7. Knowledge-Intensive Product Search and Customization in Electronic Commerce

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A major requirement of today's online shops is the availability of competent virtual sales agents that guide the customers through the vast space of available products, services and other opportunities. This function is mostly implemented by search agents that should help customers to find relevant product information. While these search functions are considered quite important by the online sellers, the quality of the retrieval results is miserable [7.4]. The key to enhancing search quality and, more generally, to approaching the vision of intelligent, knowledgeable virtual sales agents, is to incorporate more knowledge about products, customers and the sales process into the sales agent. The quality of service becomes the dominating factor for achieving customer satisfaction and a good customer relationship. As a consequence customer relationship management [7.9] and knowledge management [7.10, 7.3] have been recognized as core disciplines with strategic importance for successful future business. In the context of companies which communicate with their customers and partners via electronic online media, this requires one to make the company knowledge available and visible through the virtual agents that are supposed to be the primary access points to the company. This chapter describes a knowledge-based technology and related applications for developing intelligent virtual sales agents.

7.1 Introduction: A Knowledge-Based View of E-Commerce

One of the core difficulties in setting up a customer-friendly electronic shop is caused by the large amount of knowledge involved in a sales process, which is unfortunately neglected by most electronic shops. Therefore, many current shops appear more like a warehouse, where you must know exactly what you

want and where to find it. What is missing is real customer support and expert advice on the products. In our opinion, this is one of the main factors that at present limit the further acceptance of electronic commerce.

7.1.1 Knowledge Involved in Sales

When observing the traditional, human-based sales scenario from a knowledge perspective, we can see that many kinds of knowledge play an important role:

- *knowledge about products*: product properties and technical specifications, application areas, product structure, compatibility with other products, pricing, experience about faults, etc.
- *knowledge about clients*: requirements, wishes, preferences, shopping type, product experience, product language, cultural affiliation, etc.
- *strategic knowledge*: recommendation, communication, negotiation, sales, etc.

Typically, the vendor, distributor or manufacturer is the only entity that possesses full knowledge about the products. On the other hand, the client is the only entity that possesses the client knowledge. This leads to what we call a *knowledge gap* [7.2], which must be bridged during the sales process. In the traditional sales scenario, this knowledge gap is bridged by the human sales agent, who makes use of her/his strategic knowledge to mediate between the client and the vendor. This mediation requires communication, during which the knowledge is transferred from the vendor to the client and vice versa. This communication finally (hopefully) leads to a buying decision and the purchase of an appropriate product.

7.1.2 Online Virtual Sales Agents for E-Commerce

E-commerce offers many advantages and opportunities; however, these benefits come at the cost of not having a human salesperson in the sales process. Hence, the communication process must be realized by a virtual sales agent which must also bridge the knowledge gap through appropriate communication means. Current search technology enables only a very limited form of communication and hardly bridges the knowledge gap. Hence, it can only work in cases where the knowledge gap is not too big, as for example, for products that are well known by most customers (e.g., CDs or books).

In the future, we expect the knowledge gap to grow significantly. This is due to the fact that products to be sold online will become much more complex. First, products are getting more complex in general and second, after online sales has focused on simple products it will move to the more complicated cases. Additionally, the number of products available for online sale will increase as well. Together, the amount of relevant product knowledge

will increase. On the other hand, the number of online shoppers is increasing and new classes of shoppers will discover the Internet. This, the increasing diversity of customer wishes and the demand for individually customized products will increase the uncertainty on the seller's side about the customer and how s/he is best served. The resulting growth of the knowledge gap will become the critical problem in improving or at least maintaining the acceptance of online shopping in the near future.

7.1.3 The Role of Knowledge-Based Technologies

Knowledge-based technologies, in particular case-based reasoning, collaborative recommendation, configuration and adaptive user interfaces, can help in bridging the knowledge gap in electronic commerce. These technologies provide the means for the automatic knowledge processing that becomes part of an intelligent sales agent. This sales agent possesses the product knowledge and knowledge about typical customer behavior. During communication between the customer and the virtual sales agent, the sales agent makes recommendations on the basis of his knowledge.

In the remainder of this chapter, we introduce the WEBSELL architecture for realizing electronic commerce applications. Further, we give an overview of the applications that have been developed so far and we shall describe one application in more detail by a case study.

7.2 The General Architecture

We now introduce the WEBSELL architecture, shown in Fig. 7.1, which is a generic architecture for realizing electronic commerce applications, particularly to support the pre-sales process. To manage the requirements that are imposed on such a system, in particular by Web-based applications, the WEBSELL architecture has been designed as a component-based platform. This offers the highest flexibility in terms of

- being able to deliver tailored solutions
- integrating with heterogeneous IT environments
- ability to react to the fast-changing Internet market and its requirements.

The architecture is described in terms of server and client components, data storage and files, and XML-based communication protocols to connect these elements.

Building a solution for a specific client then corresponds to configuring a set of components and integrating the resulting system into the environment on the client's side. Whenever additional functionality is needed, new services may be added. Likewise, existing systems can easily be integrated by implementing a specific component that organizes the necessary communication between the external system and the affected WEBSELL components.

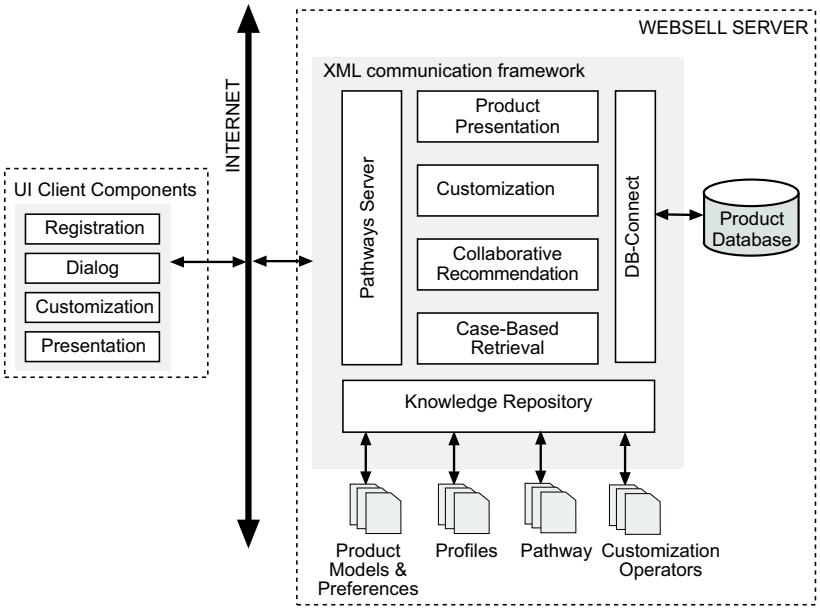

Fig. 7.1. Overview of the WEBSELL architecture

7.2.1 Case-Based Product Retrieval

Case-based reasoning (CBR) [7.7, 7.1] has become a very important technique for realizing intelligent knowledge-based product search agents [7.11, 7.16, 7.17]. From a traditional point of view, CBR is a method for experience-based problem solving: new problems are solved on the basis of stored experience about similar, previously solved problems. Therefore, previous problems and related solutions (called cases) are stored in a database (called a case base). When a new problem is to be solved, a similar old problem is first searched for in the case base and then the solution connected with this problem is reused or adapted to solve the new problem. One main characteristic of case-based reasoning is its ability to represent and process knowledge about similarity of problems and knowledge about the adaptability of solutions.

When applying CBR to knowledge-based product search, the ability to perform a similarity-based search is explored in a slightly different context. While traditional CBR searches for problem-solving experience, case-based product retrieval searches in a database of product descriptions. Hence, a product database is treated as a case base, i.e. each product record in the database is interpreted as a case in a case base. During the case retrieval phase, products are retrieved on the basis of the similarity between the product features and the customer's wishes entered during the communication with the virtual sales agent. This similarity encodes the knowledge required to assess whether a product is suitable for the customer's requirements. In

the WEBSELL retrieval component, similarity is formalized through *similarity measures* that are modeled by combining several parameterizable local similarity measures for individual product features with a global aggregation function. Thereby, global and individual preferences for product selection can be modeled.

The main purpose of the retrieval component is then to select from the product database a set of products with the highest similarity, as computed by the similarity measure. The challenge is to realize efficient retrieval on a large and highly dynamic product database. The retrieval component provides different similarity-based retrieval algorithms, such as

– complete brute-force search
– case-retrieval nets [7.8]
– similarity-based retrieval by approximation with SQL queries [7.12].

Recent applications have demonstrated the efficiency of the WEBSELL retrieval component with product databases containing several tens of thousands of products.

7.2.2 Collaborative Recommendation

In addition to the case-based recommendation approach, WEBSELL also provides a facility for collaborative recommendation based on user profiling [7.13, 7.14, 7.5, 7.6]. In the context of WEBSELL, user profiles support the potential personalization of all aspects of the sales process. A user profile stores the past electronic-commerce history of an individual user. User profiles are stored and maintained on the server as a profile database. Each user is associated with a single profile, and each profile contains user information that can be separated into three basic category types:

1. *Personal information*: This contains various personal details such as name, age, gender, home address, occupation and credit-card details.
2. *Domain preferences*: This contains user information that is relevant to a particular domain. For example, for an online travel application, the domain preferences might include information such as the type of vacation that the user is interested in (e.g. relaxing versus activity, city versus country etc.), their preferred travel arrangements (e.g. airline travel with Virgin or British Airways), and budget details (e.g. the package price should not exceed $2000).
3. Selection lists: This is the most important type of profile information from the collaborative recommendation viewpoint. Two selection lists are maintained. The *positive selection list* contains a list of products that the user has expressed an interest in or purchased. The *negative selection list* contains a list of products that the user has explicitly ignored in the past.

The collaborative recommendation service in WEBSELL is a recommendation scheme that allows products to be recommended to target users on the basis of their user profile data, and in this sense the recommendations are personalized for the user in question. The key to this form of recommendation is the ability to associate a target user with a group of other users that are similar in the sense that their profiles are similar to the target user profile. Typically, *profile similarity* is a measure of the correlation between the selection lists of two user profiles; users with a high degree of similarity tend to grade the same products in the same way. A group of users that are similar to the target user form a virtual community for the target, and recommendations are drawn from the profiles of the community members. The result is a list of recommendable products, which can be ranked according to, for example, the frequency of the product in community member profiles. Collaborative recommendation is a three-step procedure:

1. Identify the virtual community associated with a given target user.
2. Produce a ranked list of recommendable products. These are products that are listed in the positive selection lists of community members, but that are not contained within the selection list of the target user. The products are ranked according to their frequency of occurrence in the community.
3. Select the top n recommendable products as recommendations.

The final output of the collaborative recommendation service is a list of products, and ultimately these can be recommended directly to users or combined with the case-based reasoning recommendation. The collaborative recommendation service is responsible for identifying virtual communities (as groups of user ids) within the WEBSELL user population and for associating individual users with the appropriate community.

7.2.3 Product Customization

One important objective of WEBSELL was to be able to support the sale of complex products requiring customization or configuration. The WEBSELL customization component allows users to more flexibly and completely configure complex products such as holidays, insurance plans or technical equipment. Two different approaches have been developed:

Operator-based Customization. The operator-based customization approach [7.11] supports interactive modification of products by the customer. After a best-matching product has been retrieved and presented to the customer, a set of customization operators is provided, which may be applied to further customize the product. Each customization operator encodes a particular elementary way of adapting certain products. The description of such an operator contains

- a precondition that specifies under what circumstances the product can be modified
- a set of parameters to specify the details of the customization
- an action part specifying how the product is affected by the customization.

The customization component enables the customer to navigate through the space of possible customized products and takes care of the applicability of operators, the validity of parameter values and the consistency of the adapted products. In business-to-consumer scenarios, the operator-based approach is particularly suited to supporting products with limited customization capabilities since otherwise the set of applicable operators overstrains the user. However, in business-to-business scenarios in which clients have expert knowledge about the products, the operator-based approach can be applied to more complex products as well.

Incremental Compositional Customization. The incremental compositional adaptation approach [7.15] is particularly suited for complex products that require a sophisticated customization. It is assumed that products are structured into subcomponents, possibly in a hierarchical manner. Further, product databases with some preconfigured base products and individual sub-components are required. After the best preconfigured base product with respect to the customer's requirements has been retrieved, the product is customized by incrementally replacing subcomponents by more suitable ones. Components with a low similarity (weak components), i.e., components that do not fulfill the customer's requirements well enough, are candidates for being replaced. By recursively applying CBR to the level of subcomponents, alternative components are selected from the product database. Then the weak component is replaced by an alternative component and the validity of the adapted product created this way is checked. During this validation, constraints that exist between the different components are evaluated. Violation leads to backtracking to the component replacement step, giving the next-best component a chance. This adaptation cycle is executed several times. In every run, the overall suitability of the product is increased.

7.2.4 Pathways Component: Controlling the Communication with the Customer

Like a human sales agent, a virtual sales agent must be able to communicate in an appropriate way with the customer. It has to ask meaningful questions in a certain order and at some point it has to present product recommendations. In the WEBSELL architecture, the "pathways" component is responsible for controlling this dialog. The knowledge about a dialog that represents an appropriate sales strategy is encoded in a pathway. A pathway is a kind of decision tree that models interactions (e.g. questions to be asked) with the customer and the conditions of successor interactions. The pathways server component navigates through this decision logic in the pathway and

produces the user interface in the customer's browser. The pathway branches to different subtrees depending on the input from the user or on values computed at points on the decision tree. A point (or node) on the decision tree can perform one or more of the following tasks:

- Display information to the user in textual, graphical or animated format.
- Ask questions of the user with any of a range of standard controls (i.e. text, radio button, combo-box, etc.).
- Calculate equations or perform string additions as required.
- Perform a conditional or unconditional goto to jump to another node of the pathway.
- Produce a report from a designer-specified template and send this to the browser, to a server or to any valid Web address for processing.

The graphical presentation of the content of a node is fully under the control of the designer. S/he can specify the fonts to be used, the background colors or images and the graphics for any or all buttons. The custom report builder allows the designer to format the output for passing on to other components of the WEBSELL system.

7.2.5 The Knowledge Repository

As argued in the introduction to this chapter, the ability to explicitly consider the knowledge relevant to sales is important for an intelligent virtual sales agent. Each of the components introduced here makes use of a particular type of knowledge involved in the sales process. The case-based product retrieval component processes the knowledge about user preferences and product models and thereby implements a content-based retrieval. The collaborative recommendation component handles the knowledge about customers and customer classes (profiles) and thereby implements a collaborative retrieval. The product customization component processes product knowledge about product variants and, finally the, pathways component handles the strategic sales knowledge about appropriate dialogs. In the WEBSELL architecture, the access to these different kinds of knowledge is organized via a common knowledge repository that allows the representation and exchange of this knowledge on the basis of a common representation language consisting of several XML protocols.

7.3 Applications

A large variety of applications have been implemented using the WEBSELL architecture. We first provide an overview of some selected applications that have been developed. We then present an example of an application in more detail.

7.3.1 Application Overview

Table 7.1 gives an overview of some selected applications of the WEBSELL architecture that have been developed. The application type shown in the table refers to the main step of the e-commerce process that is supported by the search applications. Current applications involve

- *S*: a search for an appropriate *S*upplier for the kind of products the client is interested in,
- *P*: a search for an appropriate *P*roduct within the product spectrum of one supplier (or broker)
- *A*: a search for relevant service information as part of *A*fter-sales customer support.

The applications listed do not have the same status. Demo applications have been developed to demonstrate the potential of the technology while applications that are marked "live" are currently in productive use at the client's site.

None of these applications exploits all the components that WEBSELL offers, but each application uses a particularly tailored configuration of them. On the right of the table, the knowledge-based components that are used to implement these applications are marked (X means that component is in use; P means use of the component is planned in the future). Besides these components, of course, traditional components that do not involve any knowledge processing (e.g. for product presentation, ordering and payment) are used as well, but are not mentioned in this table.

In the following, we describe one application example in more detail. We have chosen the product catalog of Jola Spezialschalter since it involves more advanced techniques, such as product customization.

7.3.2 The Product Catalog for Jola Spezialschalter

We briefly sketch here an example of an application used for product search of parameterizable products. This application has been realized for the German company Jola Spezialschalter K. Mattil & Co.[1]. Jola produces thousands of electromechanical components and devices such as floating and magnetic switches, level controls, liquid level indicators and moisture detectors for cooling ceilings. Jola has identified that it needs to provide its customers with access to its products in three ways:

Direct access (index search). The user is a regular customer, does not need advice and has purchased Jola products before. S/he already knows article names and article numbers. For this kind of customer, there is no knowledge gap and hence no intelligent virtual agent is necessary.

[1] www.jola-info.de

Client / Description	Application: Type (Supplier Search, Product Search, After Sales)	Application: Status	Components: Pathways	Components: Case-Based Retrieval	Components: Collaborative Rec.	Components: Customization
Check Out Touristik www.reiseboerse.com	P	live		X		
Müritz Online www.mueritz.de/	S	live		X		
Handbook Precision Rhineland-Palatinate	S	live		X		
European Dealer and Solution Provider www.edsp.de	S	live		X		
Hooke & McDonald (residential letting) www.hookemacdonald.com/	P	live		X		
TourIT (City Sightseeing)	S, P	demo	X	X	P	P
Siemens Simatic Knowledge Manager www4d.ad.siemens.de/skm/	A	live		X		
Analog Devices Operational Amplifier	P	live		X		
QUOKA Used Cars Search www.autoaktuell.de	P	live		X		
Shopping24 Search in Warehouse www.shopping24.de	P	live		X		
Digital Signal Processor Search wwwagr.informatik.uni-kl.de/~readee	P	demo		X		
Personal Computer Configuration minsk.informatik.uni-kl.de:8103/launch/WebInterface	P	demo		X		X
Personal Computer Selection www.cykopaths.com/samples.html	P	demo	X	X		
Carsmart (Used Car Search) http://live.tecinno.de/projects/carsmart24com/	P	demo	X	X	X	
Jola Spezialschalter www.jola-info.de	P	live		X		X
Mobile Phone Selection www.cykopaths.com/samples.html	P	demo	X			
Intervox Score Music Sales www.intervox.de	P	live		X		
Bayer AG Plastics Product Advisor www.plastics.bayer.com	P	live		X		
Neckermann White Products Advisor www.neck.nl	P	live		X		
Otto AG Online Retail www.otto.de	P	live		X		
Software AG Knowledge Center www.sag.de	A	live		X		

Table 7.1. Overview of some WEBSELL applications

Structured access (hierarchical search). The user is a new or sporadic customer, is a technical expert and does not need advice, but has not yet purchased Jola products or has done so only a long time ago. S/he can navigate through a hierarchy of product groups (e.g. level controllers or leakage detectors) and products (e.g. float switches or magnetically driven immersion probes) to find quickly the desired devices. There is only a small knowledge gap, and the customer has sufficient knowledge for navigation.

Assisted access (intelligent sales assistant). The user is not a technical expert, needs advice and has not yet purchased Jola products or has done so only a long time ago. Hence the knowledge gap is large. S/he needs an intelligent sales assistant that asks for her/his requirements and recommends appropriate products.

Product Retrieval. The behavior of the virtual sales assistant is closer to that of of a human expert. Since communication is performed with an inexperienced user, the focus of the dialog is not on technical details, but on the purpose of the products. Typical questions are:

- What type of substance is in the container (conducting liquid, nonconducting liquid, flammable liquid, is it incompatible with water, etc.)?
- Is the installation area in an explosion hazard area?
- Is the installation area in a water protection area?
- What is the maximum permitted temperature of the substance?
- What is the viscosity of the substance (several categories)?
- What is the density of the substance (several categories)?
- What degree of turbulence does the fluid possess?
- Is the container or tank pressurized or not?

In order to be able to search for products with respect to the abovementioned purpose-oriented characteristics, the product modeling that is used by the case-based retrieval component describes each product in terms of these attributes. These attributes represent knowledge about the purpose for which a particular product is applicable. The similarity measure used for case-based retrieval encodes to what degree a deviation from the ideal application scenario of a product is still acceptable. Figure 7.2 shows the user interface of the virtual sales assistant for Jola.

Product Customization. In general, customers of Jola neither are very knowledgeable about the product variety nor know what kind of product is appropriate to their problem. The use of such very special technical products in industry is a cause of some specific constraints. Even if a product has been found that appears suitable for the customer's purposes, s/he might have further specifications such as length limitations or there may be a need for accessories. For some components, the latter are indispensable.

Suppose the retrieval system has returned a liquid level transmitter. For this type of switche, the customer has several possibilities for modifications.

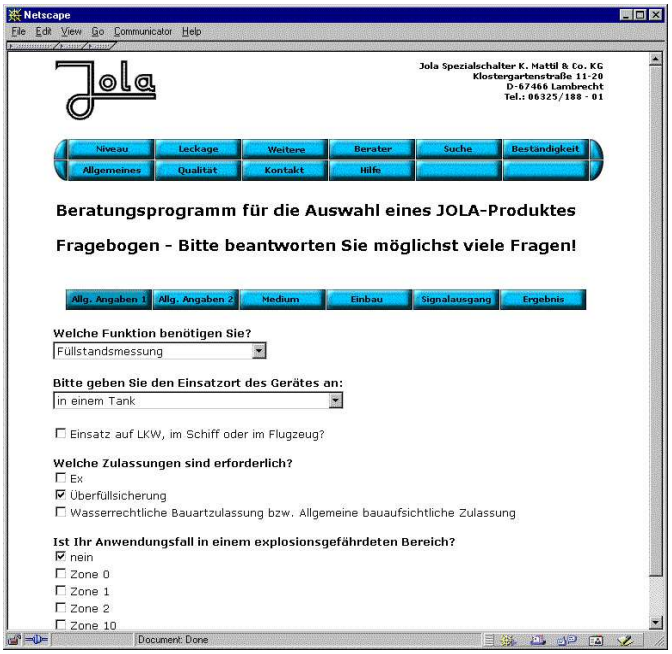

Fig. 7.2. Example of the user interface for the Jola application (in German)

S/he can adapt the length of the shaft, the diameter of the screw-in nipple or the type of float. Furthermore, there are accessory components to choose such as a transducer. Only after the latter component has been chosen can further components be chosen, e.g. a switching unit for signals from transducers or a display instrument.

Figure 7.3 shows the customization module. With the help of this customization service, it is possible to guide a customer who is not familiar with all the modification possibilities and constraints to his or her target product.

Commercial Evaluation. The benefits for Jola are manifold:

- Building the knowledge model for the sales assistant required that not only Jola's product data model was re-engineered but also that it was completed. By this means, a significant improvement of the product data and its availability was obtained.
- To enable customers to search by product applications rather than the products themselves use cases were collected for all products. This step made a wealth of knowledge of the experienced sales staff explicit that would have been easily lost in the past. This knowledge enabled Jola to serve its customers better and to optimize its product portfolio.
- Today, customers that use the online system provide the Jola sales department with a detailed description of their application requirements by

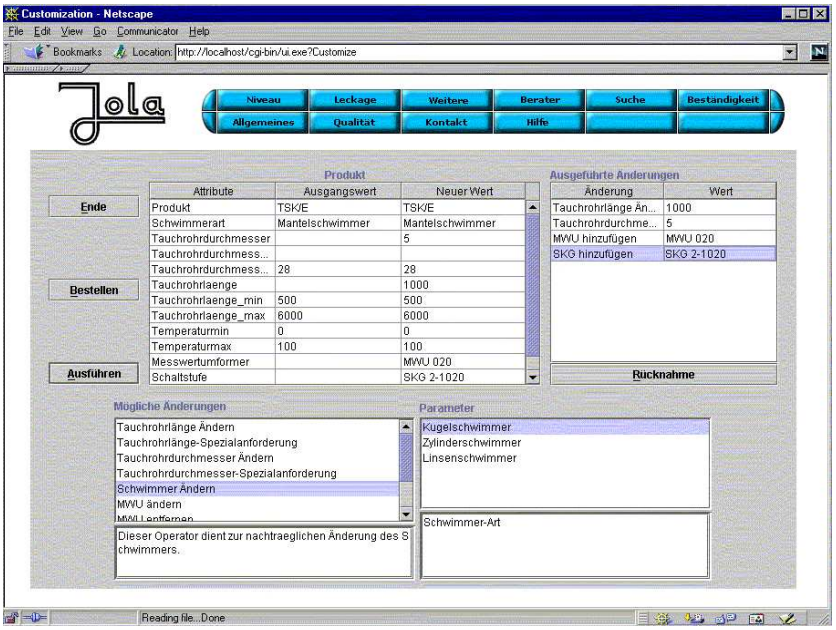

Fig. 7.3. Graphical user interface of the customization system (in German)

simply filling in the sales assistant questionnaire. If they have not found an appropriate product directly through the internet site, then it is at least much easier for the sales engineer to quickly propose alternatives. The questionnaire is also used by the sales force during customer interactions to ensure completeness of information. In both cases, the sales process has become much more efficient and more satisfying for the customers.

- The sales assistant is already in use by the external sales force of Jola. It has turned out that the lower the experience of the sales person was, the higher was its usefulness. This finding met our expectations and illustrates the necessity to have the index, the search and the assistant interface vary according to the seniority level of the user.
- The sales assistant is also an important means to collect very precise market data, i.e. each customer request delivers detailed information on the required application. This will enable Jola to react quickly to new application needs that arise and, eventually, to better predict market needs.
- Monetary benefits will be obtained from increased sales, increased productivity of the sales department and cost reductions. The latter will be especially true when the paper-based catalog is replaced completely by digital media.

At the time of writing, Jola is in the course of finalizing the catalog content. This content will be delivered to all its customers and potential

customers together with the next paper-based catalog, and will be available in English, French and German.

7.4 Summary and Future Work

The objective of WEBSELL was to produce a set of tools that would extend the range of products and services that can be marketed successfully on the Web. The first challenge was to tackle scenarios where expressing the users' requirements in terms of product descriptions was difficult. The second challenge was to help users to find the best products that matched their requirements and to provide a flexible mechanism to help the user customize these products. The WEBSELL suite of tools is completed with a user-profiling and collaborative-recommendation facility that exploits the available data to bring customers together with products that should interest them. In B2C e-commerce the challenge is to bridge the knowledge gap between the customer's world and the technical specifications of products. We feel that the WEBSELL tools are only a first step in this direction. In the future, there is a need to develop more flexible mechanisms for managing dialogs with the user; at present the pathways can only select between preconfigured dialogs. More importantly, we need to recognize the difference between the language of requirements and the language of product descriptions and develop mechanisms for mediating between these two representations.

Acknowledgments

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