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A Group Decision Support System for Collaborative Decisions Within Business Intelligence Context

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Abstract

In this work we present a web based Group Decision Support System, which can be integrated within a firm's Business Intelligence (BI) architecture to support decisions in small collaborating teams. It is based on web technology and can be used in asynchronous mode from group members. It implements a multicriteria methodology for classification decisions where aggregation of members' preferences is executed at parameter level. Individual preferences are aggregated by appropriate operators, and a group parameter set is produced which is used as input for the classification algorithm. NeXClass multicriteria classification algorithm is used for the classification of alternatives, initially at a training set of alternatives and later at the entire set. Group members evaluate results, and consensus as well as satisfaction metrics are calculated. In case of low acceptance level, problem parameters are redefined by group members and aggregation phase is repeated. The system has been utilized to solve real world group classification problems, integrated to Business Intelligence environment supporting mainly financial decisions. Empirical findings provide evidence that the approach is valid for decision support in numerous business environments, and the GDSS can be a valuable tool for enhancing a BI framework with advanced decision capabilities.

Keywords

Group Decision Support Systems, NeXClass Methods, Multicriteria Classification, Business Intelligence

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1. Introduction

The majority of processes and decisions in large firms and organizations can be characterized today as data driven. The ability of acquisition and organization as well as development and diffusion of knowledge has become a critical factor for market performance and firm viability. Moreover, the amount of information gathered from traditional and novel sources such as customers, Internet and information systems, is excessively increasing requiring additional organizational effort. As a consequence, increasing complexity at the knowledge level has led to additional needs for advanced decision support (Mierzejewska, 2002). Provision thus of appropriate decision support tools at managerial as well as at operational level is critical for efficient performance, and moreover it offers a competitive advantage to firms.

One of the Information Technology directions that aims to support firms handle the above complexity is Business Intelligence (BI). BI provides a set of methods, processes and tools to support firms' decisions through intelligent exploration, integration, aggregation and analysis of data from various resources (Olszak, 2002). The origins of BI tools can be traced back at the early developments of Decision Support Systems (DSS) (Power, 2004), while current needs for advanced intelligent decisions due to information complexity has led to massive development of BI systems with DSSs' being a subset of BI domain. Within BI architecture, a DSS stands on top of BI tools, utilizing

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aggregated information provided though them, to assist decision makers optimize their decisions. Additionally, since most of the decisions within firms today require the participation of a group of decision makers, it is critical to provide tools to assist them within the context of a BI framework.

Group decision support has received significant attention from researchers due to its potential application to various business domains. Research in decision support systems targets towards supplying decision makers with appropriate tools to assist them in optimizing their decisions.

Several methodologies and tools have been developed in order to support groups, ranging from collaborative techniques to negotiation ones, depending on whether group members share a common goal or support individual goals (Rigopoulos et. Al, 2008a, 2008b, 2010). Technologies acquired for developing a GDSS tend to follow advances in Information Technology, resulting in recent advanced systems. Incorporation of web technologies nowadays, for example, can support collaboration features which could not be implemented in the very early GDSSs. However, from literature analysis there are no relevant approaches in combining BI concepts and Group Decision Support Systems (GDSS), which is the main contribution of our work.

Following the above, we developed a structured methodology which is based on multicriteria analysis and supports group classification decisions and a GDSS which implements it. In this paper we present the methodology and the GDSS, as well as an illustrative example of a real world application along with empirical findings on GDSS evaluation. The objective is the assignment of a set of alternatives to a number of predefined non-ordered categories, according to their performance on a set of evaluation criteria, by a group of decision makers.

The overall architecture and development of the GDSS was based on web technology in order to be easily integrated within an existing BI infrastructure. We followed a layered approach, implementing concepts from Service Oriented Architecture (SOA), aiming to provide a subset of the functionality of the GDSS in terms of Web Services. The proposed GDSS can comprise part of existing BI architecture within a firm or organization, gathering input from several BI subsystems to integrate them into a decision support framework.

The GDSS has been tested in real business environment and evaluated by decision makers, . Empirical findings from GDSS application have been analyzed and enhancements have already been incorporated in order to improve existing functionality and provide additional features. Regarding the overall methodology, findings provide evidence that it is a valid approach for similar decision problems in numerous business environments within a BI architecture.

Following the introduction (Section 1), the paper is structured in five sections, starting from relevant background information in BI and decision support, group decisions and multicriteria analysis (Section 2), where we also present a brief survey of similar approaches. Next, in Section 3 we present the integrated group decision multicriteria methodology which is implemented by the GDSS. Section 4 presents the architecture of the GDSS in details mentioning key features of the system. Following is the conclusion (Section 5) which summarizes the key points.

2. Background and Relevant Work

2.1. BI and Decision Support

BI is generally defined as “a term to describe leveraging the organization’s information assets for making better business decisions” (Kimball and Ross, 2002). Intelligence in BI is often defined as the discovery and explanation of hidden, inherent and decision-relevant contexts in large amounts of business and economic data. BI consists today one of the fastest developing domains in Information Technology. It is widely assumed that in the near future BI systems integration with CRM (Customer Relationships Management) and ERP systems (Enterprise Resource Planning) will provide firms a strong competitive advantage, enhancing quality of managerial decisions (Liautaud and Hammond, 2001; Olszak, 2002).

In general, BI systems combine data from internal information systems of a firm and integrate with data coming from the environment such as. statistics and financial databases, to provide adequate and reliable up-to-date information on different aspects of firms’ activities . The use of BI tools is popular in industry (Pedersen, 2004), indicating the firms’ growing needs to handle the vast aggregation of information orienting from business documents and data, including business forms, databases, spreadsheets, e-mails, articles, technical journals and reports, contracts, and web documents. Distinction between knowledge management and BI is not always clear (Herschel and Jones, 2005), although knowledge and content management technologies search, organize and extract value from information sources, while BI focuses on the same purpose, but from a different scope.

BI is mainly targeting in advancing decision making utilizing data warehousing and online analytical processing techniques (OLAP), collecting relevant data into repositories, where organized and validated can be further available for decision making. In general, business data are extracted, transformed and loaded from various transactional systems into a data warehouse after data cleansing processes and multidimensional models are created to support drill down and roll up analyses. A number of vendors provide tools and platforms for such operations and advanced end user functionality to support large amount of data (Cody et al., 2002).

From the above, the linkage between BI and decision support within firms is evident. Moreover, BI origins can be traced back at the early data-driven DSS approaches such as the DSS built for Procter & Gamble that linked sales information and retail scanner data by Metaphor Computer Systems. Later, BI term was promoted and used as an umbrella term "to describe a set of concepts and methods to improve business decision making by using fact-based support systems" (Power, 2004). Although BI is sometimes used instead of the term of executive information systems (EIS), in general BI systems can be defined as data-driven DSSs. With the advent of Internet, BI vendors shifted their BI solutions towards web technologies and enterprise BI portals emerged (Bhargava and Power, 2001).

2.2. Group Decisions

Group decision making has become an essential component of both strategic planning and everyday operations for the majority of today's organizations and enterprises. Since complexity of business environment requires sufficient knowledge from a wide range of domains, contribution of a team of experts with key skills is the only way to achieve efficiency in decisions. In order to support groups' needs, various researchers work on developing tools and methodologies, ranging from collaboration technologies to decision support systems.

However, group decisions are quite more complex compared to single decision making, since a number of contradicting factors are involved such as individuals' personal opinions, goals and stakes resulting in a social procedure, where negotiation and strategy plays a critical role.

Group decision making in real business environments raises also some issues such as:

Conflicting individual goals,

Not efficient knowledge,

Validity of information,

Individuals' motivation.

Despite the inherent complexity, within a group decision making setting, a member is able to express personal opinions and suggest solutions from a personal perspective. In addition, negotiation and voting advance efficiency of decisions and increment acceptability and adoption since all participants have contributed to the result, smoothening thus any disputes.

In general, group members can be motivated by individual perceptions to work within the group either towards collaboration or towards competition. While in the first case, members express similar opinions and goals, in the second one they state opposite opinions. Although collaborative teams work towards a common goal contradictions may also occur .

Some key techniques that have been acquired in order to facilitate group work and decision include:

Brainstorming,

Nominal group technique,

Delphi method,

Voting,

Multicriteria analysis.

2.3. Group Decisions and Multicriteria Analysis

Group decision support is a subset of the more extended research area of group support and negotiation. Group decision support is an active research topic and existing literature is quite extensive covering business as well as social issues. Limiting the scope of relevant literature to integration of multicriteria analysis within group decisions, we performed a detailed survey focusing on relevant approaches, and especially on developed Group decision support systems. An extensive review of multicriteria analysis integration within GDSSs is presented by Rigopoulos (Rigopoulos, 2008).

In general, multicriteria analysis can be incorporated as a method to model preferences and facilitate decision making within a group of decision makers. Modeling under a multicriteria setting can be formulated under two major directions:

In the first approach, individual multicriteria models are developed, which capture individuals' preferences. Each group member formulates a multicriteria problem defining the parameters according to her preferences and solves the problem getting an individual solution set. Next, the separate solutions are aggregated by aggregation operators providing thus the group solution.

In the second approach, one multicriteria model is developed for the entire team. Each group member provides a set of parameters which are aggregated by appropriate operators, providing finally a group parameter set. Upon this set the muticriteria method is applied and the solution expresses the group preference.

Each approach poses both positive and negative aspects depending on the aggregation operation, which is followed.

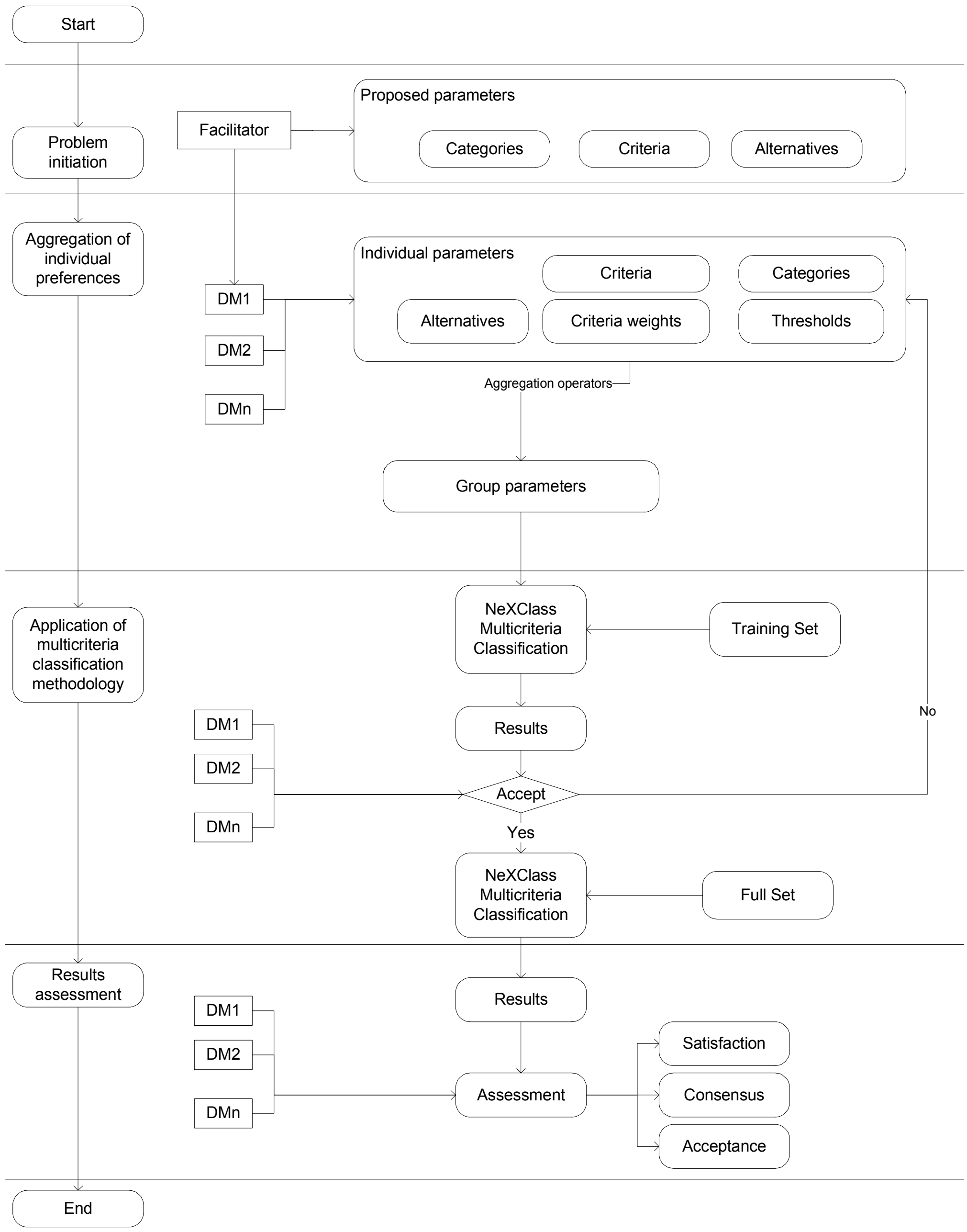

Figure 1. Structured group decision methodology.

3. Proposed Group Decision Methodology

3.1. Overview

The main objective of our work is to provide support to a group of decision makers in classification problems. The problem refers to the assignment of a set of alternatives in a number of predefined non-ordered categories, according to their performance on a set of evaluation criteria.

For this reason, we have developed a structured group decision methodology (Figure 1), which is based on the following principles:

The decision group is a small homogeneous team of collaborating decision makers. Although the methodology can be extended to large decision teams, our approach is based on collaborative teams, which target towards maximizing consensus. Non-collaborative teams require a negotiation-based approach, which is out of scope of the present methodology.

A facilitator coordinates the entire decision process. The entire group decision process is coordinated by a Facilitator.

Usually, in group decision making a negotiation phase takes place at the preliminary steps of the decision problem formation. During this negotiation, which can be structured or not, basic parameters are defined. Since our methodology is not focusing on group formation procedure and initial negotiations, we consider that a preliminary negotiation step has already been executed, possibly by utilizing brainstorming technique, between stakeholders, and the outcome of this process is an initial proposal of parameters. This set is expressed from Facilitator as the initial proposal upon which group members will express their preferences. Facilitator guides the entire process in order to produce efficient and timely results.

Decision problem is structured or semi structured. The team solves a structured classification problem contributing their preferences. Non structured problems are out of scope.

Multicriteria analysis is utilized for the classification. For the classification problem we utilize multicriteria analysis which provides appropriate support to similar problems.

Following the above principles, we developed a group decision methodology which is separated in the following major phases:

Problem initiation. In this phase Facilitator defines the basic parameters of the problem. The parameters are related to the specific multicriteria methodology, and refer to criteria, alternatives and categories.

Aggregation of individual parameters. During this phase, each member evaluates the proposed parameter set and expresses her preferences in numeric and linguistic format. Next, individual preferences are aggregated and a group parameter set is produced which is used as input for the classification algorithm.

Application of multicriteria classification algorithm. In this phase, using the group parameter set, the multicriteria algorithm is initially applied to a training set of alternatives. Group members evaluate results and if accepted, the same parameter set is used for the classification of the entire set of alternatives.

Results evaluation. At this phase, group members evaluate the classification results of the entire set expressing their opinion.

3.2. Phases of Methodology

Notations

$A=\{a_1,a_2,...,a_m\}$: a set of alternatives for classification in a number of categories,

$G=\{g_1,g_2,...,g_n\}$: a set of evaluation criteria,

$C=\{C^1,C^2,...,C^h\}$: a set of categories,

$B^h=\{b_1^h,b_2^h,...,b_k^h\}$: a set of prototypes for category h, where $B^h=\{b_i^h \mid i=1,..k,h=1,...L_h\}$ and b_i^h is the ith prototype of hth category. These prototypes define the category as thresholds of entrance to category.

Alternatives' performance on criteria is calculated in way such that $\forall a, g(a)=(g_1(a),g_2(a),...,g_n(a))$ and $\forall b_i^h, g(b_i^h)=(g_1(b_i^h),g_2(b_i^h),...,g_n(b_i^h))$.

Problem initiation. In this phase Facilitator initiates the decision problem, defining all appropriate parameters. In details:

Basic parameters. Initially, Facilitator defines a number of basic parameters, related to classification problem such as the number of group members, the number of categories, the number of criteria, and to results assessment such as the consensus, satisfaction and acceptance levels. These levels define minimum required levels for the group decision. In case they are not satisfied, a second round is executed with modification of individual preferences.

Members. Facilitator defines the group members $\mathrm{M}=\{\mathrm{m}_1,\mathrm{m}_2,...\mathrm{m}_\mathrm{n}\}$ assigning all necessary contact details.

Categories. Facilitator defines the set of categories $C=\{C^1,C^2,...,C^h\}$ for the classification of alternatives.

Evaluation criteria. Facilitator defines the set of evaluation criteria $G=\{g_1,g_2,...,g_n\}$ according to problem requirements.

Criteria weights. Facilitator defines the criteria weights.

Alternatives. Facilitator defines the set of alternatives $A=\{a_1,a_2,...,a_m\}$ for classification, and defines their performance on the evaluation criteria $\forall a, g(a)=(g_1(a),g_2(a),...,g_n(a))$.

Entrance thresholds. Facilitator defines appropriate entrance thresholds $B^h=\{b_1^h,b_2^h,...,b_k^h\}$ for each category $C=\{C^1,C^2,...,C^h\}$.

For each threshold Facilitator defines preference, indifference and veto thresholds similar to ELECTRE TRI method.

Training set. Facilitator defines a subset of alternatives as training set, in order to evaluate parameters' accuracy.

After the initiation of the parameters, Facilitator communicates through the GDSS with group members informing them about the problem and asking them to submit their preferences.

Aggregation of individual parameters. In this phase group members express their preferences on the proposed parameter set. Member preferences are expressed in numeric values and linguistic preferences. For the aggregation of numeric values we utilize the Social Judgment Scheme (SJS) (Rigopoulos, 2008), while linguistic terms are aggregated in terms of an Ordered Weighted Averaging Operator (OWA) (Rigopoulos, 2008).

Aggregation of member preferences is executed for the following parameters

Criteria. Group members express their acceptance on each proposed criterion in a five point linguistic scale and their preferred weight in numeric value.

Alternatives. Group members express their acceptance on alternatives' performance or submit their preference in numeric value.

Categories. Group members express their acceptance on each category definition, and submit their preferences on category thresholds in numeric value. .

Facilitator proceeds with validation of members' input and aggregates the values. Parameters with low acceptance level are marked and are subject to review if final results are not acceptable by group members.

Application of multicriteria classification algorithm. After the aggregation of individual members' parameters a group parameter set is created and NeXClass algorithm for multicriteria classification is applied on this group parameter set.

NeXClass algorithm classifies an alternative to a specific category with respect to alternative's performance to the evaluation criteria, considering a set of alternatives, a set of predefined non-ordered categories and a set of evaluation criteria (Rigopoulos, et al., 2010).

Application of NeXClass classification algorithm is executed through the following steps

Training set classification. Classification algorithm is initially applied to the training set initially, as it has been defined by group members. Classification is executed by Facilitator, and group members are informed to assess the results.

Evaluation of results. Each member expresses her preference on the results in a five point linguistic scale, and in case of low acceptance level, Facilitaror executes a second round of parameter definition from members in order to calibrate the model. When training set classification is acceptable, Facilitator proceeds with the classification of the entire set of alternatives. In case of low acceptance level after the second round, Facilitator terminates the process in order to revise the problem with stakeholders.

Training set classification. Classification algorithm is finally applied to the entire set by Facilitator, and group members are informed to assess the results.

Results assessment. Group members assess the results expressing their preference in a five point linguistic scale. In case of low acceptance level, Facilitator reruns the model, requesting modifications from members.

4. Group Decision Support System

4.1. Overview

A GDSS was developed to implement the above methodology (Section 3). In the following we present the architecture of the GDSS pointing to the key features of the system.

The design of the GDSS was based on the following requirements:

Collaboration. The GDSS should promote collaboration between group members by appropriate functions. Group members for similar decision problems, can be selected ad hoc without any prior collaboration. The GDSS should thus promote the feeling of a common goal to members minimizing thus individual goals.

Communication. Since business operations may span over several locations, members can be located separately. Communication thus between facilitator and group members should be efficient enough in order to provide results in a timely way. The GDSS should thus provide appropriate communication tools.

Anonymity. Although anonymity poses some negative issues, it encourages members express their preferences without restrictions or external influence. For this reason, the GDSS should support anonymity at presentation level.

Asynchronous operation. Different time zones and locations of today's business operations require asynchronous operation and decision making. The GDSS should thus provide asynchronous operation efficiently.

Considering the above requirements, a layered approach which can be easily deployed in an existing BI infrastructure was selected for the GDSS architecture (Figure 2). BI architecture components such as transactional data source systems and data warehouses can be easily connected and integrated with the GDSS, being the sources of input data. In the same way, GDSS output can be deployed in firm's BI systems advancing firm's knowledge. Regarding the technology utilized, GDSS modules have been entirely developed in Java language using JCharts library for chart preparation. Apache web server is used to host the entire site with Tomcat as servlet container and Tomcat Axis used for the deployment of web services. Data layer has been implemented in MySQL database, but can be hosted in any relational database.

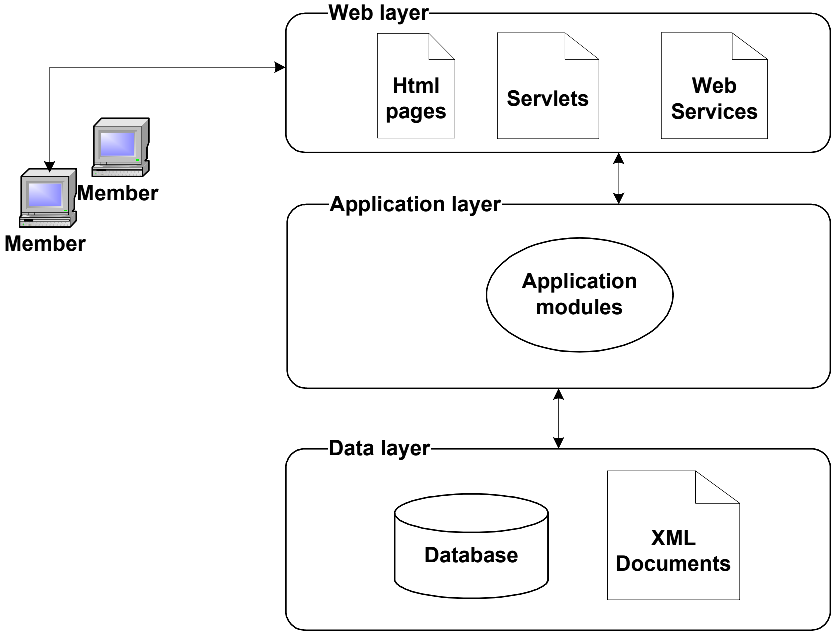

Figure 2. Overall GDSS architecture within a BI framework.

4.2. Architecture

The GDSS is comprised of the Data, Application and Web layers described in the following:

Application layer hosts all the functional modules which implement the methodology. The layers is comprised of the following major functional modules, which have been developed in Java language:

Group facilitation module. It is the core module of GDSS, which is responsible for the coordination of group decision process.

Communication module. This module implements all the necessary functionality, which is required for the communication between group members and Facilitator.

Multicriteria algorithm module. This module implements the NeXClass multicriteria classification algorithm (Section 3.2).

Aggregation module. This module implements all the aggregation processes following the methodology. SJS and OWA aggregation as presented above (Section 3.2), are implemented on individual members' preferences.

Presentation module. This module is responsible for the presentation formatting, in both simple numeric and graphical formats. Utilization of graphs for result visualization, increases familiarization and understanding from group members. For the development of graphs JChart library has been utilized.

Data layer, stores all the necessary data for decision problems (Figure 3). It is one of the core components of GDSS architecture, and is responsible for storing all the necessary data for each classification problem. Since the orientation of GDSS is to operate into business environment, the data model was designed to meet relevant demands. It can store problem parameters from multiple simultaneous decision problems and can handle any combination of group members and parameters without conflicts. It can also store previous problems or demonstration ones for educational purposes, with specific consideration to privacy issues. In order to meet the above needs, we have implemented a relational model distinguishing three major virtual groups of entities: Problem parameters, Preferences and Results. Each one consists of a number of tables which along with the relations satisfy the needs of the GDSS.

Problem parameters group stores all necessary data related to a group problem. Parameters include all necessary data for a decision problem referring to criteria, categories, alternatives and members.

Preferences group stores all the data representing group members' preferences. Preferences group is separated into two sub groups, which store individuals' and aggregated preferences accordingly. Aggregated preferences data is the input for the multicriteria classification methodology.

Results group stores all the data related to the results of the problem.

The model can reside in any relational database available at business environment. In addition, there is the option to import data in the form of XML documents for decision problems with large number of alternatives, when the data are already present into another system. Data can be originated from several sources of a firm's BI infrastructure and further the entire Data layer can be itself a part of the BI infrastructure.

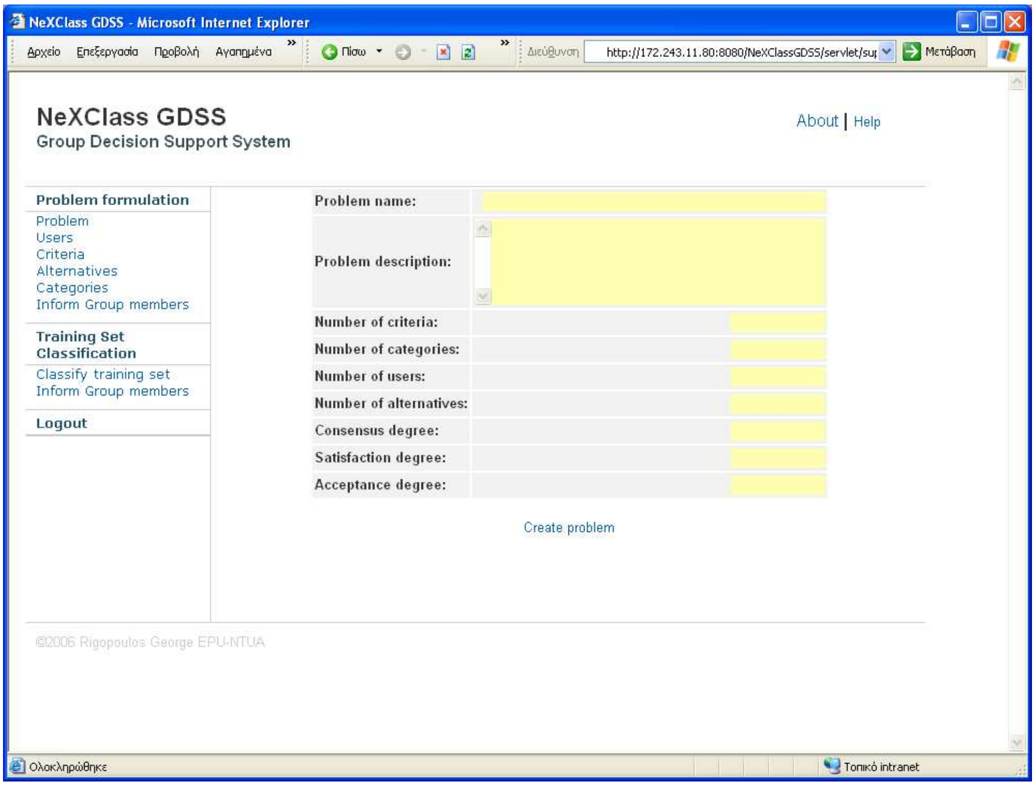

Figure 3. Facilitator's mode for problem initiation.

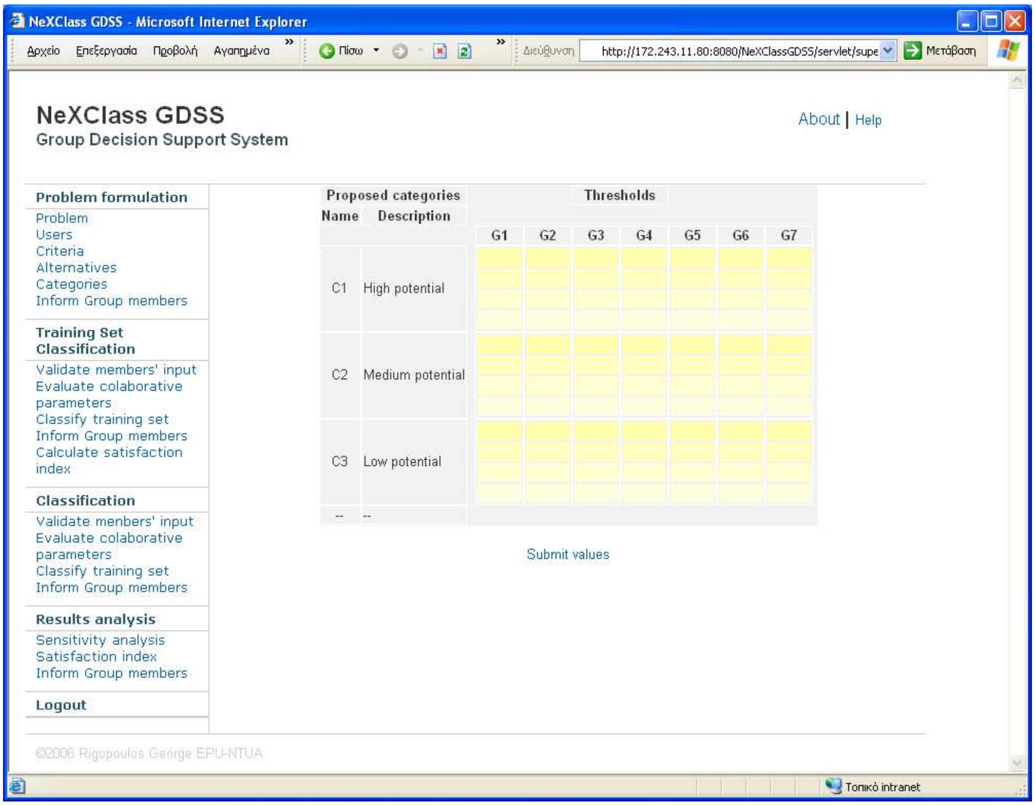

Figure 4. Facilitator's mode for category thresholds definition.

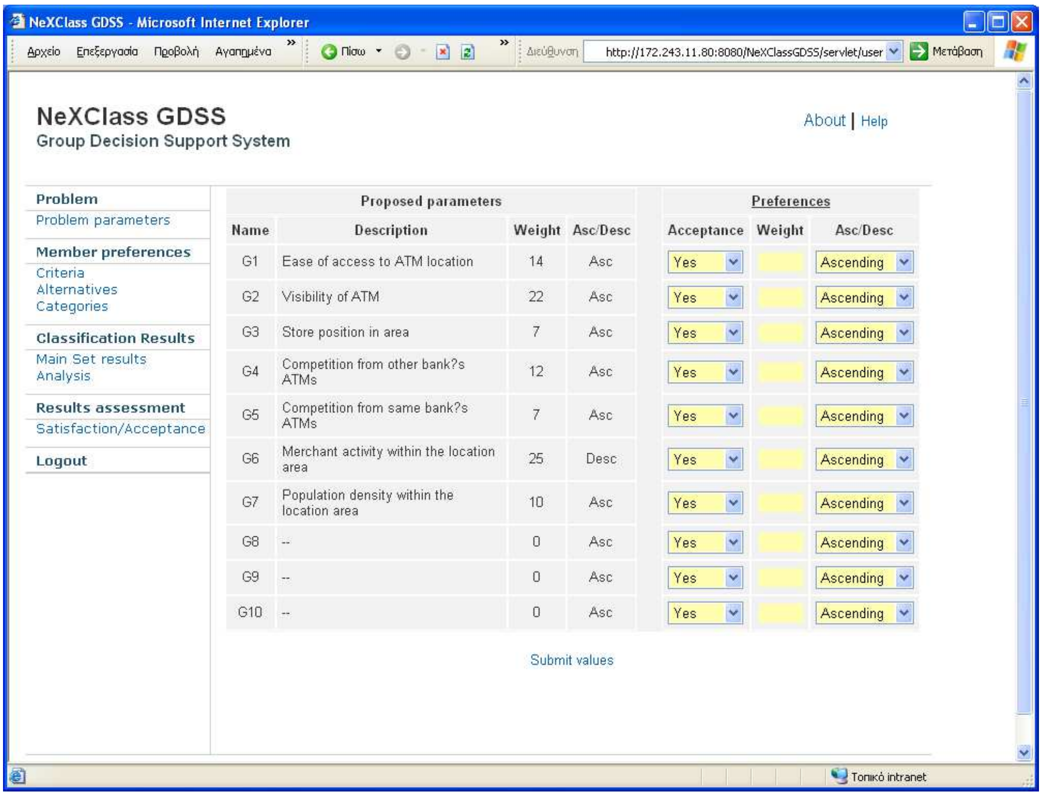

Figure 5. Member's mode for parameter definition on criteria.

Figure 6. Member's view of classification results.

Web layer, provides all the user interface functionality. User interface has been designed in order to guide users through the steps of the methodology and has been implemented using web technology. Servlets and html pages offer GDSS functionality to group members in a user friendly way. In addition, an XML interface has been developed for importing data for large scale problems which are already stored in existing systems. Finally, a subset of GDSS functionality can be provided as a web service.

GDSS is accessed through a login page, where users have to provide appropriate password. The system recognizes two roles: Facilitator and Member. Facilitator works on a full functional mode of the system, while group Members work on a mode presenting a subset of functionality. Facilitator initiates a new problem (Figure 3) or selects to process an existing one. For a new problem, he defines the proposed parameters and informs group Members. For an existing problem, he can validate Members' input, and proceed to aggregation of preferences and classification of the training set.

Members after logging into the GDSS, can select a problem and insert their preferences upon the proposed parameter set (Figure 4). Several graphs provide visualizations over the numeric parameters helping members' understanding on them (Figures 5).

After validation of members' input and aggregation of preferences, facilitator executes the classification algorithm using the appropriate functions from his menu, and informs members for the classification results for the final assessment phase (Figure 6).

5. Conclusion

In this paper we presented a web based Group Decision Support System for small collaborating teams based on web technology. It implements a group multicriteria decision methodology for classification decisions where aggregation of members' preferences is executed at the parameter level. We presented the methodology as well as the GDSS architecture and functionality. The overall architecture and development of the GDSS is based on web technology in order to be easily integrated within existing business infrastructure. A layered approach was followed, implementing concepts from Service Oriented Architecture and a subset of the functionality of the GDSS can be provided in terms of Web Services.

Empirical findings from GDSS application have been analyzed and provide evidence that the methodology and the GDSS provide a valid approach for similar decision problems in business environment. We believe that this methodology and GDSS can be easily deployed to support group decisions in similar environments.

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