Abstract for the First International Workshop on Intelligence and Multimodality in Multimedia Interfaces: Research and Applications

INFORMATION MAPPING IN PRACTICE

Rule-based multimodal interface design

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1. Introduction

The design of a user interface can be considered an *information mapping* task. The task consists in mapping (a) information from the task domain of the artefact being designed as well as other relevant constraints on the design process, onto (b) a set of input/output modalities which, when fully specified, will constitute the user interface of the artefact. Interface designers thus essentially solve information mapping problems whether or not they think of themselves in those terms. This raises the question if it might be possible to provide knowledge-based support of the information mapping process. At a recent workshop at CHI'95 on "Knowledge-Based Support for the User Interface Design Process", it was proposed that current human-computer interaction research adopt a weak sense of the term 'knowledge-based support' according to which not only rule-based AI systems but also systematically developed hypertext and hypermedia training material and sets of guidelines, walkthrough methodologies, and other similar approaches would count as knowledge-based support. In this sense, several examples of knowledge-based support of the information mapping process already exist. The domain of static graphic graphs is well explored [13,18,19]. Hovy and Arens [15] wrote a seminal paper which called for a more general approach to information mapping. The Namur group has worked on AI knowledge-based support of information mapping in the domain of business oriented applications for nearly a decade [14,20]. Over the last 2-3 years we have been developing an approach to this question, called *modality theory*. This overview paper presents the research agenda of modality theory (Sect. 2), introduces modality theory and the information mapping methodology (Sect. 3), describes recent results on knowledge-based support of the information mapping process (Sect. 4), and concludes by indicating some core questions for future work (Sect. 5).

2. The Research Agenda of Modality Theory

Literally thousands of different combinations of input and/or output (information) *representational modalities* are currently becoming available to designers of interfaces for human-computer interaction, from unimodal spoken language input to complete multimodal virtual reality interactive systems. Each single modality or multimodal combination has its own specific capabilities of representing or conveying information and it is obviously important to be able to select the right combination of modalities for a given application. The question is how this might be done in a principled manner so as to optimise the usability of the interface, given the specific purpose of the artefact to be designed. Answering this question involves addressing the research agenda of modality theory whose development forms part of the Esprit Basic Research project AMODEUS-2 [2]. The agenda is as follows [3]:

(1) to establish sound foundations, both conceptually and in terms of an operational taxonomy, for describing and analysing any particular type of unimodal or multimodal output representation relevant to human-computer interaction;
(2) to create a conceptual framework for describing and analysing interactive computer interfaces so as to cover both input and output of information;
(3) to apply the results of steps (1) and (2) above to the analysis of the problems of information mapping between work or task domains and human-computer interfaces in information systems design.

The main problem raised by agenda item (1) is how to build a theoretical foundation for addressing the information representing capabilities of thousands of different, potentially useful combinations of output modalities. The only viable approach seems to be through the generation and analysis of a limited set of elementary or *unimodal* modalities from which any particular *multimodal* representation or modality combination can be built. The taxonomy of generic unimodal output modalities which resulted from adopting this approach is presented in [5,6]. Work is in progress on a taxonomy of input modalities (agenda item (2)). Agenda item (3) is to develop an operational ‘bridging’ representation between the science base of modality theory and design practice [1]. We call this bridging representation the *information mapping methodology* or IMAP.

3. The Information Mapping Methodology and Modality Theory

The IMAP methodology is assumed to proceed in two main phases [12]. In the *first phase,* the aim is to obtain the information which is needed to select a reasonable and possibly optimal mapping onto some interface input/output representation. The nature and variety of the information relevant to this end should not be underestimated. Relevant information includes information on task domain, intended users, task environment, task performance on representative tasks, user preferences, standards, resource constraints etc., but, of course, with a special focus on the actual information to be exchanged between user and system during task performance. The information or these interface requirement specifications should be represented explicitly and succinctly in some way. We ourselves use the Design Space Development (DSD) notation for representing design space structure [4, 10,11]. In the *second phase* of IMAP, the rules of modality theory are applied to the results of phase one in order to map the collected information onto a suitable set of input/output modalities. From the point of view of IMAP, modality theory consists in a large set of rules, such as, e.g., the following:

> Visualise high-specificity information in 1D, 2D or 3D spatial, such that freedom of visual inspection is less important than development, movement or change <->
> Consider using dynamic analogue graphics.

The expression '<->' is read, from left to right, as the 'if-then' of production rules. From right to left, rules are read 'modality X (e.g., dynamic analogue graphics) is [good/bad] at representing [left-hand side of rule]'. Core terms occurring in the rules such as 'specificity', 'dynamic analogue graphics' or 'freedom of visual inspection', are technical terms of modality theory. Technical terms belong to one of two categories, modalities and supporting theoretical terms. Modality theory includes 70 different unimodal modalities or modes of information representation in the media of graphics, acoustics and haptics. Modalities are analysed at up to 4 different levels of abstraction and the theory in fact claims exhaustiveness in its coverage of possible modalities at the levels of abstraction at which it operates [5,6]. The supporting theoretical terms are the terms, such as 'information channel', 'saliency', 'dimensionality' or 'freedom of perceptual inspection' which are needed in order to analyse individual modalities. One result of analysing the characteristics of individual modalities are the rules of modality theory.

An application of modality theory for the purpose of information mapping can be thought of as the application of rules such as those illustrated above. Rules 'fire' when triggered by appropriate information about the task domain of the artefact which is being designed. The result of information mapping will be sets of possible input/output modalities and modality combinations which are capable of representing the information required of the artifact. The next section describes how this works in practice.

4. The CERD Case Study

IMAP has been explored in a series of case studies. Early design of a spoken language dialogue system and the design of a toy 'water bath' monitoring and control system were analysed in [7]. In [21] IMAP was applied to PaTerm, an interactive tool for adding lexical databases to the commercial English-Danish patent text machine translation system PaTrans. Our understanding of the strengths and limitations of IMAP has been further advanced through a recent study of CERD, a flight sequencing tool for use by air traffic control officers [12]. The PaTerm and CERD studies represent applications of IMAP to full-scale realistic design processes.

Our analysis of CERD departed from a comprehensive DSD representation of the CERD design process, which had been done with no particular regard to the requirements of IMAP [17]. This representation turned out to be suitable for the purpose of IMAP as it provided a comprehensive representation of the design commitments which constrained the design of the CERD interface. The DSD representation thus allowed us to quickly proceed to the second phase of IMAP, i.e. the actual information mapping using the already existing rules of modality theory as well as new ones constructed for the purpose of handling the CERD problem.

Information mapping was done according to the following basic principle. Information mapping is inference. This type of inference leads from abstractly (i.e. linguistically) represented information representation requirements to physically instantiated human-computer interface modalities which express the required information. The basic principle, then, is that information mapping is only allowed when based either on general principles of logic or on rules of modality theory. In other words, inference based on designer's craft skill is not allowed. In this way, it can be made clear to what extent modality theory, being the science base of IMAP, actually does contribute to user interface design.

Briefly, the CERD functionality covers: the representation of data on a large number of flights waiting to be allowed to land; a small number of more or less complex operations which the air traffic control officer (ATCO) may execute on the flight queue, such as swapping or resequencing of flights; and e-mail communication between the ATCO and the National Airspace System (NAS) which authorises the ATCO's operations. To do the information mapping, one selects the pieces of DSD information one at a time and asks whether this particular piece of information either (i) directly implies a certain interface property or (ii) triggers a modality theory rule which in its turn produces constraints on the properties of the user interface being designed. A certain piece of DSD information may also do both (i) and (ii) or neither of them. The result of this process is called an *abstract interface sketch.* The sketch includes the interface objects and their properties in so far as these can be determined from application of modality theory. In the case of the CERD, which eventually turns out to require a static graphic interface including a number of different static graphic representational modalities, this abstract interface sketch can actually be drawn [12]. In any case, the interface objects can be succinctly described in language as a basis for their subsequent implementation [ibid.]. The reason why the interface sketch is necessarily abstract is that the rules of modality theory are not relevant to the fine details of interface design nor to the results of a very detailed user task analysis which can only take place once there is an approximate interface sketch to work on. The abstract interface sketch is such an approximate sketch.

The following example illustrates the IMAP treatment of actions on incoming flights.

(a) What to represent
There are 4 different types of action to be performed on the represented incoming flights using the CERD rest (or main) menu: assign, reposition, resequence and swap.

(b) IMAP Rules
10. Allow alternative types of action to be performed on the same represented data <->
Create interactors which clearly indicate the alternative types of action.

(c) Information representation
Create 4 static (Rule 7) graphic (Rule 2) interactors (Rule 10) which clearly indicate alternative types of action: an assign interactor, a reposition interactor, a resequence interactor and a swap interactor. Label the interactors ‘Assign’, ‘Reposition’, ‘Resequence’ and ‘Swap’, respectively (Rule 9). Interaction is through pointing gesture or touch (Rule 6).

Step (a) represents a piece of information drawn from the DSD representation of CERD. Step (b) shows the firing of a modality theory rule (Rule 10). Step (c) describes the derived interface properties. Their derivation requires the use of rules which have fired earlier during IMAP and which are referred to in brackets. The numbering of rules is done for ease of reference during IMAP. Some of the information represented in (c), such as there being 4 interactors, results from straight inference from (a) without the need for modality theory rules.

The IMAP analysis of the CERD required a total of 19 rules, many of which were re-used several times, and the result was an abstract interface sketch which could be used for detailed analysis of the more complex among the ATCO's operations, such as that of simultaneously resequencing a large number of flights. Arguably, this interface sketch comes close to representing all of the output objects and interactors needed for the CERD. The detailed representation of objects through choice of information channels and layout, however, is beyond IMAP which terminates when the objects represented in the abstract interface sketch have been grouped according to their functionality [12].

5. Conclusion and Future Work

The CERD IMAP analysis has been helpful in clarifying basic and interrelated issues in IMAP development such as (a) the level of interface design detail supported by modality theory. The PaTerm IMAP analysis had convinced us that the vast space of possibilities relevant to low-level interface design probably would exclude rule-based IMAP analysis at that level. This is supported by [20]; (b) the fact that IMAP should be used during early interface design where the space of possibilities is smaller; (c) proposing the abstract interface sketch as the end-product of using IMAP; (d) the role of the abstract interface sketch in supporting more detailed task analysis; and (e) how to maintain a 'purist' IMAP analysis based solely on rules and logic.

Many important problems remain, however. At the level of the science base, and even when we might have completed the full taxonomy and theory of unimodal input modalities, we would still need an understanding of *interaction* based on input and output theory and, if possible, "grammars" for how to combine different unimodal output modalities, different unimodal input modalities, and different unimodal input and output modalities. Given the applied purpose of modality theory, these issues will have to be addressed in close relationship with IMAP development.

At the level of information mapping, it remains unclear whether it will be possible to achieve consistency and completeness of the rules generated by modality theory. If not, modality theory may still be useful to, e.g., designer training or as a basis of a "lightweight" IMAP walkthrough methodology, but it will not be possible to mechanise IMAP. So a closely related question is whether and how to eventually mechanise IMAP. So far, we have created two generations of a hypermedia modality workbench and theory demonstrator which is being used to explore and demonstrate modality theory [9,16]. Use of this system for interface design support, however, still requires a good deal of natural intelligence. We are addressing these questions through further case studies in which IMAP is being applied to realistic interface design processes. A first commercial design case study has just been completed and the data are currently being analysed. IMAP was applied to the re-design a series of graphic-acoustic interfaces to a next-generation system for greenhouse monitoring and control. We, i.e. the IMAP developers, acted as consultants to the interface designers. Preliminary results indicate that the non-expert designer who did most of the design derived significant benefit from IMAP [8].

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Acknowledgements. The work reported in this paper was done on a grant from the Esprit Basic Research project AMODEUS-2 whose support is gratefully acknowledged. Thanks are also due to the anonymous reviewers whose comments have been taken into account to the extent possible within the space limitations imposed.