A Context-sensitive Nomadic Information System as an Exhibition Guide

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1. Introduction

The paper describes the goal and practice of the nomadic exhibition guide Hippie[1]. Hippie takes into account the context of use of the nomadic system. An information system is said to be nomadic when the user has access to both his or her personal information space and to the public information space from all places independent from specific devices—for nomadic systems see (Kleinrock 1997). For nomadic information systems not one particular (small, wearable, mobile) appliance is crucial. Nomadic information systems include mobile devices as well as stationary desktop computers or kiosk systems with all having access to information spaces relevant for the user. Users will increasingly be nomads (Makimoto & Manners 1997). Like they always wear a bundle of keys in the pocket to have access to physical spaces future nomads will have an electronic key to get access to information spaces no matter with which devices they currently work with.

To be useful for the user the information content and the information presentation should take into account the context of use. The context of use is defined by plenty of parameters. We can distinguish physical environment, geographical position, social partners, task requirements, user characteristics etc. The more parameters are considered for the information selection and presentation the more effective, efficient and satisfactory the interaction will be for the user (Dzida 1996). The user himself is most competent in specifying the context of use but the more complex and the bigger the information spaces the more effort the user needs for the information selection and presentation. A context sensitive information system can help the user to pre-select and appropriately present information automatically. In this paper we will introduce and discuss new potentials of nomadic information systems to exploit the context of use for automatic information selection and presentation. Nomadic information systems give some new possibilities to identify the context of use. A nomadic system can follow the stream of activities of the user over the process of a task at different locations, and can take into account the specific current location of the user (Abowd et al. 1996; Abowd, Dey, Abowd, Orr, & Brotherton 1997; Brézillon

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[1] The prototype Hippie was developed by GMD within the project Hyperinteraction within Physical spaces (HIPS), an EU-supported LTR project in ESPRIT I[3]. The partners of the consortium are University of Siena (co-ordinating partner), University of Edinburgh, University College Dublin, ITC, SINTEF and GMD, CB&J, and Alcatel.

1998; Schmidt, Beigl, & Gellersen 1998; Wallace & Anderson 1993). Furthermore a nomadic information system can integrate these new parameters into the consideration of the user's needs already evaluated by traditional user model based adaptive systems.

2. Structure of a Context-Sensitive Nomadic Information System

The nomadic information system to be presented in this paper contains several models to identify the context of use. A *domain model* describes and classifies the objects of the domain information are to be presented and processed about. A *space model* describes the physical space where the nomadic system is used and the location of the domain objects in the space. A *user model* describes the knowledge, the interests, the movement, and the personal preferences of the user. The domain model and the space model is assumed to be static, i.e. the domain objects are described and their location are identified before the usage of the systems. If changes occur in the environment the domain model or the space model have to be updated explicitly. The user model can be perceived to be dynamic, i.e. the user's interactions with the information system and his / her movements in physical space are evaluated to update the user model automatically.

The nomadic information system Hippie has been developed for a cultural environment providing information about an art exhibition. The nomadic user is supported by adaptive information all along the process of a visit in a museum, i.e., for the preparation at home, the visit in the museum and its evaluation at home again. To understand cultural heritage both is necessary, information about the background or the context of an event or exhibition as a whole and information about the details of single units (exhibits) and the experience of the authentic environment. The first aspect, the holistic view, can most probably best be studied before and after the visit. The details can probably best be studied in front of an exhibit combining the authentic sensory perception with additional information provided by a complementary medium. The main purpose of the electronic guide presented in this paper is to support the actual visit of a museum, i.e., to enrich the understanding and enjoyment of exhibits, not to replace a real visit by a virtual visit. The electronic guide provides the information access at home via normal internet connection for the preparation and evaluation of a visit and inside the museum information access is provided via wireless technologies. The latter allows the user to access information by moving in the physical space and navigating in the information space concurrently. A Web-based client-server approach allows for adaptive selection and presentation of information based on a user model evaluating the history of the usage of Hippie with respect to knowledge, interests, movement and preferences. The user can accelerate and modify the adaptation by specifying interests and preferences in a user model dialog

2.1 Domain Model

The domain model contains a taxonomy allowing to classify the objects of the art gallery used for the exhibition guide. Our taxonomy is mainly based on the structure of "ICONCLASS" – an ICONographic CLASsification System, which was published in 1974 to 1985 in Amsterdam (Heusinger 1994, 407).

The taxonomy structures all pictured topics of the occidental graphic art in nine main groups of genres, divided in at most nine subgroups, again divided in at most nine subgroups and so on. The classification is not an exclusive one where artworks can be only be classified once. It is possible that an artwork shows combined characteristics of several categories. The nine main (not exclusive) groups are:

1. Religion&Magic,
2. Nature,
3. Human Being, Man in General
4. Society, Civilisation, Culture
5. Abstract Ideas and Concepts
6. History,
7. Bible,
8. Literature,
9. Classical Mythology & Ancient History.

For our experiential gallery of artworks used for the Hippie prototype we have introduced some more detailed categories to obtain an acceptable distribution of given artworks. We also classified the artworks according to their kind: paintings, sculptures and art-crafts.

2.2 Space Model

For the location of objects in the physical space a model of the space is necessary. There are several characteristics for the construction of the space model depending on the size and the location of the objects of the domain. If all objects are located on one vertical level a two-dimensional model is sufficient; otherwise three dimensions are necessary. If all objects are to be located in one isolated environment an arbitrary plan can be constructed; if the location of objects shall be identified for several subspaces a unique scaling, e.g. the geographic latitude and longitude, is appropriate.

To locate the user in the physical space several techniques can be applied (Jaceniak 2000). For the location infrared installations can be used for small (indoor) environments; the Global Positioning System (GPS) can be used for large-scale outdoor environments. The former can use a proprietary map; the latter uses the geographic latitude and longitude system. Beside the location also the orientation of the user is needed to identify the direction of his or her focus of attention. For the orientation an electronic compass can be used in combination with the infrared receiver attached with the user.

2.3 User modelling in nomadic information systems

Adaptive hypermedia systems mostly adapt the information selection and presentation to the user's goals, preferences, knowledge, and interests. In most cases the user model acquisition is driven by monitoring the activities of users in the information space or by an analysis of their connection and device characteristics. Additionally nomadic information systems can make use of localization technologies (GPS, DGPS, Infrared, and digital compass) to adapt to a richer context model of the user's current situation. Beside an identification of the user's current position these

technologies allow for user tracking in the physical space and his/her movements within.

User preferences can be acquired by explicit user dialogs where the user can set language, select auto-started or manually controlled presentations, configure the interface and others.

The user knowledge model can be built by monitoring the user's interaction with the user interface. Positive evidence for gaining knowledge about exhibition objects comes from listening or watching presentations. Negative evidence comes from skipping or stopping presentations. Furthermore other diagnostic components can be used like interactive games or questionnaires. The adaptation of the information to the assumed current knowledge of the user provides an optimal fit to the perception capability and avoids unnecessary repetition. Repetition is helpful for in-depth learning (Newble & Entwistle 1986). For information presentation during nomadic activities, e.g. an exhibition visit, it tends to be boring. Repetition during guided tours should therefore be reduced to short summaries that provide links to already received detailed presentations.

In the following section we would like to concentrate on the user's interests and his/her movements in physical space as two variables that are tightly connected according the theories in several fields of psychological research like described below. The interests of the user are the most difficult part to model, especially because they are highly dynamic. On the one hand we are assuming an underlying relatively stable interest trait structure of a visitor, on the other hand we take into account the current situation and a multiplicity of environmental factors that have an impact on the actual activation (the state) of the interest structure.

The concept of interest is important in particular in a context of user self-directed behaviour. This is not typical for the work environment where tasks define the goals and the process of user behaviour. In a leisure or entertainment or cultural environment there are no predefined tasks but at most arranged attractions that catch or don't catch the people's attention. A visit in a museum is a good example to exploit the relationship between the properties of an attraction environment on one side and the attention of the visitors indicated by their movement in the exhibition space and their reception of explanations on the other side for hypotheses about visitor interests to predict information needs. The question in this chapter is whether and how interests of visitors can be identified during nomadic activities and whether and how interests can be used as indicators for information selection and presentation. Two aspects for this exploitation are relevant: first, which objects (items) are interesting for the visitor and, second, which contents (attributes) are interesting for him or her.

Interests as a concept relevant to explain and predict human behaviour is used in several fields of psychological research. We shall only give a very short overview about the approaches to explain human behaviour with references to interests.

According to Lewin's field theory human behaviour is a function of environmental and personal factors (see a summary of the theory by [Deutsch, 1968 #1237, 423]). Environmental aspects can be perceived as demands and affordance in a given situation. Personal aspects can be perceived as the needs and motivation of the individual. Social aspects are both, they are part of and influence the environment and they influence the development of the individuals needs and motivations.

Interest is a central variable to explain human behaviour in a variety of psychological fields.

Motivation theories refer to interest as a tendency to focus the attention of the individual towards objects or issues in a specific environment (Rubinstein 1970). Interest can be more specifically characterised by three elements, a directness of attention, an object or issue the attention is directed towards, and learning about the object or issue. Interest is a conscious direction to an object or issue, it determines the degree an individual is occupied with the object or issue by perception, by communication or by interaction. Interest is a latent variable that can be activated by external conditions, in particular by the presence of the object or issue of interest. To see somebody or something or to hear about something will evoke active engagement to learn about or interact with the object or issue of interest. Interest attracts both feelings and thoughts. It evokes the desire to be engaged with the object or issue of interest and to think and learn about it. Interest is not a constant concept but it develops according to the personal history of experiences and external affordance.

The dynamic character of interest as a condition for learning has a long history in **educational psychology** (Bruner 1961). The readiness for learning, i.e., for the acquisition of knowledge, depends on the interest of the learner. The more the individual knows and learns about an object or issue the higher the interest grows. The higher the interest is the more and more effectively the individual learns about an object or issue. Both variables are interdependent. The individual's need for change defines the saturation point when the individual relaxes or directs the attention to another object or issue. As the interest can be invoked by the presence of an object or issue the interest also tends to decrease after a period of occupation.

Psychological **perception theories** have shown that interest triggers perception behaviour in a quantitative and qualitative way (Schulz von Thun 1971). The more the individual is interested in an object or issue the more likely it its that he or she becomes aware of the object or issue or of stimuli and information about the object or issue and the more likely it is that he or she will also search for and perceive information. Perception theories have also shown that the interest determines the kind and the content the individual perceives about the object or issue of interest. Perception is selective and interpretative. The interest determines what content will be selected, perceived and memorised about the object or issue of interest.

In **social psychology** the development of interest has been studied in terms of attitude formation and social expectations (Fishbein & Ajzen 1975). In social psychological theories attitudes are considered to be a determinant of human behaviour together with social expectations and situational variables. Attitudes are the affective aspect of the belief system of an individual. It describes how an object or issue is evaluated or esteemed. Social psychology theories stress the influence of the social reference groups (peers, significant others). Social factors influence the formation of attitudes and the relevance that an attitude has in an environment where the individual feels to be under social observation. In a museum study (McManus 1991) has shown the relevance of social formations for the physical movement and the information behaviour of the visitors.

For an adaptive exhibition guide the goal of a user model is to predict the information needs of a user in a given episode of a visit. The inferences to be made are the next exhibit to be recommended and the next information content to be

presented. These two predictions have to be inferred from the previous navigation in the physical and in the information space. We now shall discuss how the concept of interest can help for this task.

Studies of human perception show that there is an interrelation between the interests of an individual and the attraction of the perceived object. Weidenmann (1988, 39, 42f., 89f.) and Kowalski (1970, 68ff.) showed this interrelation in the context of visual perception of artworks. The attraction of an artwork can be described by several variables, including but not limited to novelty, complexity, and abstractiveness. These variables are no absolute determinants but depend partly on the perceiving individual (Weidenmann 1988, 90). In a very rough sense children can be described by a holistic perception, adolescents by representational perception and adults by reflective perception following the competence and interest of the individual (Kowalski 1970, 39ff.). The more the individual grows up and the more opportunity it has had to have experience in the domain the perception and interpretation of art objects are determined by individual preferences and evaluation (Kayser & Körner 1997, 193f.). The more the individual matures in the understanding of a domain the more it can proceed in the process of perception.

The perception is not limited to cognitive determinants. Also affective dispositions of the individual and affective cues of the object determine the perception (Kayser & Körner 1997, 194) (Hofer, Pekrun, & Zielinski 1994, 232) (Weidenmann 1988, 49). The length of viewing artworks can be limited by the subject's need for diversity (Weidenmann 1988, 93) but additional external stimuli (ibid., 92) like explanations or stories can re-activate the occupation.

The studies cited above support the assumption that the perception of exhibition items can be predicted by the position of the perception episode within the individual life history (child, adolescent or adult), within the individual domain maturity (naive viewer or experienced viewer) and within the current visit sequence (at the beginning or after reaching a saturation point viewing an artwork or an exhibition). The more the user is experienced in a domain the more the concept of interest can contribute to the prediction of the user's information needs. A user model of an information system has access to the exhibits and to the content of information selected by the individual to make inferences to his or her interests.

In the context of nomadic information systems we shall discuss the potential of localisation to evaluate the user’s interests during his or her navigation in the physical space. We shall use the user’s navigation as an additional indicator for his or her interest in particular objects and particular content about the objects.

In the context of an exhibition visit there is a great chance for a nomadic information system to evaluate the physical navigation of the visitor. The visitor using a position aware device can be observed during the visit with respect to the objects he or she directs his or her attention to. The position and the time spent at the position are first indicators of attention in the particular exhibit. If the time spent in the critical position is very short it may be assumed that the visitor is not interested in the exhibit. If the time increases and the number of information pieces that the visitor selects from the information guide increase then the probability that the visitor is interested in the exhibit can be assumed to be higher.

In a nomadic usage context the user’s navigation in the information space of the system and the navigation in the physical space may be coincident. The user walks

to an object in the physical space and selects information about the object in the information space. In a location aware system the user model can evaluate both the user's navigation in the physical space and the navigation in the information space. In the positive case where the user selects information about the objects seen in the physical space there is redundancy; both navigations tell the user model that the user has approached a particular object. From both indicators the user model may infer that the user is interested in the approached object.

From the kind of an exhibit, i.e. from the quality of an exhibit identified in the taxonomy of the domain model, e.g. from its genre or style, it can be inferred which next exhibit or which series of exhibits (a tour) can be proposed to the visitor. By navigating through the physical space the visitor implicitly communicates to the user model the prevalent interests in the kind of exhibits. The interest evaluation can even be enriched by assessing the approach to the exhibit, of whether the visitor only views an exhibit from a general position or whether he or she chooses several positions to see different views and details. There is evidence about visitors' differentiated navigation behaviour. Varying distances and direction to view artworks have been found in an empirical study (Specht 1998) where over 500 visitors of five European museums were asked for their actual navigation approach to exhibits.

Visitors not only communicate their interest in particular kinds of exhibits, they also communicate their interest in specific content about the exhibits by selecting pieces of information about an exhibit from the information system. If the information about exhibits has been structured in a content taxonomy inferences can be made from the selected content to a content class of interest. The more explicit the information structure is the more effective the information can be adapted to the interest of the user. The information can for instance be structured by classes of information about the general meaning of the exhibit, the historical background, the domain-specific value (i.e., technical or artistic details), and stories about the exhibit. The most preferred information class can be proposed to the visitor automatically.

Until now movements of visitors are used to infer their interest in objects or content. Evaluations of visitor movements have been proposed without referring to underlying interests (Gabrielli, Marti, & Petroni 1999). The authors rely on the approach by Véron and Levasseur (Véron & Levasseur 1991) who propose a classification of visitors according to their "visiting style" evaluating the sequence of exhibits in the exhibition (ibid., 18). The kind of visitor movement is observed and styles of stereotypical movements are classified. Twenty-one visitors could be classified by the four categories: ANTS, FISHES, BUTTERFLYS and GRASSHOPPERS; 4 visitors showed a "mixed" style of navigation (Véron & Levasseur 1991, 193). In the reception of the approach by (Gabrielli et al. 1999) the classification of a visitor is no longer made stereotypically describing a visitor uniquely as one of the four animals but as an estimation of the "degree of compatibility between the user's movement pattern and the four stereotypes" at a given point of time (Bianchi & Zancanaro 1999, 105). The characterisation of a visitor is a list of probabilities, e.g., FISH 20%, ANT 30%, BUTTERFLY 50%, GRASSHOPPER 10%. In this reception the visiting style is assumed to be dynamic, i.e., the style can develop during the visit from one pattern to another. No explanation is made why the visitor follows a particular visiting style and no prediction is made when the visiting style changes. For a given visiting style a particular information is said to be appropriate: most for an ANT, least for a GRASSHOPPER and medium for a FISH and a BUTTERFLY. The correlation

between a visiting style and the information needs is determined by empirical observations of the visitors' overt movement behaviour and information reception.

There is another approach that tries to classify the visiting navigation by (Umiker-Sebeok 1994). In this approach visitors were observed and additionally interviewed about the visit and about their perception of the exhibition and of the exhibits they have actually seen to identify the cognitive strategy of the visiting behaviour. The author identifies 4 cognitive strategies of visitors: a pragmatic reception strategy, a critical reception strategy, utopian reception strategy, and a diversionary reception strategy. The classification can be derived partly from movement patterns in the physical space but it also refers to subjective interpretation of the experience by the visitors given in an interview. In the description of these movement patterns the author refers to the visiting style model by (Véron & Levasseur 1991) but she prefers to combine the BUTTERFLY and the GRASSHOPPER to one visiting style "leaping". So, three movement patterns are distinguished: crawling, leaping, swimming. Crawling is defined as a "steady, systematic, movement from beginning to end"; "leaping pattern (is) characterised by a more erratic jumping back and forth between displays in different parts of the gallery" and "swimming pattern" is described as "one where the visitor flows through the center of the gallery space with almost no stops" and his or her "refusal to negotiate the intended meanings of the gallery" (Umiker-Sebeok 1994). She uses a behaviour property metaphor rather than an animal being metaphor as more appropriate to describe a visiting style. Umiker-Sebeok (Umiker-Sebeok 1994) shows the relation of the cognitive styles to the movement patterns in the following table:

Table 1: Movement patterns of different groups of visitors by (Umiker-Sebeok 1994)

N=41	Pragmatic (29%)	Critical (17%)	Utopian (22%)	Diversionary (32%)
Crawling (46%)	50%	71%	56%	23%
Leaping (44%)	25%	14%	44%	77%
Swimming (10%)	25%	14%	0	0

The two navigation approaches were originally meant to be analytic. The visiting style model has been adopted by (Gabrielli et al. 1999) as a pragmatic model for inferences of information content of a mobile information guide. Based on the current visiting style information presentations are composed. Long and detailed presentations are proposed for ANTS, short presentations are proposed for GRASSHOPPERS. The inference of information presentations is limited by the unknown persistence of a visiting style. It is supposed to be subject to change: An ANT may mutate to a GRASSHOPPER from one minute to another or from one exhibition hall to another. The visiting style may be determined by temporary physical obstacles or other visitors (crowds) in the room. Or the visiting style may be determined by the kind of artworks relevant to the interests or the knowledge of the visitor acquired during the visit. As far as the physical movement of the visitor is not reflected together with the domain model (taxonomy of the artworks) the space model (location of the artworks in the physical space) and the user model (especially the visitor's interests) the predictive power of the visiting style approach may be

poor. It may be a first guess if no knowledge about the taxonomy of the artworks, about the location of the specific artworks in the physical space and about the interests of the visitor in particular kinds of artworks is available. But the predictive power of the evaluation of the movement of the visitor will considerably increase once all these factors are considered in a combined model. In figure 1 we try to show a process model of variables constituting the information needs of a visitor and possible adaptations of information presentation that can be inferred from the information needs by an adaptive information system we shall present in the next chapter.

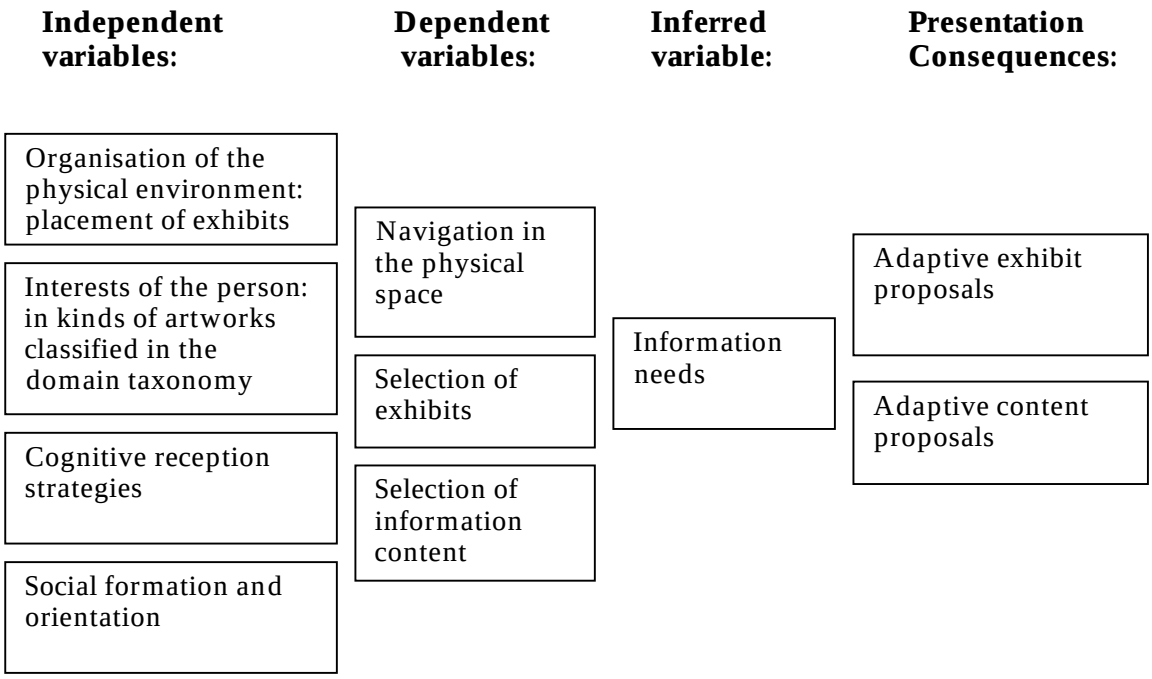

Figure 1: A process model of variables constituting the user's information need in a mobile context

3. A Prototype of a Context-Sensitive Nomadic Information System

Hippie as an internet-based guide offers added value to current information facilities by supporting all along the process of mobile activities. The process support is made possible by the nomadic characteristic of the system that allows the user to have access to his or her personal information space from all places independently from specific. The information selected and presented to the visitor reflects the location (at home or in front of an exhibit), the interests, the knowledge and the presentation preferences of the user. Dynamic elements for animated interpretation and auditive modality complement the visual modality preoccupied by the physical environment. The user is equipped with a handheld computer and a headphone to listen explanations of the current object and environment to immerse into the subject of interest. The user is left alone with the physical environment and the complementary explanations; via the communication function of the system he or she can also get in

touch with other individuals present in the real or virtual exhibition for appointments or for communicating suggestions.

In the following we describe the main features of the system to explain the benefit for the users: the process support by permanent system accessibility, the location awareness of the system to present information suitable to the current position of the visitor, multimodal information presentation to exploit the range of human perception, and the information adaptation to the user's knowledge and interests. Additionally some features are described that increase the practical value of the system.

3.1 Internet connectivity for continuous information with different devices

Internet connectivity provides access to the information basis from all over the world. At home the user can access the system with a desktop computer with high resolution representations to study the site of interest, e.g., a content list and pictures of an exhibition, descriptions of individual artworks and artists as well as practical information about opening hours, ticket prices etc., and to prepare an actual visit. The visit in the exhibition is supported by a handheld computer (PDA) with wireless LAN connection.[2] Access points provide the network connection within the museum. Being in the museum the user can receive the same information space he or she is already familiar with from sessions at home. The same richness of information is available even the visitor will not see a high-resolution representation. On a small screen only a thumbnail icon will be presented to reassure the visitor that the information that is presented is about the artwork he or she is in front of. Not the device follows the user but the information access is ubiquitous.

3.2 Location awareness

The user of the nomadic system is free to move around in the physical space. The system identifies the current position of the user in two ways. It knows about the type of computer and the environment the user is connected to. At home a big computer with high resolution and high bandwidth is used. In the museum a small computer with a small screen and lower bandwidth requires an adaptation of information presentation: less explicit interaction, more implicit interaction by navigation in the physical space, more audio presentation than text, less detailed graphical presentations and more thumbnails.

The second type of location awareness means the current co-ordinates of the visitor within the museum. By infrared infrastructure the position and by an electronic compass the direction of the visitor is identified and transmitted from the handheld computer to the server so that the server can automatically send the appropriate information for the visitor about the current exhibit. The infrared infrastructure consists of emitters being installed on the walls underneath each exhibit. The emitters send an ID to a receiver being fastened on the jacket of the visitor or attached to the user's headphones and connected to the handheld computer. Additional emitters are installed above each door of the museum allowing the

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[2] Currently no PDA is available with a PCMCIA slot for the wireless and for infrared receiver (see next paragraph). Therefore at present we use a Toshiba Libretto 100 CT. Suitable PDAs are announced for the near future.

identification of the visitor passing the entrance of a room before entering into the cone of an exhibit emitter. By this means a continuous localisation of the visitor can be used for the information selection and be displayed on a map of the museum if the visitor requires support for the navigation in the physical space, e.g., to find an exhibit of interest.

If a new item of potential interest is detected by the infrared component the system presents an “earcon” combined with a blinking “News” icon on the screen that can be clicked by the user. Then the system displays one or more names and thumbnail presentations of the current exhibits[3]; with a follow up hyperlink the user can start the presentation. A sequence of the "News" notification, the display of close paintings to be selected and the interesting presentation of the third option "Armour and Mercury" is shown in figure 2.

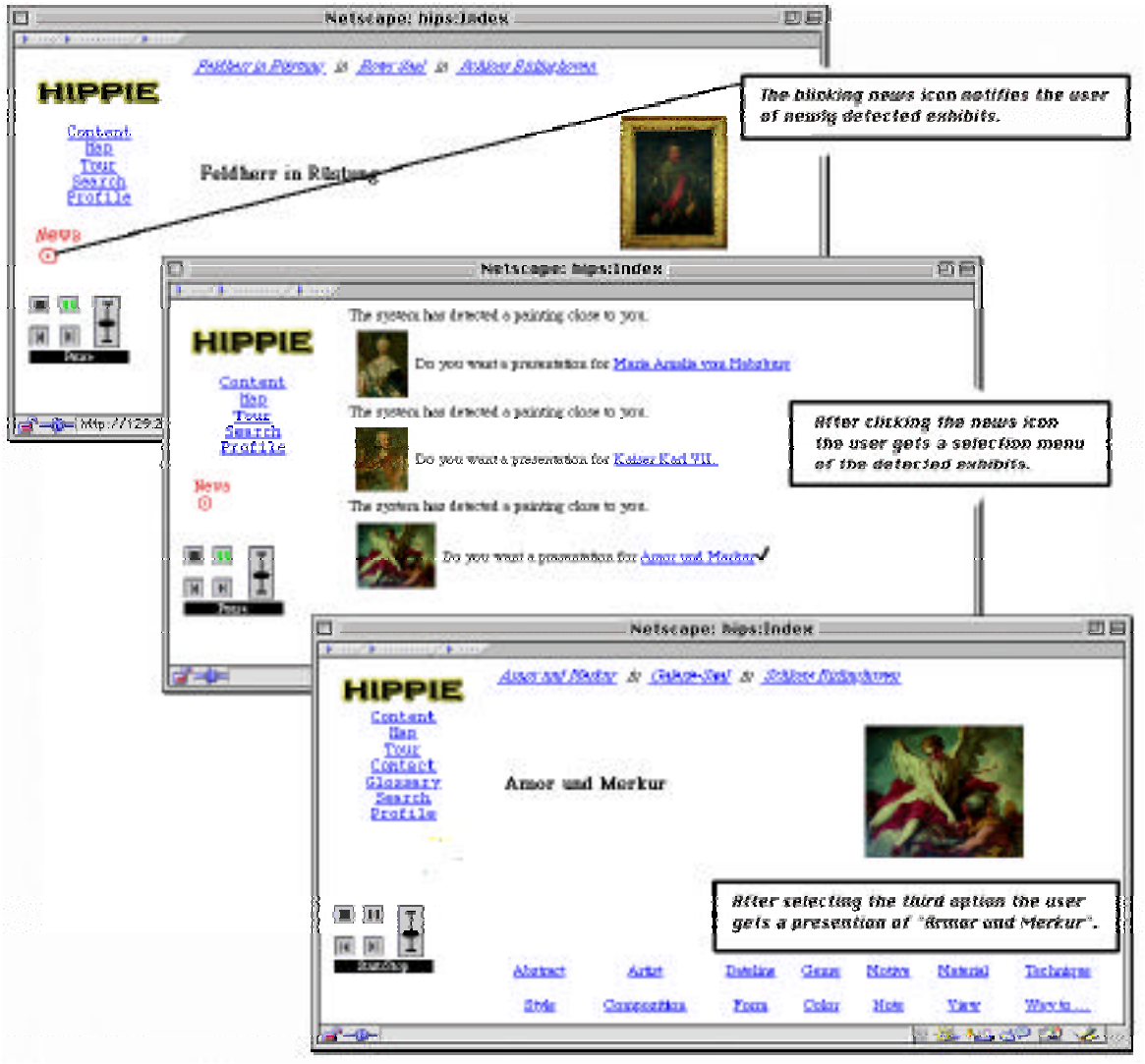

Figure 2: Notification of a new exhibit next to the wandering visitor

[3] In case of small exhibits or exhibits one above the other an infrared emitter is connected to several exhibits so that having clicked the “News” button the user receives a list of items.

3.3 Multimodal information presentation

The information presentation for visitors during the preparation and evaluation phases is unimodal containing pictures and text. This type of presentation reflects the typical interaction and perception style of a user at a desktop and enables easy reading and printing including scanning and browsing the information space. The information presentation during the visit is multimodal containing written text on the screen and spoken language via headphones and multicodal including text, graphics and animations. The visitor's visual attention is free for the physical environment, especially for the exhibits. Most information is presented without requiring a look of the visitor on the screen. The audio information to be presented is currently composed by snippets of canned texts spoken by a human being. Later also computer-generated language can be used, once it is of sufficient quality. At present 819 audio objects are included in the system. For the paintings between 160 and 300 sec of presentations of 7 to 25 attributes are offered with an average time of 207 sec. For all artworks, including sculptures and art crafts, an average time of 90 sec is offered.

There are some cases when a look of the visitor on the screen is necessary. The first is the navigation support that goes beyond a simple direction giving hint, e.g., go right, turn left and the like. An orientation in the physical space and the location of oneself and of exhibitions of interest may require a graphical map with identifiers for the visitor and for the exhibitions. The second case where visitors may need screen displays are visual aids to understand an artwork, e.g., the composition, the form design or the colour design. The electronic guide provides explanations of such features of artworks not only by textual descriptions but also by graphical illustrations and videos. Figure 2 shows an example of a graphical form design explanation and explaining text displayed right to the graphical illustration (the text is also presented auditively via headphones).

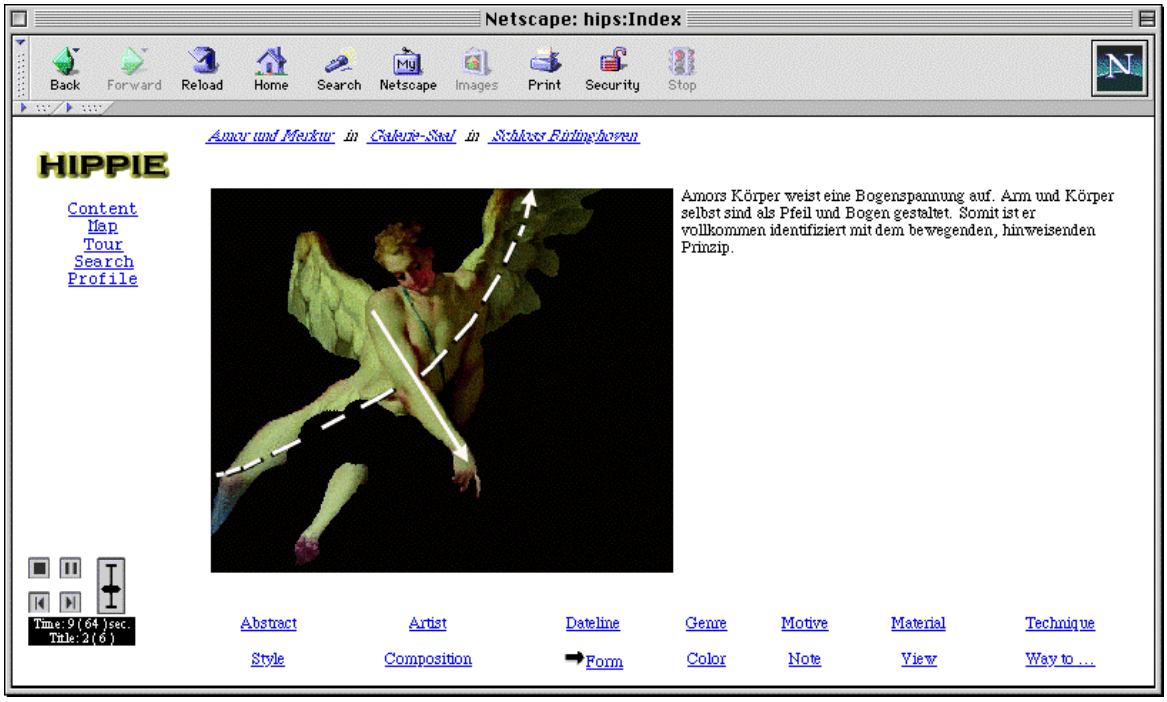

Figure 3: Form design description by graphical teaching lines with written and spoken text

3.4 Information adaptation to user's knowledge and interests

As described above the information selection and presentation is adapted to the currently used device, to the network connection, and to the location of the user. Now we will describe the adaptation of the information selection and presentation to the individual user (for user adaptation see (Kobsa & Wahlster 1989; Oppermann 1994). The user can be more or less competent of and interested in the domain in question. The adaptive component runs a user model describing the knowledge and the interests of the user. The user model automatically evaluates the user's interaction with the system in the information space and the user's navigation in the museum, i.e., in the physical space. Externally acquired knowledge is not accessible to the system; interests can only be evaluated based on the interaction of the user with the system; alternatively the system allows the user to specify prominent interests in a user profile dialogue.

If the user has used the system to select information about an exhibition, an artist, an artwork, particular attributes of an artwork and so on, the system updates the user model for seen entities and seen topics. For the following presentations it can adapt the information to the user's assumed pre-knowledge and interests. The adaptation to the assumed pre-knowledge is performed by avoiding redundancy (see also (Not, Petrelli, Stock, & Zancanaro 1997)). A painting that has already been seen by the user and explained to him or her by its name, author, dateline and style will only be reassured by its name when the user selects it a second time; more information are offered of course for explicit requests of the user.

The adaptation to the assumed interests of the user is provided by adaptive tips. If a user selects a number of exhibits the user model identifies common attributes of the selection in terms of, e.g., artist, style or genre. In case of exceeding a rule-defined threshold the system initiates a "Tip" displayed by a three times blinking light on the screen that can be clicked by the user. The system presents an observation as a list of objects the user has selected, e.g., paintings from the genre "mythology", and a recommendation of a tour the user can start encompassing other paintings of the genre "mythology" to be seen in the museum. Two screenshots with a blinking light notifying the user of available tour proposals and a cumulating of three tours with the system's observations and inferred tour proposals are shown in figure 3.

The same rule-based mechanism is applied for the presentation of attributes of the artworks. If the user selects a set of particular interesting attributes for the user the system recommends to present the set of attributes as a default sequence of topics for the given class of artworks. The user who is more interested in the history and social background gets a sequence of topics like biography and period, the user who is more interested in art analytical topics gets a sequence of composition and form and colour design.

By adaptations of the information selection and presentation the benefit of a visit for the user is expected to be higher, especially the knowledge and understanding of the exhibition in general and the exhibits in particular but also the richness of experience can be intensified by personalised information.

Figure 4: Notification of an adaptive tour proposal

3.5 Annotation, explanation and communication

Hippie provides additional features to support the individual user and a user group. For the process of a visit at different times and places it is helpful for the user to make notes attached to exhibitions or to individual artworks in order to store personal explanations or bookmarks available during a visit. An annotation button “notes” attached to the presentation of the exhibits supports this goal.

The “contact” function of the system allows the user to communicate with other users. The communication can be directed to a dedicated addressee (a partner, a family, a group). A list of currently present users is offered as well as the possibility to enter a full e-mail address to contact a remote user. Recommendations can be exchanged while moving independently through the physical space or simply appointments can be made to meet in the cafeteria in half an hour. Messages can also be directed to the public as a contribution to a growing knowledge base about the environment.

For definitions of terms and descriptions of names a “glossary” is available that can be addressed as a function via the main menu and in the context of content description on the fly via hyperlinks.

By the combination of features described above Hippie makes use of Weiser's vision, called calm technology by ubiquitous computing (Weiser 1991). The equipment used in the museum and the information and communication interface is designed to let the visitor walk in the physical space of the museum getting access to a contextualised information space tailored to the individual needs and the current environment.

4. Evaluation

The added value of the system compared with current information media has got positive feedback from experts from computer science and cultural heritage domain (museum curators, art educators). During the development of the system formative evaluations have been conducted with human factor experts and an art educator. The input has been used to improve the content and the user interface of the system. The current issue of evaluation is the dynamic of the meta-dialogue between the system and the user for the location aware presentation and for adaptation proposals. There is a goal conflict between the full control of the dialogue to the user and a short and easy confirmation of system initiated proposals. In case of the location aware presentation of a new item of potential interest a sound icon (earcon) is presented combined with a blinking "News" icon on the screen that can be clicked by the user. The system presents the exhibit the user is in front of and the user can start the presentation. Sound (earcon), blinking "News" icon, and exhibits are presented and have to be perceived and controlled by the user. In case of the adaptive tour proposal a blinking "Tip" icon, observation(s) of seen objects and proposal(s) of suggested tour(s) have to be perceived and controlled by the user. At least for the mobile scenario we are looking for simpler ways of a meta-dialogue that reduces the dialogue steps but keeps the user in control.

Summative evaluations of the system have been performed with domain experts, i.e., artists, art educators, and museum curators during a one-day demonstration and feedback workshop. The experts confirmed the added value of the nomadic information system both for the process support of preparing, conducting, and evaluating a museum visit and for the understanding of the artworks with respect to the wide spectrum of information provided by the system. The participants pointed out that the user-system interaction of a mobile guide has to be designed for specific requirements of the exhibition domain. On the one hand, for technical exhibitions a mix of automatic offers and active requests of information might have a stimulating effect. On the other hand, in art exhibitions, perceiving art might be limited by a conflict between promenading an exhibition and searching information. The permanent offer of structured information might obstruct the visitor to get involved in a silent conversation with an artwork and to develop an individual understanding. Providing personalised views and individual tours was appreciated. Especially personalised information for visitor interests and knowledge was considered important. Adaptive information selection reduces redundancy and information overload. The overall feedback was very positive expecting that new media guides increase the attraction of museums.

Evaluations with real users are currently conducted. Four media are compared to analyse the relative value of information presentation methods: the mobile guide Hippie, a stationary kiosk information system placed in the centre of the exhibition, an audio guide playing back descriptions with simple play and skip controls, and a

book guide with texts and pictures. All media present identical content but different modality and interactivity. The richest modality and interactivity provide the mobile Hippie and the kiosk system, the former identifying the position and history of the user automatically the latter requiring all controls manually by the user. The most restricted but also the most comfortable and easy to use media are the audio guide and the book, the former being familiar from CD-players and the latter from classical catalogues.

Limited numbers of visitors supported by the mobile Hippie showed that users with extensive interest and pre-knowledge in art immersed into the perception of the exhibits on the wall and the information presented by the system. They exploited the richness of the information space both quantitatively with an average presentation time of 2.5 min. per exhibit and qualitatively with audio and text presentation and additional graphical support for the art analytical understanding of aspects like composition, form or colour design. Visitors with only curiosity and low pre-knowledge used the system for short snippets of information while wandering through the exhibition. Visitors using the other media were less engaged in system interaction and more relaxed with presentations. Whether the average visitor can be stimulated to perceive a more intensive presentation and develop a more extensive understanding of artworks will be investigated in the in-depth evaluation study.

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