model**	**Quadratic Model**	**Cubic Model**
R^2	79.1	95.4	95.5
$R^{2\ adjusted}$	75.6	93.6	92.1
MAPE	0.026	0.011	0.011
SSE	0.041	0.021	0.023
F value	22.67	52.21	28.20
P value	0.003	0	0.004

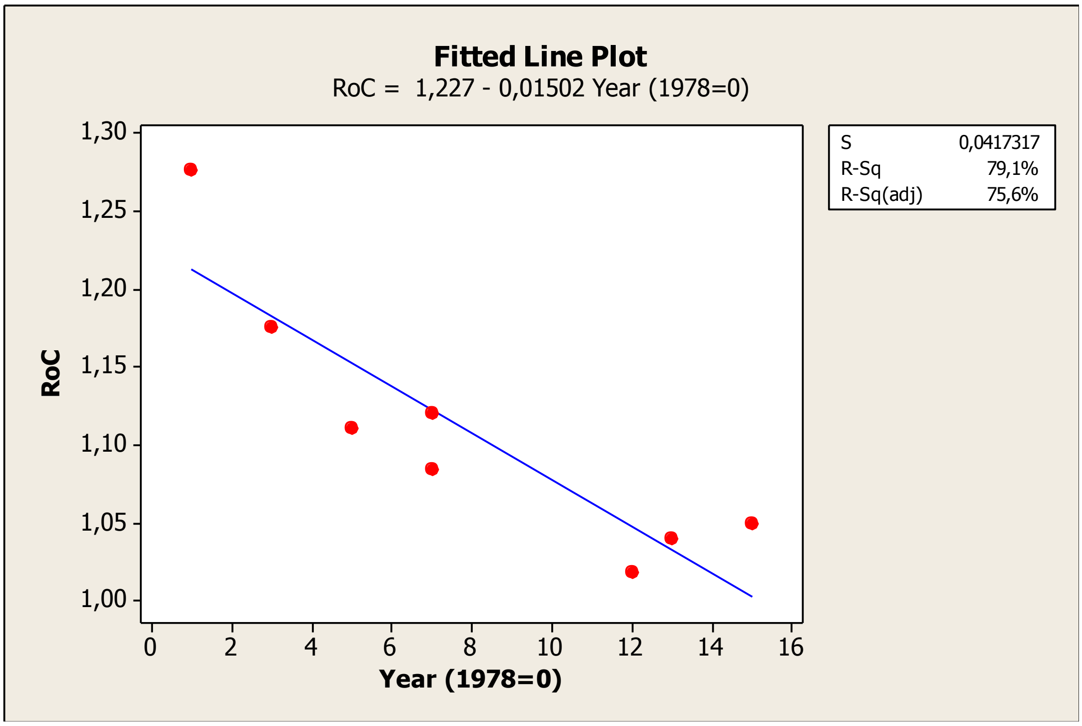

Figure 5.3 Fitted linear curve vs. actual data (Base year: 1978=0)

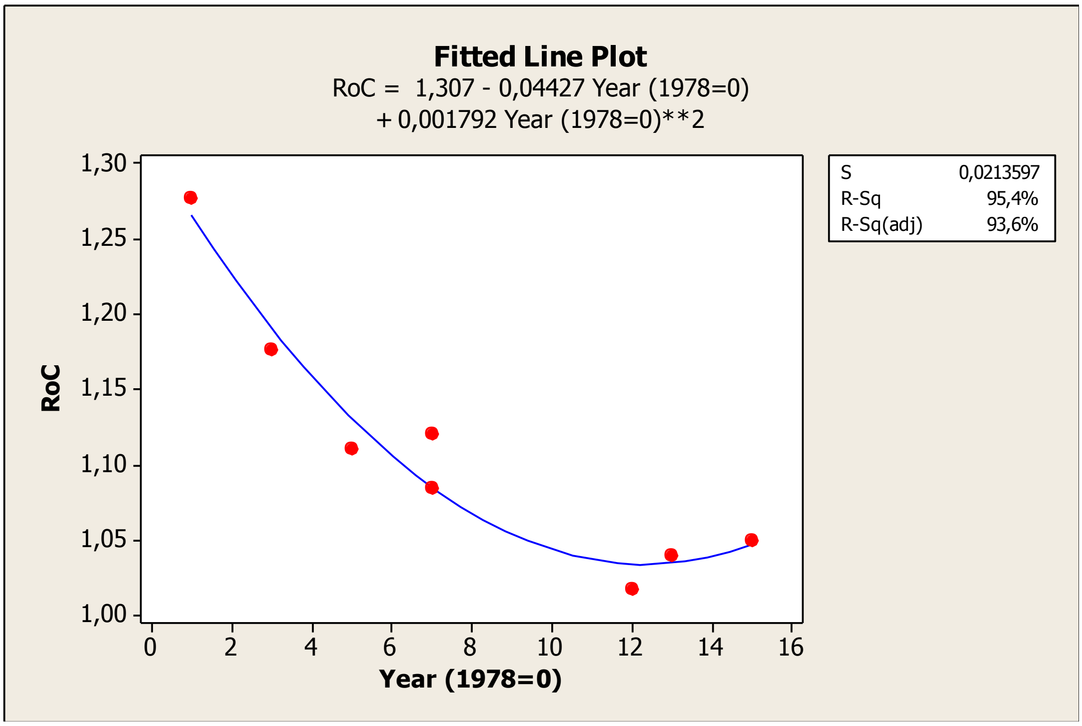

Figure 5.4 Fitted quadratic curve vs. actual data (Base year: 1978=0)

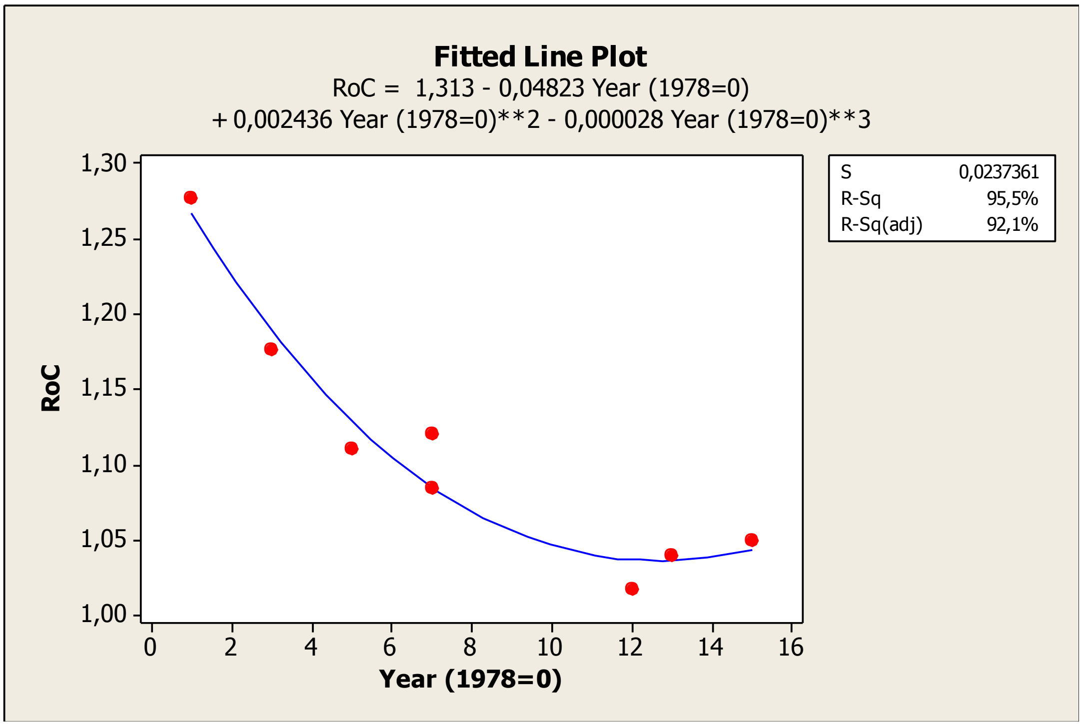

Figure 5.5 Fitted cubic curve vs. actual data (Base year: 1978=0)

5.6 Comparison of the Fits and Statistical Significance of Findings

There are several statistical indicators used for setting the best fit from the alternative ones. R^2 is one of these indicators. It is computed from the sum of the squares of the distances of the data points from the best-fitted curve that is determined by the regression. R^2 quantifies goodness of fit indicating a fraction between 0.0 and 1.0. Higher values mean better fits by indicating that the curve came very close to the points. In this regard, as presented in Table 5.2, R^2 values are high enough for all three modeling alternatives to explain relationship between time and RoCs. At the same time, quadratic and cubic curves have higher R^2 values when compared to the linear model and R^2 values.

Although R^2 values are important indicators for curve fitting, using R^2 alone as the criteria of goodness of fit can be deceptive and some further consideration can be required. The F test is also another indicator, enabling the comparison of the fits of multiple curves. It is usually expected that the more complex equation (it is assumed that the one with more parameters is more complex) fits better (has a smaller sum-of-squares) than the simple curve. Therefore it is investigated whether this decrease in sum-of-squares is worth to add a variable since degrees of freedom is lost. The P value of corresponding to the F test results indicate if the fits obtained by chance or not. If the P value is low, conclude that the more complicated model is significantly better than the simpler model. It is widely accepted that the more complicated model with the P value which is smaller than 0.05 should be employed for future use purposes. In our findings, all error statistics regarding the linear fitness is undesirably much more than the others. On the other hand, cubic and quadratic curves can compete with each other in terms of their goodness of fit. However, the F value and the p value of "cubic curve" and the complexity that it has make it much more preferable. Thereby cubic model is selected to be employed for forecasting total data capacity of wireless technologies. It should also be noted here that coefficients that are detected are statistically significant where p values are smaller than 0.05.

5.7 Verification of the Proposed Method

Since the forecasts had not been actually realized at the time that the article was published (Anderson et al., 2008), a comparison has not been available to be made. Now there are new CDMA technologies available ("CDMA Development Group," 2010) with advanced actual total data capacities (presented in Table 5.3). Thereby, TFDEA and its extension provided in this part of the thesis can be tested for verification of the methods.

With this purpose in mind, Table 5.3 presents the forecasts calculated by (Anderson et al., 2008) for the wireless technologies using TFDEA. The forecasts obtained by (Anderson et al., 2008) using TFDEA are also provided in Table 5.3. It is remarkable to state one more time that, these forecasts cover a constant Rate of Change (RoC), which is 10.9 % for the wireless technology case.

At the other column of Table 5.3, calculated Varying Level of Rate of Changes (VLRoC) by the use of quadratic curve is also given. As described in the proposed procedure, data capacity at the end of 2001 is multiplied with the VLRoC to find the predicted value of total data capacities of the future technologies. Thereby the forecasts obtained with the use of VLRoC are also presented in Table 5.3. "Mean

Absolute Percentage Error"(MAPE) values these method has also been calculated. It is found that TFDEA with RoC produce error with 46.34 %, and the TFDEA with VLRoC produce MAPE with 21.34 % which is apparently better.

Table 5.3 Comparison of the original TFDEA with the modified one for CDMA technologies

Name of the technology	**Year**	**Actual Total Data Capacity**	**Target Data Capacity Forecasted by (Anderson et al., 2008)**	**Forecasted RoC values using the best fitted line**	**Forecasts of Total Data Capacity**
1xEV-DO Release 0	2002	163.392	112.329	1.17426	118.941
	2003			1.19534	141.175
	2004			1.21712	171.827
	2005			1.23944	212.969
1xEV-DO Revision A	2006	261.760	169.900	1.26212	275.651
	2007			1.28501	268.792
	2008			1.30793	357.687
	2009			1.33072	475.980
Multicarrier EV-DO & EV-DO Revision B	2010	940.800	256.982	1.35321	644.104
		MAPE	46.34 %		%21.34

5.8 Expected Total Data Capacity for CDMA Technologies

After verification of the model Varying Level of Rate of Changes (VLRoC) can be used to estimate future levels of technology performance for SOA technologies. Expected future orientation for the change in output capacity of CDMA technology is presented in Figure 5.6. Table 5.4 takes the CDMA Multicarrier EV-DO & EV-DO Revision B technology which was commercialized by 2010 as the base technology for the forecasts. The actual data capacity of CDMA Multicarrier EV-DO & EV-DO Revision B technology is multiplied by VLRoC to predict corresponding total output of the next year.

This forecast predicts that in order for successors to the CDMA-based technologies to be technologically state-of-the-art in 2015, they will need to support a data transmission capacity of 5192.72 Mbps.

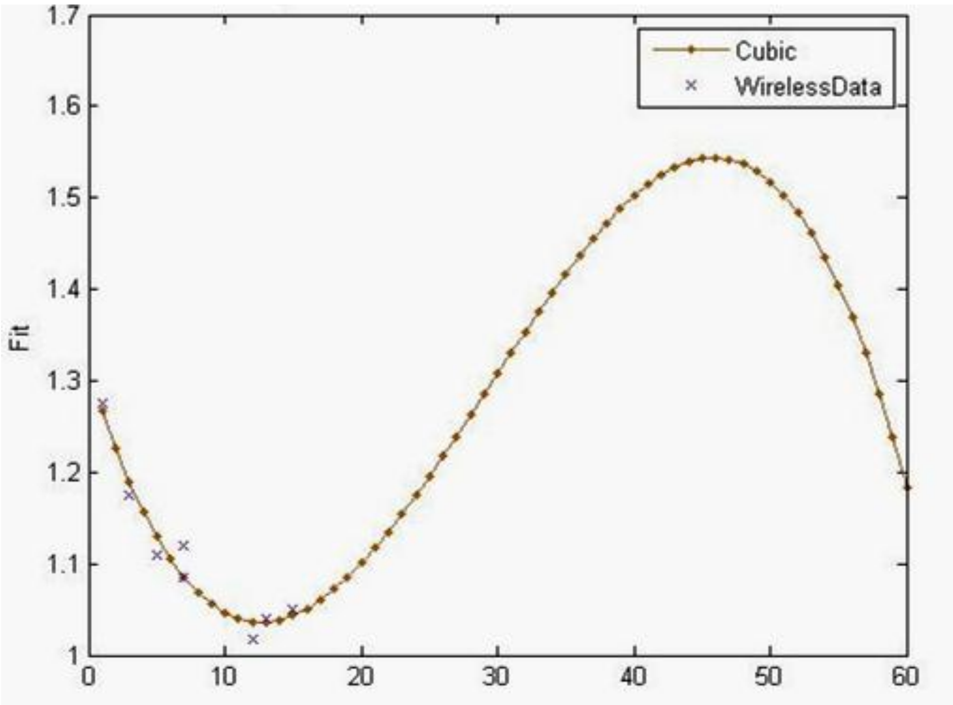

Figure 5.6 Expected rate of changes over the years (Base year: 1978=0)

Table 5.4 Expected data capacity for future CDMA technologies

Year	**2011**	**2012**	**2013**	**2014**	**2015**
Expected Rate of Change	1.368	1.389	1.409	1.427	1.445
Expected Total Data Capacity	1286.9	1787.2	2517.3	3593.3	5192.7

5.9 Concluding Remarks

CDMA based wireless technologies have been favorable technologies by providing several distinctive advantages. The incredible increase in the demand for larger data capacities for wireless technologies has been attempted to be met with the advances in CDMA technologies. In this respect, it has been desirable to foresee the balance between the demand and the capabilities to supply it. TFDEA, as being one of the popular technology forecasting tools in last decade, has been the one previously predicting total data capacities for wireless technologies (Anderson et al., 2008). By the implementation of TFDEA, an average rate of change was foreseen for the future of wireless technologies. Through this section of the thesis, calculated RoC values have been borrowed from them (Anderson et al., 2008) and it is attempted to be accessed to varying levels of changes. Past values of RoCs have been used to obtain a fitted curve indicating the relation between the time and amount of change. In this regard, promising results has appeared as an opportunity to improve quality of the forecasts for wireless technologies. The results presented in this chapter are expected to shed a light on the future of CDMA based technologies. Proposed considerations for TFDEA can also add value to the future implementations of TFDEA.

CHAPTER 6

DEVELOPMENT OF A MEASURE FOR PERCEIVED INNOVATIVENESS

6.1 Introduction

It has been a known fact that today's industry is faced with a tough and fierce competition than ever. As the consequence of this competition, companies have been in search for creating values to cope with the challenges arising from the fierce competition. In this context, innovation has been an essential instrument/tool for creating values to overcome existing tackles (Dereli and Durmuşoğlu, 2011a). Therefore, companies have attempted to develop capabilities for innovating and thereby their efforts have been extensively intensified on different collaboration structures and forms to innovate much more. Recent attempts, especially in Turkey, have been usually structured to develop collaboration architectures among the sellers or with the supporting governmental organizations. However, it is mostly omitted that, the real value of an innovation comes out when it has been perceived by the customers and unfortunately customers are the omitted collaborators.

In this regard, there is also an actual need of collaboration among the sellers and buyers. In this chapter of the thesis a framework is presented for the collaboration of sellers and buyers to enhance the innovation capabilities of firms through measurement of innovation perceptions which is indeed the output of the innovation process. The framework provides a space and a map for the employment of the proposed measurement scheme. Along with the proposed framework, customers are expected to collaborate with sellers by answering the questions given in the specifically prepared innovation survey. The survey should include the questions prepared based on the "Rogersian Characteristics of Innovation Perception" (*RCIP*) just to be applicable for the proposed framework. Perceptions are subsequently attempted to be measured by using the belief functions which fuzziness of perception is already included in. Furthermore, by the use of fuzzy triangles and consensus operator, perceptions of customers on each of the *RCIP* are fused into a single and meaningful output on the innovativeness of a certain product.

An application for a favorable cellular (I-phone) has been also included at the end. The contribution of the proposed scheme is expected to be in twofold: (1) developing a collaboration framework among customers and business owners to enhance innovation capabilities; (2) developing an innovation measurement scheme which returns an objective measure by adding subjective opinions of individuals on innovativeness of certain product.

6.2 Statement of Purpose

Innovation has been an essential tool to create value in today's turbulent business environment. It is recognized as driving force for economic growth and company's survival. Therefore, numerous attempts have been performed to develop novel innovation capabilities or to enhance existing capabilities. However, in contrast to common beliefs and considerations, results of these attempts have indicated that innovation is not a black art and it is an integrated process (Hitcher, 2006). Thereby it requires systematic and scientific management as the other processes does (Benedetto, 1996). Studies in the literature propose some approaches and present several good practices that can be useful to add value to the successful management of innovation process.

In this sense, collaboration has been one of these approaches which are known as a crucial source of competitive advantage. Several different types of collaboration structures are established like central R&D units, networks, partnerships, alliances and clusters to enhance innovation processes. These collaborations are structured among different types of actors for different stages of innovation (Elfving, 2009) in conjunction with special resource sharing policies. However, recent attempts on collaborations have been extensively intensified on collaboration of companies on design and manufacturing stages. Thereby, they frequently ignored establishing a customer collaboration which certainly set a bridge among the sellers and the buyers through a systematic *"feedback channel"*. Consequently, there has been a need for more powerful collaboration architectures which establishes necessary linkages among the customers and businesses. This framework proposes a collaboration scheme for the sellers and the buyers to enhance the innovation capabilities of firms. In the proposed framework, a feedback channel is facilitated to measure the perceived innovativeness of the supplied products which is in fact the output of the innovation process. The emphasis and intelligence of the proposed framework is centered on a novel scheme developed for the measurement of innovativeness.

The need for a novel scheme to measure innovation perception can be explained in the following way. Although there are a variety of methodologies on innovation measurement, there has not been a consensus on the measurement of innovation yet. Methodological departure between the efforts to measure innovation has originated from the different approaches on the perception of innovation. Level of perception is usually expressed in forms of linguistic terms by the customers. Having known that one way of deeper understanding of gradual reality is fuzziness, innovation measurement should be reconsidered using utilizes of fuzzy theory.

Along with the developed framework, customers are expected to collaborate with a seller by responding to the proposed “innovation measurement survey”. The survey includes the questions prepared based on the “Rogersian characteristics of innovation perception” (RCIP) and customers express their opinions using a scale ranging from 0 to 4 (where 0 indicates the disbelief; 4 indicates certain belief about a given statement). Consequently, by the use of belief triangles, perceptions on each of the RCIP are fused into a single and meaningful output on the innovativeness of a certain product.

The contribution of this framework is expected to be in twofold: (1) developing a collaboration system among the sellers and buyers to enhance innovation capabilities; (2) developing an innovation measurement scheme which returns an objective measure by adding subjective opinions of individuals on innovativeness of certain product.

6.2.1 Need for measuring perceived innovation

Similar to other processes, innovation process should be managed and controlled in terms of the outputs created and the inputs utilized (Dereli and Durmuşoğlu, 2011a). Thereby, measurement of innovation has been essential to understand real added value by the innovation. Measuring innovation has been a major issue since the innovation has been a costly process for the firms and the governments. Therefore, several methodologies have been proposed to measure innovation to avoid possible failures (Griffin, 1997; Griffin and Page, 1993).

A traditional approach to measure innovation was the use of proxies such as: number of patents, amount of profits or competencies which are intangible outputs of innovation. The first effort to measure innovation by the use of patents was pioneered by Schmookler (1950). However, as Dereli and Durmuşoğlu (2009) mentioned in their studies, there are still some discussions on the capability of patents to measure innovation. It is known that, an improvement on a service/product/ or process itself may not be adequate to grant that innovation as a patent. There are some strict requirements to grant a novelty as patent. However, patents are very significant indicator of technological change; they are not capable to indicate the commercial value of the invention/innovation developed.

In 1960's, a second attempt to measure to innovation has been initialized with the use of R&D surveys. Traditionally, attempts to measure R&D as the proxy of innovation have adopted on macroeconomic approaches, as they have been largely based on broad surveys (Cañibano et al., 2000). These surveys have been continuously improved and they are structured based on the Oslo Manual, which OECD member countries had adopted in 1990's (Oslo Manual, 1991).

R&D has also been a proxy indicator and it has never been clear whether the innovation has been perceived in a positive/negative manner by the customers. Beside this serious concern; these surveys have been limited with the measurement of R&D. As Business Council of Australia (BCA) declared in their annual report "innovation cannot be reduced to expenditure on R&D" (Business Council of Australia).

Even though there are serious efforts to regulate innovation manuals and questionnaires, it is not clear that basic assessments are fairly evaluated since entrepreneurs have different perception of ‘what the innovation is’. Data collected on R&D and innovation expenditures tend to vary a lot even among similar economies (Tether et al., 2002). Some authors argue that innovation is a fuzzy concept (Godin, 2002), which depends on many variables -some of them intangible and immeasurable. As listed above and furthermore, numerous attempts to measure innovation have been issue of hot discussions. Therefore; it would not be wrong to claim that the concept of innovation and its measurement have not been yet to be steady.

In perspective of marketing, the real value of an innovation is created when it has been perceived by the customers. The perceived novelty is usually expressed orally and do not cover any certain numeric values. Level of perception is expressed in forms of linguistic terms which are gradual in fact. It is already known that one way of deeper understanding of gradual reality is fuzziness.

Innovation is a fuzzy concept, and is depending on the author cited, defined and measured either as a product or as an activity (Yamini and Meenakshi, 2008). This relativity and subjectivity can be noted as essential rationale for methodological deviations on innovation measurement. Thereby, level of perception on innovation is the primary source of bias occurred in the measurement. Therefore, it can be claimed that measurement of the perception of the innovation by the target market will lead more absolute and more significant results. However, perception of innovation may demonstrate a high variety by customer’s geography/characteristics/socio-economic conditions, or by the product/service itself.

In literature, there have been several different attempts to quantify this perceptual variety which is labeled as “perceived innovation” (Yamini and Meenakshi, 2008). In accordance with marketing diffusion theory, a person’s decision to accept an innovative product/service relies on that individual’s perception on the specific characteristics of that innovation.

The first marketing study that examined the effect of perceptual variables on innovation adoption was conducted by Ostlund (1974). Ostlund hypothesized hundreds of variables to have effect on perceived innovation; however most of the variables did not indicate a significant outcome and then he concluded that "personal characteristics variables were unimportant predictors."

Several other researchers (Labay and Kinnear, 1981; Tornatzky and Klein, 1982; Holak, 1990; Holak and Lehmann, 1988) have followed Ostlund and performed numerous different analyses. The most credible one of these studies has been conducted by Rogers (1995). He identified five innovation-specific characteristics (relative advantage, compatibility, simplicity, trialability/divisibility and observability/ communicability) after reviewing thousands of innovation studies that influence consumer adoption of innovation. These attributes are named as "Rogersian Attributes" in the literature. Bauer (1960) suggested adding "perceived risk" attribute to this list of perceptual beliefs and his suggestion has been widely recognized by the authorities. A list of the Rogersian characteristics and perceived risk along with their respective definitions and relationships to adoption are displayed in Figure 6.1.

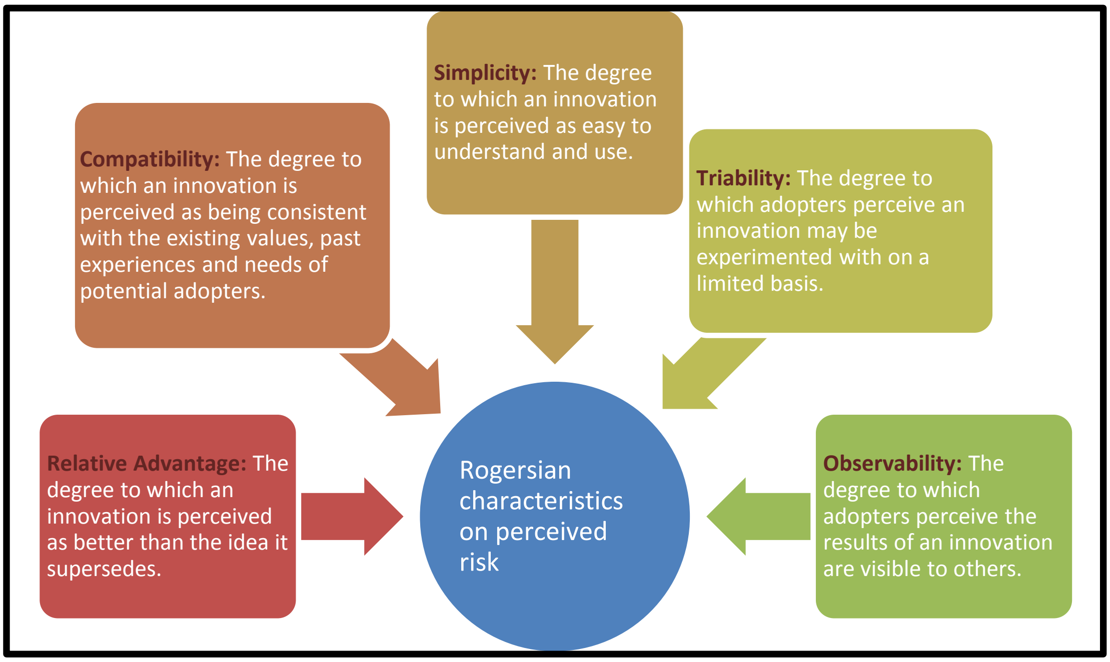

Figure 6.1 List of the Rogersian characteristics and perceived risk

6.2.2 Need for a framework for innovation enhancement

Collaborative systems enable organizations to communicate, interact and cooperate with each other to achieve their business goals (Lu et al., 1960). Collaborative architectures have been widely used structures for innovation enhancement. There are several different architectures for executing collaborations like central R&D units, networks, partnerships, alliances and clusters. Each of these collaboration architectures are focused on different strategies and resource sharing policies. The architectures are designed or selected by the collaborators consistent with the market's competiveness and the targeted value to be created. Even though conditions and policies for collaboration architecture may vary, the main inspiration for all kinds is sharing high risk associated with the innovation processes. In addition to the opportunity of the risk sharing, some other benefits of the collaborations can be widely found in the corresponding the literature (ie: (Eisenhardt and Schoonhoven, 1996; Oudshoorn and Pinch, 2003; Rohracher, 2005; Patrakosol and Olson, 2007, Motohashi, 2005; Smits, 2007; Boon et al, 2008; Baba, 2009)

There has been numerous numbers of cases for collaborations where actors are from same (intra-industry) and different (inter-industry) industries, suppliers, government or universities. The roles of actors and the reliance of actors to each other in all of these cases have evolved by the time. In initial attempts, firms were managing their research and development (R&D) internally and their trust was limited to relatively simple functions or products (Mowery, 1983; Richard, 1990). However by the time, good practices of collaborations and the cheaper communication channels provided by the Internet facilities led more reliable collaborations. Today, companies in a wide range of industries are executing nearly every step in the production process, from discovery to distribution, through some form of external collaboration (Powell et al., 1996).

In parallel to these changes, growing internet facilities as novel communication paradigms have presented some prospects to the classical collaborations. The current web technology has provided platform independence for users to publish and access data anywhere and anytime to support global network collaboration (Lin and Harding, 2007). Customers have been only a mouse click away from producers and it has been possible to include them in the collaboration architectures. In this context, it has been important to establish robust communication channels among customers and sellers. Dissimilar to the existing communication channels provided for receiving the customer complains, a novel channel which is capable of analyzing a set of structured information scientifically, would add inevitable value to the innovation process. With this purpose in mind, a framework is proposed for the collaboration between the buyers and the sellers based on perception of customers on the innovativeness of the supplied products. The main objective of the proposed framework is to monitor innovation process by measuring the actual output of it. The discussions on the innovation measurement have put some necessities of forming a new scheme for the measurement.

6.3 Proposed Collaboration Framework

The proposed framework put forwards solutions for the above defined emerging needs for a novel scheme to measure the perceived innovation and its integration to seller/buyer collaboration. The framework presented in this thesis, implicitly includes the proposed measurement scheme as intelligence of the proposed framework. The framework provides a map for the employment of the proposed measurement scheme. In accordance with the proposed framework, customers collaborate with the company by answering the questions given in the specifically prepared innovation survey and consequently, by the use of fuzzy triangles, perceptions on each of the RCIP are fused separately into a single and meaningful output on the innovativeness of a certain product.

The framework consists of three main stages: data collection, data evaluation and data fusion as it is illustrated in Figure 6.2.

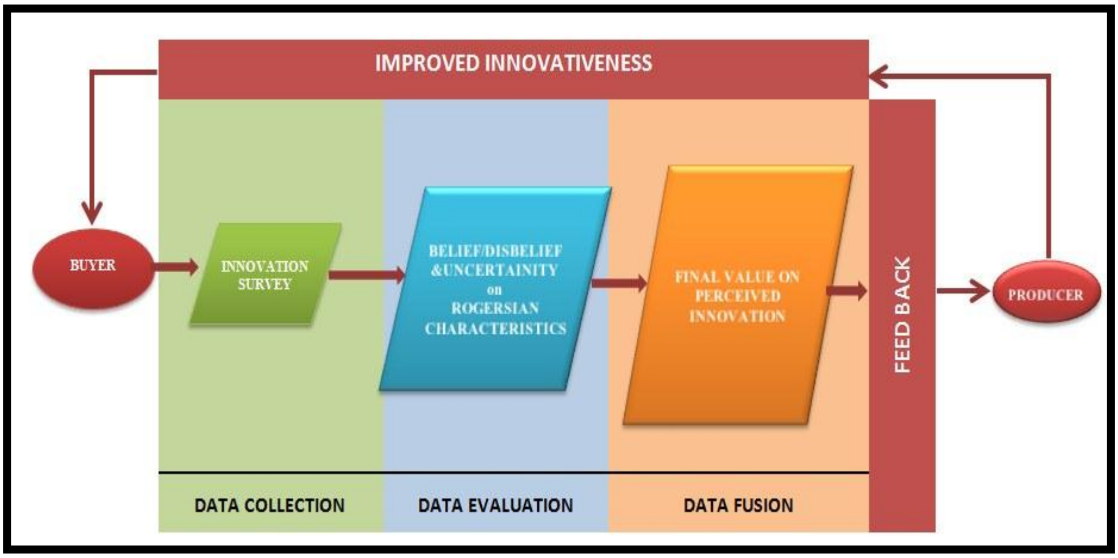

Figure 6.2 Architecture of the collaboration framework

6.3.1 Data collection

Data collection stage involves an investigative process about the innovativeness of the supplied products. Since beliefs of the customers on each attribute are subjective opinions and the surveys are the best tools for assessing belief-disbelief-certainty values of the individuals, surveying is employed in the proposed framework. It must be stated here that expertise on the preparation of the questions can be very vital to obtain robust results.

Questions are prepared in form of statements about the innovativeness of products based on RCIP. Each customer expresses his/her opinion about the given statements using a scale ranging from 0 to 4 (where 0 indicate the disbelief; 4 indicate certain belief about a given statement). An example can be found at the case study.

6.3.2 Data evaluation

In the second step data are evaluated by the use of belief functions since subjective opinions can be expressed in terms of the “Belief Functions” to represent a general and objective idea. In the evaluation stage, each customer’s evaluation on the corresponding questions is converted into a mathematical form of expression. For instance consider a product where one of the customers (C_i) has responded on the simplicity of that product as 4. This belief can be expressed as (C_i, simplicity (product)); which means that customer C_i believes the product's simplicity utility. Based on the given statement, it is certain that the customer has no hesitation about the defined statement. Let suppose that customer C_i's belief about the simplicity of a specified product is denoted by S, then (Dempster, 1968);

$$\text{belief (S)} = 1, \text{ disbelief (S)} = 0 \tag{6.1}$$

The example given above posses the properties of classical probability since the sum of belief on S and its complement is equal to one. This case indicates that important aspects are missing in the way that standard logic captures and that it is more designed for an idealized world than for the subjective world in which we are all living (Jøsang, 2009). Belief theory and functions is proposed by Dempster in 1960 and the major idea behind the belief theory is to discard additivity principle of probability theory (sum of the mutually exclusive events may not be equal to one). The main improvement of this approach is that ignorance, such as the lack of confirmation about the truth of the states, can be explicitly expressed. In the proposed innovation measurement scheme, several beliefs of target customers on each of attributes effecting "perceived innovation" are included in order to represent a general and objective belief on the innovation to be measured. Therefore, using "subjective logic" is expected to be beneficial since it is intended to measure customer' uncertainty about the RCIP statements.

The opinion triangles are a moderately novel illustration methodology where an opinion on x is the ordered with three variables -3 tupple- ω_x=(b,d,u) where: b belief is the belief value that given statement is true, d disbelief is the value supporting that the given statement is false, u uncertainty is the amount of indecisive belief. These components should satisfy b+d+u =1 and b,d,u € [0,1]. The "Opinion Triangles" supply a geometric visualization of binomial opinions. The triangle and each of the bars provide various visualizations of the same opinion data. The aim of the "Opinion Triangle" is to be able to rapidly get an awareness of the value of an opinion at a quick look. The three axis of belief triangle determine the position of an opinion within the triangular space. As it is illustrated in Figure 6.2, three axes are used to illustrate the position of an opinion in the triangle. In a typical opinion triangle, there is a line connecting absolute belief and absolute disbelief which is called as probability axis (Bagheri and Ghorbani, 2009). The points which are situated on probability axis are dogmatic opinions since they do not have any degree of uncertainty. Among dogmatic beliefs, the two opinions located on the extreme ends of the probability axis are called absolute opinions and represent inflexible agreement or disagreement with the hypothesis (Bagheri and Ghorbani, 2009). As stated in previous example, the opinion expressed by the customer about the simplicity is an example of absolute opinion. Suppose that another customer (B) has expressed its opinion about the simplicity (s) with the following values ω_S=(0.50, 0.25, 0.25). This means that the customer is somewhat uncertain and further believes the simplicity of the proposed product. The belief and disbelief values for the responses ranging from 0 to 4 have been converted to the 3 tupple by the use of central gravity method as (Bagheri and Ghorbani, 2009) did previously. Corresponding belief, disbelief and uncertainty values on a belief triangle for the given scales is as shown in Table 6.1. The points are also illustrated on the belief triangles as given in Figure 6.3.

Table 6.1 Corresponding belief values for the survey scale

Scale	Belief	Disbelief	Uncertainty	Points
0	0.125	0.750	0.125	A
1	0.25	0.50	0.25	B
2	0.125	0.125	0.750	C
3	0.50	0.25	0.25	D
4	0.750	0.125	0.125	E

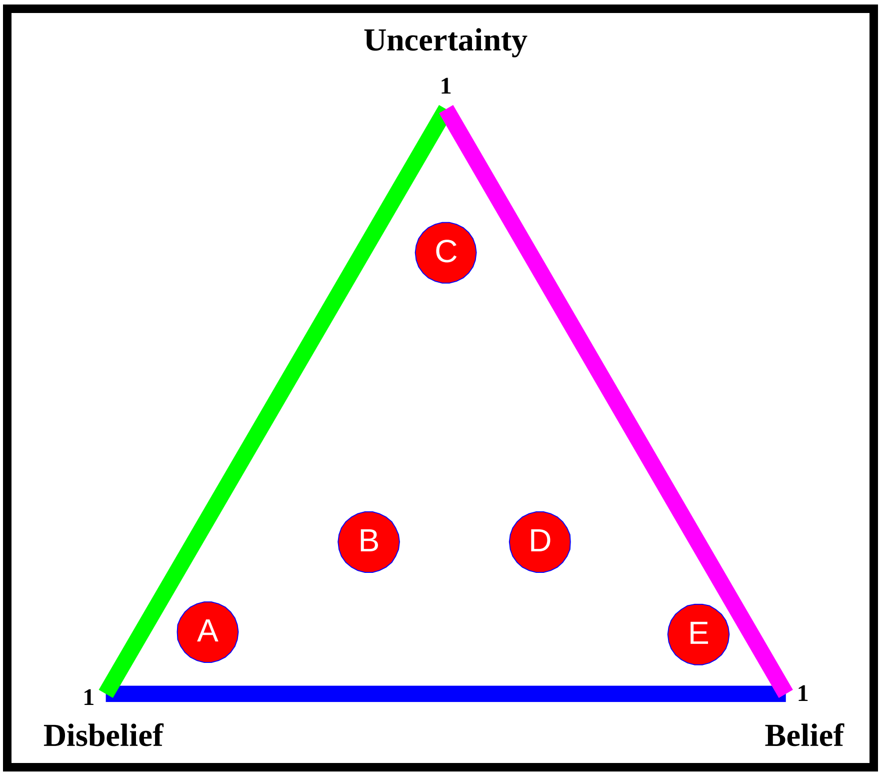

Figure 6.3 Belief triangle and the placement of the corresponding points

6.3.3 Data fusion

A major step in a fusion system is the step at which the new incoming piece of information is combined with the older one to give a better estimate of the environment, in particular, the value of innovativeness. Therefore, at the third stage, each responder's categorical belief is merged to correctly represent the perception of all the customers. There have been various proposals for fusion of belief functions (ie: (Inagaki, 1991; Lianwen, 1994; Didier and Henri, 1999) each with certain advantages and disadvantages. Although some of these fusion methodologies may properly work for the proposed measurement scheme, Josang's (2002) the consensus operator is selected to fuse due to the some well-known advantages. It has been favorable due to its stable behavior under various extreme conditions and its ability to merge even the conflicting dogmatic beliefs (Josang et al., 2003). Josang et al. (2003) has also verified the commutativity ($A \oplus B = B \oplus A$), and associativity ($A \oplus [B \oplus C] = [A \oplus B] \oplus C$) properties of consensus operator, which avoids possible miscalculations which could occur from changing order of belief sets.

Consider $w_S^A = (b_S^A\ ,\ d_S^A, u_S^A)$ and $w_S^B = (b_S^B\ , d_S^B, u_S^B)$ be two opinions about a simplicity of products stated by two different customers A and B, and let $K = u_S^A + u_S^B\ - u_S^A u_S^B$ when $u_S^B \rightarrow 0$ and $u_S^A \rightarrow 0$, the relative dogmatism between the A and B opinions are defined by $\gamma = u_S^B\ /\ u_S^A$ and $w_S^{A.B} = (b_S^{A.B}, d_S^{A.B}, u_S^{A.B})$ is opinion obtained as the consequence of fusion (Bagheri and Ghorbani, 2009);.

$$w_S^{A.B} = \begin{cases} ((b_S^A u_S^B + b_S^B u_S^A)/K), ((d_S^A u_S^B + d_S^B u_S^A))/K), (u_S^A u_S^B/K))\ , & K \neq 0 \\ \left(\frac{\gamma b_S^A + b_S^B}{\gamma+1}, \frac{\gamma d_S^A + d_S^B}{\gamma+1}, 0\right), & K = 0 \end{cases} \quad (6.2)$$

The employment of the consensus operator can provide a basis for merging conceptual models that are in essence uncertain (Bagheri and Ghorbani, 2009). Desired “Belief Functions” are approximated by evaluating each customer’s response for each opinion with the corresponding question. The consensus scheme will need the ability to fuse or summarize membership opinions from customers. Since “perceived innovation” is the aggregation of some attributes (as indicated by Rogers), a data fusion methodology is required to determine a real perception value on the innovation. Fortunately, possibility theory and the aggregation of operations from fuzzy-set theory provide some tools to merge information coming from a number of different sources.

6.4 An Application of the Proposed Model

An application has been considered for a favorable cellular phone which known as innovative at the moment. For the purpose of having a fused idea about the innovativeness of the product, series of statements prepared by three experts were given to the users of the cellular phone, and they were asked to express their opinions according to the certainty of their beliefs. Statements were defined using “Rogersian characteristics of innovation perception”. Table of the questions are as presented in **APPENDIX B**. A scale from 0 to 4 was defined for users to express their level of belief about the given statements. Subsequently they were informed to tick 4, if they extremely believe to the statement; to tick 0, if they disbelief, if they are uncertain about the statement they were asked to tick 2, if their belief is in-between two choices, they were told to tick 1 or 3 according to the their tendencies. 50 users of this phone have answered the survey. Numbers of responses are as illustrated at table 2. These responses subsequently were converted into belief tupples using the conversion table given at Table 6.2.

Table 6.2 RCIP scores of questions

Relevant RCIP	**Abbreviations**	**0**	**1**	**2**	**3**	**4**
Relative Advantage	RA1	8	2	7	8	25
	RA2	1	2	6	6	35
	RA3	1	0	2	5	42
	RA4	6	22	8	10	4
	RA5	3	7	9	6	25
	RA6	4	12	6	16	12
	RA7	7	3	9	8	23
Compatibility	C1	3	13	5	12	17
	C2	2	1	2	2	43
	C3	4	5	2	7	32
	C4	4	10	2	16	18
Simplicity	S1	9	7	8	9	17
	S2	3	8	3	8	28
	S3	8	1	2	9	30
	S4	1	1	2	3	43
Triability	T1	2	11	11	12	14
	T2	9	8	7	8	18
Observability	OBS1	5	7	4	9	25
	OBS2	2	1	0	2	45
	OBS3	3	5	3	7	32
Perceived Risk	PRS1	5	5	5	11	24
	PRS2	5	5	3	3	34
	PRS3	3	4	2	9	32
	PRS4	5	11	2	9	23
	PRS5	3	1	2	13	31

Finally converted belief values were fused using consensus operator in order to calculate the belief, disbelief and uncertainty of the given statements. The results found are illustrated at Table 6.3. Customers' highest belief has been on the prestigious of the cell-phone. Customers do not believe the statements "the cellular phone can't be imitated" and "it will be favorable phone for at least three years" as much as the other statements. The highest uncertainty has been about the phone's uniqueness on the offering of accessibility features to assist users who are visually or hearing impaired and about it is an imitable phone.

Table 6.3 Belief, disbelief and uncertainty values of the customers

Abbreviations	Belief	Disbelief	Uncertainty	K
RA1	0.825933	0.169127	0.004940	0.041954
RA2	0.838083	0.158159	0.003758	0.051232
RA3	0.844421	0.152361	0.003219	0.063186
RA4	0.735016	0.248772	0.016212	0.063148
RA5	0.829806	0.165119	0.005075	0.050780
RA6	0.777712	0.214882	0.007406	0.031135
RA7	0.822552	0.172158	0.005289	0.041593
C1	0.804360	0.189298	0.006342	0.033964
C2	0.849218	0.147545	0.003236	0.128276
C3	0.836365	0.159582	0.004053	0.048274
C4	0.798803	0.195505	0.005692	0.027842
S1	0.810578	0.182742	0.006680	0.040642
S2	0.830982	0.164514	0.004504	0.043288
S3	0.830639	0.165174	0.004188	0.039302
S4	0.847582	0.149213	0.003206	0.094501
T1	0.791957	0.200833	0.007210	0.034425
T2	0.816196	0.177283	0.006521	0.044136
OBS1	0.825355	0.169752	0.004893	0.039543
OBS2	0.849639	0.147261	0.003100	0.134014
OBS3	0.835905	0.160048	0.004048	0.047633
PRS1	0.819047	0.176044	0.004909	0.033762
PRS2	0.845201	0.150784	0.004015	0.094143
PRS3	0.832333	0.163710	0.003957	0.039113
PRS4	0.824177	0.170551	0.005272	0.040812
PRS5	0.823823	0.172297	0.003880	0.029008

6.5 Concluding Remarks

With the proposed framework, collaboration along with a perceived innovation measurement scheme has been presented. Surveying customers and asking them to grade any of innovative product/service based on "Rogersian Characteristics of Innovation Perception" (RCIP) has been constructed as the mechanism of supplying required collaboration between buyers and sellers.

However the measurement of perceived innovation has not been an easy job since there are a variety of methodologies which a consensus has not been reached. Relativity and subjectivity of innovation measurement has been the essential rationale for methodological deviations on innovation measurement. It is widely accepted that probability theory could not cope alone with these kind of uncertainty, therefore alternate theories like possibility theory, evidence theory, fuzzy set theory and random set theory has emerged as novel approaches in data fusion. Therefore, a perceived innovation measurement scheme addressing this incomparability problem is proposed to tackle the challenges of objectivity and relativity of the innovation. This framework was successfully applied and tested on a cellular phone manufacturer.

To our knowledge the methodology proposed in this framework has been novel to literature with two folds. A collaboration framework among customers and business owners has been constructed using a systematic data analysis. An innovation measurement scheme has been developed which is capable of returning an objective measure by adding subjective opinions of individuals on innovativeness of certain product.

Future studies can test and refine this methodology using other attributed effecting perceived innovation. Other subjective logic models and other fusion operators can also be utilized and tested on future studies. In parallel to growing internet facilities as novel communication paradigms have presented some opportunities to execute the proposed framework online. Since customers are only a mouse click away from producers and it has been possible to include them in the collaboration architectures.

CHAPTER 7

CONCLUSION

7.1 General Remarks

Problems handled with this thesis have been identified briefly in Chapters 1 and 2; the proposed frameworks as solution approaches to those problems are detailed in Chapters 3, 4, 5 and 6. During the development of these frameworks, continual focus has been translating solution approaches into appropriate and simple steps to be applicable for each user. Another focus has been technical accuracy. Primitive versions of these frameworks have been introduced during several courses and conferences (please see references) to discuss the technical validity. In this chapter, degree to satisfy stated objectives has been discussed thoroughly. In this respect, this chapter provides an overview of the key discussion issues associated with each developed technology management frameworks and methods in this thesis. It builds upon the discussions of the analysis, findings and case studies. It also presents the conclusions, contributions and implications that emerge from this research. The following Section 7.2 of this chapter individually addresses the research objectives and outcomes of each framework of the technology/investment selection. The next section discusses the contributions of this research to the body of knowledge on technology selection and the directions for future research. Finally, Section 7.3 concludes the thesis with a brief summary of findings.

7.2 Research Objectives and Outcomes - Overview

Based on the technology management, four proposed frameworks and method(s) were developed for: (1) Extraction of the possibilistic trend changes in the technologies (2) Clustering technologies with respect to patenting density (3)

Development of TFDEA to produce more promising technology forecasts and (4) Developing a novel and comparable scale for the measurement of innovation. The development of the proposed frameworks has involved a number of major tasks, which are summarized below, together with the associated conclusions.

7.2.1 Fuzzified Patent Alert System

A previously defined approach, PAS, has been useful in many regards. Several different applications have also applied it to find the frequency of change for certain technologies. The fuzzied version PAS presented in this thesis uses possibilistic trends to find direction of changes in patenting activities, technology and research. The developed model, using fuzzified trend lines along with PAS, creates both visual decision support and mathematical lines to inform managers. Fuzzified version of PAS is a quick to respond and a self-motivated alert system with the following contributions offered:

* Contrary to the existing trend analysis conducted on patent data, PAS always use fresh and continuously patent data to analyze.

* PAS searches the direction of the changes in patent counts using a novel “trend extraction algorithm” which is able to detect trends in a set of continuously changing online data.

* PAS detects the trend changes in patent data and forward them as alerts to be used as a decision aid for technology and investment planning.

* PAS presents a visual support for the users which is more useful than conventional ways such as textual, tabular, and list for quick and easy knowledge discovery documents

* The trend lines provided are not strict and they are capable to reflect possibility of a trend change.

It is remarkable to state that, the lines detected by the “trend extraction algorithm” do not aim to set up a model which fully explains the variation in patenting activities. A more advanced and sophisticated model may be required to enlighten the variation in patenting activities. PAS, as extended before, gives the direction of the changes in patenting activities. The information (extracted trends) created by the direction of the changes can be used with several scopes listed as in the follows:

- to evaluate the value of existing technologies
- to decide upon whether owned technology is trendy or not?
- to find promising technology-related investment areas
- to avoid unnecessary investment.
- to be informed from trendy research topics
- to establish a long-term strategic plan including technology planning.

7.2.2 Technology Clustering Using GDA

The proposed Great Deluge Algorithm (GDA) based clustering framework significantly contributes to the technology clustering problem. Technologies have been previously clustered via their functionalities, usage areas; however this has been the first that they have been clustered via patenting density of them. The purpose has been clustering technologies via the demand for them to be patented. On the other hand, the proposed framework can be empowered with the consideration of additional factors (like the inclusion of the "utility models") which are also indicating the demand.

7.2.3 Extending TFDEA

Although, TFDEA has been a very useful approach to forecast technical characteristics of several technologies, some modifications can create better forecast. In this regard, proposed framework has attempted to model the "Rate of Change" as the function of time. Findings have indicated significant improvements for the forecasts. This proposed extension can also be improved with the exemption of several different mathematical models like econometric models.

7.2.4 Measuring Perceived Innovation

Future studies can test and refine this methodology using other attributed effecting perceived innovation. Other subjective logic models and other fusion operators can also be utilized and tested on future studies. In parallel to growing internet facilities as novel communication paradigms have presented some opportunities to execute the proposed framework online. Since customers are only a mouse click away from producers and it has been possible to include them in the collaboration architectures.

7.3 Limitations of the Thesis and the Future Work

Although there have been several different contributions of this thesis to technology management literature, there are also some limitations for it which can be handled with possible future studies. These limitations can be also perceived as the opportunities for future studies.

The proposed frameworks in this thesis are a bit distinct from each other, and they can be used as separate decision support tools. In future studies, they can be combined into a novel framework with the consideration of linkages among them. These frameworks can all be utilized for technology selection. Technology selection is sometimes equivalent to selection of business. Since selection of a novel business may require much more, it can be considered as the second limitation of this thesis. In the developed frameworks, financial and market constraints have not been considered. Therefore the frameworks can be extended using these critical factors such as: timing of investment, state of the rivals, cost and expected benefits of the investment and in this way these frameworks can be converted to technology selection roadmaps.

The findings of this thesis can also be utilized for establishment of national policies. It should be also noted that with this thesis; it is once more recognized that a systematic approach to technology selection is necessary for developing countries like Turkey. These countries can take stock of their resource base and capabilities; identify the technologies available, the modifications necessary, and the strategies for implementation within the sustainable development context (Dereli and Durmuşoğlu, 2006). A time and result specific plan can then be developed for the implementation of the promotion and adoption of new technologies within the identified sectors, with the necessary evaluation mechanisms put in place to determine success or failure. This approach will remove the non-methodical approach to technology implementation so prevalent in developing countries.

The proposed frameworks in this thesis can also be used to solve the “incentive system” problem in Turkey. The current incentive system in Turkey has been topic of hot discussions. Currently, the incentives are paid off on the base of national income of the regions. Since this thesis puts several methodologies to find promising technologies, the incentives can be paid off on the base of technology selected.

7.4 Closure

The knowledge discovered from this thesis is expected to be vital for all organizations and it is wished that to be in service for humanity. In this respect, possible outcomes of this PhD thesis can be listed as follows:

- Identification of emerging technologies: It is strictly required to foresight the future technologies and its extensions. Especially in the countries like Turkey, which is frequently a technology buyer, the investments in the older technologies can create a considerable amount of inefficiencies for the national budgets and welfare of the country.
- Construction of novel innovation metrics since most of the existing indicators have not been definitive metrics of innovation: Innovation is defined as the output of a systematic process where a commercial product/service is developed. The research on corresponding relationship between inputs and outputs of innovation process has significantly increased. Although there have been a variety of methodologies proposed on the innovation measurement, there has not been a consensus on it yet. Methodological departure among the efforts to measure

innovation is assumed to be originated from perception differences. Therefore, to address this relativity problem of innovation measures, a novel innovation measurement framework is required to be proposed to tackle the challenges of objectivity of the innovation.

- Discovery of the overlaps or similarities within the research activities: There may be some companies or research institutes investing on finding an already invented product.
- Identification and categorization of the main research areas and sub-areas in the large body of technical literature and patents
- Construction of more valid and fair incentive policies (ie: In Turkey "GNP per capita" is still considered as the fundamental criteria for the incentive payments).

In completing this research, a substantial amount of patent information regarding the developed technology selection frameworks was collected and analyzed. This has helped validating the developed frameworks. In addition, this investigation also provides a foundation for future research, in a number of related areas, offering new and exciting directions for the research and practice of managers, entrepreneurs and the government.

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APPENDICES

APPENDIX A - LIST OF INTERNATIONAL PATENT CLASSIFICATION SYSTEM

Section A
Human Necessities

Subsection: Agriculture
A01 Agriculture; Forestry; Animal husbandry; Hunting; Trapping; Fishing.

Subsection: Foodstuffs; Tobacco
A21 Baking; Edible doughs.
A22 Butchering; Meat treatment; Processing poultry or fish
A23 Foods or foodstuffs; Their treatment not covered by other classes
A24 Tobacco; Cigars; Cigarettes; Smokers' requisites

Subsection: Personal or Domestic Articles
A41 Wearing apparel
A42 Headwear
A43 Footwear
A44 Haberdashery; Jewellery
A45 Hand or traveling articles
A46 Brushware
A47 Furniture; Domestic articles or appliances; Coffee mills; Spice mills; Suction cleaners in general

Subsection: Health; Amusement
A61 Medical or veterinary science; Hygiene
A62 Life-saving; Fire-fighting
A63 Sports; Games; Amusement

Section B
Performing Operations; Transporting

Subsection: Separating; Mixing

B01 Physical or chemical processes or apparatus in general
B02 Crushing, pulverising, or disintegrating; Preparatory treatment of grain for milling
B03 Separation of solid materials using liquids or using pneumatic tables or jigs; Magnetic or electrostatic separation of solid materials from solid materials or fluids; Separation by high-voltage electric fields
B04 Centrifugal apparatus or machines for carrying-out physical or chemical processes
B05 Spraying or atomising in general; Applying liquids or other fluent materials to surfaces, in general
B06 Generating or transmitting mechanical vibrations in general
B07 Separating solids from solids; Sorting
B08 Cleaning
B09 Disposal of solid waste; Reclamation of contaminated soil

Subsection: Shaping

B21 Mechanical metal working without essentially re- moving material; Punching metal
B22 Casting; Powder metallurgy
B23 Machine tools; Metal working not otherwise provided for
B24 Grinding; Polishing
B25 Hand tools; Portable power driven tools; Handles for hand implements; Workshop equipment; Manipulators
B26 Hand cutting tools; Cutting; Severing
B27 Working or preserving wood or similar material; Nailing or stapling machines in general
B28 Working cement, clay, or stone
B29 Working of plastics; Working of substances in a plastic state in general
B30 Presses
B31 Making of paper articles; Working paper
B32 Layered products

Subsection: Printing

B41 Printing; Lining machines; Typewriters; Stamps
B42 Bookbinding; Albums; Files; Special printed matter
B43 Writing and drawing implements; Bureau accessories
B44 Decorative arts

Subsection: Transporting

B60 Vehicles in general
B61 Railways
B62 Land vehicles for travelling otherwise than on rails
B63 Ships or other waterborne vessels; Related equipment
B64 Aircraft; Aviation; Cosmonautics
B65 Conveying; Packing; Storing; Handling thin or filamentary material
B66 Hoisting; Lifting; Hauling
B67 Opening or closing bottles, jars or similar containers; Liquid handling
B68 Saddlery; Upholstery

Section C
Chemistry; Metallurgy

Subsection: Chemistry

C01 Inorganic chemistry
C02 Treatment of water, waste water, sewage or sludge
C03 Glass; Mineral or slag wool
C04 Cements; Concrete; Artificial stone; Ceramics; Refractories
C05 Fertilisers; Manufacture thereof
C06 Explosives; Matches
C07 Organic chemistry
C08 Organic macromolecular compounds; Their preparation or chemical working up; Compositions based thereon
C09 Dyes; Paints; Polishes; Natural resins; Adhesives; Miscellaneous compositions; Miscellaneous applications of materials
C10 Petroleum, gas or coke industries; Technical gases containing carbon monoxide; Fuels; Lubricants; Peat
C11 Animal or vegetable oils, fats, fatty substances or waxes; Fatty acids there from; Detergents; Candles
C12 Biochemistry; Beer; Spirits; Wine; Vinegar; Microbiology; Ensymology; Mutation or genetic engineering
C13 Sugar industry
C14 Skins; Hides; Pelts; Leather

Subsection: Metallurgy

C21 Metallurgy of iron
C22 Metallurgy; Ferrous or non-ferrous alloys; Treatment of alloys or non-ferrous metals
C23 Coating metallic material; Coating material with metallic material; Chemical surface treatment; Diffusion treatment of metallic material; Coating by vacuum evaporation, by sputtering, by ion implantation or by chemical vapor deposition, in general; Inhibiting corrosion of metallic material or incrustation in general
C25 Electrolytic or electrophoretic processes; Apparatus there- for
C30 Crystal growth

Section D
Textiles; Paper

Subsection: Textiles or flexible materials not otherwise provided for

D01 Natural or artificial threads or fibers; Spinning
D02 Yarns; Mechanical finishing of yarns or ropes; Warping or beaming
D03 Weaving
D04 Braiding; Lace-making; Knitting; Trimmings; Non-woven fabrics
D05 Sewing; Embroidering; Tufting
D06 Treatment of textiles or the like; Laundering; Flexible materials not otherwise provided for
D07 Ropes; Cables other than electric l

Subsection: Paper

D21 Paper-making; Production of cellulose

Section E
Fixed Constructions

E01 Construction of roads, railways or bridges
E02 Hydraulic engineering; Foundations; Soil-shifting
E03 Water supply; Sewerage
E04 Building
E05 Locks; Keys; Window or door fittings; Safes
E06 Doors, windows, shutters or roller blinds, in general; Lad- ders

Subsection: Earth drilling; Mining

E21 Earth drilling; Mining

Section F
Mechanical Engineering; Lighting; Heating; Weapons; Blasting

Subsection: Engines or Pumps

F01 Machines or engines in general; Engine plants in general; Steam engines

F02 Combustion engines; Hot-gas or combustion-product engine plants

F03 Machines or engines for liquids; Wind, spring, weight or miscellaneous motors; Producing mechanical power or a reactive propulsive thrust, not otherwise provided for

F04 Positive-displacement machines for liquids; Pumps for liquids or elastic fluids

Subsection: Engineering in General

F15 Fluid-pressure actuators; Hydraulics or pneumatics in general

F16 Engineering elements or units; General measures for producing and maintaining effective functioning of machines or installations; Thermal insulation in general

F17 Storing or distributing gases or liquids

Subsection: Lighting; Heating

F21 Lighting

F22 Steam generation

F23 Combustion apparatus; Combustion processes

F24 Heating; Ranges; Ventilating

F25 Refrigeration or cooling; Combined heating and refrigeration systems; Heat pump systems; Manufacture or storage of ice; Liquefaction or solidification of gases

F26 Drying

F27 Furnaces; Kilns; Ovens; Retorts

F28 Heat exchange in general

Subsection: Weapons; Blasting

F41 Weapons

F42 Ammunition; Blasting

Section G
Physics

Subsection: Instruments
G01 Measuring; Testing
G02 Optics
G03 Photography; Cinematography; Analogous techniques using waves other than optical waves; Electrography; Holography
G04 Horology
G05 Controlling; Regulating
G06 Computing; Calculating; Counting
G07 Checking devices
G08 Signalling
G09 Education; Cryptography; Display; Advertising; Seals
G10 Musical instruments; Acoustics
G11 Information storage
G12 Instrument details

Subsection: Nucleonics
G21 Nuclear physics; Nuclear engineering.

Section H
Electricity

H01 Basic electric elements
H02 Generation, conversion or distribution of electric power
H03 Basic electronic circuitry
H04 Electric communication technique
H05 Electric techniques not otherwise provided for

APPENDIX B- A SURVEY SAMPLE

Abbrevation	STATEMENT
Relative Advantage	
RA1	It is the most innovative cellular phone that I know
RA2	It has several distinctive properties when compared to others
RA3	It is the most improved cellular phone over previous generation of Apple iPhones
RA4	It cannot be imitated
RA5	It will be favorable phone for at least three years
RA6	It is the unique phone offering accessibility features to assist users who are visually or hearing impaired
RA7	What makes it innovative is its relative advantage
Compatibility	
C1	The phone presents several solutions for the existing problems of the cellular phones
C2	The phone is consistent with the existing infrastructure (ie: charging units, network facilities)
C3	Some existing accessories like memory cards, headphones are compatible with this phone.
C4	What makes it innovative is its compatibility
Simplicity	
S1	Usage of this phone is the simplest that I know
S2	It has a practical use
S3	It facilitates internet access
S4	What makes it innovative is its simplicity
Triability	
T1	A few trial is enough for me to recognize this product
T2	What makes it innovative is its triability

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Durmuşoğlu, Alptekin
Nationality: Turkish (TC)
Date and Place of Birth: 14 March 1982, Alaca
Marital Status: Married
Phone: +90 342 3172605
Fax: +90 342 3604383
email: durmusoglu@gantep.edu.tr

EDUCATION

Degree	Institution	Year of Graduation
MS	University of Gaziantep	2008
BS	Çankaya University	2004
High School	Mehmet Emin Resulzade Anatolian High School	2000

WORK EXPERIENCE

Year	Place	Enrollment
2005- Present	University of Gaziantep	Research Assistant
2004-2005	Köksal Patent Consultancy	

FOREIGN LANGUAGES

ENGLISH (Advanced)
GERMAN (Beginner)

PUBLICATIONS

In International Journals:

Dereli, T., Baykasoğlu, A., **Durmuşoğlu, A.**, Durmuşoğlu, U. Z. D., Enhancing technology clustering through heuristics by using patent counts, Expert Systems with Applications, 38(12), 15383-15391, 2011.

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HOBBIES

He is interested in watching football, reading history, philosophy and he enjoys cooking.