RC 22045 (98939) 24 April 2001 **Computer Science**

IBM Research Report

Design and Implementation of an Interactive Visual Analysis System for e-Sourcing

Juhnyoung Lee, Martin Bichler, Sudhir Verma, Ho Soo Lee
IBM Research Division
Thomas J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598

Research Division
Almaden - Austin - Beijing - Haifa - T. J. Watson - Tokyo - Zurich

Design and Implementation of an Interactive Visual Analysis System for e-Sourcing

Juhnyoung Lee, Martin Bichler, Sudhir Verma, and Ho Soo Lee

IBM T. J. Watson Research Center
P. O. Box 218
Yorktown Heights, NY 10598
{jyl, bichler, vsudhir, leehs}@us.ibm.com

Abstract

Sourcing is a business process of identifying, evaluating, negotiating, and configuring optimal groupings of trading partners into a supply chain network that responds to changing market demands. In this paper, we focus on a crucial step of the sourcing process, namely, the bid evaluation and selection. More specifically, we present a decision analysis system that helps sourcing professionals analyze offers and select suitable ones in reverse auctions and RFQs (Request-For-Quotes). Unlike conventional bid evaluation systems that depend on multi-criteria decision analysis methods to rank offers by score, this system provides a novel interactive visual analysis capability at its core. The system allows the users to effectively explore the information space comprised of the submitted offers, and selectively utilize various analysis facilities in a controlled manner. We demonstrate that the visual interface of the system is an effective communication mechanism that is to add value and meaning, illuminate, simplify, and clarify, and, furthermore, an efficient decision analysis tool that allows buyers to view, explore, navigate, search, compare and classify submitted offers.

Keywords: e-commerce, sourcing, decision analysis, visualization, user interface

1. Introduction

E-sourcing is an Internet-based business process for identifying, evaluating, negotiating, and configuring optimal groupings of buyers and suppliers into a supply chain that responds to changing market demands. E-procurement is an important part of e-sourcing. Procurement of materials and services from suppliers should address important decisions of what to buy, how much to buy, whom to buy from, and how to manage relationship with suppliers. It provides the largest opportunity for an organization to impact on the cost, structure, and overall efficiency of its supply chain [1, 7].

Successful strategic sourcing requires a holistic process that automates the entire sourcing process, including order planning, RFQ generation and distribution, RFQ evaluation, offer formulation, offer evaluation and selection, negotiation, settlement, and order execution. Sourcing is a continuous process of analyzing expenditure flow, vendor performance, user requirements and market conditions to optimize the total value. Figure 1 depicts a typical sourcing process that shows the steps of requirements, negotiation, and selection.

A system for supporting the sourcing process needs to satisfy several requirements related to decision analysis. First, when evaluating and selecting offers in an auction, the buyers needs to take a number of different factors into account. For example, there may be factors related to the *product specification* such as price, material quality and properties, color and size. In addition, there may be factors related to the *service specification* such as delivery time and cost, and warranty. Furthermore, there may be *supplier qualification* factors such as trading history, experience and reputation. These factors should be considered across multiple suppliers and weighed against specific purchasing policies or business rules such as limiting award to no more than three suppliers, no supplier receiving more than 40% of the contract, and one or more designated suppliers receiving 20% of the award. Note that often some factors are more important in making sourcing decisions than others. Also, the values of some factors may be dependent on those of others.

Another requirement is “soft” navigation capability. In online buying processes, it is important to distinguish “hard” and “soft” navigation [12]. Decision support systems that provide only hard filtering mechanisms exclude offers that do not match the constraints specified in navigation. Hard filtering mechanisms interpret buyers’ requests as requirements and not as preferences, although in many cases, it is natural to interpret them as preferences. Soft navigation capability alleviates this problem of hard filtering by allowing buyers to distinguish between requirements and preferences. One of the proposed soft navigation methods is *product scoring*, and we will propose another solution (based on visualization) to this problem in this paper.

Finally, it is important that the system should be able to make buyers comfortable and confident about their purchasing decisions. Also, the buyer should be able to account for decisions s/he recommends (e.g., why certain suppliers won and others lost). *Accountability* is crucial particularly for business buyers such as corporate procurement professionals whose decisions always need to be justified in terms of savings in time and cost. To achieve this goal, it is important that the decision support system allows the users to explore the information space comprised of the given options, learn and understand the properties of alternatives, compare their values, and inspect the recommendations.

In this paper, we present a decision analysis system referred to as ABSolute. IBM Research's ABSolute decision engine has been developed to provide buyers with intelligent decision support functions, for example, in evaluating RFQ offers from suppliers. ABSolute aims to transform sourcing into an efficient process by satisfying complicated decision analysis needs for e-sourcing. It provides effective buyer side decision support by evaluating and scoring weighted preferences of multiple attributes such as quality, delivery condition, warranty period, contract terms, supplier rating, as well as price. Besides traditionally employed scoring mechanisms used by other sourcing decision support tools, ABSolute allows the users to effectively navigate through the information space of the submitted offers, and selectively utilize various analysis facilities in a controlled manner. It provides an interactive visual analysis capability that allows buyers to effectively view, explore, navigate, search, compare and classify submitted offers. The basic design goal of the ABSolute system is to visualize multi-dimensional data comprised of submitted offers, and to help users manipulate the visualization to rapidly gain insight for making sourcing decisions.

The rest of this paper is structured as follows: Section 2 summarizes the traditional approaches to sourcing in businesses. Section 3 describes the design of the ABSolute system and its basic analysis facilities. In Section 4, we explain advanced decision analysis features of ABSolute. Section 5 describes the architecture and the implementation of the ABSolute prototype system. In Section 6, conclusions are drawn and future work is outlined.

2. Traditional Approaches

Traditionally, sourcing initiatives have relied on consulting engagements to facilitate the sourcing process. This approach has several limitations: expensive fees, lack of scalability, limited knowledge transfer, limited stakeholder buy-in, and execution inefficiencies. Recently, B2B exchanges have automated portion of corporate procurement process facilitating transactions and workflow through hosted dynamic on-line events. However, they provide only point solutions that address part of the sourcing process leaving organizations in need of additional solutions to complete the process.

Despite the imminent needs for strategic sourcing in organizations, only a little work has been done for sourcing decision support. There are a few bid analysis products currently available from companies such as Emptoris (www.emptoris.com), Frictionless Commerce (www.frictionless.com), MindFlow Technologies (www.mindflow.com), Moai Technologies (www.moai.com), Perfect (www.perfect.com), Rapt (www.rapt.com), and Zilliant (www.zilliant.com). Most of these products depend on a multi-attribute decision analysis method or an optimization technique, and are limited in their capabilities for supporting decision-making processes.

Bid analysis products from Frictionless Commerce and Perfect use multi-criteria decision analysis techniques, which have been actively studied as an area of management information systems. There are a number of multi-criteria decision analysis algorithms including AHP (Analytical Hierarchy Process), MAUT (Multi-Attribute Utility Theory), and SMART (Simple Multi-Attribute Rating Technique) known in the literature [3]. Each of these bid analysis products works basically in the same way. It requests the user to assign relative weights to individual attributes of alternatives (i.e., offers), and then uses a multi-criteria decision analysis algorithm (whose details are not available in public) to compute the scores of the alternatives. The system ranks the alternative offers by score, and the user is supposed to select the winning offers among the top-rankers.

One weakness of this approach is that it does not account for the analysis results well, for example, why certain offers received a high score and others not, and how sensitive offer scores are to attribute weights. Another related weakness is that the resulted scores may not be reliable due to subjective weight assignment. When a user assigns weights to attributes for the first time, s/he might not understand their effect well. The situation becomes especially difficult when the number of attributes is larger than a certain number, say, 10, that an ordinary person can easily remember and comprehend. Another drawback of this approach is that it is limited in incorporating business rules and constraints (e.g., purchasing policies) into analysis. The user has to satisfy these constraints by manually identifying the best possible solution as a combination of the top-rankers.

Another approach used in commercial bid analysis products is optimization techniques such as linear programming, and/or constraint programming. Bid analysis products from Emptoris and Rapt belong to this category. These products recommend a set of offers from multiple suppliers that optimizes one or more objectives, e.g., minimizing the total cost, set by the user. A drawback of this approach is that its capability for recommending a combination of bids is limited by its inability to express complex objectives for optimization. While this approach can be effective for simple objectives such as minimizing the total cost, it does not work well if the objectives involve complicated business rules over multiple attributes. Most importantly, this approach is weak in explaining its analysis results. The optimization-based systems do not allow the users to easily inspect the results and explore the offer information space, understand the properties of different offers, and compare the given options.

3. Design of the ABSolute System

ABSolute provides a visual user interface which is not "just another pretty interface". Rather, the visual interface is designed to be an effective communication mechanism that is to add value and meaning, to illuminate, to simplify, and to clarify. Furthermore, it provides a decision analysis capability that allows buyers to view, explore, navigate, search, compare and classify submitted offers. For interactive analysis, the interface provides a set of useful visual facilities such as dynamic filtering and querying, tagging, color-coding, and zooming. As shown in Figure 2, the visual interface provides a tree-view for RFQ specification and revision, and a table-view and a multi-dimensional visualization for displaying submitted offers. In this section, we describe the details of these views and explain how they work together for interactive analysis of offers.

3.1. RFQ View

An RFQ consists of two parts: the header and the feature. The header part contains relevant information such as an identifier, the name of the requested product or service, the issue date, the quote due date, and the buyer information. The feature part specifies one or more features of the requested product, service or contract. For example, it may contain several product features (e.g., price, material quality and properties, color and size), service features (e.g., delivery time and cost, and warranty), and/or supplier features (e.g., delivery experience, reputation, and stock values). In this view, these three categories of features are displayed in a tabbed pane: one tab for each feature category.

In Figure 2, the pane shows the product features. Each feature category is displayed by a tree structure that hierarchically shows the features in that category. Each feature can have zero or more children and each child feature has two elements: importance and a set of values. The importance element represents how important this feature is relative to other features in a scale of 1 to 10 (also described in text as "don't care", "informational", "negotiable", "non-negotiable" and "critical"). The importance values are used to calculate scores by a multi-criteria decision analysis algorithm. (In the current ABSolute prototype system, we use an implementation of MAUT.) The user can dynamically change an importance value by using a sliding bar (which appears when the user click on the importance value for editing), and see the effect in terms of bid scores shown in the Bid View (both the tree-view and the visualization) in the right-hand side of the interface.

The lower and upper limit values of a feature represent a value range that the buyer desires for this feature in this request. The user also can dynamically specify and modify the lower and/or upper limit values of each feature that has numeric values (regardless that they are discrete or continuous). In addition, each feature has a checkbox in front of its name. The user can dynamically de-/select individual features by using the checkbox; only checked features will be considered in the Bid View in showing submitted offers.

The ABSolute system reads in RFQ data in XML (eXtensible Markup Languge) format that provides the initial values of features. (In Section 5, we will explain this assumption with regard to ABSolute's connection to a private exchange for covering the entire sourcing process flow.) Then the user can dynamically modify the importance element and values of individual features, if necessary. The user can apply the change to the Bid View by clicking on the "Apply" button on the tool bar. The Bid View, both the visualization and the table-view, is updated to reflect this change. For example, by changing the importance of one or more features, the user can see how the corresponding attribute axes in the parallel coordinates visualization and the feature columns in the table view are re-ordered, and how the offer scores are affected (as will be explained in the next section). The user can utilize this "Apply" mechanism to test and learn how sensitive offer scores are to the change of the weights (i.e., importance) assigned to attributes. It helps the user understand how to assign weights to attributes to achieve reliable results in bid scores. Another button on the tool bar, "Reset" is used to restore the initial values for individual RFQ attributes as given in the input RFQ file. The "Save" button on the tool bar is used to store the revised RFQ (and hence the Bid View) in a file for a record purpose and/or later analysis.

4.2. Bid View

The Bid View displays offers submitted to the request as shown in the RFQ view in two different analysis mechanisms: a multi-dimensional visualization and a table. In this section, we will explain the design philosophy of the visualization and interactive visual analysis, and describe the basic visual analysis facilities.

Interactive Visual Analysis

The central piece of the ABSolute system is the interactive visual analysis capability using a multi-dimensional visualization mechanism based on *parallel coordinates* [8] and augmented by a number of visual facilities. While the multi-criteria decision analysis method (e.g., MAUT) provides a simple way to sort out a set of submitted offers by score, the interactive visual analysis provides an effective means to navigating through the information space comprised of the submitted offers, intuitively understanding the properties of given options, and perceiving interesting patterns among and/or within offers.

The basic idea of the ABSolute's visual analysis is to visualize multi-dimensional data of submitted offers, and to help users manipulate the visualization to rapidly gain insight for making sourcing decisions. It is believed that humans are good at recognizing patterns and that they are the strongest link in data analysis [11]. There is every reason to endeavor to take full advantage of this human capability. If data is visualized in a potentially revealing picture and a human is given effective means to manipulating the picture, s/he will quickly glimpse the most important facets of the complex decision analysis problems involved with bid selection, find relationships among submitted offers, and, through an interactive process, arrive at a solution with understanding and confidence.

A parallel coordinate system was proposed as a more practical way of displaying multi-dimensional data sets [8]. Visualization of higher (i.e., more than three) dimensional geometry with the traditional Cartesian coordinate system where all axes are mutually perpendicular is difficult. Because we live in a three-dimensional world, understanding the space involved with a Cartesian coordinate system of more than three dimensions is a near impossible task for most people. The ABSolute visual interface uses parallel coordinates to display and view the entire set of offers and their attributes in a single 2-dimensional screen.

Figures 3 and 4 shows visualizations of a set of offers where each axis represents an attribute, i.e., a feature, a short vertical line (referred to as “matchstick”) along the attribute axes represents attribute values, and the plot of a multi-dimensional point, that is, the straight-line segments connecting appropriate values (with the same color) across the attribute axes (referred to as “bid line”) represents an offer. In this visual interface, the layout of the typical parallel coordinate system is rotated clockwise by 90^{o} so that the parallel axes are horizontal. The axes are rotated from the standard vertical position because users are generally more accustomed to using the vertical scrollbar, which would be necessary if the buyer specified many attributes so that all the axes do not fit on a single screen. The background color is black since it is generally more visually pleasing when the color-coded offers are placed on a black background than when they are placed on a light gray or white background.

Figure 3 is the initial view of the visualization in a full screen showing only the selected attribute axes, the matchsticks that represent attribute values of individual offers, and a target area that represents the range of desirable attribute values determined by the lower and upper limit values of attributes in the RFQ specification. The attribute axes in the visualization are ordered by their importance specified in the RFQ view. They are dynamically re-ordered as the user edits the attribute importance in the RFQ specification. The matchsticks are color-coded by a selected categorical attribute (as will be explained in the next section). This initial view provides the user an impression of the data set s/he will analyze and meaningful cues such as how offer values are distributed for each attribute, how dense or sparse the distribution is for a particular attribute or overall, if there are any clusters of values, how many values are in the target area, and so on.

A note regarding the target area is that it is a mechanism for the soft navigation capability that was described in the introduction. The range of desirable attribute valued specified by the buyer with the lower and upper limit values is interpreted as preferences and not as requirements, and the target area is used to illustrate how well an offer matches the specified preferences. Offers that match fewer or no preferences receive low scores, but are not excluded from the visualization.

The ABSolute visual interface provides the user with several visual facilities that the user can utilize to further navigate, explore and search the information space directly in the visualization. First, the user can point a matchstick with his/her mouse to trigger a tool-tip that shows its value, as shown in Figure 3. Also, the user can add a bid line to the view by left-clicking on an attribute value (i.e., a matchstick) of the offer. Along with the bid line, all the attribute values of the offer are displayed in text below the corresponding matchstick, as shown in Figure 4. Another left-clicking on a matchstick of the offer will remove the bid line from the view. In addition, a mouse fly-over on a bid line triggers a tool-tip that shows brief text information describing that particular offer such as its identifier number, supplier name, and score, as shown in Figure 4. Yet another mouse operation on a bid line, i.e., double-click, triggers a pop-up window that displays detail information about the offer. (Another mouse operation, right-click, on a matchstick is used in relation with the importance determination feature of ABSolute, and will be briefly described in the next section.)

Figure 4 shows three selected offers in the view. The user can easily examine all the attribute values of individual offers in a single screen and also compare their values. In this example, the offer depicted by the left-most bid line (colored purple) excels the other two in every attribute. It is referred that the offer depicted by the left-most bid line *dominates* the other two. The domination relationship among offers will be discussed in detail in the next section on the *pareto optimality analysis*.

In summary, the multi-dimensional visualization of the entire information space comprised by the submitted offers in a single screen provides meaningful cues for analysis. By using useful visual facilities augmented to the visualization, a user can visually explore the information space and compare any offers s/he is interested in. The user can easily have only essential information in the decision-making process presented in the visualization; however, more detailed information is accessible by using visual operations. The user, not the system, determines what is essential information and what is extra. Despite the depth and breadth of information that can be displayed and analyzed in a single page, the effective and well-organized visual presentation does not show any sign of information clutter.

Table View

It is important to have a table view of the submitted offers in addition to the multi-dimensional visualization, because most business buyers are accustomed to view and manipulate data in a table form such as spreadsheet programs. The table view in ABSolute shows the entire set of submitted offers, one offer per each row. Initially it displays bids in the order of score from the multi-criteria decision analysis algorithm (currently a version MAUT implemented in the ABSolute system). Columns of the table that represent features of the requested product, service, or contract are ordered by their importance given in the RFQ view. Because a sorting capability is augmented to each column, the user can sort offers for each column in ascending or descending order, if necessary. For example, in Figure 2, the importance of biodegradability is given the highest value, and the column for that feature comes first in the table after the score column.

It is also important to synchronize the table view with the visualization all the time, although both views are constantly changing on the user's interaction to the system. The table view is tightly integrated with the visualization in several ways as shown in Figure 5. First, each row in the table has a checkbox that can be used to de-/select the corresponding offer in the visualization. When a user checks an offer in the table, its bid line appears in the visualization. Also, when the user de-checks the offer in the table, its bid line disappears from the visualization. This operation works vice-versa. Namely, if a user displays a bid line in the visualization by left-clicking on one of the matchsticks of the offer, then the corresponding offer in the table view is also checked. In this way, the table view and the visualization are always synchronized. Also, double-clicks (for viewing detail information in a pop-up window) and right-clicks (in relation to importance determination) work exactly the same way for matchsticks in the visualization and offer rows in the table view.

4. Advanced Analysis Features

In addition to the basic multi-dimensional visualization and visual facilities that help the user interactively explore the information space and gain insight for purchasing decisions, the ABSolute system provides a number of advanced decision analysis features which are described in this section.

4.1. Multi-Attribute Utility Theory (MAUT)

ABSolute allows a user to assign relative weights to individual attributes of alternatives (i.e., bids), and then uses an additive value function in order to compute the scores of the alternatives. The system then ranks the alternative bids by score, and the user selects the winning bids among the top-rankers. The current ABSolute prototype system uses MAUT for this purpose. The basic hypothesis of MAUT is that in any decision problem, there exists a real valued function *U* defined along the set of feasible alternatives, which the decision maker wishes to maximize. This function aggregates the criteria $x_1 \ldots x_n$. Besides, individual (single-measure) utility functions $U_1(x_1), \ldots, U_n(x_n)$ are assumed for the *n* different attributes. The utility function translates the value of an attribute into “utility units”. The overall utility for an alternative is given by the sum of all weighted utilities of the attributes. For an outcome that has levels $x_1, \ldots, x_n$ on the *n* attributes, the overall utility for an alternative *i* is given by

$$U(x_1 \ldots x_n) = \sum_{i=1}^{n} w_i U(x_i)$$

The alternative with the largest overall utility is the most desirable under this rule. Each utility function $U(x_i)$ assigns values of *0* and *1* to the worst and best levels on that particular objective and

$$\sum_{i=1}^{n} w_i = 1,\ w_i > 0.$$

Consequently, the additive utility function also assigns values of *0* and *1* to the worst and best conceivable outcomes, respectively. A basic precondition for the additive utility function is preferential independence of all attributes, which has been the topic of many debates on multi-attribute utility theory [3, 6]. Even in cases with inter-dependencies, the additive utility function is often used as a rough-cut approximation for a more complex non-linear utility function.

4.2. Show Filter

The "Show" feature on the tool bar is a special filter that a user can utilize to view a subset of offers in the Bid View based their score. Namely, the user can select to view "None", "All", "Top-3", "Top-5", "Top-10", … offers ranked by the multi-criteria scoring algorithm (e.g., MAUT). In Figure 6, the "Show" feature displays Top-3 offers in the view. A buyer who needs to make a decision rapidly may employ this feature to quickly identify top rankers, and view and compare their individual attributes for confirmation. This feature is implemented as an editable pull-down menu in the current ABSolute prototype system. That is, the user can edit the number in the filter to choose any number of top-rankers. The "Count" feature on the tool bar displays the number of bid lines currently shown in the visualization. The count gives the user an idea how much s/he has narrowed down her/his search.

4.3. Dynamic Filters, Dynamic Querying, and Color Coding

The parallel coordinate-based visual interface has coordinates (i.e., parallel lines) only for numeric attributes such as unit price, biodegradability, softening point, and delivery cost and date, as shown the figures. Categorical attributes of offers such as supplier, manufacturer, and the supplier's location, are recognized by the ABSolute system, and placed in a pop-up window that can be open by clicking on the "Filters" button on the tool bar. The filters formulated from the categorical attribute values of the submitted offers are used for two purposes: color-coding and dynamic querying.

Figure 7 shows three categorical attributes in a pop-up "Filters" window. The user can select an attribute in the window for color-coding by using radio buttons. The color assigned to each value is shown in the check-box column of the selected attribute's table. Color has long been used for visualization in many ways [4]. ABSolute uses color dynamically and interactively to distinguish subsets of data points, i.e., submitted offers. Recognition and possible coupling of data subsets is critical to interactive data analysis. The use of color is one way used in this system for that requirement. Also, the user can create a dynamic filter by checking zero or more values of individual categories that s/he is interested in, and apply the filter to view only the offers that satisfy the given criteria. This dynamic query feature provides an alternative way to explore and search the information space of submitted offers. Figure 6 shows six offers that meet the criteria dynamically created in the "Filters" window.

4.4. Pareto Optimality Analysis

A pareto analysis identifies and addresses a small number of principle causes. It is named after the 19th-century economist Vilfredo Pareto, and is based on the principle that most effects come from few causes [10]. When many alternatives are present, it is common to reduce the choice set to a more manageable size by first eliminating "inferior" alternatives. The pareto analysis entails the identification of alternatives that are equal to or worse than some other alternative on every single dimension. For two alternatives with the associated consequences $\mathbf{x}' = (x_1', ..., x_i', ..., x_n')$ and $\mathbf{x}'' = (x_1'', ..., x_i'', ..., x_n'')$, $\mathbf{x}'$ is said to *dominate* $\mathbf{x}''$ whenever $x_i' \geq x_i''$, for all i and $x_i' > x_i''$ for some i. The set of consequences that is not dominated is called the *efficient frontier* or *pareto optimal set*.

The “Pareto” button on the tool bar is used to dynamically perform the pareto analysis for offers shown in the visualization. The pareto optimality analysis feature of the ABSolute system detects all the dominated offers among the submitted offers shown in the visualization to reduce the data set size without sacrificing the quality of analysis. The result of a pareto optimality analysis is displayed in a pop-up window showing which offer dominates which in a tree structure as shown in Figure 8. Because this analysis is computation-intensive, the ABSolute system removes offers that do not have a value in the target area (referred to as “outsiders”) before the pareto analysis to reduce the target data set size and hence computation.

4.5. Weight Determination via User Interaction

In traditional multi-attribute scoring methods, decision makers face difficulties in assigning appropriate weights (i.e., importance) to attributes when the number of attributes is large. Hence, they may not have confidence in their results. Weights assigned to attributes by human would be inconsistent from one person to another, and from one situation to another. To overcome this weakness of traditional scoring methods, ABSolute provides an innovative approach, where decision makers only provide sample rankings over subsets of offers. The visual interface of ABSolute helps users examine and select subsets of bid offers, and create and arrange multiple sample rankings. From the information implied by these sample rankings, the system derives a set of weights for attributes, and then overall ranking of all the given offers. With additional information from the decision maker, these results are iteratively refined. Figure 9 shows a flow chart of the iterative weight determination process.

Based on the idea outlined in the previous paragraph, we have developed a theory for estimating weights for multi-attribute decision analysis, and formulated linear and integer programming problems for it. By using simulation, we have validated the theory and its applicability. We have further developed the method by answering questions critical to its feasibility such as how many sample orderings and/or iterations are needed to obtain a good enough estimate of weights, and how sample orderings should be determined and what bids should be included in sample orderings to minimize the number of iterations. Details of this work are beyond the scope of this paper, and we have a separate paper discussing its theory, experiment results, and implementation [2].

5. Prototype Implementation

Figure 10 shows the current prototype architecture. It is assumed that the system is connected to one or more private exchanges, receiving information on RFQs and offers from the exchanges in XML format. The design of classes use the well-known *Model-View-Controller* (MVC) pattern [5]; different views and decision analysis facilities share the common set of data managers and controllers, which help synchronize the status among different views. While the data managers of the system comprise the basic classes for offers and RFQs, and database/file operations, the data controllers handles view management, visual operations, dynamic filtering, pareto optimality analysis, and weight computation using linear programming.

Interactive analysis of ABSolute requires exceptional performance. Small delays may detract from a user's attention span. At worst, s/he may become frustrated and give up. Regarding performance, a distinction can be drawn between speed and responsiveness, both of which are important to interactivity. Speed has to do with how long it takes to perform a task from start to finish. Responsiveness is related to the delay between a request for specific processing and its actual initiation. While significant improvements to speed on the order seconds can make difference in usability, even relatively small improvements to responsiveness on the order of tenths of a second may be readily noticed and appreciated by users. Speed and responsiveness have been primary requirements for ABSolute throughout its development. General efficiency was achieved by avoiding work that is not absolutely necessary and by doing what is necessary in the most efficient manner possible. Partial and intermediate results were saved whenever possible at the expense of memory, but for the benefit of avoiding probable recalculation later.

The system is a Java application that consists of about 200 classes and 2000,000 lines of code. The software is designed so as to make it easy to customize and add new features. Its interface, including the visualization of offers, is implemented by using only Java Foundation Classes. The ABSolute system uses IBM's XML for Java parser to handle RFQ and offer data in XML format. Also, it uses an optimization- programming package for attribute weight computation through user interaction. Currently, the ABSolute system is a stand-alone Java application communicating with private exchanges through file systems, but it will later provide network connections over the Internet.

6. Concluding Remarks

In this paper, we have presented a decision analysis system that helps corporate procurement buyers analyze offers and select suitable offers in reverse auctions and RFQs (Request-For-Quotes). Unlike conventional bid evaluation systems that depend on multi-criteria scoring methods to rank offers by score, this system provides an interactive visual analysis capability that allows the users to effectively explore the information space comprised of the submitted offers, and selectively utilize various analysis facilities in a controlled manner. We have demonstrated that the visual interface of the system is an efficient communication mechanism that is to add value and meaning, illuminate, simplify, and clarify, and also that it is an effective decision analysis tool that allows buyers to view, explore, navigate, search, compare and classify submitted bid offers for insight into the alternative offers.

The work presented in this paper is preliminary results from an on-going research and development project at IBM T. J. Watson Research Center for software systems automating and assisting business processes for e-sourcing. We plan to extend this work in several ways for future research. First, we will perform a structured usability study for the prototype to understand how the system affects the users' perception of the bid evaluation problems and efficiency in finding solutions, and how it can be improved. In parallel, empirical studies need to be done for understanding the performance of the proposed system in terms of savings in cost and time in real-world situations.

In addition, we will expand the capabilities of the system in many different ways. For example, we will make the ABSolute system be able to handle multiple line items per sourcing event, and suggest offers via supplier combinations. Also, the system will be connected to Internet-based private exchanges to provide necessary features such as online-negotiation and settlement, and event-based notification for buyers and suppliers. Additionally, the decision analysis capability of ABSolute will be applied to other buyer-side analysis needs in the sourcing process flow, for example, in requirement specification, and configuration and distribution of RFQs. Finally, we will customize the ABSolute system for supplier-side decision analysis needs in evaluating and selecting RFQs, and configuration and submission of offers.

Reference

[1] Aberdeen Group, "e-Sourcing Best Practices: One Size Does NOT Fit All", *Aberdeen Group Report*, November 2000.

[2] M. Bichler, J. Lee, C. Kim, and H. S. Lee, "Design and Implementation of an Intelligent Decision Analysis System for e-Sourcing", To appear in *the International Conference on Artificial Intelligence*, Las Vegas, Nevada, June 25-28, 2001.

[3] R. T. Clemen, *Making Hard Decisions: an Introduction to Decision Analysis*, Wadsworth Publishing Company, Belmont, CA, 1996.

[4] W. S. Cleveland and M. E. McGill, *Dynamic Graphics for Statistics*, Wadsworth and Brooks/Cole, 1988.

[5] J. W. Cooper, *Java Design Patterns: A Tutorial*, Addison-Welsley, 2000.

[6] W. Edwards, "How to Use Multi-Attribute Utility Measurement for Social Decision Making," *IEEE Transactions on Systems, Man, and Cybernetics SMC*, vol. 7, pp. 326-340, 1977.

[7] M. Greaver, *Strategic Outsourcing*, AMA Publications, New York, NY, 1998.

[8] A. Inselberg and B. Dimsdale, "Parallel Coordinates: A Tool for Visualizing Multi-variate Relations", *Human-Machine Interactive Systems*, Plenum Publishing Corporation, 1991, pp. 199-233.

[9] J. Lee and M. Podlaseck, "Using a Starfield Visualization for Analyzing Product Performance of Online Stores", *Proceedings of the 2nd ACM Conference on Electronic Commerce*, Minneapolis, Minnesota, October 17-20, 2000.

[10] V. Pareto, *Applicazione di teorie sociologiche*, Bedminster Press, Totowa, N. J., 1968.

[11] B. E. Rogowitz, D. T. Ling, W. A. Kellogg, "Task Dependence, Verdicality, and Pre-Attentive Vision: Taking Advantage of Perceptually-Rich Computer Environments", *SPIE Vol. 1666 Human Vision, Visual Processing, and Digital Display III*, 1992.

[12] M. Stolze, "Soft Navigation in Product Catalogs", *Proceedings of the 2nd European Conference on Research and Advanced Technology for Digital Libraries*, Heraklion, GR, 1998, pp. 385-396.

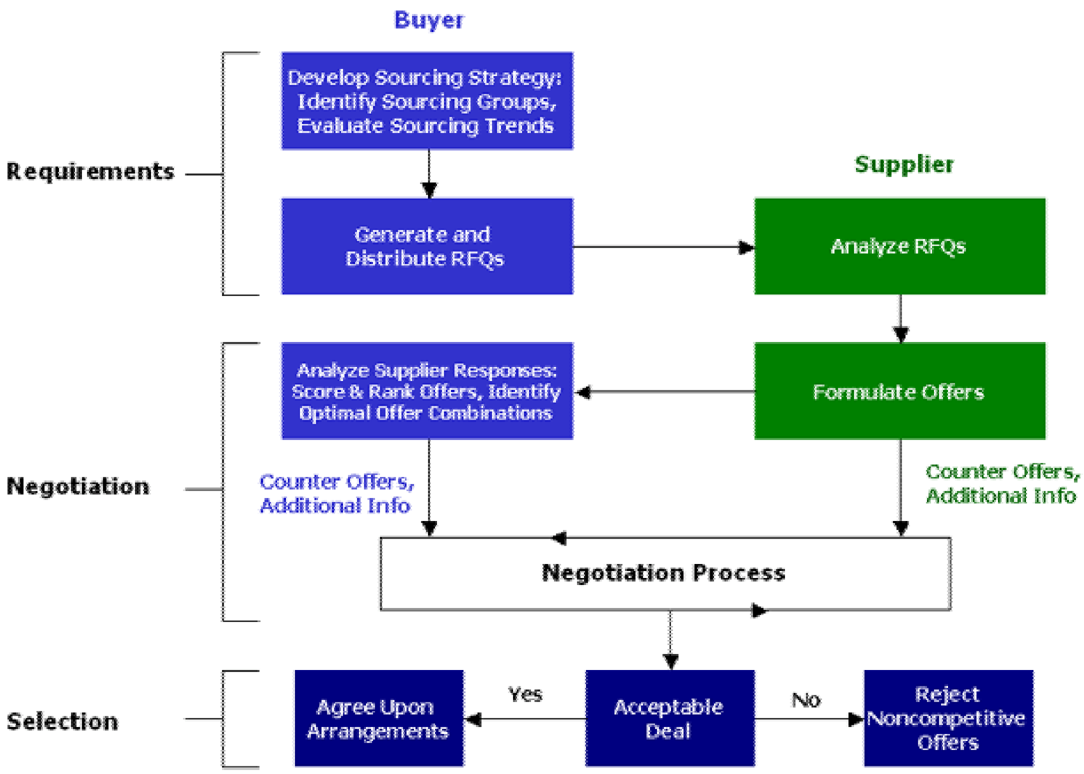

Figure 1. Sourcing process flow

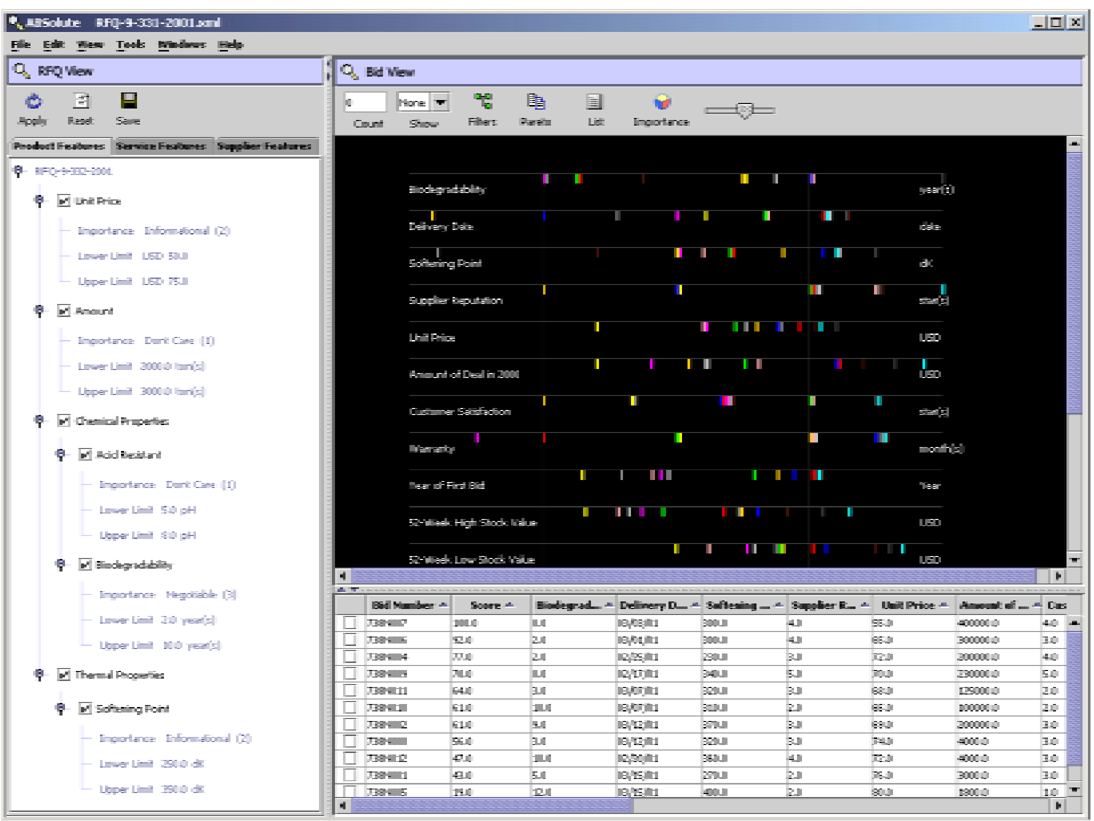

Figure 2. Initial view of the ABSolute system

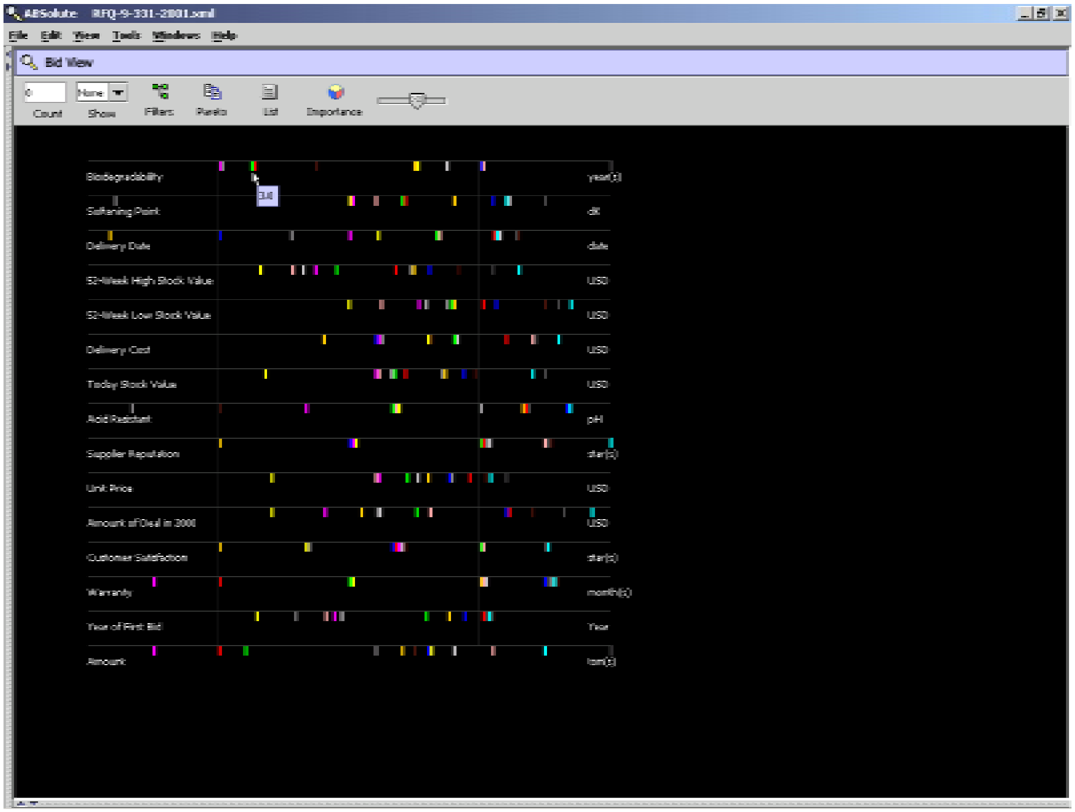

Figure 3. Initial view of the parallel coordinates visualization

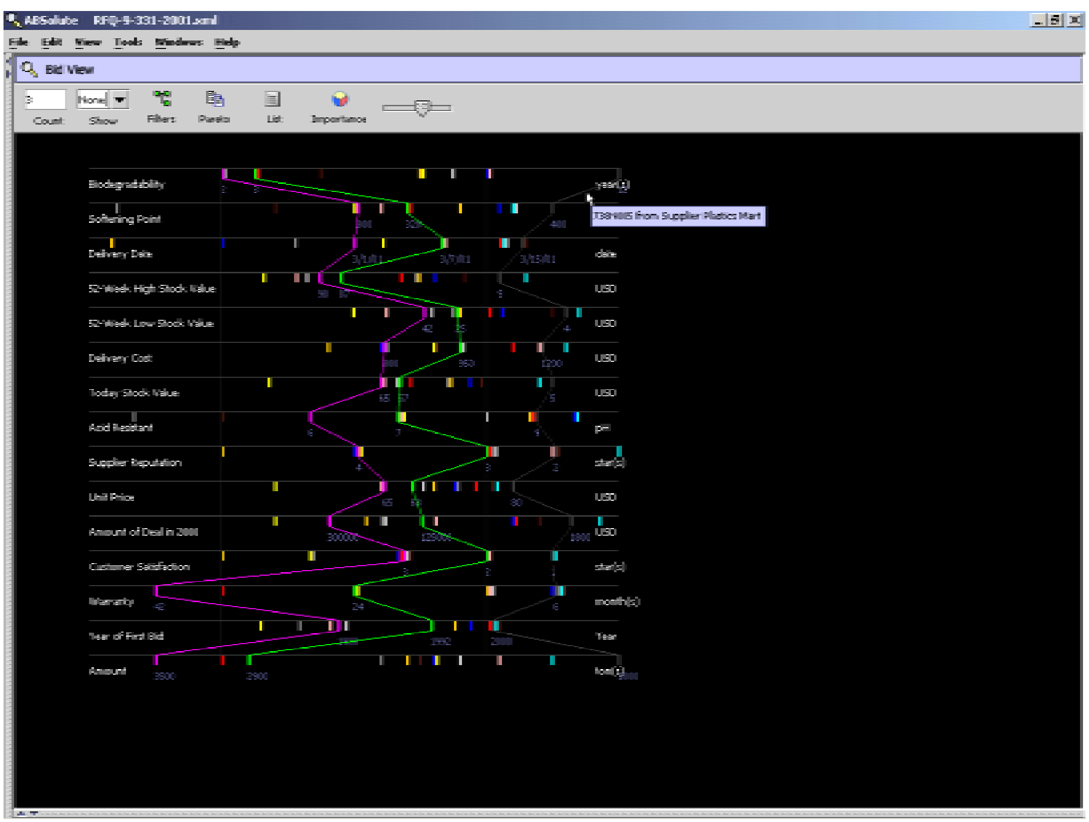

Figure 4. Bid lines

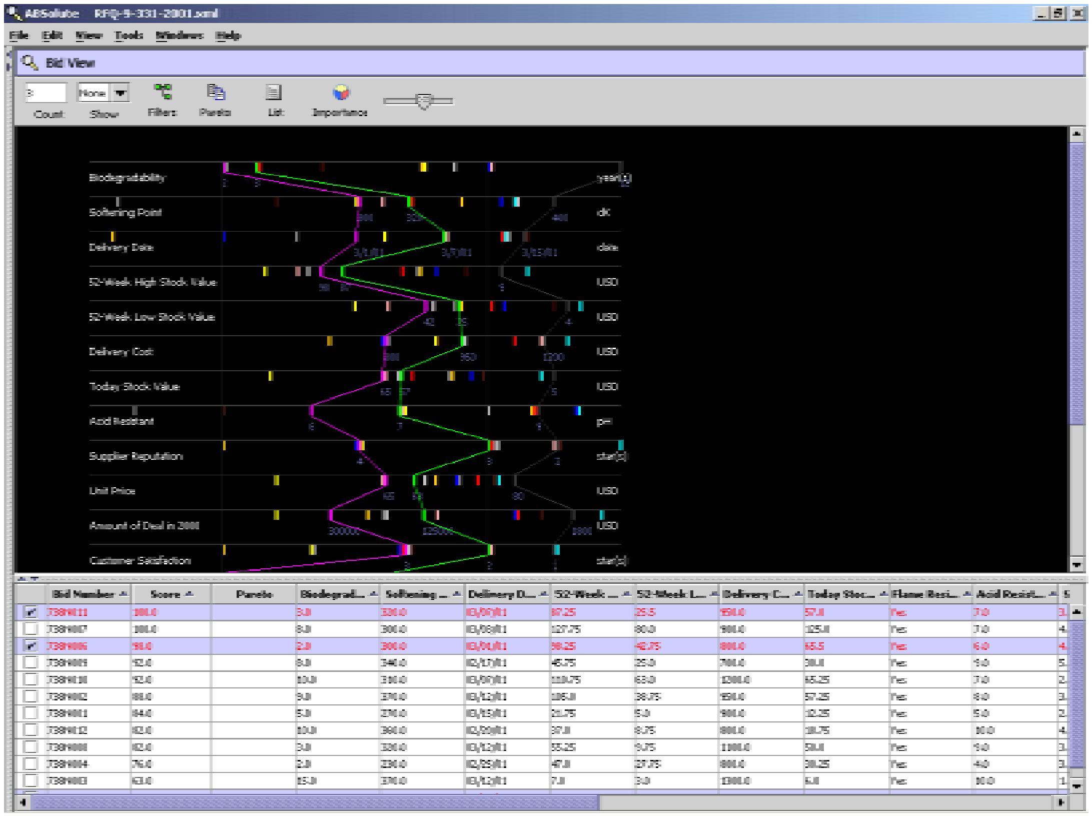

Figure 5. Visualization and table view

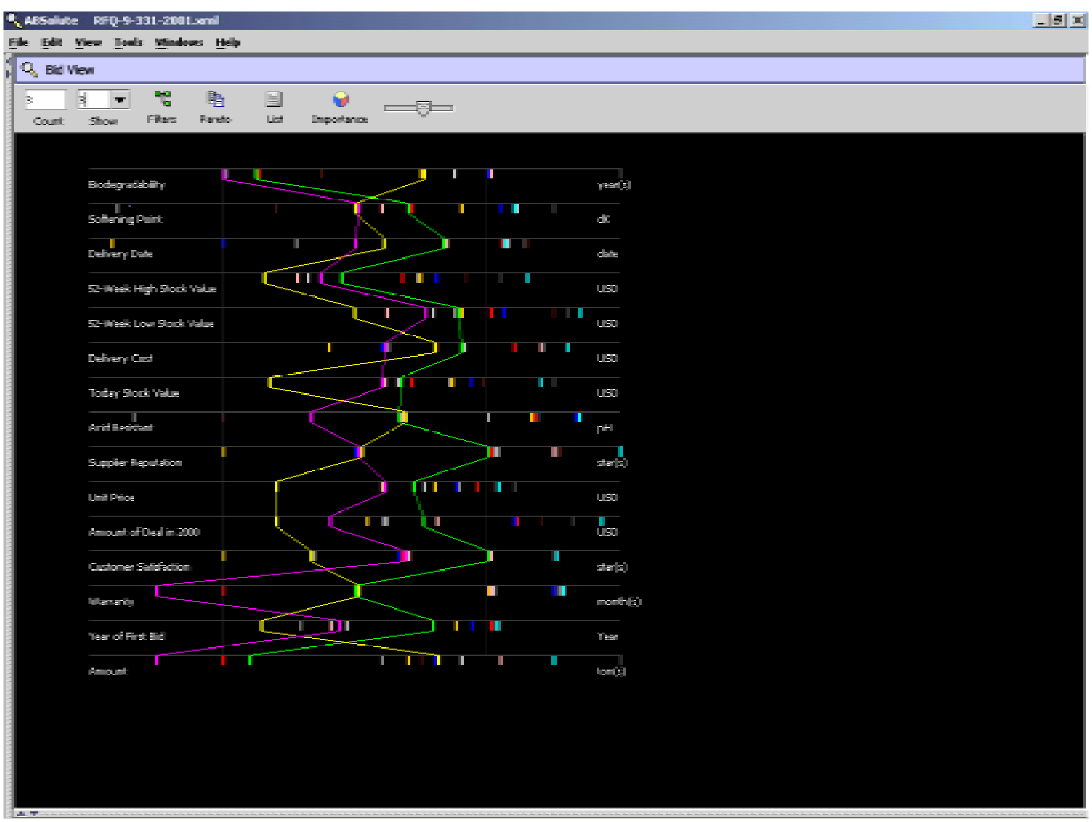

Figure 6. Show filter

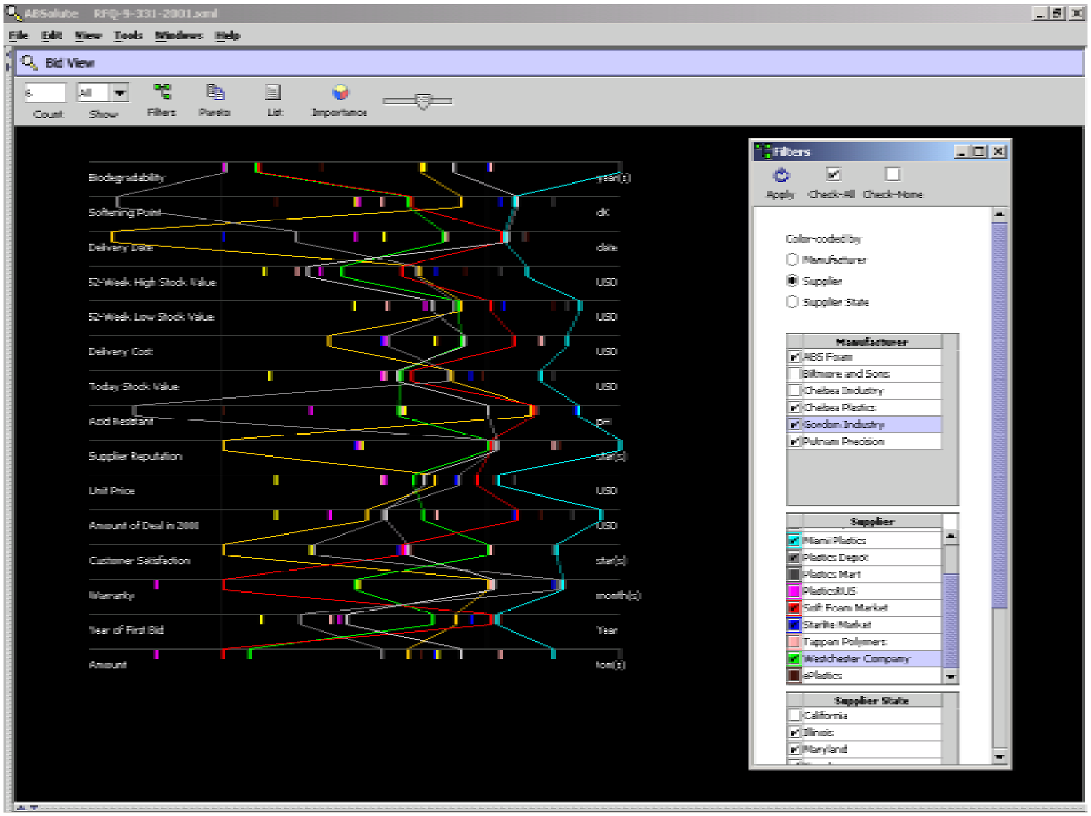

Figure 7. Filters window

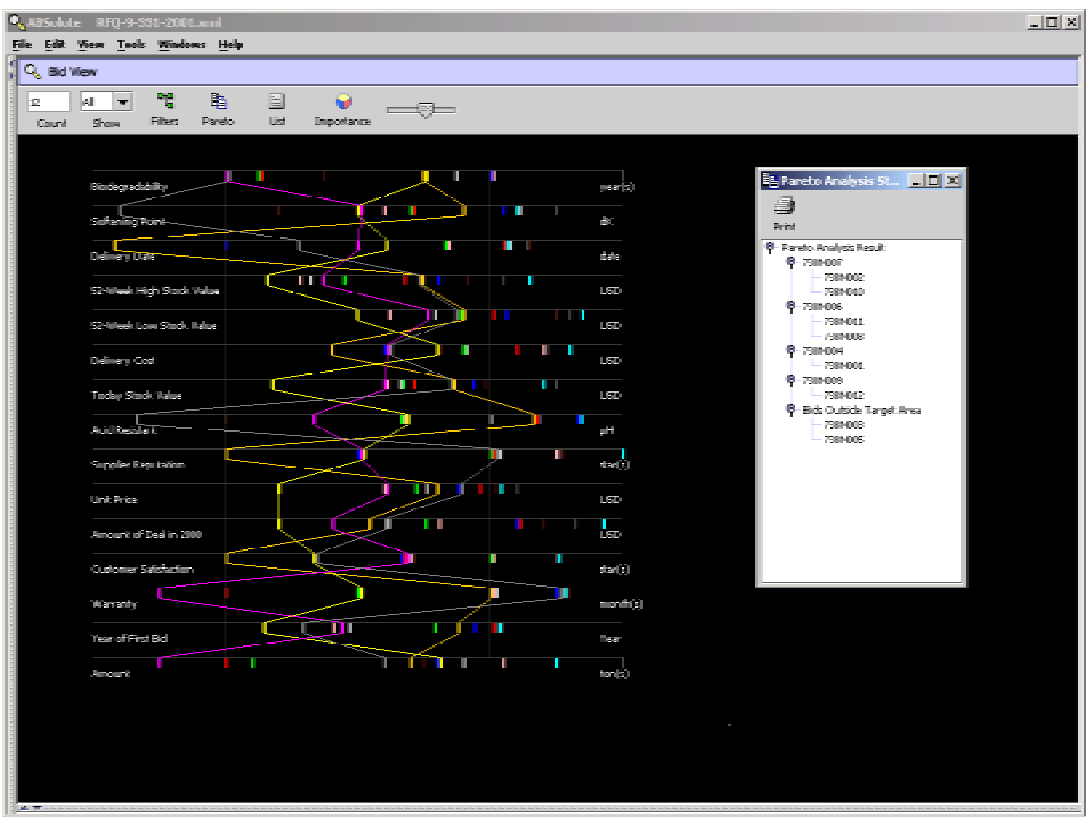

Figure 8. Pareto analysis window

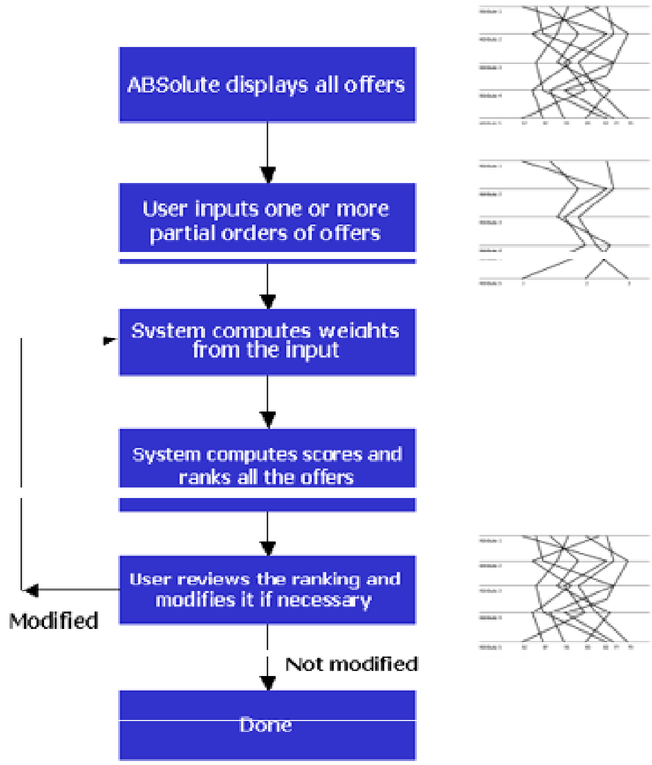

Figure 9. Weight determination through user interaction

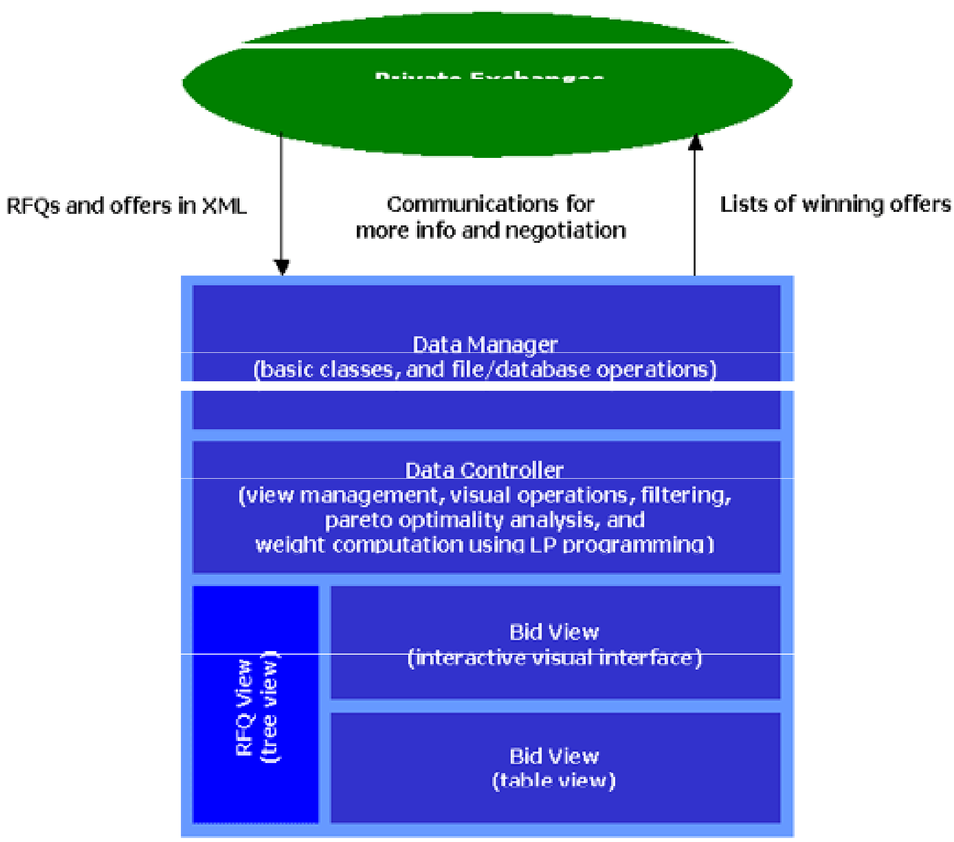

Figure 10. Prototype architecture