Adaptive Interfaces

Computer interfaces are becoming ever richer in functionality, software systems are becoming more complex, and online information spaces are becoming larger in size. On the other hand, the number and diversity of people who use computer systems are increasing as well. The vast majority of new users are thereby not computer experts, but rather laypersons such as professionals in nontechnical areas, elderly people, and children. These users vary with respect not only to their computer skills, but also to their fields of expertise, their tasks and goals, their mood and motivation, and their intellectual and physical capabilities.

The traditional strategy for enabling heterogeneous user groups to master the complexity and richness of computers was to render computer interaction as simple as possible and thereby to cater to the lowest common denominator of all users. Increasingly, though, developers are creating computer applications that can be "manually" customized to users' needs by the users themselves or by an available expert. Other applications go beyond this capability. They are able within certain limits to recognize user needs and to cater to them automatically. Following the terminology of Reinhard Oppermann, we will use the term *adaptable* for the manual type of application and *adaptive* for the automatic type.

Adaptable and Adaptive Systems

Adaptable systems are abundant. Most commercial software allows users to modify system parameters and to indicate individual preferences. Web portals permit users to specify the information they want to see (such as stock quotes or news types) and the form in which it should be displayed by their web browsers. Web shops can store basic information about their customers, such as payment and shipping data, past purchases, wish lists for future purchases, and birthdates of friends and family to facilitate transactions

online. In contrast, adaptive systems are still quite rare. Some shopping websites give purchase recommendations to customers that take into account what these customers bought in the past. Commercial learning software for high school mathematics adapts its teaching strategies to the presumed level of expertise of each student. Advertisements on mobile devices are already being targeted to users in certain geographical locations only or to users who perform certain indicative actions (such as entering certain keywords in search machines).

User adaptability and adaptivity recently gained strong popularity on the World Wide Web under the notion of "personalization." This popularity is due to the fact that the audiences of websites are often even less homogeneous than the user populations of commercial software. Moreover, personalization has been recognized as an important instrument for online customer relationship management.

Acquiring Information about Users

To acquire the information about users that is needed to cater to them, people can use several methods. A simple way is to ask users directly, usually through an initial questionnaire. However, this questionnaire must be kept extremely short (usually to less than five questions) because users are generally reluctant to spend efforts on work that is not directly related to their current tasks, even if this work would save them time in the long run. In certain kinds of systems, specifically tutoring systems, user interviews can be clad in the form of quizzes or games. In the future, basic information about users may be available on smartcards, that is, machine-readable plastic cards that users swipe through a reading device before the beginning of a computer session or that can even be read from a distance as users approach a computer terminal.

Various methods draw assumptions about users based on their interaction behavior. These methods include simple rules that predict user characteristics or assign users to predetermined user groups with

known characteristics when certain user actions are being observed (the latter method is generally known as the "stereotype approach" to user modeling). Probabilistic reasoning methods take uncertainty and evidences from different sources into account. Plan recognition methods aim at linking individual actions of users to presumable underlying plans and goals. Machine-learning methods try to detect regularities in users' actions (and to use the learned patterns as a basis for predicting future actions). Clique-based (collaborative) filtering methods determine those users who are closest to the current user in an *n*-dimensional attribute space and use them as predictors for unknown attributes of the current user. Clustering methods allow one to generalize groups of users with similar behaviors or characteristics and to generate user stereotypes.

Types of Information about the User

Researchers have considered numerous kinds of user-related data for personalization purposes, including the following:

- Data about the user, such as demographic data, and information or assumptions about the user's knowledge, skills, capabilities, interests, preferences, goals, and plans
- Usage data, such as selections (e.g., of webpages or help texts with certain content), temporal viewing behavior (particularly "skipping" of webpages or streaming media), user ratings (e.g., regarding the usefulness of products or the relevance of information), purchases and related actions (e.g., in shopping carts, wish lists), and usage regularities (such as usage frequencies, high correlations between situations and specific actions, and frequently occurring sequences of actions)
- Environmental data, such as data about the user's software and hardware environments, and information about the user's current location (where the granularity ranges from country level to the precise coordinates) and personalization-relevant data of this location

Privacy

Storing information about users for personalization is highly privacy relevant. Numerous consumer surveys show consistently that users are concerned about their privacy online, which also affects personalized systems on the Web. Some popular personalization methods also seem in conflict with privacy laws that protect the data of identified or identifiable individuals in more than thirty countries. Such laws usually call for parsimony, purpose specificity, and user awareness or even user consent in the collecting and processing of personal data. The privacy laws of many countries also restrict the transborder flow of personal data or even extend their coverage beyond the national boundaries. Such laws then also affect personalized websites abroad that serve users in these regulated countries, even if there is no privacy law in place in the country where the websites are located. Well-designed user interaction will be needed in personalized systems to communicate to users at any point the prospective benefits of personalization and the resulting privacy consequences to enable users to make educated choices. A flexible architecture, moreover, will be needed to allow for optimal personalization within the constraints set by users' privacy preferences and the legal environment. Alternatively, anonymous yet personalized interaction can be offered.

Empirical Evaluation

A number of empirical studies demonstrate in several application areas that well-designed adaptive user interfaces may give users considerable benefits. Boyle and Encarnacion showed that the automatic adjustment of the wording of a hypertext document to users' presumed familiarity with technical vocabulary improved text comprehension and search times significantly in comparison with static hypertext. Conati and colleagues presented evidence that "adaptive prompts based on the student model

effectively elicited self-explanations that improved students' learning" (Conati et al., p. 404). Corbett and Trask showed that a certain tutoring strategy (namely subgoal scaffolding based on a continuous knowledge trace of the user) decreases the average number of problems required to reach cognitive mastery of Lisp concepts. In studies reviewed by Specht and Kobsa, students' learning time and retention of learning material improved significantly if learners with low prior knowledge received "strict" recommendations on what to study next (which amounted to the blocking of all other learning material), while students with high prior knowledge received noncompulsory recommendations only. Strachan and colleagues found significantly higher user ratings for the personalized version of a help system in a commercial tax advisor system than for its nonpersonalized version.

Personalization for e-commerce on the Web has also been positively evaluated to some extent, both from a business and a user point of view. Jupiter Communications reports that personalization at twenty-five consumer e-commerce sites boosted the number of new customers by 47 percent and revenues by 52 percent in the first year. Nielsen NetRatings reports that registered visitors to portal sites (who obtain the privilege of adapting the displayed information to their interests) spend more than three times longer at their home portals than other users, and view three to four times more pages. Nielsen NetRatings also reports that e-commerce sites offering personalized services convert approximately twice as many visitors into buyers than do e-commerce sites that do not offer personalized services. In design studies on beneficial personalized elements in a Web-based procurement system, participants, however, "expressed their strong desire to have full and explicit control of data and interaction" and "to readily be able to make sense of site behavior, that is, to understand a site's rationale for displaying particular content" (Alpert et al. 2003, p. 373).

User-adaptable and user-adaptive interfaces have shown their promise in several application areas. The increase in the number and variety of computer users is likely to increase their promise in the future.

The observation of Browne still holds true, however: “Worthwhile adaptation is system specific. It is dependent on the users of that system and requirements to be met by that system” (Browne 1993, p. 69). Careful user studies with a focus on expected user benefits through personalization are, therefore, indispensable for all practical deployments.

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See also Artificial Intelligence and Human Computer Interaction; Privacy; User Modeling

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