Customizing the Interaction with the User in On-Line Configuration Systems

L. Ardissono[1] and **A. Felfernig**[2] and **G. Friedrich**[2] and **A. Goy**[1] and **D. Jannach**[2] and **M. Meyer**[3] and **G. Petrone**[1] and **R. Schäfer**[3] and **W. Schütz**[3] and **M. Zanker**[2]

Abstract. The provision of services on the Web is challenged by its heterogeneous customer base: Web catalogs are accessed by users differing in interests and knowledge about the products and services they search for. Moreover, in the companies selling complex configurable products and services, configuration systems are used by employees playing different roles: e.g., technical engineers and managers. For some of these people, the configuration task is problematic, as it exposes them to a large number of technical details to be specified. Effective personalisation strategies are thus critical to the development of successful Web-based configuration systems.

This paper presents the personalisation techniques applied in CAWICOMS, a prototype toolkit for the development of Web-based configuration systems that personalise the interaction with their users, supporting individual needs during the configuration task and the presentation of the solutions. The overall goal is that of assisting the user during the configuration process by suggesting suitable choices and providing her[4] with the information she needs for making informed decisions. To this purpose, our framework integrates user modelling and personalisation techniques with constraint-based configuration techniques.

1 INTRODUCTION

The provision of services on the Web is challenged by its heterogeneous customer base: as the popularity of Web shopping has dramatically increased, electronic catalogs are visited by users differing in interests and knowledge about the products and services they search for. The one-to-one recommendation of items, based on the recognition of the customer's preferences, has been introduced in several Web-based systems to help users find the goods best satisfying their needs [4, 5, 6, 11, 14, 17, 19]. However, this facility does not support the creation of personalised solutions on the fly: only pre-configured items can be managed by the traditional recommender systems. As the configuration of items is essential to comply with the customer's requirements when purchasing complex products, or registering for services, the need for assistance in this task is emerging as an important requirement. At the current stage, this type of activity can be performed by using non-personalised configuration systems offering a single type of interface. Moreover, as the configuration of complex items would challenge the user with technical details, the systems available on the Web typically solve simple configuration tasks, which can be reduced to exploring a pre-determined set of already configured solutions; for instance, see [8] and [9].

This paper presents the personalisation facilities offered by the CAWICOMS[5] framework for the personalised configuration of products and services [2, 3]. This framework is based on the idea that although, during the configuration of an item, technical details have to be addressed, an intelligent user interface can fill the gap between the system's point of view, focused on the implementation of the solutions, and the customer's one, focused on the usage of the product, or on the service fruition. This approach supports the use of the system by heterogeneous users such as inexperienced customers and technicians configuring items for third parties. CAWICOMS customises the following aspects of the interaction:

- *Configuration process:* during the selection of the features of the product/service, the system assists the user by suggesting, whenever possible, the values best fitting her requirements. Moreover, it provides information about such features, to help the user make informed decisions.
- *Presentation of solutions:* when a configuration solution is produced, the system presents it by focusing on the most interesting features, given the user's role. In this way, different perspectives on the product/service are offered (e.g., consider the presentation of technical details, with respect to the provision of information about the price and the main functions offered by the solution).

In order to achieve these two types of personalisation, the system applies user modelling strategies, aimed at identifying the user's individual interests and expertise, as well as the company's requirements. In several application domains, configuration systems are used by specific categories of users, identified by their roles in the organisations: e.g., sales engineers and managers. Our framework uses this type of information by applying stereotypical user modelling techniques [18], aimed at estimating the user's interests and domain expertise since the beginning of the interaction with the system. Moreover, to take into account individual characteristics, dynamic user modelling techniques are applied to update such estimates, according to the user's behaviour.

The system also employs probabilistic inference techniques to reason about the user's requirements and customise the configuration process. Furthermore, it uses personalisation strategies that, on the basis of the recognised interests, skills and requirements, prescribe the configuration and presentation actions to be performed: e.g., sug-

[1] Università di Torino, Italy.
[2] Computer Science and Manufacturing Research Group, University of Klagenfurt, Austria.
[3] DFKI, Saarbruecken, Germany.
[4] We refer to the user in a unique gender for readability purposes.

[5] CAWICOMS is the acronym for "Customer-Adaptive Web Interface for the Confi guration of Products and Services with Multiple Suppliers" (www.cawicoms.org). This work was funded by the EU through the IST Programme under contract IST-1999-10688.

gesting a value for a feature of the item to be configured, or focusing the presentation of a solution on a of its features. A rule-based approach is employed to tailor the interaction to the user's requirements and to integrate business rules in the configuration process.

The CAWICOMS framework has been applied to the development of a Web-based system supporting the configuration of high-technology products (telecommunication switches) and services (IP-VPN, Internet Protocol Virtual Private Networks) on the Web. In the present paper, we describe the user modeling and personalisation techniques applied in the system by referring to the prototype supporting the configuration of telecommunication switches.

This paper, which represents an extension of [1], is organised as follows: Section 2 outlines one of the application scenarios guiding the development of our framework and Section 3 summarises the main personalisation requirements on configuration we identified. Section 4 describes the CAWICOMS framework for the personalised configuration of items by specifying the typical flow of the interaction with the user (4.1), the graphical interface used to elicit information about the product/service features needed by the user (4.2), the personalisation strategies for customising the configuration task (**??**) and the inference techniques for reasoning about the user's interests and expertise (4.5). Section 5 outlines the system architecture and Section 6 concludes the presentation.

2 THE TELECOMMUNICATION SWITCHES DOMAIN

The development of the CAWICOMS framework was guided by application scenarios from the telecommunication domain. One of them is the configuration of large telecommunication switches for next-generation public telephony. The core of the product consists of a *switching network* that can be decomposed into a set of building blocks called *racks, frames* and *modules*. The number of these building blocks and their structure depends on the required performance characteristics and features specified by the customer. Therefore, the core of the switching system is complemented by routing components to conform future IP-based telephony requirements or software packages that offer control and maintenance functionality. In order to completely specify such a product, up to several hundreds of parameters and questions may be posed to the sales person interacting with the configuration system. Users can easily become overstrained and are unable to overview the configuration process. This is especially a problem when sales personnel is not well trained or lacks deep technical knowledge. In those cases, configuration systems play a crucial role as a corporate knowledge management tool, where user specific knowledge presentation requires an intelligent interface.

In our application domain we identified four user groups differing in the level of product knowledge and the frequency of system interaction: *Sales engineers* have deep technical knowledge. These users want to be able to drill down to configuration details and are able to interact with a non-personalised configuration system without any assistance. *Senior sales representatives* typically have good knowledge about the products and services to be configured and reasonable experience in the usage of configuration systems. *Junior sales representative*: this category encompasses sales personnel with almost no experience, and/or low level of technical understanding. *Customers*: the system is not allowed to assume any training on the product and must be prepared to give several explanations. This type of user is particularly important, when the configuration system is used as a medium to deliver product information.

In CAWICOMS, we addressed the requirements of these user classes, which are represented by stereotypes providing information about their skills and interests.

3 PERSONALISATION REQUIREMENTS OF CONFIGURATION TASKS

In order to take the user's interests and knowledge requirements into account, a configuration system should fill the gap between the underlying representation of the product/service and the user's perception of such an entity. While an expert user is assumed to have precise knowledge about the features of a product/service and its structure, a novice one only perceives its most "external" aspects. For instance, a telecommunication switch is characterised by a large set of features, some of which are very technical, such as the number of trunk lines to be exploited. However, the novice user's view of the product may only concern a subset of all the features: e.g., she may want to specify whether a Voice-mail function is needed, or how many terminals will be connected to the switch.

We have identified a set of requirements concerning the personalisation of the interaction by interviewing people regularly using the configuration systems available to a telecommunication company and occasional users of on-line configuration systems. The most relevant issues follow.

1. The configuration process may require the specification of a large set of data.
2. Depending on the user's knowledge, the specification of the parameter values may be difficult, if not impossible, as the user might not know the impact of her selections on the configuration solution.
3. Most users are only interested in the cost and the usage characteristics of the solution, while they do not care about how it is implemented (and therefore about the values to be set during the configuration process).
4. Some configuration parameters depend on the customer's features and should be automatically set: e.g., the customer's nationality determines the currency for payments.
5. Other configuration parameters are so critical that the user must take the responsibility to set them. At least in these cases, she should be supported with extra-helpful information about the parameter.
6. The user should be enabled to postpone some configuration decisions, when she is uncertain about the preferred value for a parameter, and carry on the configuration of the other aspects of the item under definition.

We have also identified requirements on the presentation of configuration solutions, but we only sketch them, as this paper is focused on the adaptation of the configuration task.

- The features of the configuration solution should be presented by taking the structure of the product/service into account. For instance, the structure of a telecommunication switch could be used to present the solution component by component, instead of showing a flat list of features (as most configuration systems do).
- Very critical information should be presented, regardless of the user's interests. However, if the information is too complex for the user, additional information should be available in order to help her understand the presentation.
- The presentation of solutions should be focused on the features most relevant to the user's interests: different types of information about the configured product/service should be presented, depending on the user's role. For instance, a technical engineer should get

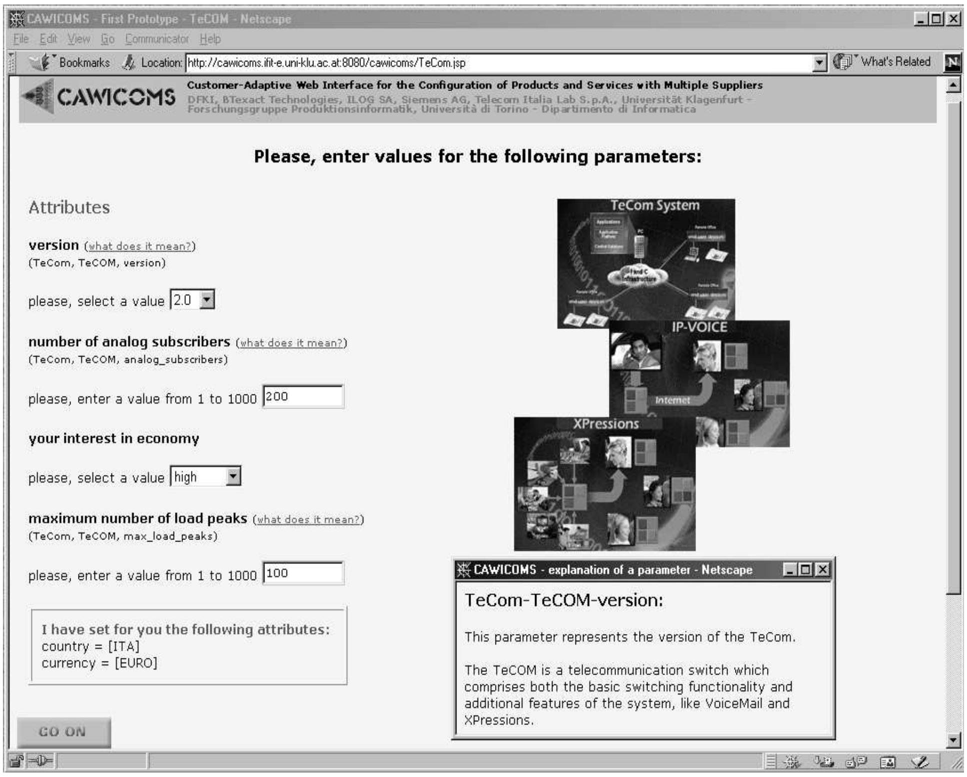

Figure 1. A personalised question page generated during a confi guration step.

technical information about the solution, while a manager could benefit from a presentation focused on its performance and economic aspects.

- The presentation should be tailored to the user's knowledge about the product/service: for instance, technical details should be hidden, if they are too complex for the user (and do not represent particularly critical information).
- As a general rule of Adaptive Hypermedia systems, the user must always be able to access the complete information about the solution. This means that details considered irrelevant, or too complex for the user, should be made available as additional information about the product/service. In this way, they can be reached on demand (by following "more info" links).

4 MANAGEMENT OF PERSONALISED CONFIGURATION TASKS

4.1 Interaction Flow

In the CAWICOMS system, the configuration process is organised in phases corresponding to the logical structure of the item to be configured: in each phase, a different component of the product/service is configured. Moreover, as each phase may consist of a possibly complex task, the interaction with the user within a phase is managed according to a dynamically generated sequence of configuration steps.

At each step, the user selects values for a subset of the product features: these features are represented by configuration parameters, each one associated with the set of its possible values (the domain of the parameter). After the selection of the parameter values, the user submits such values to the configuration engine. As in our framework this engine is based on a constraint satisfaction system, the values are propagated in a constraint network representing a partial solution. The propagation may trigger domain reductions on other parameters. After each propagation step, the user is shown another set of parameters to be set and their current domains, until the phase is over. Then, another configuration phase is started, until the whole product/service is specified. When the constraint network evolves to a solution where each parameter is set to one value, the system presents the solution. In contrast, if the user's choices generate a failure in the constraint propagation process, the configuration fails.

4.2 Management of a configuration step

The selection of parameter values within a configuration step is performed by filling in a form that shows the parameters to be set, together with their domain. The form may also include questions about the user's preferences for high-level properties of the product/service, such as its reliability. After having selected the values for the various questions, the user can submit the form to the configuration system by clicking on a "go on" button.

For instance, Figure 1 shows a typical page generated by our system during the configuration of a telecommunication switch (TeCOM). The leftmost part of the page displays the list of questions the user is asked about and includes configuration parameters (e.g., version of the switch, number of analog subscribers) and information about the customer's requirements: her interest in the economy of the product, i.e., on how costly the solution will be.

As shown in the figure, a help button ("what does it mean?" link) is available behind each parameter to retrieve detailed information about its meaning: for instance, Figure 1 shows the explanation window for the "version" of the TeCOM. Notice also that, at each config-

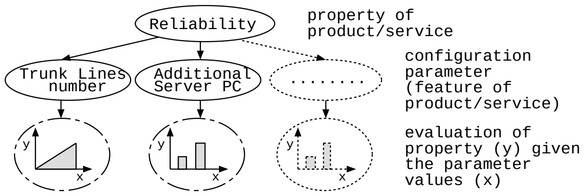

Figure 2. Relations between parameters and properties in the Frontend Model.

uration step, the system may set some parameters, by applying personalisation techniques. When this happens, the system shows these settings below the list of questions. For instance, in Figure 1, the system has set country and currency for the switch.

4.3 Knowledge about Products/Services and Users

4.3.1 Introduction

The satisfaction of the requirements in Section 3 is based on the integration of user modelling, personalisation and flexible dialogue management techniques, and on the use of a domain ontology describing personalisation oriented information about products and services.

4.3.2 Representation of information about products and services

The technical knowledge about products and services is described in a *Product Model* supporting a conceptual, structured description of entities with features, components and constraints among components; see [10] and [7]. This model specifies the technical information needed by the configuration engine to generate solutions, but does not include high-level information typically addressed during the interaction with the user. This further type of information is stored in the *Frontend Model*, that extends the Product Model with data such as the explanation of the meaning of configuration parameters and an estimate of their technicality and of their criticality degrees. The Frontend Model also stores the impact of parameters on the utility of the solution regarding different aspects and the difficulty of knowing such information. For example, Figure 2 shows the representation of the impact of some product features (number of trunk lines, additional server PC) on the reliability of a switch. As shown in the figure, the number of trunk lines has positive impact on the reliability of a switch. Similarly, the number of additional servers enhances this product property.

4.3.3 Representation of information about users

The system manages an individual user model storing information about the user: this model is stored in the system's database, so that it is available after the first interaction, and includes various types of information:

- The user's *personal characteristics*, such as nationality and enterprise type, are represented as <feature-value> pairs;
- The user's *knowledge* about each product/service feature, corresponding to a configuration parameter, is represented as a probability distribution on the values of a binary variable, associated to the feature; this variable represents the system's estimates that the user knows/does not know the meaning of the feature.
- The user model also describes the user's *interests* in different aspects of the product, such as its reliability and economy, corresponding to the properties defined in the Frontend Model. These interests are represented as probability distributions on the values (levels) of variables associated to such properties. For each variable, three level of interest are considered: low, medium and high.
- The user model stores information about individual defaults, representing preferences for particular parameter values. This type of preference may be available because the system enables the user to set "long-lasting" preferences about product features.

The estimates about the user's interests and expertise are initialised by means of stereotypical information [18] about the most relevant classes of users interacting with the configuration system (private customers, sales representatives and technical engineers). Moreover, to take individual properties into account, the system's estimates are dynamically updated on the basis of an interpretation of the user's observable behaviour. (see Section 4.5).

4.4 Personalisation Strategies

The conceptual representation of products and services stored in the Frontend Model guides the system in the management of a structured configuration session, suggesting the configuration of the product/service one component after the other, in a possibly hierarchical order. However, the system enables the user to postpone the setting of parameters and to select the components that she wants to configure first. In this way, mixed-initiative dialogues are managed, where both the system and the user can take the initiative during the configuration process (requirement 6 in Section 3). The Frontend Model also supports the user during the setting of parameter values by providing her with with explanations of the meaning of the parameters to be filled in (requirement 5).

Finally, the assessment of the user's interests and expertise, together with the exploitation of the information stored in the Frontend Model, supports the satisfaction of the first four requirements, as it enables the system to automatically set parameters and to personalise the formulation of questions. Given a configuration parameter to be filled in, alternative strategies can be used to identify the value(s) to be set and a personalisation module evaluates the alternatives, searching for the most promising one:

1. *If the criticality of the parameter is over a threshold, then ask the user about the value to be set.*
2. *If the user model contains an individual default value for the parameter and the value is included in the current domain of the parameter, then set the parameter accordingly.*
3. *If a personalised default matching the user is available for the parameter and the intersection between the suggested values and the current domain of the parameter is not null, then set the parameter to the intersection.*
   Personalised defaults represent business rules suggesting parameter settings based on customer's characteristics and are represented as production rules. The head of the rule specifies a possibly complex and/or condition on the user data. The consequent suggests a set of values for the requested parameter, together with the result of the evaluation of the head on the user model. For instance, in the interaction of Figure 1, a simple personalised default is applied that sets the "currency" parameter of a telecommunication switch to the appropriate currency (USD vs. Euro) on the basis of the user's nationality.

4. *If the parameter is related to some properties for which the user's estimated interest is low, then set a standard (non personalised) default value consistent with the current domain.*
5. *If the user's estimated expertise is sufficient to choose a value for the parameter, then ask her to set the preferred value, given the current domain.*
   This strategy relies on a comparison between the user's expertise and the difficulty of the parameter in order to estimate the likelihood that the user will be able to answer the question [12].
6. *Given the parameter domain, select the best value and set it, given the user's interests in the product/service properties.*
   This strategy exploits the information in the user model to predict the preferred values for the parameter. The properties related to the parameter in the Frontend Model are used to focus on the corresponding user interests, which are analysed to check if a sufficiently substantiated prediction of the best value can be made. Section 4.5 describes the evaluation model ascribed to the user in our system.
7. *Elicit (if not yet done) information from the user about her interest in properties of the product/service that are influenced by the parameter to be set. Then, apply strategy 6 to possibly set the parameter values.*
   This strategy is applied to let the user self-assess her interests, when the information in the user model is not sufficient to perform any prediction.
8. *Postpone the parameter setting to a later stage of the configuration process (last resort).*

These strategies are sorted by priority because, whenever safe, automatic parameter settings are favoured over questions to the user. However, the selection of the strategy to be applied is a little more complex: while the evaluation of the first three strategies is binary (either they suit the current situation, or they do not), the other strategies rely on uncertain information. For instance, strategy 4 depends on the estimation of the user's interest for the properties related to the parameter in focus; similarly, strategy 5 is based on the probability that the user knows the meaning of the parameter. In order to take this uncertainty into account, the suitability of a strategy is evaluated, in the [0..1] range, and applicability thresholds are defined to rule out weak strategies.

For each parameter to be filled in, the personalisation module evaluates the strategies, according to their priority, and selects the first one exceeding the application threshold. The selected strategy is applied to continue the interaction with the user, either by eliciting information from her, or by autonomously setting the value. The question pages submitted to the user reflect the fact that the various parameters may be filled in according to alternative strategies. For instance, in Figure 1, the user is questioned about parameters and interests; moreover, some parameters are set by the system.

4.5 Reasoning About the User's Knowledge and Interests

For applying the personalisation strategies described in Section 4.4, the user's interests and the user's *expertise* have to be estimated based on her observable behaviour. The inference mechanism used for this estimation process has to take into account the uncertainty associated with the interpretation of the observations. This is the reason why we use a probabilistic inference mechanism, namely *Bayesian networks* [16], for this purpose.

For estimating the user's interests, we have to ascribe the user an evaluation process which she employs for assessing products and services. In an idealisation, we use Multi-Attribute Utility Theory (MAUT [21]) for this purpose. MAUT is a general evaluation scheme which is applied or at least compatible to the schemes applied by many user modelling approaches for estimating the user's interests [20]. Many users are also already familiar with MAUT, because it is used by consumer organisations for evaluating products. For example, in Germany, Stiftung Warentest uses MAUT for evaluating consumer products (e.g., digital cameras [22]). According to MAUT, the *overall evaluation* of an object determines its utility for the user. Usually, many aspects of an object can be evaluated and not all the users are interested in the same aspects to the same degree. These aspects are called *value dimensions*. For example, a telecommunication switch can be evaluated on the performance, reliability, and economy dimensions. In this example, some users are more interested in performance and reliability and less in economy.

The overall evaluation is expressed on a numerical scale, e.g., from 0 to 10 and the overall evaluation is defined as a weighted addition of the object's evaluation on its relevant value dimensions [21].[6] A weight is associated with each dimension to describe the user's interests. The more interested the user is, the bigger the weight is.

In the same way as for the overall evaluation, the evaluation of the object on each dimension is based on a weighted addition of the evaluation of the attributes relevant for this dimension. In order to evaluate attributes (in our configuration task, corresponding to parameters to be set), a numerical scale is constructed which represents the properties of the levels of an attribute (levels correspond to the parameter values). Then, an *evaluation function* maps evaluation values onto the attribute levels. For example, regarding reliability a guaranteed uptime of 99% yields 10, whereas an uptime of 50% yields 2. For simplicity, we assume that the evaluation functions of the attributes and their weights are fixed. The described weights and the evaluation functions are defined in the Frontend Model. See bottom of Figure 2 in Section 4.3.

For fulfilling the goal of estimating the user's interests, the weights associated with the dimensions have to be determined. In CAWICOMS, this is done by means of a probabilistic approach and the weights are represented as a probability distribution. Initially, a first estimate is obtained by using stereotypical knowledge about users. A set of stereotypes define categories of users, such as representatives of a small company. These stereotypes are activated based on the user's personal characteristics. Then, the user's observed behaviour in typical situations is interpreted in order to update these estimates. The following situations can be processed:

- Self assessment: especially at the beginning of the interaction, the system may ask the user about her interests. The user's answer reflects her self-assessment, which is very likely related to her interests, but this fact should not be taken for granted because the user might misunderstand the meaning of the terminology used by the system.
- The user can also change the parameter values that the system proposed as defaults by applying personalisation strategies. This type of action provides evidence that the user believes that the change has a positive impact on the overall evaluation of the configuration solution. In other words, the user believes that the new parameter settings cause a positive shift in the evaluation of the item to be configured, with respect to the evaluation with the values proposed by the system.
- After generating a configuration solution, the system presents it. Then, the user has to decide whether accepting the solution and

[6] Other possibilities for aggregation are described by [21].

ending the configuration process, or not. If she accepts the solution, her overall evaluation of the solution is probably quite good.

For each of these situations, a Bayesian network has been specified which reflects the above described dependencies. These specifications are domain independent. At runtime, the actual network for processing the situation with the parameters involved is created and used for the interpretation of the user's behaviour. This interpretation results in an update of the probability distributions representing the weights of the dimensions corresponding to the user's interests.

For estimating the user's expertise we use an approach based on [12]. For example, if a user is observed to click on a help button, she probably does not know the implications of the parameter and therefore her expertise is probably low. If we observe that the user knows the implications of a parameter (e.g., because she specifies a parameter value), her expertise is probably high.

5 SYSTEM ARCHITECTURE

The CAWICOMS system is based on a modular, distributed architecture, where a specialised module is associated with each main task to be carried out during the interaction with the user: e.g., configuration, user modelling, personalisation and generation of the Web pages. The system is implemented in Java and exploits standard software development environments. The user interface consist of a sequence of Web pages, implemented as JSPs, whose content is dynamically generated on the basis of the interaction context and the application of the personalisation strategies. The JSPs run within an Apache Web Server. Specialised, commercial engines are used within the system to perform complex tasks: for instance, the ILOG's JConfigurator engine [10, 15, 13] is used to generate configuration solutions.

6 DISCUSSION

We have presented the personalisation facilities offered by CAWICOMS, a framework for the Web-based configuration of products and services. These facilities allow tailoring the interaction style to the individual user and also support her in the configuration of the product/service which suits her needs best. The personalisation of the interaction is based on the integration of a user-oriented view of the configuration task with the technical level at which configuration systems usually work. This result is achieved by integrating constraint-based configuration techniques with user modelling, personalisation and dialogue management techniques. Our approach also uses a domain ontology describing personalisation-oriented information about the items to be configured. We have applied this framework to the development of a prototype system for the configuration of telecommunication switches; moreover, a second prototype, supporting the configuration of IP-VPNs, is under development.

We have performed a first test of the personalisation facilities offered by the telecommunication switches prototype, with a limited number of users having different background and playing different roles in their organisations (managers, technicians, etc.). The results show that such facilities are appreciated, especially as far as the automatic setting of parameters is concerned, because it speeds up the configuration process, leveraging the selection of the values for the parameters to be set. However, they want to control the system's decisions, possibly overriding them. For this reason, we have modified the user interface, to produce editable personalised suggestions: these suggestions should respect the user's preferences, but if they do not, she can correct the settings.

The users also appreciated the system's explanation capabilities, although only partially developed, because they shed light on the comples underlying configuration process.

Moreover, the users asked for more flexibility in the management of the dialogue between system and user. For instance, they suggested that the user should be enabled to notify the system that she does not care about a value, therefore the system should set it autonomously. We have incorporated these facilities in our prototype.

Finally, requests for a more flexible management of the overall configuration task came. For instance, the management of reconfiguration, with its implications (corrections of previous parameter settings, revision of a configuration solution, recovery from a configuration failure), was considered essential and is part of our future work.

REFERENCES

[1] L. Ardissono, A. Felfernig, G. Friedrich, A. Goy, D. Jannach, M. Meyer, G. Petrone, R. Schaefer, W. Schuetz, and M. Zanker. Personalising on-line configuration of products and services. In *Proc. 15th Conf. ECAI*, to appear, Lyon, 2002.

[2] L. Ardissono, A. Felfernig, G. Friedrich, A. Goy, D. Jannach, R. Schaefer, and M. Zanker. Web-based commerce of complex products and services with multiple suppliers. In Thoben, editor, *E-Business Applications*, to appear. Springer Verlag, Berlin.

[3] L. Ardissono, A. Felfernig, G. Friedrich, D. Jannach, R. Schaefer, and M. Zanker. A framework for rapid development of advanced web-based configurator. In *Proc. 15th Conf. ECAI*, to appear, Lyon, 2002.

[4] L. Ardissono and A. Goy. Tailoring the interaction with users in Web stores. *User Modeling and User-Adapted Interaction*, 10(4):251–303, 2000.

[5] L. Ardissono, A. Goy, G. Petrone, and M. Segnan. Personalization in business-to-consumer interaction. *Communications of the ACM, Special Issue "The Adaptive Web"*, 45(5):52–53, 2002.

[6] BroadVision. Broadvision. http://www.broadvision.com.

[7] A. Felfernig, G. Friedrich, and D. Jannach. UML as domain specific language for the construction of knowledge-based configuration systems. *Int. Journal of Software Engineering and Knowledge Engineering (IJSEKE)*, 10(4):449–469, 2000.

[8] FIAT. buy@fiat: la tua prossima auto. http://www.buy@fiat.com, 2001.

[9] Fidelity Investments. Insurance center @fidelity. http://www400.fidelity.com:80/, 2001.

[10] ILOG. ILOG JConfigurator. http://www.ilog.com/products/jconfigurator/, 2002.

[11] Net Perceptions Inc. Net perceptions. http://www.netperceptions.com.

[12] A. Jameson. *Knowing What Others Know: Studies in Intuitive Psychometrics*. PhD thesis, University of Amsterdam, 1990.

[13] U. Junker. Preference-programming for configuration. In *IJCAI Configuration Workshop*, pages 50–56, Seattle, 2001.

[14] A. Kobsa, J. Koenemann, and W. Pohl. Personalized hypermedia presentation techniques for improving online customer relationships. *The Knowledge Engineering Review*, 16(2):111–155, 2001.

[15] D. Mailharro. A classification and constraint-based framework for configuration. *AI in Engineering, Design and Manucturing*, 12:383–397, 1998.

[16] J. Pearl. *Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference*. Morgan Kaufmann Publishers, San Mateo, CA, 1988.

[17] P. Resnick and H.R. Varian, editors. *Special Issue on Recommender Systems*, volume 40. Communications of the ACM, 1997.

[18] E. Rich. Stereotypes and user modeling. In A. Kobsa and W. Wahlster, editors, *User Models in Dialog Systems*, pages 35–51. Springer Verlag, Berlin, 1989.

[19] D. Riecken, editor. *Special Issue on Personalization*, volume 43. Communications of the ACM, 2000.

[20] R. Schäfer. Rules for using multi-attribute utility theory for estimating a user's interests. In *Proc. 9. GI-Workshops: ABIS-Adaptivität und Benutzermodellierung in interaktiven Softwaresystemen*, 2001.

[21] D. von Winterfeldt and W. Edwards. *Decision Analysis and Behavioral Research*. Cambridge University Press, Cambridge, UK, 1986.

[22] Stiftung Warentest. Digitalkameras: Pixeljagd. *test*, (6), 2000.