The AVANTI Project: Prototyping and evaluation with a Cognitive Walkthrough based on the Norman's model of action

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ABSTRACT
In this paper, we present a contribution to the way in which two design issues encountered by the AVANTI project in designing a Web service supporting the mobility of disabled people can be faced. The design issues are: the problems deriving from distribution of the teams collaborating to the project in several cities (sometimes different European countries); and the need to face high-level interaction problems in the evaluation process. One important action taken to face these issues was the development of a variation of the Cognitive Walkthrough based on the Norman's model of action.

Keywords
Cognitive walkthrough, Norman's model of action, prototyping evaluation, web services.

INTRODUCTION
AVANTI is an European project (AdaptiVe and Adaptable iNteractions for multimedia Telecommunication applIcations) recently funded by ACTS (Advanced Communication Technology & Services), an European programme that addresses the problems of exploiting telecommunications in order to deliver multimedia information to different user groups, to set up experimental applications, and to test obtained results in field trials. AVANTI mainly aims at supporting the mobility of people, especially disabled and elderly people, in planning their movements. The objective of the project is to design a Web service for people planning their movements either as city dwellers, within their own city, or as tourists. The system design is projected towards adaptable and adaptive user interface. Adaptability is based on the knowledge of the users' needs, skills and preferences as well as task requirements. The user interface can, automatically, show different interaction modalities to different users. The term adaptivity refers to the capacity of interactive software applications to dynamically modify their communication characteristics during the human- computer interaction in accordance with the history of interaction.

AVANTI adopts a user-centered approach to the design of the Web service, which implies the well established principle of the involvement of real end users in designing and evaluating the application from the very beginning, and the development of many prototypes, in the iterative process of design-evaluation-redesign (Dumas & Redish, 1993). The development of the AVANTI prototypes was set out after an initial user needs and requirements analysis founded on the scenario-based design (Carroll, 1995). This method for prototype development implies the construction of scenarios on the basis of stories that people - real end users - tell. The stories reveal the difficulties and facilitations people encounter in ordinary life and are particularly useful at the beginning of the design process: they tell us a lot about what users do and how they do it and also allow us to get a grasp of the context in which such practices are carried out.

On the basis of the stories, we built up scenarios that consist of practical frameworks in which possible alternative environments can be figured out and various actions can take place. Each scenario describes all the actions needed by a disabled person to achieve his/her goal. To each action corresponds an amount of information concerning the place to reach and how to reach it, such as means of transport, routes, parking places, railway stations, bus stops, ticket offices, public offices, cultural and tourist places. Scenarios provide a well established context for describing interaction modalities, so, scenarios can be also seen as devices for facilitating communication among members of the design team (Carroll, 1995).

DESIGN ISSUES
In the following we will focus on two basic issues faced by the design team during the early prototyping phase of the project: the distribution of the design teams in several cities (sometimes different European countries); and the need to face high-level interaction problems in the evaluation process. One important action taken to face these issues was the adoption of the Cognitive Walkthrough. However, we did not adopt the Cognitive Walkthrough method (Polson et al. 1992) based on the theory of exploratory learning (Polson and Lewis, 1990) and GOMS (Kieras), but we devised a new method based

on the Norman's model of action (Hutchins, Hollan and Norman, 1986).

Cognitive Walkthrough

The Cognitive Walkthrough is a task-based inspection method widely adopted in evaluating user interface (Wharton et al, 1994). It is applied to well specified mock-ups and prototypes that allow for a system response to any user action. An analysis based on the Cognitive Walkthrough involves simulating user interaction with the system, with the aid of a simply functional model based on the theory of exploratory learning (Polson and Lewis, 1990):

Goal setting - The users start with a rough plan of what they want to accomplish - a task

Exploration - The users explore the system interface to discover actions that may be useful in accomplishing their current task

Selection - The users select actions that they think will accomplish their current task

Assessment - The users interpret the system's responses and assess whether progress has been made towards the achievement of the task.

Through the simulated interaction the analyst deals with four main questions (Wharton et al., 1994):

- Will the user try to achieve the right effect?
- Will the user notice that the correct action is available?
- Will the user associate the correct action with the effect s/he is trying to achieve?
- If the correct action is taken, will the user notice that progress is being made toward the accomplishment of the task?

While the application of the Cognitive Walkthrough method allows for the detection of likely interface problems, there are some drawbacks (Baecker et al., 1995): i) it is a time consuming method, and ii) the low-level focus on keystrokes and mouse clicks does not easily allow the recognition of high-level problems. In the AVANTI project we do not have the serious time constraints that development organisations have to face, however we have different constraints, such as the fact that the design team is located in different laboratories in different European countries. Thus, it is important to have some tools in common that would enable a high consistency in their application and that would allow for a detailed analysis of the interface problems. The strength of the cognitive walkthrough lies on the functional model of exploratory learning. While this model seems to work well when applied by people who share the same background and belong to the same team, we found that it generates some problems when used by people with different cultural backgrounds who need to communicate about the problems they encountered. Thus we decided to adopt as a theoretical background for the Cognitive Walkthrough a different model, the Norman's model of action.

Norman's Model

The Norman's model of human action provides a sound yet simplified theoretical framework of design and evaluation. It allows the definition of some basic cognitive steps in the analysis of human interaction with artefacts. The model describes five states (goal, intention, action, perception, evaluation) and three distances (semantic, referential and intereferential, the first two are present on both sides of the model, see Figure 1)

According to Hutchins, Hollan and Norman (1986), cognitive distances indicate the amount and quality of information processing needed to fill the gap between two states. The notion of cognitive distance can be applied both for action execution and for outcome evaluation. In the former case, it refers to the amount of information processing needed to bridge the gulf between an intention and the physical actions by which the intention is communicated to the system. In other words, it refers to the act of translating the thoughts and goals of the user into the system's language. In the latter case, cognitive distance refers to the amount of mental effort needed to translate the information displayed by the system in the terms of the conceptual model adopted by the user. In both cases, cognitive distance can take two forms: semantic and referential.

Referential distance, as for output evaluation, refers to the amount of mental effort needed to translate the form of the information displayed by the system into a form which allows the operator to grasp its meaning (e.g. what does a given icon or layout mean? What's the meaning of a given modification produced by my action? - the changing of an icon shape or sound- track). Whereas, in terms of action execution, it refers to the extent to which the user's understanding of the meaning of a physical action is similar to the user's understanding of the form of the action (i.e. can I grasp the meaning of my physical action on the interface? - What is the effect, if any, of my clicking longer on a given surface?).

Semantic distance, as for the output evaluation, refers to the amount of human information processing needed to translate the meaning of the output of an action in the terms of the intention it serves (e.g. after obtaining a given result how close am I to the fulfilment of my intention?). In terms of action execution, it concerns the relationship between the user's intentions and the meaning of the actions that are possible in the interface language (e.g. is there any immediate way to map my intention in action that the system allows?).

Finally there is the intereferential distance, that is the cognitive processing needed to put in relationship the information processed in action execution and the information available as result of the action (e.g. where does the output of my action come out? which are the modalities of the feedback to my action?).

These forms of distance allow us to describe cognitively the relationship between the task the user has in mind and the way the task can be performed via the interface.

However, in Norman's model all forms of cognitive distance involve a stable relationship between the goal the user has in mind and the way it can be accomplished, or at least, the model does not suggest any explicit way by which a goal can be modified during the activity. But there can often be a goal shift since either the user might not have the relevant knowledge to fulfil the goal or, in the given conditions, the goal might even be not feasible. Thus, human activity can fail, and it can require a modification in goal settings. But a goal-shift might take place even before a failure: the human knowledge that sets the goals is continuously activated and inhibited during the activity and the frame of knowledge is by nature a dynamic one. Even more important, the incoming information can recall by itself the knowledge by which it will be evaluated (Kahaneman & Miller, 1986). In other words, even if we are able to accomplish our goal and fulfil our intention, there are many cases in which during the activity we can "adjust" the way we interact with the environment, depending either on the action carried out or on the produced results. The interface can be both a gap to be filled but also a source for opportunities. Thus a shift in goal can be a frequent event during the interaction, and since the cognitive distances are related to the goal, the model needs to be updated to account for these goal shifts. We suggest two modalities by which a goal shift might be produced: i) the goal cannot be accomplished (lack of competence, or physical constraints); ii) different states of the world are suggested on the basis of the performed activity (incoming information activate alternative patterns of knowledge).

Bagnara and Rizzo (1989) define the distance between two different goals, mediated by a performed action or an evaluated outcome, as scenario distance. In order to avoid any misunderstanding with the scenarios used to perform the Cognitive Walkthrough, we prefer to use the term 'issue distance'.

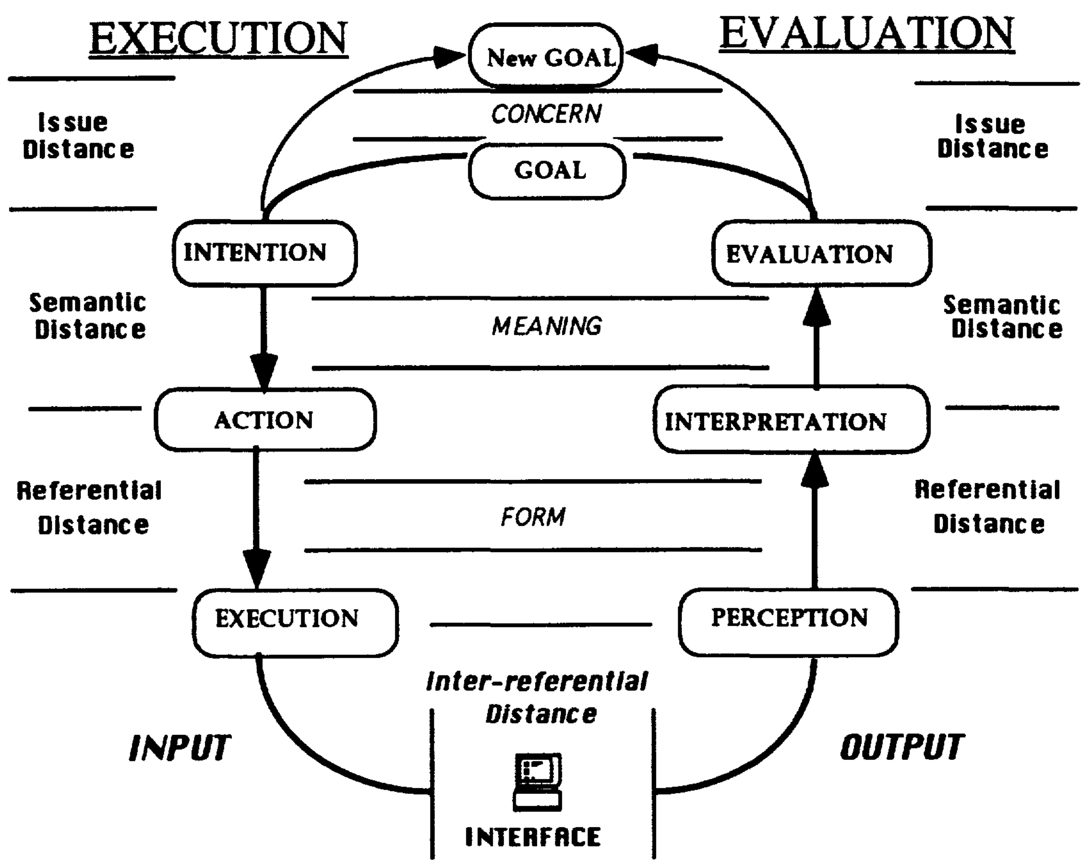

Figure 1. The Norman' s model of action with modification.

For both execution and evaluation purposes, issue distance refers to the amount of processing needed to understand that the goal cannot be achieved (e.g. If the DNS cannot be identified is it because the address is wrong, my internet server is down, or my Mac is unplugged?) or that a different goal, more suitable to the activity in which the user is involved, could be achieved (If there are simpler ways to carry out my activity can I discover it with practice?).

This last distance, is particularly important not only to the aim of supporting the proper user mental model but also to identify how a certain sequence of interactions could be eliminated or replaced by a higher-level modification in designing the interaction.

Norman's Cognitive Walkthrough

The Cognitive Walkthrough tries out the activities of the user who performs one or more tasks within a given scenario. The evaluator explores the system looking for actions that might contribute to the performance of the task. S/he selects those actions whose description or appearance most closely matches what s/he is trying to do, then s/he interprets the system's response in order to assess whether progress has been made towards completing the task or re-considering the goal. Thus it is possible to identify if the meaning and the shape of the interface are well interpreted by the user as well as if s/he is able to set feasible goals and to perform the right action on the right object.

Following the scenarios defined with the users, each component of the design and evaluation team performs a specific task asking, at each step of the interaction, the following questions:

Q1: Will the feasible and correct action be made sufficiently evident to the user and do the actions match with the intention as stated by the user? (Intention-Action)

Q2: Will the user connect the correct action description with what s/he is trying to do? (Action-Form)

Q3: Will the user receive feedback in the same place and modality as where s/he has performed her/his action? (Action Input - Feedback Output).

Q4: Will the user interpret the system's response to the chosen action correctly, (i.e. will s/he know if s/he has made a right or wrong choice?) (Outcome - Form).

Q5: Will the user properly evaluate the results, (i.e. will s/he be able to assess if s/he got closer to her/his goal?) (Form - Assessment).

Q6: If the goal is wrong (or can be ameliorate), will the user understand that the intention s/he is trying to fulfil cannot be accomplished within the current state of the world (or will s/he find out alternative goals?) (Action/Outcome - Concern).

Any time the answer is not completely affirmative the question is communicated to the other people in the team together with the specification of the alternative solutions which are implemented and then repeatedly tested.

Example

In order to give just a rough idea of the method, we provide a short summary of one example. It is impossible to give a detailed description of the method without graphically presenting the sequence of the human-computer interactions.

The system was explored using a scenario in which Michele Apicella, a wheelchair-bound person who lives in Rome, decides to plan a short one-day visit to Siena. He has never been to Siena before and a friend has suggested that he travels by bus since the railway station in Siena is far from the city centre.

For each activity of the task the members of the design and evaluation team, applied the questions of the action model in a repetitive way.

The overall goal of the proposed scenario is to reach Siena, while the first related goal is to get information regarding the buses from Rome to Siena. Thus, the first suitable activity to perform the task is the choice of the means of transport. Among the possible choices the user chooses the path related to the buses. At this point the user knows that the bus service is not accessible for a wheelchair-bound person, the only possibility to reach Siena is to go by train or by car. The user is then forced to establish a new goal that is, in our case, to get information about train facilities. Actually, at this point, the system does not provide support for this eventuality, so this path sends the user back to the previous choice taken: the choice of the city.

In applying the questions related to the Action Model, we noticed a semantic distance in the evaluation side between the outcome and its form, and the form and its assessment. As a matter of fact, while the user is able to provide an affirmative response to the first three questions of the model (Q1, Q2, Q3), the same cannot be said for Q4, Q5 and Q6. Actually, the user, selecting the entry "train", would expect to receive information related to the route already chosen (train from Rome to Siena) instead s/he is presented with the information concerning all the train routes to and from Siena. The user can not get closer to her/his new goal (Q6) since the system sends her/him back to a previous step.

The solution proposed by all the members of the team was to partially invert the structure of the interface in order to perform the task.

The system could be organised as follows:

1. choice of the path (Rome-Siena);
2. choice of the means of transport;
3. information: the bus is not accessible but the user can go by train;
4. information about trains from Rome to Siena.

Thus, the category of the path is hierarchically higher than the category means of transport so that the user needs not to repeat the choice already taken when the goal shifts.

During the interaction with the system the user can be induced to shift her/his goals. For this reason the interface should inform the user effectively and, moreover, provide alternative solutions to fulfil her/his intention to overcome the drawbacks due to the issue distance. This was also considered one of the cases in which the system should support the user through adaptivity, that is, it should take into account the previous selections made by the user so to provide context-relevant information.

CONCLUSION

The Cognitive Walkthrough based on the revised Norman's model of action allowed the easing of two of the design issues faced by the AVANTI design team. It allowed the

the design team working in different laboratories to avoid ambiguity in communicating the problems discovered during the evaluation by pointing out the questions that received a negative answer and the factors involved (e.g. Intention-Action or Action/Outcome - Concern) with an indication of both the cognitive and the physical aspect of the problem. It also allowed more strategic issues in interaction design to be faced since the same aim of the activity could be discussed and evaluated.

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