Composition Through Agent Negotiation : A Step Towards Fluid Interfaces

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Abstract. One of the next challenges in research on Human Computer Interfaces (HCI) is to give users the means to perceive and manipulate easily huge quantities of information in the minimum amount of time. Intelligent User Interfaces (IUI) have been proposed as a means to solve this problem. The *intelligence* in the interface makes the system more flexible and more adaptable. One subset of IUI is adaptive interfaces. An adaptive interface modifies its *behaviour* according to some defined constraints (technical, psycho-sensory and user-defined ones) in order to best satisfy globally all of them. In this paper we introduce the concept of fluid interfaces, a particular kind of adaptive interface on which the flow of information composes itself smoothly without any predefined fixed pattern but according to several parameters. We introduce the problems raised by self-composition in user interface, then describe our proposition of an agent architecture to achieve fluidity. Information is modelled through agents that negotiate according to technical, psycho-sensory and user-defined constraints in order to compose a dynamic display. We detail a prototype that validates the model and introduce a European project which is derived from the model and tackles industrial applications.

1 INTRODUCTION

More powerful hardware combined with its constant decreased cost brings about new needs and expectations from users. Henceforth users will still want efficient tools but also tools that are user-friendly, interactive, co-operative and smarter [6, 19]. Thus, quite a substantial amount of HCI research and development during recent years has focused on multimedia interfaces - with or without intelligence - in different domains such as document presentation, pilot's assistants, intelligent training or help to disabled people [3, 8, 9]. The most worthwhile feature of multimedia interfaces is of course the availability of several media to present information. It is particularly important where there is a need for different communication channels between an application and its users. So, more suitable presentations of information in different communication situations are possible.

IUI is an active field in which works are quite widespread and diverse [13, 24]. Research that aims to propose adaptivity, varies in the ways and means used to achieve adaptation. For example, the Intelligent User Interfaces group at DFKI, the German Research Center for Artificial Intelligence, uses a Knowledge-Base Systems (KBS) approach in automated multimedia authoring and multimedia presentation tools [2, 1]. [20] describes a dynamic news and email display. In this work, a design solution is considered as an emergent behaviour of a collection of active design agents, each of which being responsible for the presentation of a particular element of information. [21] presents the concept of plastic interfaces which are interfaces that are able to adapt themselves to the constraints of the hardware and of the environment.

We introduce in this paper the concept of fluid interfaces, a particular kind of adaptive interfaces. A situation, arrangement or idea that is fluid, does not have any fixed pattern or structure and is likely to change often. Furthermore a fluid movement is relaxed, smooth and graceful. In the same way, a fluid interface is an interface on which the flow of information composes itself smoothly without any predefined fixed pattern but according to the current state.

In industrial HCI, operators, system and context are continuously changing and are sometimes in contradiction with one another. Thus, this kind of interface can be viewed as the result of a balance between these three components and their changing relative importance. Our approach considers that such an interface can be modelled as a multi-agent system. The agents negotiate with one another to compose information on what we call the Interface Representation Space (IRS). The IRS is the union of all the physical output devices available to display information to users, for instance several screens and loudspeakers. As the importance of the agents changes according to modifications in the constraints, the composition evolves to keep representing the balance of each agent's point of view.

2 THE COMPOSITION PROBLEM

2.1 Background

The aim is to propose a model for a fluid interface in which flows of information are composed dynamically and smoothly, allowing users to visualize and manipulate them easily. Thus, the composition function takes flows of information as input and gives a particular organization of these flows of information as output (figure 1), taking into account :

1. A model of the system which has produced the information. This model gives the semantic and pragmatic knowledge about the information. This knowledge is used in the calculation of the relevance of each flow of information.
2. A model of the user, decomposed in two parts :
   - The definition of general human psycho-sensory rules.
   - A profile of user-defined preferences.
3. A model of output media and modalities which is used to find the most relevant way to display a piece of information.
4. A model of the IRS along with the resources currently available to choose the means to display information.

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5. The reactions of the user to what is presented to him.

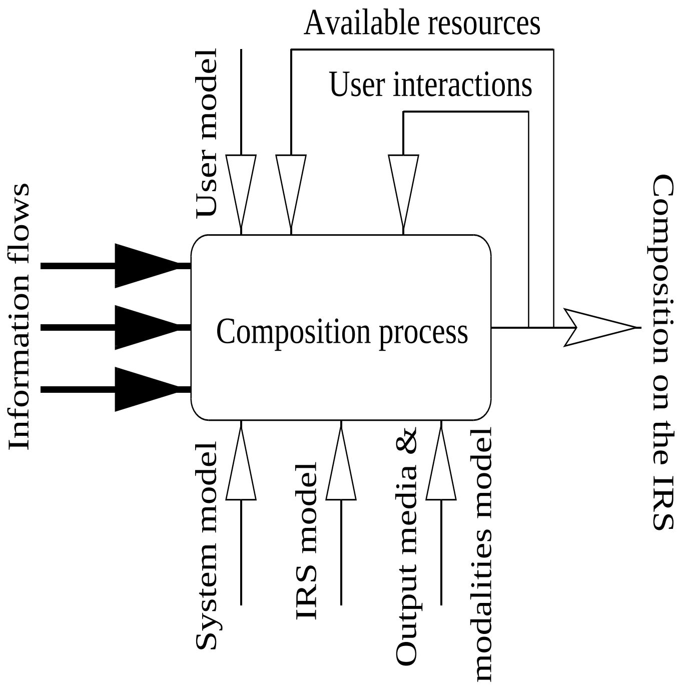

Figure 1. The composition process

In this paper, we particularly consider two points in adaptive composition :

1. The selection of the most appropriate pieces of information based on the system model and possibly on the user model.
2. The choice of the most relevant way to display them according to available resources, the IRS model, the user's model and the output media and modalities model.

2.2 Composition Requirements

To design the models needed in the composition process, we consider and analyze three types of composition requirements: constraints, style and preferences.

2.2.1 Constraints

Constraints are the rules necessary to produce meaningful compositions. In multimedia applications, these rules can be numerous and not easy to formalize [4, 7]. In the following, we present some of them that are simple and have already been integrated into our experimental model.

1. Technical constraints. They give the limits for the technical means used for presentation. They are described in the IRS model. For instance, a screen and a sound output apparatus form the IRS. These two devices can be divided into channels in which information is brought to be displayed. A simple technical constraint is that two pieces of information cannot occupy the same channel at the same time.
2. Psycho-sensory constraints. They deal with the capacity of the users to perceive and get information that is presented. There are a lot of possible rules. Most of them have to be given by an expert of this field but a few are common sense. For example, a window displaying an important piece of information should not be covered by another window which displays a less important piece of information. We present below three examples of these constraints :
   - Spatial stability. A piece of information should not move very much and suddenly on the screen without good reasons.
   - Time stability. The information must stay long enough to be consulted by the users. This minimum time is called the Semantic Critical Section (SCS). The SCS can vary a great deal according to the type of information and according to the context.
   - Semantic consistency. It deals with the meaning associated by the users to what they see or hear. For example :
     - Dynamic semantic consistency. Several pieces of information can be presented either in succession or simultaneously. If they are presented simultaneously, they will be interpreted by users as representing simultaneous phenomena. If they are presented in succession, they will be interpreted by users either as being semantically in succession, or being simultaneous, according to the context and the convention of style. For instance, an alarm is displayed and after this the schema of the system where the alarm occurred.
     - Static semantic consistency. When several semantically linked pieces of information are presented at the same time, their combined meaning should be respected. For example, related pieces of information should be placed close to one another, in order to emphasize their link and to ease the general understanding. For instance, in the case of the alarm and schema example of the previous paragraph, the schema should be placed close to the alarm.
   - Comfort constraints. They take care of the media and semantic workload of the users. For example :
     - Avoid static (too many pictures at the same time) and dynamic (two many pictures in succession) complexity.
     - Present several perspectives of the same piece of information.

2.2.2 Style

Style is in our work one particular predefined way information should be displayed. As in the Model-View-Controller framework [12] where the view is separated from its model or as with XML and XSL [22, 23] where information is separated from the way it is displayed, several different styles can be associated with one set of information. Style should facilitate the users's understanding and in so far as it can be useful for the objectives, should bring about perspectives concerning aesthetics. The style is expressed in the type of pictures (colors, angles, etc.), of sounds and in the way information is arranged or arranges itself on the IRS.

2.2.3 Preferences

Whatever the kind of interface, the users should have some way to customize it to their needs. Moreover, from a psychological point of view, the users should have somehow some kind of control over the interface especially if it is self-adaptive, thus less predictable and seemingly less under their control. So, the users should be able to give *semantic* preferences i.e. preferences about the information that is the most important for them, preferences on the style, and so on. For instance, in a control room an operator may want to favour sound media sooner than a graphical representation for a particular alarm.

3 AN AGENT ARCHITECTURE FOR FLUID INTERFACES

We adopt a multi-agent approach. Indeed, the theoretic background of agent-oriented systems seems well-suited to propose interesting solutions for some kind of complex systems [15, 14]. This approach seems particularly suited to fluid interfaces. In fact, a fluid interface has to remain adapted to the dynamic evolution of the constraints and preferences of users. Furthermore, it seems quite natural to achieve a smooth composition of information through the agents' local negotiation and decision. The result composition emerge from the agents' interactions [16, 17].

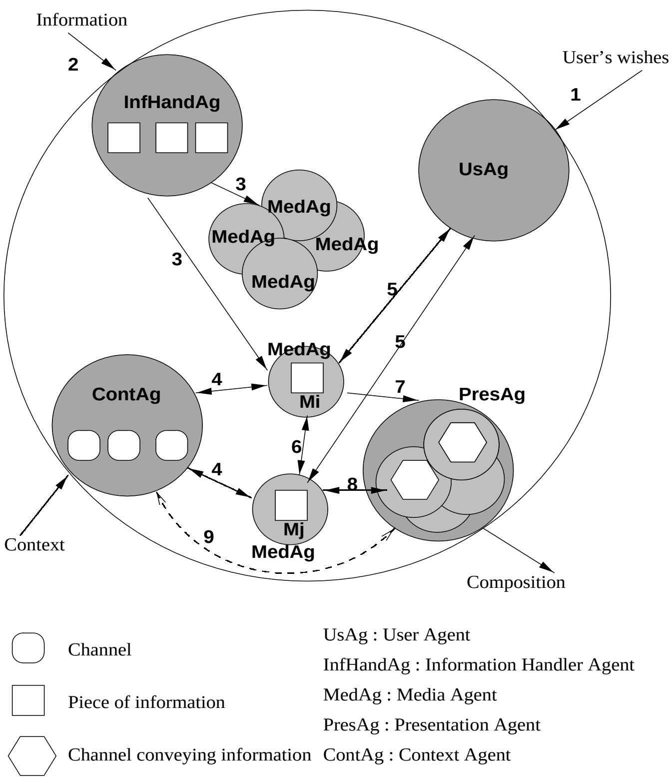

Figure 2. Agent architecture

The architecture is composed of the agents described below that are modelled as BDI (Belief-Desire-Intention) agents [5, 11]. The numbers between parenthesis in the text refer to the numbers in figure 2. They correspond to the functional steps of the composition process. However, since several pieces of information are present at one time in different states, the composition process is not sequential. The different agents work in parallel :

- **User Agent (UsAg)**. This agent takes into account the users' wishes and preferences that form its beliefs (**1**). Its main goal is to answer the Media Agent's requests (**5**). Its plans consist in answering these requests and vary according to the exact content of each request.
- **Information Handler Agent** (InfHandAg). This agent receives the information from the underlying system and from application processes (**2**). Its goals and related plans are to filter pieces of information and have them queue up according to system defined priorities and relevance (contained in a knowledge base). Then, it forwards these pieces of information with their relative priorities and relevance to the Media Agents (**3**). From a technical point of view, this agent also ensures some independence between the whole implemented architecture and the system. In fact, it is the only agent that communicates directly with the underlying system and is very similar to the *façade* design pattern [10].
- **Media Agents (MedAg)**. Each piece of information is endowed with a Media Agent. The piece of information and its related information constitutes its beliefs. Its main goal is to have its piece of information displayed by the Presentation Agent. Thus, it negotiates with the other Media Agents and the Context Agent to obtain a channel to *express* it (**4,5,6**). The constraints exposed in 2.2.1 (contained in the User and Context Agent) and the system defined priorities and relevance embedded in the Media Agent permit the calculation of the relative importance of a piece of information. This value is used in the negotiation as it is explained in 4.2.
- **Context Agent (ContAg)**. The Context Agent provides Media Agents with channels on the basis of a negotiation as explained in the previous paragraph. Its beliefs are formed by the available resources and technical constraints specific to the current IRS. When a channel is allocated to a Media Agent, the latter gets in contact with the Presentation Agent to have the information displayed (**7**).
- **Presentation Agent (PresAg)**. the Presentation Agent's goals are to fulfil the presentation (**8**) and to maintain the knowledge of the Context Agent concerning the available resources of the IRS up-to-date (**9**). Thus, it is endowed with plans to fulfil the display and to inform the Context Agent of the change on the IRS.

4 A PROTOTYPE : ACHI

4.1 General Overview

ACHI stands for Adaptive Car Human Interface. ACHI is written in Java. It is a prototype developed to validate the agent architecture presented above. Its aim is also to study experimentally fluidity in multimedia industrial interfaces. It simulates some of the pieces of information that can appear on a car dashboard, windscreen and rear-view mirror. A screenshot of the application is presented in 4.

The application is composed of four visible parts :

1. The window which allows to start, suspend or resume the simulation, is placed in the top left-hand corner.
2. Below the previous window, there is a window used to display a log file of the system.
3. In the bottom left-hand corner, there is a control panel that allows for the adjustment of the parameters of the simulation. This is this way the users has some influence on the agents negotiation. It will be developed further in 4.2.
4. The IRS is a square that can be divided up into four channels. Several combinations of the occupation of the channels are possible (3).

4.2 Negotiation Policy

Each piece of information is characterized by an importance (**I**). This importance is a calculated value that depends on six parameters. The

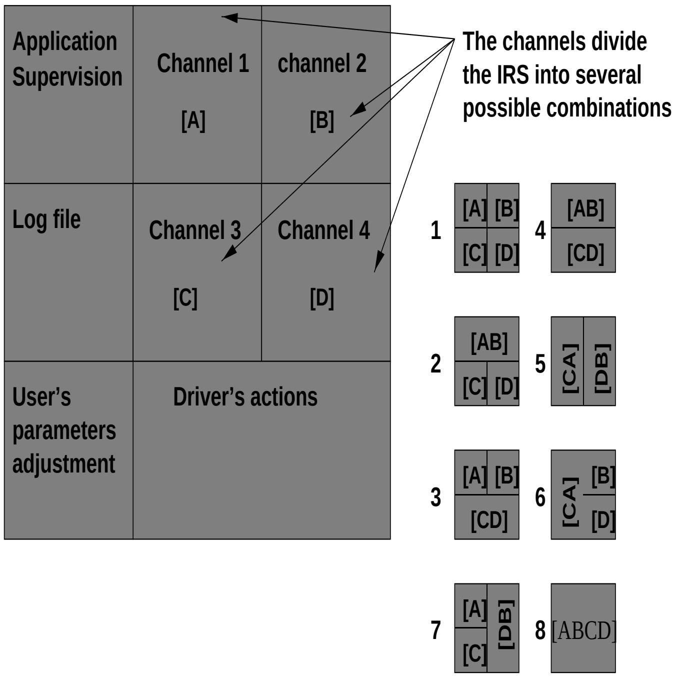

Figure 3. ACHI's Principles

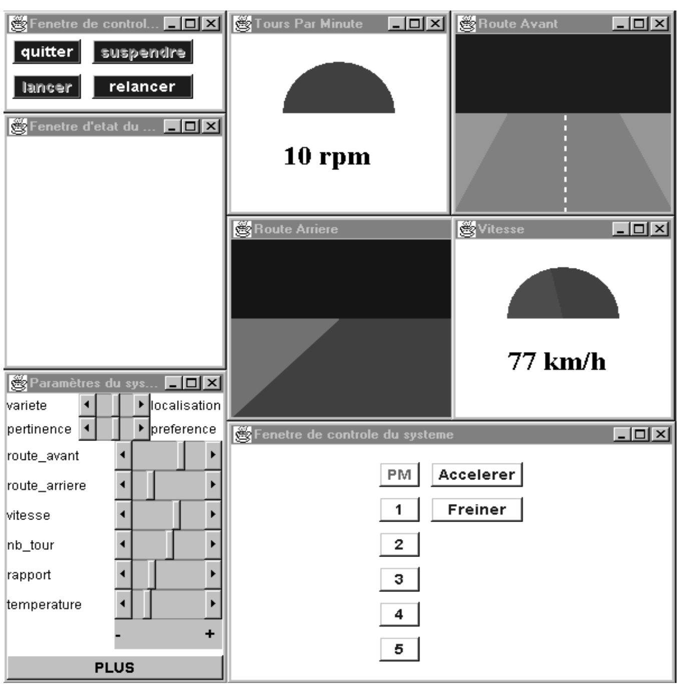

Figure 4. A screenshot of ACHI

formula is.

$$I = RCoef * R + PCoef * P + VCoef * V \qquad (1)$$

Two of these parameters are associated with each type of information in the simulation and cannot be changed at runtime :

1. The relevance (**R**) of the considered type of information in the system. For instance, it has been decided that for the driver the speed of the car seems a more relevant piece of information than the temperature of the engine. So, the speed has a higher relevance value than the temperature.
2. The variety (**V**) is the result of a computation which takes into account the time some information has been presented or has been waiting for presentation to enhance or decrease its importance.

The four others are modified in real-time by the users through the *user's parameter adjustment* windows (figures 3 and 4) :

- The preference (**P**) is defined by the users for each piece of information. The users changes it with the six last sliders of the window.
- The preference coefficient (**PCoef**) and the relevance coefficient (**RCoef**) are both modified with the second slider. In fact, this slider allows the users to determine which one between the preference or the relevance is the most influential on the value of the importance.
- The variety coefficient (**VCoef**) is adjusted with the first slider of the window. This parameter determines whether a piece of information should change localization and means of representation often.

Given the importance of all pieces of information, the negotiation policy consists in defining how they will dynamically share the channels. We have introduced a metrics on the channel that is part of the beliefs of all the Media Agents. This metrics orders the channels with the idea *the bigger the best* which is a part of the Media Agents desires. As a consequence, the most important piece of information requests the bigger channel. When several pieces of information have the same importance, they share the IRS using different channels of the same interest. A simple way of proceeding has been defined to start with using a metrics that is applied to the channel. If we accept the presence of an empty channel [ ], this metrics considers that the channels present the structure of a lattice, with

$$[ABCD] > [AB], [AC], [BD], [CD], ... > [A], [B], [C], [D] > [\,] \qquad (2)$$

A Media Agent M$_i$ wants a channel already used by another Media Agent M$_j$. M$_i$ sends a message to M$_j$ to initiate a negotiation with the aim of obtaining the release of the channel currently used by M$_j$. The message comprises the importance value of the piece of information. M$_j$ recalculates its importance by consulting the User Agent to know whether some parameters values have changed. Then, it compares its importance value with the one sent by M$_i$ (stages **4** to **6** in figure 2). Three reactions are possible :

1. $$ValueOf(Importance_{M_i}) > ValueOf(Importance_{M_j}) \qquad (3)$$

   M$_j$ leaves its channel and asks the Context Agent for another channel. For instance, M$_j$ is currently using [AB] and M$_i$ wants this channel. M$_j$ releases [AB] and M$_i$ takes it. M$_j$ asks for another channel and obtains [C] that is currently free and compatible with M$_j$'s needs.

2.

$$ValueOf(Importance_{M_i}) < ValueOf(Importance_{M_j}) \quad (4)$$

In this case, M_i cannot obtain the desired channel and must ask the Context Agent for another available less interesting channel.

3.

$$ValueOf(Importance_{M_i}) = ValueOf(Importance_{M_j}) \quad (5)$$

M_j leaves its channel and both Media Agents try to find two available channels of equal importance.

When a piece of information cannot go through onto the IRS, it waits for a channel to be freed and resumes a request to the Context Agent. However, with a negotiation on such a basis, there is the risk that the most important pieces of information monopolize the IRS whereas they can be displayed in a smaller channel at the same time. To temper this, we introduce the calculation of another value, the global satisfaction (**GS**):

$$GS = \sum_{i \in \{activeMedAg\}} (I_i * PC_i) \quad (6)$$

I_i is the importance for the Media Agent i and PC_i is the preferred channel. It is the Context Agent which calculates all the possible values of the GS at a particular time as it knows the channels that each Media Agent requests. The objective is to favour a solution in which the most important piece of information does not take all the resources and leaves nothing for the others.

5 FUTURE WORKS

On the basis of some of these ideas a european ESPRIT research project named AMEBICA was initiated. AMEBICA stands for Auto-adaptive Multimedia Environment Based on Intelligent Collaborating Agents. This project involves Alcatel and LGI2P (France), Elsag and Softeco (Italy), Iberdrola and Labein (Spain), IFE (Norway) and Loughborough University (UK). Its goal is to build up a conceptual model that will be applied to industrial supervision and to develop an object-oriented framework for Adaptive Multimedia Interface, along with its methodology for instantiation and trade-off results [18]. The project began in October 1998 and will last 2 years.

6 CONCLUSION

We have introduced in this paper the concept of fluidity. This property characterizes an interface on which the flow of information composes itself according to several dynamic parameters. We have developed the idea that fluidity is better achieved through the use of agents negotiating with one another. Thus, we have proposed a multi-agent architecture along with a prototype to illustrate its feasibility. In the future, we intend to propose a more formal model of self-composition and an improved agent architecture. Among the desired features we investigate the use of learning techniques to reduce the numbers of parameters the user's control.

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