CHI'95 Workshop on

Formal Specification of User Interfaces

Position paper

TITLE: **FORMAL SPECIFICATION OF MULTIMODALITY**

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ABSTRACT :

We propose two topics for discussion at the workshop and describe one of our contributions to the field. One activity relevant for the workshop would be to classify current formalisms and provide recommendations for using a particular class of notations given a goal and a specific development context. The second issue to consider is the difficult problem of interoperability between notations. Our contribution to the field covers the formal definition of properties useful for characterizing multimodal interactive systems in terms of design, usability and implementation.

CV'S : THE POSITION PAPER WILL BE PRESENTED BY LAURENCE NIGAY

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KEYWORDS: Multimodal interaction, complementarity, assignment, redundancy, equivalence, usability.

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1. INTRODUCTION

Formal specification of user interfaces is an emerging area of research. Although promising, this domain appears like a mosaic of approaches which calls for structure. The multiplicity of approaches and notations is quite acceptable but users of formal techniques need to know which notations to use for a particular design goal in a specific development context. One way of structuring the "formal notation space" is to consider the software development process and, for each step, identify the appropriate candidates relative to some criteria (purpose, coverage, readability, etc.).

Given a formal notation space, we need then to consider the interoperability between notations. Clearly, in user interface design the “one notation fits all” principle is not conceivable. Each scientific community involved in the development of an interactive system should be able to keep its preferences for better performance but these preferences should be expressable in terms transferable to other partners. It is our belief that mechanisms that insure the interoperability between existing notations is one concrete way for bridging the gap between developers and designers with different background, and also for avoiding loss or distorsion of information through the development process.

At LGI, we have developed Siroco, an object-oriented conceptual model of the interaction supported by a specification language [10]. A Siroco description is compiled to produce an executable user interface on top of Motif. Siroco is one of the first model-based rapid prototyping tools like UIDE and Humanoid. Recently, we have deviated from using formal specifications for user interface generation to consider predictive evaluation. We are currently studying predictive evaluation for critical situations in groupware [4] as well as for multimodal interaction. This paper focusses on our contribution to the formal definition of properties that characterize the usage of modalities within a user interface.

2. MULTIMODALITY

Multimodal user interfaces support interaction techniques which may be used sequentially or concurrently, and independently or combined synergistically [7]. Novel aspects of interactions must be considered, such as the fusion and fission of information, and the nature of temporal constraints on the interactions. Numerous formal notations are dedicated to user interface design including the FSM (Formal System Modelling) analysis [3], the LIM approach (Lotos Interactor Model) [12] or more recently the ICO formalism based on Petri Nets [11]. Although they consider temporal constraints, these formalisms do not cover the specifics of new interaction technology such as multimodal user interfaces.

In this paper, we propose a notation to formalize the CARE properties as a simple way of specifying and assessing aspects of multimodal interaction: the Complementarity, Assignment, Redundancy, and Equivalence that may occur between the interaction techniques available in a multimodal user interface. Equivalence expresses the availability of choice between multiple modalities while assignment designates the absence of choice. Redundancy and complementarity go one step further by considering the combined used of multiple modalities under temporal constraints. Redundancy is defined by the existence of redundant information specified along different modalities and complementarity is characterized by cross modality references.

Our motivation for formalizing the notion of multimodality in terms of the CARE properties is two-fold:

1- Multimodal interaction is complex and underspecified. New concepts are emerging and expressed informally [5]. As observed in [6], the imprecision of informal definitions opens the way to interpretation, errors and omissions. In order to communicate effectively with designers and implementers, we have defined some of the dimensions of multimodality in an unambiguous way.

2- Formal specifications can help designers to discover inconsistencies and usability problems before the interface is developed. They also make explicit the consequences on software implementation. In this article we will consider the usability issues of the CARE properties. Implications on software design are discussed in [9].

The next section provides the formal definitions for the CARE properties. In the last section, we use the notion of compatibility between user preferences and system properties to show how the CARE properties interact with user modelling and predict usability during system design.

3. CONCEPTS AND FORMAL DEFINITIONS: THE CARE PROPERTIES

The formal expression of the CARE properties relies on the notions of state, goal, modality, and temporal relationships that are crucial concepts to define multimodality.

A *state* is a vector of observables, that is, a set of properties that can be measured at a particular time to characterise a situation. A *goal* is a state that an agent intends to reach. An *agent*, e.g., a user, or the system, or a component of the system, is an entity capable of initiating the performance of actions.

A *modality* is an interaction method that an agent can use to reach a goal. To model the expressive power of a modality m, that is, its capacity to allow an agent to reach state s' from state s in one step, we use the function *Reach(s, m, s')*. A sequence of successive steps (or states) is called an *interaction trajectory*.

A *temporal relationship* characterises the use over time of a set of modalities. The use of these modalities may occur simultaneously or in sequence within a *temporal w*indow, that is, a time interval. Alternatively, only one modality from a set may be used. Let *Pick(s, m, s')* be a predicate that expresses the use of *m* among a set of modalities to reach *s'* from *s*.

Modalities of a set M are used simultaneously (or in parallel) if, within a temporal window, they happen to be active at the same time. Let *Active (m, t)* be a predicate to express that modality *m* is being used at some instant *t*. The simultaneous use of modalities of a set M over a finite temporal window tw can be formally defined as:

$$Parallel\ (M, tw) \Leftrightarrow (Card\ (M) > 1) \wedge (Duration(tw) \neq \infty) \wedge (\exists t \in tw \cdot \forall m \in M \cdot Active\ (m, t))$$

where *Card (M)* is the number of modalities in set M, and *Duration(tw)* is the duration of the time interval *tw*.

Sequential events may have to occur within a temporal window to be interpreted as temporally related. If they occur outside this window, then they may be interpreted differently. Modalities M are used sequentially within a temporal window tw if there is at most one modality active at a time, and if all of the modalities in the set are used within tw:

$$Sequential\ (M, tw) \Leftrightarrow (Card\ (M) > 1) \wedge (Duration\ (tw) \neq \infty) \wedge (\forall t \in tw \cdot (\forall m, m' \in M \cdot Active(m, t) \Rightarrow \neg Active(m', t)) \wedge (\forall m \in M \cdot \exists t \in tw \cdot Active(m, t))$$

Temporal windows for parallelism and sequentiality need not have identical durations. The important point is that they both express a constraint on the pace of the interaction. For example, using multiple modalities simultaneously may be appropriate for the user but may require extra processing resources from the system side or imply a specific software architecture [9]. The absence of temporal constraints is treated by considering the duration of the temporal window as infinite.

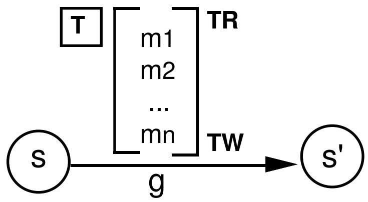

Figure 1: A notation for expressing CARE properties.

Figure 1 shows the relationships between the concepts used in CARE: an agent having reached state s, may have (or has) the goal g to reach state s' by means of the non-empty set of modalities M={m1, m2 ... mn}. These modalities are linked by temporal relationship TR (TR::=|| | ; | 1, for parallelism, sequentiality, and selection of one interaction technique respectively), and constrained by a temporal window TW (TW::=<interval> | ∞). The symbol T at the upper left denotes the CARE property (T::=C | A | R | E).

Equivalence: Modalities of set M are *equivalent* for reaching s' from s, if it is necessary and sufficient to use any *one* of the modalities. M is assumed to contain at least two modalities. More formally:

$$Equivalence\ (s, M, s') \Leftrightarrow (Card(M) > 1) \wedge (\forall m \in M\ Reach\ (s, m, s'))$$

Equivalence expresses the availability of choice between multiple modalities but does not impose any form of temporal constraint on them.

Assignment: Modality m is *assigned* in state s to reach s', if no other modality is used to reach s' from s. In contrast to equivalence, assignment expresses the absence of choice: either there is no choice at all to get from one state to another, or there is a choice but the agent always opts for the same modality to get between these two states. Thus we can define two types of assignment:

$$StrictAssignment\ (s, m, s') \Leftrightarrow Reach\ (s, m, s') \wedge (\forall m' \in M.\ Reach(s, m', s') \Rightarrow m'=m)$$

$$AgentAssignment\ (s, m, M, s') \Leftrightarrow (Card(M) > 1) \wedge (\forall m' \in M.\ (Reach\ (s, m', s') \wedge (Pick\ (s, m', s')) \Rightarrow m'=m)\ )$$

Redundancy: Modalities of a set M are used *redundantly* to reach state s' from state s, if they have the same expressive power (they are equivalent) and if all of them are used within the same temporal window, tw. In other words, the agent shows repetitive behaviour without increasing its expressive power:

$$Redundancy\ (s, M, s', tw) \Leftrightarrow Equivalence\ (s, M, s') \wedge (Sequential\ (M, tw) \vee Parallel\ (M, tw))$$

Complementarity: Modalities of a set M must be used in a *complementary* way to reach state s' from state s within a temporal window, if all of them must be used to reach s' from s, i.e., none of them taken individually can cover the target state. To express this adequately, we need to extend the notion of reachability to encompass sets of modalities: REACH(s,M,s') means that state s' can be reached from state s using the modalities in set M.

$$Complementarity\ (s, M, s', tw) \Leftrightarrow (Card(M) > 1) \wedge (Duration(tw) \neq \infty) \wedge (\forall M' \in \mathbf{P}M\ (M' \neq M \Rightarrow \neg REACH\ (s, M', s'))) \wedge REACH\ (s, M, s') \wedge (Sequential\ (M, tw) \vee Parallel\ (M, tw))$$

Deictic expressions, including the "put that there" paradigm, are examples of complementarity. A source of complexity for software designers is that distinct actions produced within the same temporal window through different modalities are not necessarily complementary. Elsewhere [8] [9] we describe how these issues can be supported consistently through a reusable software mechanism.

To be complete, we need to discuss issues of coverage and refinement. Coverage is defined by the set of states for which a particular property holds. Coverage of a property over states can be used as a metric for assessing consistency. The CARE properties can also be applied at multiple levels of refinement for examples in terms of devices and interaction languages, as well as in terms of goals [8].

Designers can exploit the recursive nature of the definition of CARE to reason about multimodality at the appropriate level. For example, in the early stage of the life cycle, one may reason at a coarse grain to flesh out the most salient requirements about multimodality. Once the system is designed, one may need to go into more details to make sound predictive assessments. Once the system is implemented, effective use of the system can be observed and interaction traces may be analyzed at fairly low level of details. In all of these circumstances, the CARE properties apply.

4. USABILITY ASSESSMENT

As explained in [2], the CARE properties of the computer system have a counterpart in corresponding properties of the user: the User-CARE properties. As with the system CARE properties, the user properties are concerned with the choice between different modalities for communicating with the computer.

The compatibility conditions between CARE and User-Care properties are defined in [2]. Those conditions define the way in which CARE and user CARE-like properties interact in the design of the computer system. They provide a framework which puts the computer and the user on an equal footing, and within which the concrete circumstances of a particular design can be fleshed out to guide the assessment of usability. An important conclusion is that neither the properties of the system alone, nor those of the user alone, determine usability. System modelling can determine the properties of the system, but to understand those of the user, and hence usability, we need to turn to user modelling such as the Programmable User Modelling [1].

5. CONCLUSION

In this paper we have proposed two topics for discussion at the workshop and described one of our contributions to the field. One activity relevant for the workshop would be to classify current formalisms and provide users with recommendations for using a particular class of notations in a given development context. The second issue to consider is the difficult problem of interoperability between notations.

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