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An Interactive Visual INterface for Online Product Catalogs

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Abstract

One of the key elements of e-commerce systems is the online product catalog. It provides sellers with a content management system that assembles, aggregates, normalizes, and distributes product information. It also provides potential buyers with an interactive interface that offers a multimedia representation of the product information as well as retrieval, classification and ordering services. In this paper, we discuss the interface aspect of online product catalogs, focusing on its ability to help shoppers navigate and analyze product information. Specifically, we present a new interactive interface for online product catalogs that effectively enables the shopper to navigate through the product information space and analytically select suitable products. The interface is useful especially when the shopper makes purchasing decisions based on multiple factors such as price, manufacturer, delivery time and cost, and warranty. For supporting the multi-attribute analysis, the interface uses a multi-dimensional visualization mechanism based on parallel coordinates, but it goes beyond the plain visualization; it adds a number of visual interactivity facilities for helping the shopping process in navigating product data and making a mental structure for analysis. To demonstrate the capabilities of the product catalog interface for online retail stores and marketplaces, we implemented a proof-of-concept prototype displaying a set of automobile data. We explain how the prototype visualizes the entire product information space in a single page and supports intuitive exploratory analysis with the visual facilities.

Keywords: electronic commerce, product catalog, visualization, user interface

1 Introduction

Over the past few years, *electronic commerce* (or *e-commerce*) on the Internet has emerged as a dramatic new mode of business. One of the key elements of e-commerce systems is the *online product catalog* (or *electronic product catalog*). Online product catalogs are much more than the electronic version of printed product catalogs [18]. On one hand, they are a *content management system* that provides sellers with the ability to assemble, aggregate, and normalize product (or service) information from supplier databases and to quickly, inexpensively, and easily distribute the information. On the other hand, they provide potential buyers with an *interactive interface* by offering a multimedia representation of product information as well as retrieval, classification, and ordering services.

There have been extensive research and development activities for both aspects of the online product catalog. For content management, a number of commercial products are available from companies such as CardoNet, Interwoven, OnDisplay, and Vignette, and are used by many e-commerce sites [15]. For catalog interfaces, various methods supporting product search and navigation have been developed and are being utilized. They include hierarchical browsing, search based on keywords or parameters, interactive product design or configuration, dialog-based product filtering, product ranking, and the side-by-side product comparison table [23]. These product information navigation methods are sometimes referred to as *shopping metaphors*. The usability of several product selection mechanisms was empirically studied in [2, 23]. Also, the impact of different shopping metaphors on the effectiveness of online stores in terms of click-through and conversion rates was analyzed and visualized in our previous work [11, 12].

In this paper, we revisit the interface aspect of the online product catalog focusing on its ability to help shoppers solve the *product selection problem*. When selecting a product (or service) to buy, a shopper often needs to consider a number of different factors. 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 delivery experience and reputation. To make reasonable decisions about which products to buy, the shopper should be able to analyze and compare the multiple attribute values of alternative products (and their suppliers). In this sense, product selection is a *multi-criteria decision analysis* process [27]. One of the important functions of the online product catalog interface is to facilitate the analysis process by helping buyers effectively forage and analyze product information. Intelligent catalogs are expected to carry out the function of salespeople in traditional commerce, i.e., to understand the wishes of their shoppers and match them to the products that best fit them.

The salient point of this paper is to apply the *information visualization* technology to the problem of product selection in e-commerce sites such as online retail stores and trading exchanges. Information visualization provides not only compact graphical presentation but also sophisticated user interfaces for *directly* manipulating large number of items that enables users to make discoveries, decisions, or explanations about patterns, groups of items, or individual items [1, 3, 19, 24]. Human perceptual skills are quite remarkable and largely underused in current information and computing systems. Based on this insight, information

visualization researchers, for the past several years, have developed a variety of widgets and interactivity facilities to present, search, browse, filter, and compare rich information spaces. There can be many visual alternatives, but the basic principle for browsing and searching is summarized as the "Visual Information Seeking Mantra," i.e., overview first, zoom and filter, then details-on-demand [1, 3, 19, 24]. The work presented in this paper was motivated to understand how the recent developments in information visualization can be used to solve the online product catalog problem and how this approach is compared with existing ones.

This paper presents a product catalog interface referred to as *Visual One-Page Catalog* (VOPC). The primary objective of this catalog interface is to facilitate the multi-criteria decision analysis process for solving the product selection problem. For basic multi-attribute support, the interface utilizes a multi-dimensional visualization mechanism called *parallel coordinates*. In addition to the product data visualization, it also provides a number of visual interactivity facilities designed for helping the shopping process in navigating product data and creating a mental schema for analysis. In [3, 26], *interactivity* (including direct and indirect manipulation) was categorized as a primary dimension in visualization along with representations and input/output across time, and its importance in human perception was explained in terms of the balance of control between the user and computer. The focus on the multi-attribute decision analysis process and the use of visual interactivity facilities set VOPC apart from earlier work on online product catalogs.

To demonstrate the effectiveness of the VOPC interface to Web sites such as online retail stores and marketplaces, we implemented a proof-of-concept prototype displaying a set of automobile data. This paper explains the prototype implementation, and provides several anecdotes of how the prototype supports intuitive exploratory analysis and enables dynamic analysis with the visual facilities. Also, we discuss the possibility of applying the presented catalog interface to other problems within the e-commerce area that require multi-attribute decision analysis such as the bid evaluation and selection process for industrial procurement in business-to-business marketplaces.

The rest of this paper is structured as follows: Section 2 explains the requirements of the online product catalog. In Section 3, prior work on analytical product selection is evaluated and summarized. Section 4 presents user scenarios of the status quo of online product catalogs. Section 5 describes the design and facilities of the VOPC interface. Section 6 revisits the user scenarios and explains how the VOPC interface would help with its capabilities for navigation and analysis. In Section 7, we describe the implementation of the VOPC prototype with a set of automobile data. Finally, in Section 8, conclusions are drawn and future work is outlined.

2 Requirements for Analytical Product Selection

The ability to efficiently navigate and analyze product information in Web sites is particularly important to *rational buyers* (or *analytical buyers*) [22]. Unlike emotional, habitual, or social buyers who shop for fun, to exchange ideas and opinions, or to share the shopping experience with others, rational buyers analyze and compare different product offers looking for the one that best fits their specification (e.g., best value for price). In [14], a framework was proposed for classifying shopping behavior on the Internet, which identifies four

shopping strategies: directed buying, search and deliberation, knowledge building, and hedonic browsing. Rational buyers use the first three shopping strategies among them; they tend to acquire a bank of relevant product information potentially useful for immediate purchases or in the future, and their shopping behavior is focused and targeted toward specific product items [14, 22].

Many consumers who search the Web for good deals for immediate buying or knowledge building are rational buyers. Also, business buyers are typically rational buyers. For example, when a business buyer who works for procurement in her/his company visits an online MRO (Maintenance, Repair, and Operations) market such as Grainger.com and searches its product catalog, s/he is primarily concerned about finding products that best fit her/his company's needs. In this section, we summarize several basic requirements for the product catalog interface in effectively supporting such rational buyers in their needs for analytical product selection.

First, the online product catalog interface should provide a multi-attribute matching capability. As explained earlier, product selection is a multi-attribute decision analysis process that takes into account multiple attributes of products in various categories such as product and service specification, and supplier qualification. In addition, there are a couple of factors that make the analysis process even more complicated. First, some attributes are more important than others. For example, express delivery service or extended warranty may be more important than the product price for some buyers. Second, there may be relationships among product attributes. For example, the importance of one attribute may be conditioned by the value of another attribute. Regarding the multi-attribute matching requirement, the catalog interface should facilitate frequent operations such as finding one or more products having a certain set of multiple attribute-value pairs, finding a set of multiple attribute values of a given product, and comparing multiple attribute values of two or more products.

Second, the online product catalog interface is required to facilitate efficient navigation of the product information space. Often in online stores, buyers are required to go through many Web pages (and therefore, mouse clicks) to locate information of interest. Also, search facilities often provide many results that seem unrelated to the request. It was reported that navigation problems are the second most cited reason for not shopping online (after security concerns) [13]. Online catalog interfaces should allow rational buyers a high level of analyzability by providing the ability to easily navigate through the product information space and locate information of interest.

Another requirement related to navigation is "soft" navigation capability. In online buying processes, it is important to distinguish "hard" and "soft" navigation [22]. Product catalog interfaces that offer only hard filtering mechanisms exclude products 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 (or flexible navigation) reduces this problem by allowing buyers to distinguish between requirements and preferences. One of the proposed soft navigation methods is *product scoring* [22]. While requirements are still used for product filtering, preferences are used for computing a product score that describes how well a product matches the specified preferences. Products that match fewer preferences receive a low score, but are not excluded from the catalog view.

Finally, the online product catalog interface should support buyers in terms of allowing them to feel confident that their purchase decision using the interface saved them both time and money. This requirement is particularly important for business buyers whose purchase decisions always need to be justified. To achieve a high level of accountability, it is critical for users to understand why the selected product best fits the buyer's specifications. That is, the catalog interface should simplify thorough navigation of relevant products and comparison of their attribute values.

One objective of the work presented in this paper is to design an online product catalog interface that fulfills these inter-related requirements for analytical product selection. As we will explain, by utilizing the multi-dimensional visualization mechanism augmented by interactivity facilities for exploratory analysis, the VOPC interface provides a novel solution to the product selection problem, which enables buyers to make multi-attribute purchase decisions with a high level of confidence and knowledge.

3 Related Work

In this section, we briefly review existing methods for navigating the product space in online product catalogs. We examine the methods one by one to see if/how they fulfill the requirements for analytical product selection. Also, we consider a few example interfaces using each method. Note that this section is not intended to be an exhaustive survey on the work in this field. Instead, we intend to explore alternative approaches to analytical product selection in online product catalogs, and explain how the VOPC interface is different from prior approaches.

First, browsing products along a category hierarchy is the most popular navigation method and is used by most online product catalogs. It is familiar and easy to understand for most users. Unfortunately, however, it provides fairly limited ability to navigate and analyze product information, and thus fails to meet the given requirements. It does not support multi-attribute matching, because it categorizes products by a single dimension (e.g., the subject in a book store catalog) in the hierarchy and ignores the other attributes. It provides a limited navigation capability and requires buyers to do substantial work, e.g., make several mouse clicks in order to locate information of interest. Also, this method does not normally support flexible navigation, although some hierarchical catalogs do by placing the same product information (or hyperlinks to the information) in multiple categories. Due to relatively poor capabilities for navigation and analysis, hierarchical browsing does not support buyer confidence in purchase decisions well.

Second, search based on keywords and/or parameters is also a popular navigation mode and is widely used by stores and marketplaces. For example, IBM WebSphere Product Advisor provides the feature-based parametric search facility [7]. Compared to hierarchical browsing, search provides a better navigation capability, because it can retrieve and collectively present relevant product information. In some cases, however, the effectiveness is hampered by excessive retrieval of irrelevant information. Such a situation can be mitigated to some degree by providing a flexible navigation method such as product scoring. However, increasing the accuracy and relevancy of search results and providing a useful scoring

mechanism have been open problems actively studied by the Information Retrieval (IR) community. While feature-based parametric search helps locate products by matching multiple attribute values to some extent, it does not work well in terms of supporting various products that have different attribute sets.

Third, another approach is a table-based view which presents products side-by-side in one or more tables. The view helps comparison of different attribute values of alternative products. Often it allows buyers to construct filtering queries for an individual column or row. After each query, only the filtered set of products remains in the table. Examples of table-based interfaces include Focus [20], InfoZoom [2], IBM WebSphere Product Advisor [7], and Eureka!, a research system from IBM [17]. This approach meets the given requirements somewhat well compared to the previous two. However, as pointed out in [2], it suffers from information cluttering when the number of products and product attributes become large.

Next, a dialog-based product filtering mechanism is another method for navigating the product space. It engages a shopper in a dialog to elicit preferences and requirements. Then it uses the elicited data to compile an ordered list of matching products, with the best match first. An example of such dialog-based product filtering systems is one from PersonaLogic (www.personalogic.com). This approach effectively meets the multi-attribute matching requirement, but provides limited ability in terms of helping buyers inspect and understand the product filtering results, that is, why a product is selected based on a certain set of constraints. Also, it requires substantial effort to collect and understand the product information and product interdependencies, i.e., creating rules for filtering products.

An approach related to dialog-based product filtering is interactive product design or configuration (also known as build-to-order). Unlike the previous method, this one is used for building a compound product, rather than for buying an existing product in the catalog. It walks shoppers through product features, analyzes their needs, budgets and time constraints, and considers only components and options compatible with the shoppers' constraints. There are several commercial product configurators available from companies such as Calico Commerce, FirePond, Selectica, and Trilogy Software. Also, it is known that companies such as Dell and Cabletron use product configurators in their Web stores [5]. This approach shares common strengths and weaknesses with the dialog-based filtering approach. While it supports multi-attribute matching, it does not allow users to inspect the suitability of the results. Also, it requires significant work for collecting and understanding the product information and product interdependencies, i.e., creating rules for building products.

Next, the product scoring method mentioned in the previous section provides another means of product navigation. It uses preferences assigned by shoppers to individual attributes for computing a product score that describes how well a product matches the specified preferences. Products that match fewer preferences receive a low score, but are not excluded from the catalog view. This approach effectively meets the requirements of multi-attribute matching and soft navigation. One weakness of this approach is the possibility that the reliability of its results may be hampered by users' subjective preference assignment. When a user assigns preferences for the first time, s/he might not understand the importance of the preferences in this product navigation mode. The product scoring method itself does not provide a guideline for the preference assignment. This problem can be

alleviated by providing a tool for training users about the sensitivity of preferences. Another weakness is that important attribute values that can affect the purchase decision are sometimes hidden by the product score and ranking.

An example tool in this category is IBM's ScorCat, which uses MAUT (multi-attribute utility theory) for ranking products with multiple attributes [22]. Also, similar multi-attribute decision analysis methods from companies such as Emptoris (www.emptoris.com), Perfect (www.perfect.com), and Frictionless Commerce (www.frictionless.com), are used in several online marketplace systems for evaluating bids with multiple attributes. Another example is IBM's Eureka! which first allows a buyer to navigate to a certain product, and then ranks other products according to the degree of similarity between the given product and the initially selected product [17].

Finally, information visualization, which uses interactive, visual representations of abstract data to amplify cognition [3], provides another alternative method for product space navigation. One example is Attribute Explorer, which uses parallel coordinates to display product features and values [25]. Each product value is represented by a dot on each of the feature coordinates. Shoppers can specify filtering constraints by selecting values on the coordinates. Products that satisfy all constraints are highlighted. Also, the system uses color-coding to indicate how many constraints a product satisfies. This approach is promising in meeting the requirements given in the previous section, because visualization enhances cognition in a number of ways, i.e., by increasing the amount of information available to the user, by reducing the search for information, by enhancing the detection of patterns, and by encoding information in a medium that can be easily manipulated [3].

The VOPC interface presented in this paper is similar to Attribute Explorer in that it utilizes parallel coordinates (with some differences in presentation). However, the primary difference between the two visualization mechanisms lies in the interactivity facilities they provide; while Attribute Explorer mostly focuses on filtering, the VOPC interface provides a richer set of interactivity capabilities that facilitates navigation and analysis beyond filtering. The set includes tagging, color-coding by product category, dynamic querying, linking to auxiliary multimedia data (e.g., images, sound, and hypertext pages), reordering axes, adding or removing attributes and changing the displayed attribute value ranges. These facilities will be described in detail in Section 5.

Table 1 summarizes how different approaches to navigating the online product information space meet the requirements for analytical product selection. Note that this table provides only general characteristics of each navigation approach, and that specific implementations may show different results, for example, an interactive table interface or search incorporated with product scores in a column will be effective in distinguishing requirements from preferences. A more rigorous study on this subject needs to be done.

	Examples	R1	R2	R3	R4
Hierarchical browsing	Most online stores	Poor	Poor	Poor	Good
Search	IBM Product Advisor	Fair	Fair	Poor	Poor
Interactive tables	InfoZoom, Eureka!	Good	Fair	Poor	Fair
Dialog-based filtering	PersoanLogic, Trilogy Software	Good	Poor	Poor	Poor
Product scoring	ScorCat	Good	Poor	Good	Poor
Visualization interface	Attribute Explorer, VOPC	Good	Good	Good	Good

R1 = Multi-attribute analysis support
R2 = Navigation capability
R3 = Distinction between requirements and preferences
R4 = Understandability

Table 1. Methods for navigating online product information space

4 User Scenarios of Online Product Catalogs

The status quo of online product catalogs is the key motivator in the design of the Visual One-Page Catalog (VOPC). Typical online product catalogs are comprised of a number of product pages, Web pages that provide information about one or more products being sold. Each page usually only provides information about a small number of products, e.g., one to ten products, which tend to belong to the same or a similar product category. As a result, shoppers normally need to browse multiple product pages in order to accumulate information about one or more products of interest. This task in itself is a hassle. In addition, add the task of comparing different attributes of different products, and the whole process of comparison-shopping on the Internet becomes cumbersome.

Perhaps the best way to understand the problems with the majority of online product catalogs is by taking a close look at specific examples. For analyzing the problem domain, we roughly followed the use-case analysis method [10]. A team of researchers and developers has reviewed the product catalog interface of a number of online stores and marketplaces, and created several user scenarios. Walking through each scenario helped the team understand necessary operations and design the VOPC interface. Below, we present a couple of scenarios to understand how shopping and product selection is conducted in traditional online product catalogs. Note that the scenarios are based on real interfaces at the time of this research in June 2000.

4.1 An Online Retailer: CarsDirect.com

CarsDirect.com is one of the popular automobile stores on the Web. It provides an online catalog for new automobiles, and also services related to car buying, e.g., financing, insurance

quotes, and various review information. The home page of CarsDirect.com's Web site is divided into three sections: folder tabs on the top, the main space in the middle, and links for promotion and services below the main space. The folder tabs at the top of the page correspond to the table of contents in a paper catalog, and provide links to the major sections of the catalog. In the main space in the center of the page, s/he can simply do a search on the car's make and model, if a shopper knows roughly what car s/he wants to buy. If the shopper only knows the general category s/he is interested in or wants to research on various options, s/he can browse the appropriate category. The "Research" page that the shopper can access from the folder tab provides various categories by manufacturer, vehicle type, price range, etc. The shopper can start browsing at this page. Below the main space of the home page, there are links for ads, which virtually have a particular theme (e.g., Luxury Car Guide, Safety Ratings). Each sub-page features more ads and often includes a "Top 10 Lists." There are also links to shopping services (e.g., financing, insurance quotes, and extended warranties). In general, an abundance of information is presented on each page, and the shopper must actively engage in shopping or risk being overwhelmed. Most of these design aspects are not specific to CarsDirect.com's online product catalog but are common to the majority of online product catalogs for online retailers.

User Scenario

Jason, an IT engineer, wants to buy a new car that he will use for commute. He does not have any particular car in his mind except that he prefers a passenger car as opposed to vans, trucks, or SUVs (Sports Utility Vehicles). Jason wants to explore possibilities, and goes to CarsDirect.com. Instead of using the parametric search based on car's make and model, he proceeds to browse the "Research" page, then "Buying Guide," and then the "Passenger Cars" section. At this point, he can choose between four categories: *Compact, Midsize, Luxury*, and *Sporty*. He decides to browse *Midsize*. There are about 40 cars in this category. Now Jason is faced with the task of reviewing the information of each car and deciding which car to buy. The online catalog of CarsDirect.com provides a separate page for each car. To read information about products, i.e., cars, Jason needs to visit their page, one by one. He finds that each product information page comprises several sub-sections (folders) accessible by using folder tabs: *Car Snapshot, Reviews, Specification & Features, Safety, Compare*, and *Options*. Jason finds that it is not simple to review information of even a single car because he has to go over several folders. Furthermore, he finds difficult to compare car descriptions. Jason must either make mental comparisons or jot down information. If he is interested in a number of the cars, mental comparison is very difficult if not impossible. At the same time, jotting down information for many cars is time-consuming and a hassle. He decides to try out the *Compare* feature given in individual car pages, which allows comparison of two or more cars in a table format. He finds this table is useful for comparing different cars, but only to a limited extent. There are about 200 fixed attributes in the comparison table spread out over nine pages, which makes it difficult to read and compare the attribute values. Also, with more than 4 or 5 cars in the table, Jason feels overwhelmed by the amount of the information displayed in the screen. After reviewing only 20 cars by comparing 3 cars at a time in the table, and jotting down a list of 5 candidate cars with a selected set of 12 attributes (including manufacturer, model, MSRP, invoice price, average review rating, horse power, highway mileage, basic warranty, braking distance, zero to sixty speed, fuel tank capacity, and AM/FM stereo), Jason develops a cramp in his hand and although he still has 20 more items to look at, he decides to just select one among the items he has already

written down. His mood at the ending of his shopping experience could be described as somewhat frustrated. Note that among the existing approaches to exploring online product catalogs described in Section 3, CarsDirect.com provides three methods, hierarchical browsing, search, and tables (though not interactive). Although partially useful, none of these methods provided satisfactory shopping experience to Jason.

4.2 An Electronic Marketplace: VerticalNet

One of VerticalNet's features is its targeted communities, where professionals and companies in a particular industry can go for fast, efficient business information, interaction, and transactions. The focus here is on the manner in which transactions can be made between professionals and industries. Currently, VerticalNet sponsors 56 industry communities, which are grouped by industry type, and are accessible through links on VerticalNet's homepage. All of the community pages have consistent/identical designs, making it relatively easy for a shopper to navigate through any community's page once the shopper has gotten the feel of one particular community. In addition, professional shoppers can search for auctions or fixed price deals through the link to *Industry Deals*.

User Scenario

A clerk at a dentist's office needs to order more x-ray film. The clerk, Melissa, decides to try ordering using one of VerticalNet's health care communities. Since this is her first time using VerticalNet, she must first search the product catalogs of each of the five health care communities. She finds a match for 'x-ray film' in only one of the five communities, *Hospital Network.com*. The match indicates that there are seven companies associated with *Hospital Network.com* that sell x-ray film. To automatically contact the listed companies to request a price quote, literature, a sample, customer service or service assistance, she must first register to be a member of the community. Alternatively, she can click on a link for a particular company to see a more comprehensive product list as well as the company's basic contact information or she can go directly to the company's storefront (a showcase for the company's business and products) if it has one. Ultimately, Melissa must register with the *Hospital Network.com* community to get the most out of VerticalNet. When registering, she selects 'e-mail' as her preferred contact method and 'immediate' as the urgency of the requested info. Within a day, she receives e-mails from six of the seven companies. She decides to call the seventh company the next day since she needs to place an order as soon as possible and wants to make her order based on information from all possible companies. Finally, after collecting the seven different sets of information, she discovers that the companies sell x-ray film in two different units. She decides to make a table listing the type of film and the price per standard unit of film for each company. After placing an order with the company that offers the best deal, Melissa is satisfied that she found the best buy. However, she feels that the whole buying process was relatively lengthy, and wonders if she should have just placed an order with the company that the office bought x-ray film from in the past, even though that company's rate for x-ray film is slightly higher than this other company's rate.

The two case scenarios should have manifested the motivation driving VOPC. It would not be too surprising if Jason and Melissa decide to go to a brick-and-mortar store the next time they need to purchase something. The VOPC interface offers an alternative structure to the

typical online product catalog with the goal of making online shopping experiences more pleasant for shoppers like Jason and Melissa. The structure of VOPC involves compacting many product pages into one page using parallel coordinates. The use of parallel coordinates not only saves shoppers from needing to navigate endless product pages, but also assists shoppers in the multi-attribute decision-making process involved in choosing which product(s) to buy.

5 Design of the VOPC Interface

A parallel coordinate system was proposed as a practical way of displaying multi-dimensional data sets [9]. 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.

In parallel coordinates, all axes are parallel to each other and equally spaced (the spacing between adjacent axes is typically of unit length). In an n-dimensional space, there are n parallel axes ($X1$, $X2$, …, Xn) each representing a separate variable. To plot an n-dimensional point (x_1, x_2, …, x_n), adjacent values on their respective vertical axes are connected by a line for a total of (n-1) connected line segments. In this way, parallel coordinates allow the visualization of higher order geometries in an easily understood two-dimensional representation. Figure 1 shows the representation of a six dimensional point (4, -2, -3, 2, 1, -2) in parallel coordinates. Parallel coordinates are able to display correlations and patterns in multi-dimensional data sets [8, 9].

Parallel coordinates have been used in a few data analysis applications [8, 9, 26]. These applications augmented the coordinate system with several interactivity capabilities such as selecting subgroups of multi-dimensional points, filtering by using constraints, some color-coding schemes, and reordering axes. The Visual One-Page Catalog uses parallel coordinates to display products and their attributes in a single Web page. Each axis represents an attribute; the online shoppers dynamically determine the number and type of attributes. The plot of a (multi-dimensional) point represents a product. VOPC provides a richer set of interactivity capabilities that facilitate navigation and analysis beyond basic filtering and grouping. It includes tagging, color-coding by product category, dynamic querying, linking to auxiliary multimedia data (e.g., images, sound, and hypertext pages), reordering axes, adding or removing attributes and changing the displayed attribute value ranges. This section describes these interactivity facilities in detail.

5.1 Design Notes

In the VOPC interface, the layout of the typical parallel coordinate system is rotated clockwise by 90º so that the parallel axes are horizontal. The axes are rotated from the standard vertical position because users of Web browsers are generally more accustomed to using the vertical scrollbar, which would be necessary if the online shopper specified many attributes so that all the axes do not fit on a single screen. It is an open question if and how

the horizontal layout of parallel coordinates is also more intuitive and natural in different applications.

The selection of black for the initial background color is also experimental to see if it is more visually pleasing when the color-coded products are placed on a black background than when they are placed on a light gray or white background. The VOPC interface also provides a palette, which a shopper can invoke with a mouse click and use to change the background color interactively. The data plots along the attribute axes are short vertical lines ("matchsticks"). These lines are thin to minimize the amount of overlapping that can occur between two or more data points. The product lines consist of straight-line segments connecting appropriate values across the attribute axes. The exact design of "matchsticks" and product lines will depend on the size and type of product data sets to be rendered. Figures 3, 4, 5 and 6 show sample VOPC views.

5. 2 Product Categories

The product categories represent the different types of products in a catalog, or how products are organized in the product catalog. For example, two categories in an automobile catalog are vehicle type and manufacturer. In the VOPC interface, each category is associated with a hierarchical view of the products. Shoppers can view the different tree structures by clicking on their preferred category of organization in the tabbed pane on the left side of the user interface (see Figure 7).

Each category is also associated with a different color-coding of the products. If all categories requested do not have any sub-categories, then the products are color-coded according to their category. However, if any category has sub-categories, then products are color-coded by one category only. For example, cars can be color-coded either according to their vehicle type or according to their manufacturer (see Figure 7).

5.3 Product Attributes

The product attributes are multiple factors that a shopper considers when purchasing a product. As mentioned earlier, they include factors related to product specification, service specification, and supplier qualification. In this design, we focus on the first two types of factors.

First-Tier Attributes

Attribute values in this tier are crucial in the decision analysis process and/or have known most desirable values (i.e., most desirable values do not vary from shopper to shopper). For example, in an automobile catalog, first-tier attributes would include price and ratings. Attributes in the first tier are displayed in the parallel coordinates plot as axes.

Second-Tier Attributes

Second-tier attributes are important, but do not fit in the first tier (i.e., lower or higher boundary values are not necessarily more desirable). In an automobile catalog, second-tier

attributes might include an image of a car and fuel tank capacity. Attributes in the second tier are either included in the parallel coordinates plot with the use of target values (see "Comparing Product Lines" below), or displayed if the user decides to view additional information about a product (see "Viewing More Product Information" below).

Third-Tier Attributes

Attribute values in this tier are relatively unimportant to the typical shopper. In an automobile catalog, third-tier attributes might include number of cylinders and braking distance. Third-tier attributes are displayed if the user decides to view additional information about a product (see "Viewing More Product Information" below).

5.4 Catalog Operations

One research objective of this study is to provide a rich set of interactivity facilities to the basic parallel coordinates visualization of product data, and understand how they help shoppers navigate the product catalog and make buying decisions. These interactivity facilities are given as operations on the product catalog.

Viewing Product Attributes and Values

Figure 2 shows an example user interface that a shopper can use to request the initial product catalog view. Using this interface, the shopper can set bounds on attribute values to narrow the scope of products s/he is interested in possibly buying. For example, the shopper may wish to look at only those cars that have MSRP values between $24,000 and $40,000. In this case, the shopper must simply enter those two values as the lower and upper, respectively, MSRP bounds. Then when the associated product view is displayed, the MSRP axis is bounded by those two values. If the shopper does not specify bounds for an attribute in the initial catalog view request, the minimum and maximum values for that attribute for all products in the catalog are used for the bounds. Figure 3 displays an initial product catalog view in the VOPC model showing five first-tier attribute values of ten products from three different product categories (distinguished by the color used for the "matchsticks"). The names of the attributes and the unit of their values are specified below each axis. The attribute values displayed as "matchsticks" in the view are color-coded by product category. The visualization of attribute values provides meaningful cues about the product data and helps the shopper intuitively understand how the product attribute values are distributed over individual attribute coordinates.

Customizing Product Attributes

VOPC allows the shopper to choose all the attributes to show in the initial product catalog view. Initially, all checkboxes (each associated with an attribute) are selected. However, if the shopper later decides that a particular attribute is not that important in the analytical product selection process (e.g., if all products share the same value for an attribute), s/he can interactively de-select the checkbox for that attribute. De-selected attributes are moved to the end of the list of attributes, and are not part of product lines. The corresponding axis and points are moved accordingly (see Figure 7). Selecting a de-selected checkbox moves the checkbox and its corresponding axis and points to the end of the list of attributes that are

already selected. The shopper can do a series of de/select operations on the attribute checkboxes to order the attributes by decreasing importance. Doing so would aid the shopper's analysis process, especially in meeting the "soft" navigation requirement explained in Section 2 (see "Comparing Product Lines" below). The operation of changing the order of the attributes can be simplified by adding drag and drop capabilities to the checkboxes.

Viewing Product Lines

A product line is the line formed as a result of plotting a point on the parallel coordinates axes. Each product has an associated product line. In the initial product catalog view as shown in Figure 3, however, product lines are not displayed. Instead, only matchsticks that represent the attribute values of products are shown. This design decision is based on the basic principle for browsing and searching known as the "Visual Information Seeking Mantra," i.e., overview first, zoom and filter, then details-on-demand [3, 19]. Having only matchsticks shown in the initial catalog view, the shopper can identify patterns in the distribution of attribute values, and read meaningful cues for further exploration. Then, s/he can see the details by interactively selecting and displaying product lines in the catalog view as necessary.

The selection of the product subset is determined by another interactivity techniques called *brushing* [3, 26]. That is, the subset of products is determined by where the mouse pointer is positioned on the VOPC screen. Only a subset of product lines is visible at a time. If the mouse pointer were positioned over a data point (which is represented by a "matchstick"), all product lines that share that data point would be made visible. Figure 4 shows the display of a product line in the VOPC view triggered by a mouse fly-over. It also displays a tool-tip showing the short description of the associated product.

Tagging Product Lines

Since a product line is only displayed when the mouse pointer is positioned over one of the product line's data points, the tagging operation relieves the shopper of having to rely on visual memory when comparing two or more product lines. To tag a product line, right-click on any data point that is part of the product line and select "Tag." Figure 5 shows a pop-up menu window for tagging and other operations ("More Info" and "Add to Cart") associated with individual product lines. If multiple product lines share a data point and that data point is used as the starting point of the tag operation, the shopper is prompted to choose which product line(s) to tag. Tagged product lines remain visible in the catalog view even when the mouse pointer is no longer positioned over one of the product line's data points. Product lines may also be untagged. To un-tag a product line, right-click on any data point that is part of the product line and de-select "Tag."

Comparing Product Lines

One of the primary goals of the VOPC interface is to help the shopper analyze product information by comparing alternative products. Therefore, the layout of the product lines is key to the design of the VOPC interface. For the shopper to fully take advantage of VOPC, s/he must be aware of this layout. On each attribute axis, the values either increase or decrease according to whether higher or lower values, respectively, are more desirable in

general. In this fashion, the product lines visually show their product's desirability. That is, product lines that are closer to the right side of the screen are more desirable than product lines that are on the left side of the screen. The right side of the screen was chosen to be the "target area" because the left side is already somewhat cluttered with attribute checkboxes.

It is likely that no product line will appear completely in the target area on the right side of the screen. In this case, ordering attributes by importance helps the shopper to assess which products are most desirable. By placing the most important attributes towards the top of the screen, the shopper knows that a product line that fits in the target area in the top part of the screen and wanders out of the target area in the bottom part of the screen is more desirable than a product line that fits in the target area in the bottom but not top part of the screen. The shopper can use this kind of placement/desirability information to make a good decision about which product(s) to buy. Figure 6 shows the comparison of two products from different categories in the VOPC model.

Viewing Additional Product Information

Product values for additional attributes can be viewed by right-clicking on any data point of a product line that the shopper is interested in and selecting "More info" (see Figure 5). This operation causes a small window (or a Web browser) to pop up with the additional information. Attributes that are viewed in this fashion often include attributes that have non-numerical values such as text, image, audio, or related Web pages. Generally, these types of data cannot be ordered by desirability except by the shopper himself/herself, so they are typically not included in the catalog view. Also, it is an open question in decision support system research how categorical attributes can be used together with numerical attributes to make intelligent decisions [4].

Adding a Product to the Shopping Cart

This operation can be accomplished by first right-clicking on any data point that is part of the product line for the product to be added to the shopping cart, then selecting "Add to Cart" (see Figure 5). A product can be removed from the shopping cart by right-clicking on any data point that is part of the given product and de-selecting "Add to Cart." Clicking on the "Checkout" button launches a Web browser on a simple html page that shows the current state of the shopper's shopping cart (see Figure 7).

6 User Scenarios: Revisited

In this section, we revisit the user scenarios presented in Section 4. We explain how the VOPC interface with the design described in Section 5 would help Jason and Melissa in the buying process.

6.1 How VOPC Would Help Jason at CarsDirect.com

The Visual One-Page Catalog could have saved Jason a considerable amount of time and effort and provided him with a better overall shopping experience at CarsDirect.com. In Jason's case, the only category of VOPC would be *Mid-sized Passenger Cars* (with a total of 40

products). (Had Jason been unable to choose between the four sub-categories of the *Passenger Cars* category, all four sub-categories would be included as categories in the visual product catalog view. If Jason later decided that he did not want to browse cars in one or more of these categories, he could simply filter them out.) As for the attributes, Jason would be able to choose the 12 factors that he considers most important to his decision. For example, the main attributes might be model, MSRP, highway mileage, seating capacity, and average review rating (number of stars). In addition, Jason could customize his search by specifying attribute ranges. For example, he might only be interested in cars whose MSRP is under $30,000, and average review rating is at least four out of five stars. Jason would also be able to specify whether a low attribute value or a high attribute value is more desirable, and the product catalog would then order the products on each attribute line accordingly. In this case, a low MSRP and a high average review ratings are most desirable, so values on the MSRP attribute line would, from left to right, decrease from high to low respectively, and values on the average review rating attribute line would increase from low to high. As a result, when Jason is comparing product lines, his goal is to find a product line that is as far right as possible, as that would represent the best buy for him. To stress the relative unimportance of the seating capacity, Jason could de-select the seating capacity attribute. Doing so would cause any visible product lines to not extend to the seating capacity axis. If Jason weighs the importance of each main attribute, VOPC could even rank, say, the three best cars for him.

By having Jason himself choose which attributes are important, this prevents the catalog from initially displaying any unnecessary information. Jason can easily view additional information about products he is particularly interested in. (See "Viewing More Product Information" above.) In this case, additional information might include manufacturer, invoice price, horse power, basic warranty, braking distance, zero to sixty speed, fuel tank capacity, and AM/FM stereo. By saving Jason time and effort, VOPC would very likely encourage Jason to return to the Web site to make additional purchases in the future.

6.2 How VOPC Would Help Melissa at VerticalNet

There are a number of ways the Visual One-Page Catalog could improve Melissa's online shopping experience. Ideally, VerticalNet would need to gather information for products by category within each industry group (for all communities and companies). At the very least, for the VOPC model to be useful in this scenario, each community should gather information for products by category from all the companies associated with the particular community. With the VOPC model, Melissa would simply search for 'x-ray film', which would result in the generation of a catalog that contains different kinds of x-ray film (whose companies may or may not belong to different communities within the health care group). The categories of VOPC would be different kinds of x-ray film. The main attribute of VOPC would be price per standard unit. Another attribute might be shipping time. A zooming in operation on a data point could bring up the name of the company that offers that particular product. Clicking on a data point could bring up an order form for that product. This basic functionality of the VOPC model would save Melissa time in two key ways. First, she would not have to search for 'x-ray film' multiple times (first in the five different health care communities, then in the seven companies associated with *Hospital Network.com*). Second, the visualization method provided by the VOPC interface would save Melissa from needing to make a table comparing the different products since the relationship

between the different products could be understood simply by looking at the shapes and positions of the different product lines. (In this case, the product lines may actually be single points since the only attribute Melissa may be interested in is price.)

6.3 Discussion

Regardless of the specific business model (e.g., online retailers or marketplaces), an online shopper typically goes through two main steps before actually purchasing or bidding for a product. First, the shopper must somehow navigate through a product catalog to find the product s/he wants. If s/he knows exactly what s/he wants and finds it in the catalog, then s/he is basically done shopping; all s/he has to do then is purchase it or bid for it. If the shopper only knows roughly what s/he wants (i.e., if s/he does not know the specific brand and/or model s/he wants), then after finding the relevant pages in the catalog, s/he begins the decision-making process.

The Visual One-Page Catalog is designed to assist the shopper in this decision-making step. VOPC effectively meets the requirements for this analytical product selection step discussed in Section 2. Its rich set of versatile interactivity facilities on multi-dimensional product visualization enables the shopper to concretely view data that might otherwise be only abstractly in their heads or on paper in non-visual form. In addition, the application of the information browsing and searching principle known as the "Visual Information Seeking Mantra" [3, 19] to the VOPC interface design further enables shoppers to navigate and explore the multiple levels of information space comprised of presented products and their attributes. Only essential information in the decision-making process is represented in the product lines; however, more detailed information is accessible through operations with the mouse pointer on the data points of any product line. The shopper interactively determines what is essential information and what is extra information. In this way, the VOPC interface functions as an online shopper's assistant in the decision-making process and results in the shopper having a more pleasant online shopping experience. Also, the VOPC interface enables the shopper to visually compare all the products s/he is interested against the selected attributes in just a single page. These features of the VOPC interface enhances the capability for flexible navigation and enables the shopper to make multi-attribute purchase decisions with a high level of confidence and knowledge.

These benefits of VOPC do not come without costs and limitations. For a meaningful analysis of product data, VOPC requires a rich set of product attribute information and, hence, may need to aggregate product data from many sources. However, this requirement is not unique to the VOPC interface. Online stores and electronic marketplaces using other types of online product catalogs such as search, tables, or dialog-based filtering also share the same data requirement, which leads to the need of quickly and inexpensively aggregating and normalizing product information from various sources. As mentioned in Section 1, this problem has been actively studied in the context of content management.

Another limitation pointed out for the current VOPC approach involves the scalability of parallel coordinates-based visualization. If too many product lines are tagged, it is likely that the parallel coordinates plot would be rather complicated and the shopper's ability to make good comparison decisions might be decreased. A possible solution to this problem is to integrate a product-scoring scheme into the VOPC model for filtering products before

visualizing them using parallel coordinates. For example, if a shopper's search criteria match more than 20 products, the VOPC displays only the top 20 products as ranked by the product scoring method. This simplifies the comparison of product lines since the shopper does not have to review the lower-ranked products that have been filtered out. Also, one of the weaknesses of the scoring method mentioned in Section 3 is taken care of by the visualization involved in parallel coordinates since individual attribute values are showed in addition to the scores.

Another limitation involves the type of products that VOPC supports. VOPC is most ideal for products that have at least a handful of key attributes that have concrete most ideal values so that the parallel coordinates plot would provide a sufficient comparison of two or more products. For products with more complex attributes that are key factors in product selection, the shopper would still have to view this "additional information" on a separate Web page (outside the parallel coordinates plot) for all products s/he is even somewhat interested in. The idea is for the parallel coordinates plot to provide most of the comparison data, with the shopper probably choosing to view additional information on just a few products that s/he has narrowed her/his search down to using the parallel coordinates plot.

Also, VOPC is most ideal for homogeneous product sets in which member products share a common set of product attributes, because product lines are plotted over coordinates representing products sharing common attributes. In fact, this feature makes the VOPC model fit well with bid evaluation and the selection process in reverse auctions such as RFQs (Request For Quotes) or RFPs (Request For Proposals) where relevant attributes such as product/service specification and supplier qualification are given by the buyer for bids. Such auctions are popular in industrial procurement environments supported by business-to-business marketplaces on the Internet. However, support for analytical bid evaluation in most existing marketplaces is currently rather primitive.

7 Implementation of VOPC

The VOPC prototype has been developed in the Java programming language using IBM VisualAge for Java IDE (Interactive Development Environment) and IBM DB2 Universal Database System. The prototype runs as a Java applet because VOPC is to be used in an Internet context. For implementing graphical elements of the VOPC interface, we used the JFC Swing classes. In addition to using the JFC Swing classes, we have created several custom classes including two applets, CarData and CatalogView. CarData is an applet that represents the initial product catalog view request form (shown in Figure 2). It provides an interface that allows the user to specify which sub-categories of products s/he would like to view. The user also needs to choose the attributes that should be plotted, and can set upper and/or lower bounds on the attribute values. Only products that meet all user requirements are included in the catalog view. CatalogView is an applet that represents the view of the one-page product catalog (shown in Figure 7). Using Swing's GridBagLayout, the catalog view is split into three main sections. A left panel displays a color-coded hierarchical view of the products requested. A middle panel contains checkboxes associated with the attributes requested. The main panel is on the right and displays the parallel coordinates plot (consisting of axes and points).

The implementation uses a sample database of 39 automobiles stored using IBM DB2 Universal Database. We selected automobiles as the shopping domain for our prototype because cars make a good set of example products with many attributes of different types. The two main categories used to categorize the cars are vehicle type and manufacturer. There are six vehicle types: convertible, coupe, hatchback, sedan, SUV, and wagon, and three manufacturers: Audi, Lexus, and Saab. The six first-tier attributes are: MSRP, seating capacity, cargo capacity, horsepower, city mileage, and highway mileage, and are all integer-valued. Other attributes with integer values include dealer invoice, length, width, height, wheelbase, ground clearance, zero to sixty speed, top speed, braking distance, towing capacity, number of cylinders, valves per cylinder, driver crash test, passenger crash test, basic warranty, power warranty, and corrosion warranty. There is one double-valued attribute: fuel tank capacity. Also, there are several text-valued attributes: model, location of engine, engine type, drive train, transmission, reliability, injury frequency, vehicle theft, collision, country of manufacturer, and origin of assembly.

8 Concluding Remarks

The requirements of online product catalogs present an interesting problem of analytical product selection. The salient point of this paper is to apply the information visualization technology to this problem; the work presented in this paper was motivated to understand how the recent developments in information visualization can be used to solve the online product catalog problem and how the approach is compared with existing ones. This paper examined the analytical product selection problem, identified a number of requirements for the problem, and reviewed existing approaches to the problem on how they (do not) fulfill the given requirements. Based on the insight obtained from this preliminary research, we presented a novel solution, a product catalog interface using the information visualization technology. The primary objective of this catalog interface is to facilitate the multi-criteria decision analysis process in product selection. In addition to the product data visualization, it also provides a number of visual interactivity facilities especially designed for helping the shopping processes in navigating product data and creating a mental schema for analysis. In an attempt to demonstrate the effectiveness of the proposed solution, this paper presented a proof-of-concept prototype implementation, and provided anecdotal evidence for how the prototype supports intuitive exploratory analysis and facilitates dynamic analysis with the visual interactivity facilities.

More work needs to be done to confirm the validity of the presented product catalog interface, and also improve its design. First, we plan on several visual operations in the design. One operation is zooming, with which shoppers can view additional product information in multimedia forms (e.g., image, animation or text) on zoomed-in data point objects. In addition, we will add an operation that helps shoppers find products with similar attribute values. For this operation, we will incorporate a product-scoring scheme that is based on "nearness" among products (or more specifically, product attribute value sets). With this operation, a shopper can locate products that best fit the desirable attribute values that s/he specified. Second, we plan to add the "target area" of desirable attribute values, which we briefly mentioned in Section 5, to the product catalog view. Shoppers will be prompted to provide target attribute values during the initial product catalog request session, and will be able to dynamically modify them during the analysis session. Third, we will

incorporate the drag and drop operation into the user interface, so that shoppers can use the operation to reorder attribute lines instead of the current attribute checkboxes. As we augment the design with these new features, we plan to perform a more structured usability study for the prototype, and also experiment with the presented interface model on the Web sites of operating online retailers and marketplaces.

Acknowledgements

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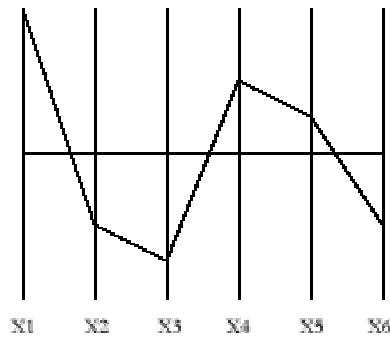[27] F. E. Webster, *Industrial Marketing Strategy*, 3rd Edition, John Wiley & Sons, April 1995.

Figure 1. A six-dimensional point in parallel coordinates

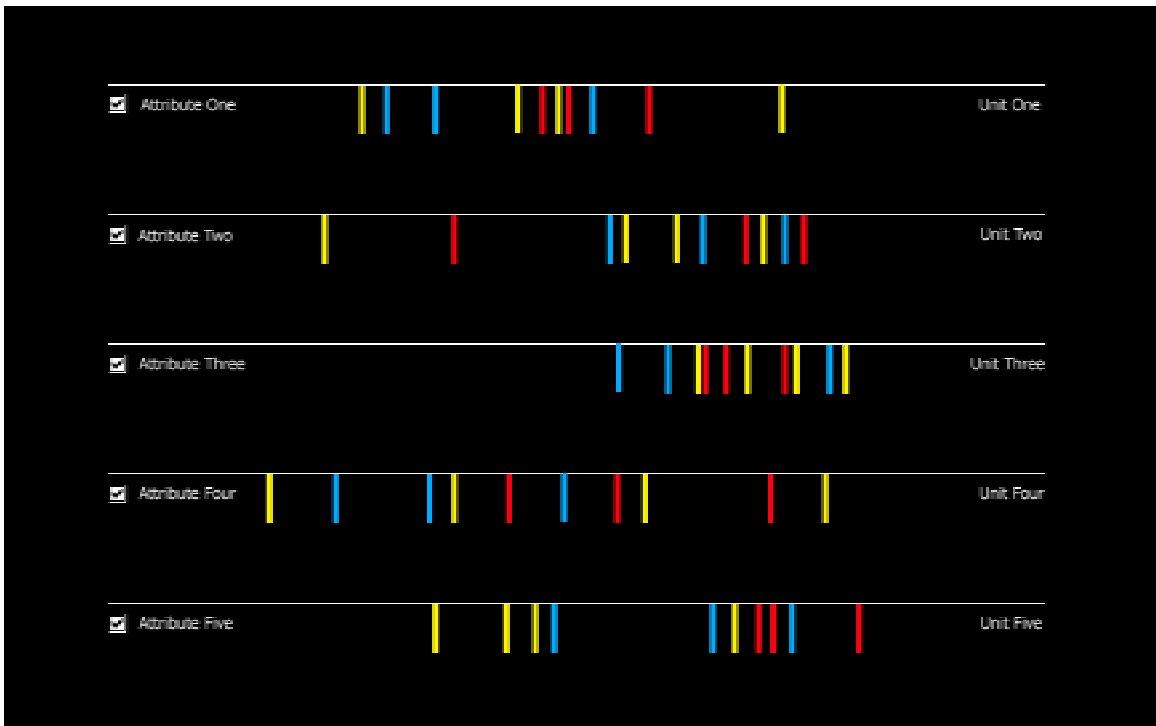Figure 2. Initial product catalog request form

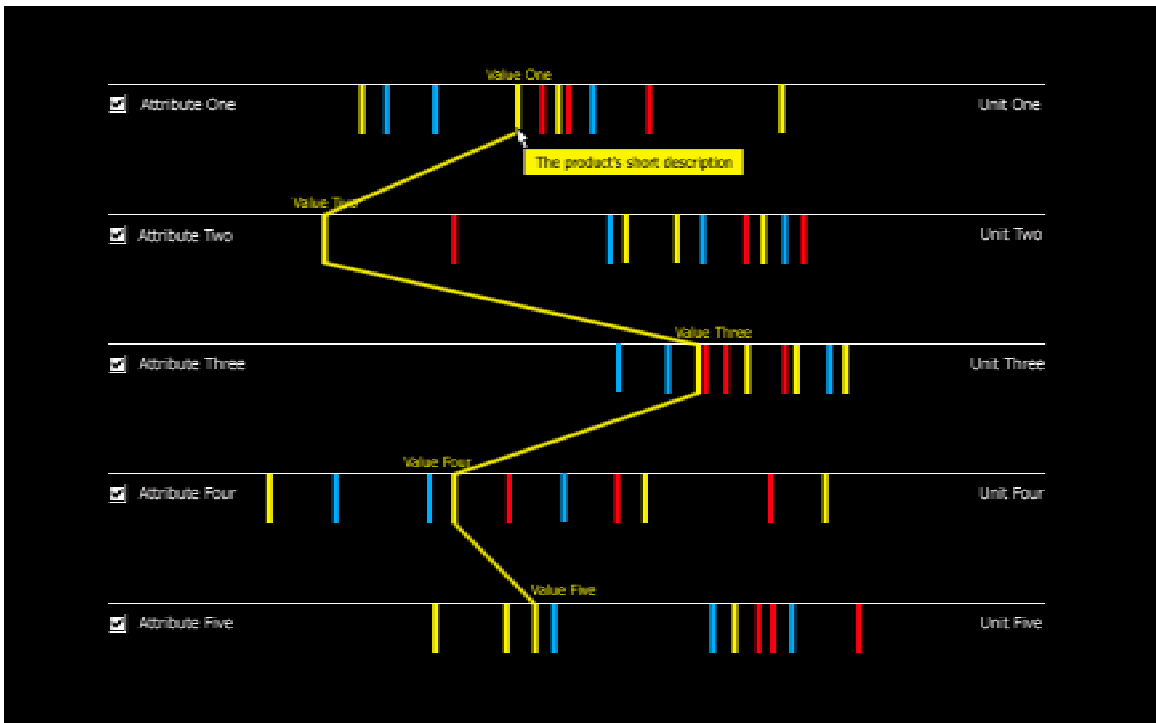Figure 3. An initial product catalog view

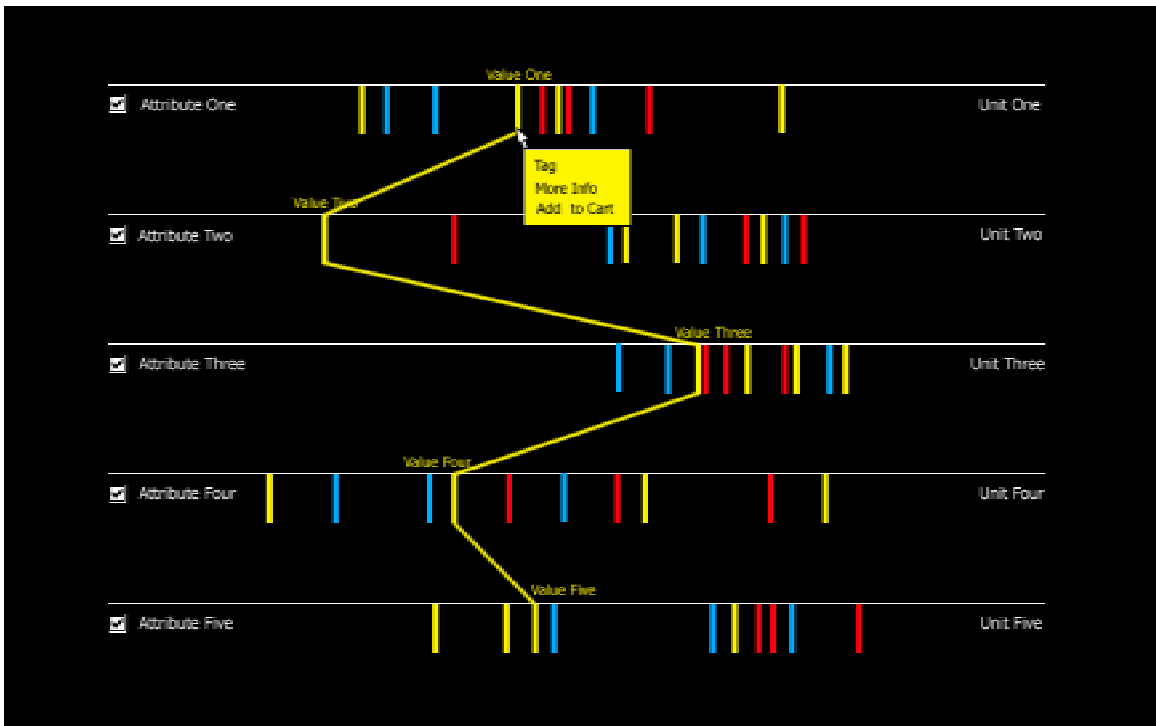

Figure 4. Viewing a product line
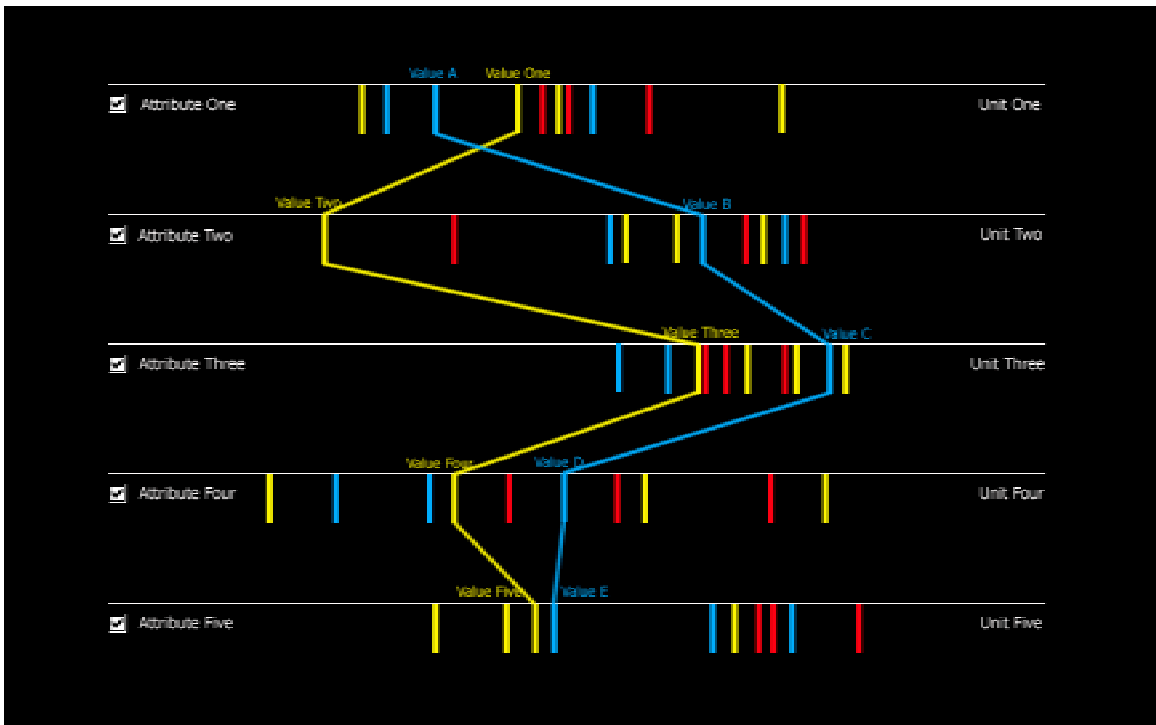
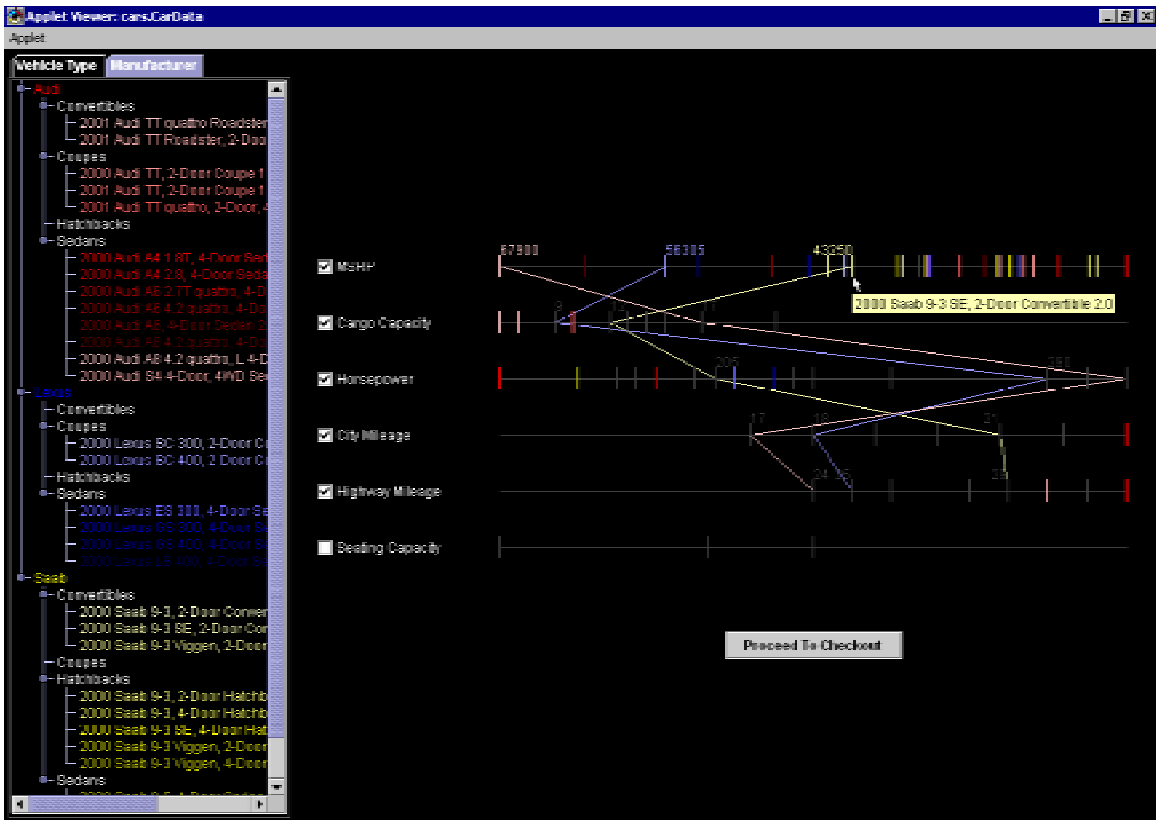Figure 5. Tagging a product line

Figure 6. Comparing product lines

Figure 7. A screenshot of the Visual One-Page Catalog prototype