Chapter 8

Towards new interactive signposts in train and bus stations

8.1. Introduction

In train, bus stations and airports, the supply of information to passengers is an essential task for the smooth running of their journey. However, the multitude of information present in these places often leads to a multiplication of display devices and overloads the passenger with information which does not necessarily concern them. This can only lead to the confusion of users and a lot of research time before finding the desired information. This is particularly true in the case of public display devices such as the display screens which can be found in airports (figure 8.1). This type of screen displays information concerning all avaible flights, whereas a passenger considered individually will only be interested in one flight. This therefore leads the user to carry out a task of information research which can be all the more tedious when there is a great deal of information present.

Based on the principle that there is no point in presenting to a person information which does not concern them, our objective is to make sure that the presentation of information is targeted at the users who receive it. We therefore suggest designing an *opportunistic* system for presenting information, which only provides information to the users situated in its proximity.

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Figure 8.1. *At Roissy airport, this wall of information displays information on more than 150 flights*

The objective is to provide information to these mobile users either by using private devices which they can transport on themselves (PDA, telephone, portable multemedia player, etc.), or if they don't have one, using public devices which they might encounter during their mobility (pubic information screens, loud speakers). Let us remark that it is not a matter of presenting personal information on public devices but rather carrying out a filtering of public information so as to present only that which could interest users in proximity[1].

All users, whoever they may be, are confronted with difficulties when they need to obtain information and direct themselves in an unknown environment. Nonetheless, there is a category of people for whom these tasks are particularly delicate: those with sensory handicaps. Indeed, the information devices are not necessarily adapted to them. Therefore, an information screen will be of no use to a blind person ; similarly, a deaf person will not perceive information broadcast by loudspeaker.

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1. If a single user is present in front of a screen, information which was initially of a public nature can take on a private nature and therefore pose confidentiality problems. In this case all that will need to be done is to display a few additional pieces of information so as to preserve the private life of individuals. This point will be discussed in the conclusion.

We therefore suggest placing *multimodality* at the centre of our system : the devices will be able to use different output modalities. Furthermore, a given device will only provide information to a user on the expressed condition that the output modalities of the first are compatible with the input modalities of the second. This way we will for example avoid information destined to a blind person being transmitted by a video monitor. Let us note that we are only concerned with *output* interaction, and not with input : for us it is solely a matter of *providing* information to users.

8.2. Related works

Several systems have already been put forward to provide contextual information to mobile users during their journeys. For example, CoolTown [KIN 01] shows web pages to users depending on their location. The main application of this type of system consists in providing information to users regarding their envirnonment, for example, “where is the closest pizzeria?” [HUL 97]. Generally, information is broadcast by small portable devices : for example the Cyberguide [LON 96], a tourist guide for museums, used the Newton PDA from Apple.

We therefore join the vision of ubiquitous IT [WEI 93], in which IT devices are capable of talking to each other without technological constraint. However, transporting and handling a portable device is always a constraint. The concept of *ambient intelligence* [DUC 01, RAM 07] picks up on that of ubiquitous IT, an adds to it a desire to interact in a *natural, appeased* and *intelligent* way with the user.

This idea is well adapted to the world of transport, as a passgenger is often preocupied by his journey and hampered by luggage, which makes the use of a handheld device difficult and unpleasant. An interaction which is as *natural* as possible with the environment would therefore be preferable. In view of this, we can decide to use devices *present in the places visited*.

This choice was in particular made in the Hello.Wall [STR 05] system which consists of a wall capable of displaying information which is of general interest when no one is in proximity, and to provide more personal information when a user takes on an explicit interaction. A *public* device is therefore used to transmit *personal* information, which can raise issues of respecting private life. [VOG 04]. Hello.Wall resolved this problem by not displaying *clear* information, but abstract motifs made up of around a hundred cells which were either lit up or turned off. There are public motifs, which are meant to be known to everyone, and private motifs, the signficance of which is known only to the recipient.

In the context of a traveller information system, we cannot only rely on abstract motifs: it is necessary to use a presentation of information which is clear and comprehensible to all. Therefore, if we retain the concept of interaction which implicates the device only when the user approaches it, we need to imagine new solutions for the issue of respecting private life. An assessment of this point will be given in conclusion.

8.3. Targeted characteristics of the system

8.3.1. *Opportunism*

From the point of view of the user, our system will need to be capable of providing him with relevant information during his journeys. We call *opportunism* the fact that this presentation of information is done in a *fortuitous* manner, over the course of the movements of the user. The information will be provided *via* appliances which we call *presentation devices*, public *in theory* : video screens, loudspeakers, luminours signs, etc. Nonetheless, we could also imagine private presentation devices, such as for example an earpiece.

This opportunism involves the availability of means to detect users : the system must for example be able to know who is in front of a screen. Various technologies can be used: detection of Bluetooth appliances [EAG 05], mobile telephones, specialized localisation systems such as Ubisense [STE 05], or also an RFID sticker reader situated in the tickets themselves. Without making a technological choice, we simply presume in what follows that the notion of proximity between two objects is known to the system in a reliable manner.

8.3.2. *Multimodality*

An ambient environment has as its objective to interact with its users in a natural manner, so most often *via* multimodal interfaces. Under these conditions, a handicaped person, for example, no longer constitues a separate case, but simply a user profile *among others* [EMI 05]. Indeed, people who have a sensory handicap, especially visual, are often treated separately in order to offer them solutions which are adapted to them[JAC 04]. Our system will therefore be multimodal, so as to treat all users on equal footing.

In the domain of multimodality, we use Bellik's vocabulary [BEL 95] : a *mode* corresponds to the nature of a means of communication, therefore to one of the human senses : visual mode, auditory mode, tactile mode, etc. A modality is a particular practical form of a mode. For example, concerning the auditory mode, we can give the following modalities: speech, sound, song, etc.

8.3.3. *Adaptation*

The diversity of interactions that multimodal interfaces offer, their flexibility as well as their intuitive and natural nature, make them apt to target different user categories. These properties also give them important abilities to be able to accommodate frequent modifications which the physical environment can undergo and to optimally exploit the physical resources of the systems that it hosts. Consequently, they become particularly interesting to use in the context of an ambient environment which is subject to frequent evolutions. This is why we envisage the adaptatation from the point of view of multimodality. Our system will need to « intelligently » exploit all the modalities that it could have at its disposal, to communicate a piece of information to a user [RIS 05, ROU 06].

8.4. The KUP model

For thirty years now, several models of software architecture have been suggested. Among those, we can cite CVM for controler-view-model [KRA 88], PAC for presentation-abstraction-control [COU 87] or ARCH [BAS 92]. These architectures emphasise two components :

– the *model* of information to be presented. It represents the abstraction of the problem to be dealt with, in the form of trade data. It it is directly linked to the *functional core* of a given application (name given by ARCH ; PAC calls it *abstraction*). In our model, we will denote this component as K, as it provides knowledge ;

– a practical, even physical implementation of the *interface* with the user as well as the associated interactions (*view-controller* for MVC, *presentation* for PAC). In our model, we will denote this component as P, as we are only looking at output, the *presentation* of information.

8.4.1. *Source of knowledge, users, presentation mechanisms*

In order to design a system corresponding to the description that was given in section 8.3, we introduce a new architecture model for our system, this mode includes, as well as the two aforementionned entities K and P, a third entity entitled U corresponding to the logical representation of the user. Indeed, in the context of the design of our mobile and opportunist system, it seems advisable to separate two kinds of actions :

– the *supply* of a piece of information by the functional core to the user ;

– the *presentation* of this information destined for the user.

This way, the system can *gather* information opportunisticly as and when it is discovered, and memorise it, *even if at that time there is no available presentation device.* The presentation occurs later on, also opportunisticly, when the user is in proximity of a presentation device. The decorrelation between the two phases is the condition required for the doubly opportunistic functionning of the system.

To obtain this decorrelation, the functional core must not be directly linked to the presentation device: there must be an intermediary between them. Otherwise, the supply and presentation of information would necessarily be linked. We introduce a third entity, U, corresponding to the user. This entity will be situated at the centre of the model in order to allow the decoupling between the spply of information by the K entities (knowledge sources), and their presentation by P entities (presentation devices), hence the name KUP.

8.4.2. *Comparison with the existing models*

The KUP model is twice as original compared to the existing models :

– it anticipates an active software representation of the user (U), whereas this is absent or reduced in classic models. This software representation goes far beyond the simple characterization of users by a profile or preferences ;

– this software entity representing the entity is at the centre of the model and thus gives the user a dominant position : all communication within the model will hence forth transit via this *user* software entity.

Thus, the KUP model is different from the classical models (ARCH, Seeheim, PAC, MVC, etc.) due to the fact that in the latter the user is always outside the system ; he is never explicitely represented, as an active entity. In the KUP model the user entity U is the central entity (figure 8.2).

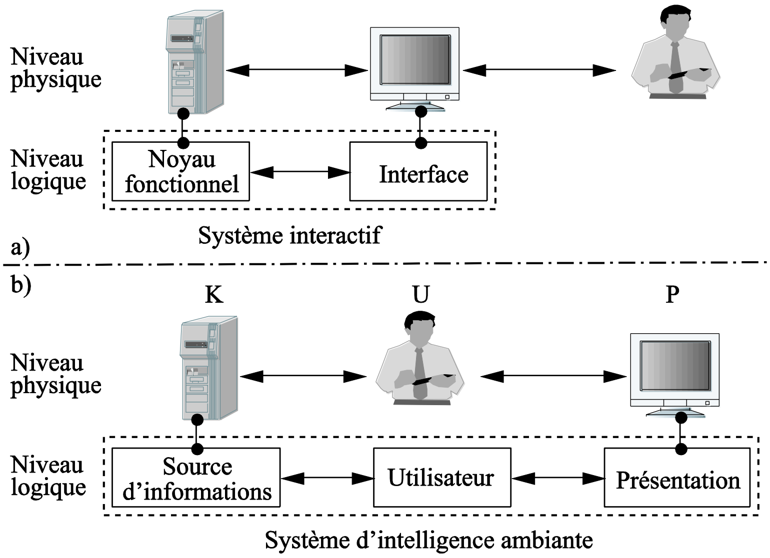

Figure 8.2. *Models for the IHM : (a) classical model in which the user is not explicitly represented ; (b) KUP model in which the user is placed at the centre of the ambient intelligence system*

8.4.3. *Notion of proximity*

In order to construct an oportunistic system based on meetings between entities we need to formally define the corresponding notions of *proximity*.

8.4.3.1. *Perceptual space*

Informally, we wish to define the *perceptual space* of a physical entity *e* as being the collection of points in space where *e* can perceive another entity that is present there. For example, for a user identity, the perceptual space could correspond to its visual field. However, this defintion is too restrictive :

– the different senses of a user have different characteristics of perception. For example the field of vision of a human being does not correspond to their zone of auditory perception. Thus, a screen situated 2 m behind will not be perceived by him, whereas a speech synthesis device will be ;

– perception depends on the *attributes of modalities.* For example, a mobile telephone ring tone emitted at 50 meters will not be perceived by a human being, whereas the sound of a siren easily will be.

Consequently, the informal definition of the notion of perceptual space given beforehand is too limited. It must be completed to take into account modalities and instanciations of the latter. To do this, we introduce an additional notion: *multimodal space*, or m-space for short. A space is the cartesien multiplication of the physical space E by all the instanciations of usable modalities. For example, let us presume, that the usable modalities for an entity are:

– *ringtone*, with a *volume* attribute continuously varying between 0 and 100 ;

– *text*, with a *size* attribute continuously varying between 10 and 60 points and a *color* attribute which can take the three discrete values of *red, green* and *blue*.

In this case, an element of the m-space could be the point which has coordinates of 46°23''32' N, 1°02''56'E, with a size 23 text and the color green.

It is now possible to formally define the *perceptual space* of a physical entity. It consists of a subset of an m-space M, which corresponds to the *points* perceivable to the entity. If the entity moves, its perceptual space will be modified: in most cases, it will naturally *follow* its entity.

For example, if we carry out a projection of the perceptual space of a user u, according to the visual modality and with constant attributes (for example, with a given character size), we obtain a *visual field*. A visual field is represented on figure 8.3 : information displayed on screens A and B are perceived by user *u*, but not those displayed by C.

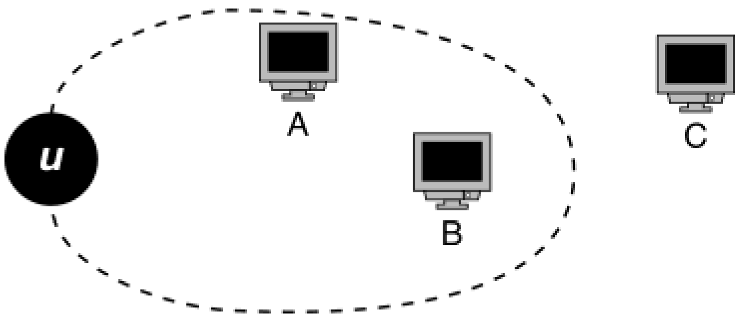

Figure 8.3. *Special case of perceptual space : visual field of a user u*

8.4.3.2. *Space of influence*

We now have all the necessary notions for the definiton of *reciprocal* notion of perceptual space. Perceptual space characterises the perceptions of an entity, in other words its *inputs,* that is to say its behaviour as a *multimodal receiver*. However, an entity can also be a *multimodal emittor*, that is to say present output multimodal characteristics. Just as input characteristics are portrayed by perceptual space, output characteristics are portrayed by what we call the *space of influence*.

Formally, we define the *space of influence* of an *e* entity vis-a-vis a *d* entity as being all the *x* points of the physical space *E* from which *d* can perceive *e,* that is to say for which *e* belongs to the perceptual space of *d* situated in *x*.

The space of influence is defined *in relation to a receptive entity* : as the perceptual spaces are different for each entity, the perception of an *emittor* in a given point in space will or will not be possible depending on the considered entity. It is therefore impossible to define a space of influence in absolute terms. Figure 8.4 deals with the simple case where the only considered modality is visual text.

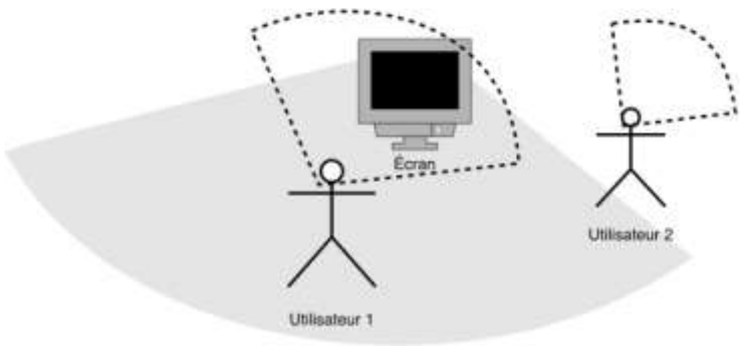

Figure 8.4. *User 1 can perceive the screen (as it is in his visual field, in dots), but this is not the case for user 2. Thus, only the former is in the space of influence of the screen (grey zone)*

8.4.3.3. *Sensory proximity : the generative element*

In the KUP model, all interactions between entities appear following a particular event: *sensory proximity*. This event occurs when an entity e_1 enters into or leaves the perceptual space of another entity e_2[2]. Given the previous definitions of perceptual space and influence, it is important to note that this sensory proximity covers two aspects : on the one hand a spatial proximity referring to the distance which separates the two entities as well as their respective orientations. On the other hand, it also refers to the capacities in terms of the input/output modalities of the two considered entities. Thus, a blind user approaching within 50cm of a screen will not set off an event of sensory proximity. It will be the same for a user situated at the same distance who can see, but who has his back to the screen.

2. This is equivalent to saying that e_2 entity enters into the space of influence of e_1.

8.4.3.4. *An opportunistic model for the presentation of information*

The KUP enables the information supply phase to be separate from its presentation phase. When a user (U) penetrates into the space of influence of an information source (K), they provide one or several relevant pieces of information. It is possible that at the moment when the user receives the information, no presentation device (P) is in proximity (as in sensory proximity). However, seeing as the users are mobile, it is possible that a presentation device penetrates into the perceptual space of the user later on. This will then cause a sensory proximity event which will have the effect of setting off the process of information presentation on the device in question.

8.4.4. *Semantic units*

The information emitted by information sources are called *semantic units* (abreviated as s.u.). A semantic unit corresponds to an elementary information, which can be trasmitted on a network, and which can be expressed in at least one modality. For example, a semantic unit can carry information corresponding to the boarding gate of a passenger in an airport or to the time of the next train going in the desired direction.

s.u. are meant to be expressed on a presentation device, and according to a given modality. It is therefore necessary to associate practical content to them in the modality in question. However, the *automatic* generation of content is a research project in its own right: [ZOC 02] : we will not explain these processes in detail. For us, the generation of practical content is seen as a *black box,* the input of which is specified (practical modality), and of which we use the output (practical content). Figure 8.5 summarises the process of practical content generation by a given semantic unit, according to different modalities.

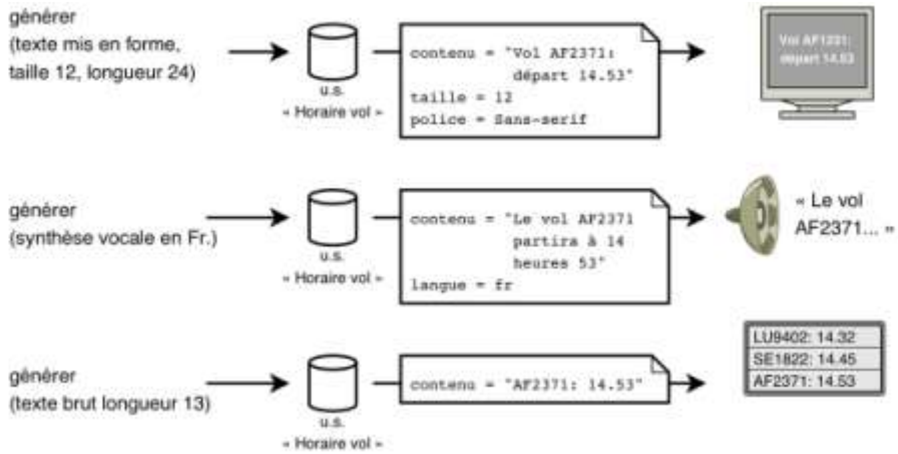

Figure 8.5. *Generation of practical content. A same semantic unit generates different practical content for each instantiated modality*

8.5. Agent Architecture

In our system of ambient intelligence, we have three types of entities (K, U, P) but there can be many of them. Furthermore, we do not set any mobility constraint. We presume that the three types of entity can be mobile. We wish to give the personnel in the places where the system is deployed the possibility of reorganizing the layout of the information sources, to move presentation devices, to bring new ones if a particular event occurs, etc, without having to configure anything. The presentation devices must be capable of adapting themselves to change, without a human intervention being necessary. This is why a decentralized software architecture, based on the notion of agent is required in this instance. Each of the three types of entities mentioned previously corresponds to a type of agent:

– user agent (U) acts as active software representation of human users ;

– informant agent (K) corresponds to the software declination of information sources ; they provide information to the user agent ;

– presenter agent (P) constitutes a software interface with the physical presentation devices.

Thus, the world of agents constitutes a « mirror » of the real world regarding our three entities of interest. We presume that all agents can communicate between themselves. Communication can be via wireless networks such as WiFi. The relationships of sensory proximity in the physical world reverberate in the world of agents. For example, if a user *a* perceives a presentation device *b*, then the same relationship will exist between the associated agent. Agents are reactive: they are dormant most of the time and react when particular events occur. In practice, a given agent *a* can react to three kinds of events :

– another agent *b* comes towards[3] *a* ;

– an agent *b*, who was close to *a*, has just moved away from it ;

– *a* has just received a message via the network, coming from a random agent *c*, which is not necessarily close to *a*.

Thus, if the agents were to find themselves on their own in the system, nothing would ever happen. Agents have reactive behaviors when the physical entities that embody them move. This means that all the proactivity of the system is ensured by physical entities, in particular human entities : it is the latter that will generally move around and from there, set off a cascade of reactions in the system.

8.6. Allocation and instanciation in KUP

Allocation consists of selecting the most adequate presentation modality for a given semantic unit (depending on the user, the device and the information to be presented). As for instantiation it concerns the definition of the most adequate values for the attributes of the selected modality [ROU 06]. In KUP, the allocation and instantiation of modalities is done in a decentralized manner. Given the disseminated nature of entities that intervene in an ambient intelligence system, it is advisable to adopt a decentralized approach, in line with the architecture of the previously described agents. Thus, when an entity U penetrates into the space of influence of an entity P, the two agents associated with these entities will negotiate to determine the most adequate modality (and its instantiation) to use in order to present information to U. This negotiation process is based on the notion of profile. A profile is an ensemble of calibrations attributed to modalities and their instances. Profiles are defined in relation to an arborescent taxonomy of modalities, common to the three types of entities. Figure 8.6 gives an example of a partial taxonomic tree of output modalities.

3. In the sense of sensory proximity.

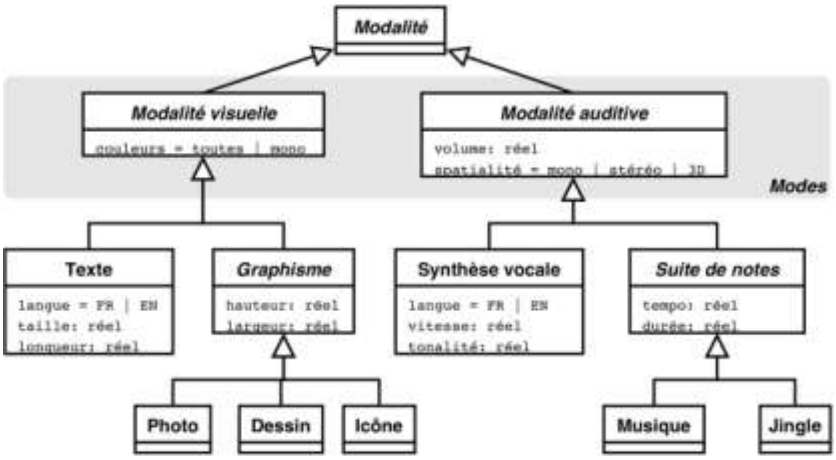

Figure 8.6. *Example of partial taxonomy of output modalities*

Each entity defines a calibration tree which it will superimpose over the taxonomic tree of modalities[4]. The principle of a calibration tree is simple : it consists of adding calibrations to a taxonomic tree in order to express the abilities, preferences and constraints of users, devices and semantic units. A calibration is a real number between 0 (included) and 1 (also included). It can be situated in two different places :

– a knot : the calibration then applies to the sub tree which has this knot as its root. A calibration of 1 signifies that the modalities of sub-trees are accepted, even desired, whereas a calibration of 0 means that the corresponding modalities are refused, or not taken into account. The intermediary values enable these two extremes to be qualified as well as to express levels of preference ;

– an attribute : we then specify a function defined over all the possible values of this attribute and with values in the real interval [0, 1]. This function indicates the calibration given to each possible value of the attribute. The meaning of these calibrations is the same as before. Thus, the values of attributes close to 1 are desired, whereas values close to 0 are not, and a calibration of 0 might even be refused.

A profile (such as previously mentioned) is defined as being a calibration tree, the root of which corresponds to the taxonomy of modalities. Figure 8.7 gives an

4. Except for K entities, which define a calibration tree for each semantic unit that they produce. Indeed, each semantic unit is likely to be able to express itself according to its own modalities. Consequently, in the case of K entities, the calibration trees are attached to produced semantic units and not to the entity which generates them.

example of a partial profile. It could correspond to a blind English speaking user, who would much rather have auditory modalities to visual ones: the corresponding calibrations are shown in white on a black background, in proximity of knots. The calibration functions are shown for a few attributes: depending on whether attributes are with continuous variations or with discrete values, the calibration functions are continuous or discreet.

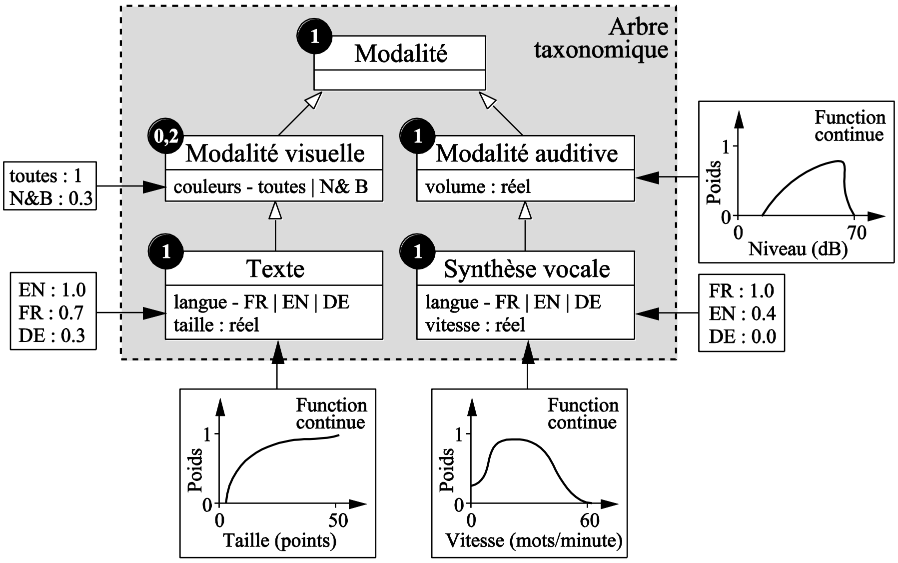

Figure 8.7. *Example of partial profile (calibration tree)*

Given a user *u* , a presentation device *d* and a semantic unit *s,* the definition of the most adequate modality (and its instantiation) to present *s* to *d* over *u,* is realized by carrying out the intersection of the three respective calibration trees. This intersection mechanism [JAC 06b] ultimately produces a calibration tree, the leaves of which indicate the candidate modalities. All that needs to be done then is to choose the modality which has the greatest calibration and to instance it by using the values of attributes also having obtained the strongest ratings. This situation corresponds, in reality, to the simplest case: that of a unique semantic unit, of a unique user and a unique presentation device. In the more general case, where several users are in proximity of the device or on the contrary, several devices are in proximity of the user (or even in the case where several users are in proximity of the same devices), more complex algorithms have been implemented so as to have several devices collaborate with one another [JAC 06a] with the aim of ensuring a global coherence of the distribution of presentations all the while guaranteeing a minimum level of satisfaction to all its users.

8.7. Implementation

We have implemented these algorithms in the form of a platform called PRIAM, (for the presentation of information in the ambient). As aforementionned, this platform is built according to an agent architecture. The agents are implemented in Java, which enables them to function in various material environments. Furthermore, they can easily exchange messages through the network via the mechanism of RMI (*Remote Method Invocation*) which is integrated in Java.

As the implementation of full scale experimentation is relatively hard and takes a lot of time, we started by making a simulator which allows the final components of an application to be tested, without having to deploy them in real conditions as early as the first tries (see figure 8.8). This simulator enabled us to verify the correct working of the algorithms. For example, figures 8.8b and 8.8c put two users in play (someone who is blind and someone who is not), as well as a screen and a sound device. When the user who can see presents himself, the screen and the sound system can give him an information (b). However, when the blind person comes close, the screen does not display anything as its output modality is not compatible with the profile of the blind person (c).

In this example, we remark that the multimodal functionning and the PRIAM platform conforms to what we have specified. Indeed, when it is a matter of carrying out the presentation of a semantic unit, the system chooses a modality adapted to the user, depending on the presentation devices present in proximity.

All the aspects of the algorithms can be tested in this manner, with the necessary number of presentation devices, users and information sources. For example, figure 8.9 presents an example of a simulation of the instanciation process of modalities. Depending on the distance which the user finds himself in relation to the screen, the attributes of instanciation are different. Thus, the text is displayed in larger characters when the user is further away from the screen.

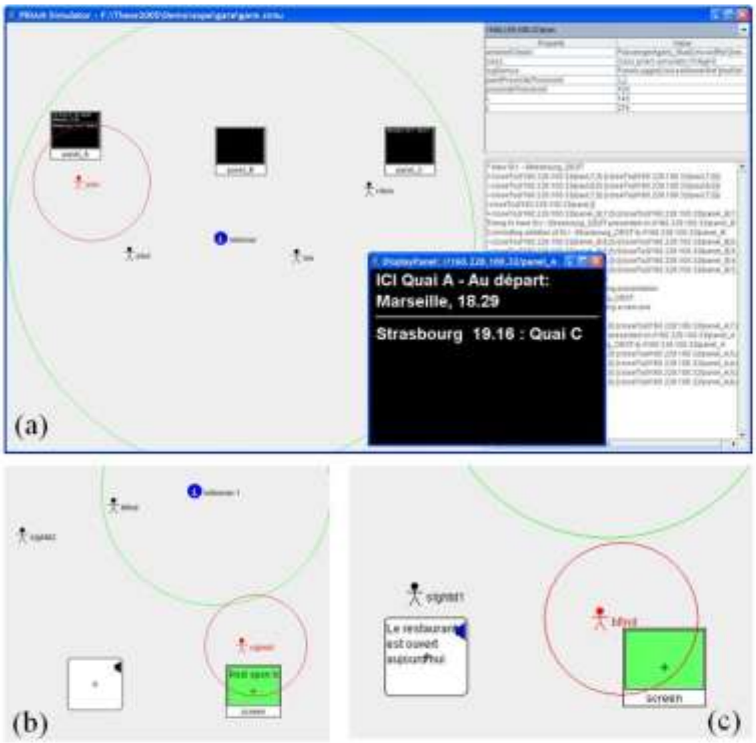

Figure 8.8. *The simulator of the PRIAM platform*

8.8. Experimentations

Initially, the simulator enabled us to verify the correct working of our algorithms. However, we then chose to evaluate the real benefit of our system : we therefore carried out two laboratory expirements with human subjects ; these were described in [JAC 09].

The first concerns the display of a list of flights in an airport. In this case, several users are meant to be in proximity of a single presentation device. The second reproduces a train station environment, in which each subject must go to the platform where it has been announced his train is leaving. In this case, a single user successively interacts with several physical presentation devices.

Figure 8.9. *When the distance increases, the process of instantiation chooses different values for attributes : the size of the text increases*

In these experiments, we have not sought to evaluate the multimodal character of our platform : these aspects were able to be tested thanks to the simulator described above. The two experiments described below had the objective of evaluating the real benefit of our system in terms of time necessary for the accomplishement of a given task. In total around twenty subjects participated in these experiments. The detection of users was carried out with the help of a system of infrared badges [JAC 07]. The use of badges would not be realistic in real conditions as users would be obliged to carry an electronic badge clearly displayed on their shirt. However, it was well adapted to an experimental context, especially as the system was sensitive to orientation: it was therefore possible to know, for example, whether or not a person was watching a screen.

8.8.1. *« Departing flights » experiment*

In this experiment, we display a list of information among which each of the subjects must look for a precise element of information that concerns him. Our idea was to compare the time taken by a user to find the information, depending on whether the list was static (paper list or static screen), or personalised and dynamic, that is to say managed by the PRIAM platform. We also wish to measure the influence of the number of people found around the display zone on research time. We will indeed predict that the more people there are in front of the screen, the more the information search will be difficult for each of them.

The information displayed concerns flights in a plane terminal. It is made up of triplets (flight, time, boarding gate). A screen displays this information. Initially, it is static (control experiment), then it becomes dynamic (verison using PRIAM). During each exercise, we provide the user with a flight number as well as a departure time. The user must then find on the screen the letter of the corresponding boarding gate, and make a written note of it. On the screen, flights are classified in chronological order (figure 8.11).

8.8.1.1. *General description*

At a given signal, one to 8 subjects approach a screen and try and find a particular piece of information. When one of them has identified their piece of information, they memorise it, raise their hand and immediately move away from the board. They then write this information on a paper form which was given to them at the beginning of the experiment. This way, by filming the progress of the experiment (figure 8.10), we were easily able to measure the search time of each user. This quantity is defined as being the time that separates the user entering the “scene” of the experiment (that is to say the zone situated in proximity of the display device) and the moment when they raises their hand.

Figure 8.10. *The subjects come close to the screen and then raise their hand once they have found the information*

The forms completed by the users enabled us to verify the exactitude of the information we found. Cases of errors were very rare and did not enable us to establish interesting statistics regarding the conditions in which they arose. In fact, the majority of errors were from a single user, who we will qualify as « distracted ».

We first of all carry out a “control” experiment in which the list of information is static. Then, we introduce dynamic lists: in this case the information displayed by screens only concerns users situated before the latter. The detection of users by the system is carried out with the help of the infrared badge system.

8.8.1.2. *Control experiment*

First of all, users look for information concerning their flight among a fixed number of pieces of information. We carried out two experiments.

8.8.1.2.1. Search for one piece of information among 12

the results of this experiment are presented in table 8.1

Number of people	**Average time (s)**	**Standard deviation**	**Minimum time**	**Maximum time**
1	3,00	0,00	3,00	3,00
2	4,00	2,00	2,00	6,00
3	4,00	1,41	3,00	6,00
4	4,63	1,22	2,00	6,00
5	5,80	0,98	4,00	7,00
6	8,67	4,38	4,00	17,00
7	7,67	2,56	5,00	13,00
8	6,88	4,28	4,00	18,00

Table 8.1. *Search time for a boarding gate on a static screen, series 1*

8.8.1.2.2. Search for one piece of information among 20 (figure 8.11)

The results of this experiment are presented in table 8.2.

Number of people	Average time (s)	Standard deviation	Minimum time	Maximum time
1	6,00	0,00	6,00	6,00
2	5,00	1,00	4,00	6,00
3	4,67	0,47	4,00	5,00
4	8,00	2,65	5,00	14,00
5	7,40	3,26	3,00	11,00
6	8,00	4,52	5,00	17,00
7	8,43	2,92	5,00	13,00
8	6,00	2,20	3,00	10,00

Table 8.2. *Search for a boarding gate on a static screen, series 2*

Figure 8.11. *Static display of a series of flights*

We remark that the times have a tendancy to be longer when the number of people simultaneously present increases, without this tendancy being very clear cut. We can also note that the search times among 20 pieces of information are a lot longer than searches among 12 pieces of information.

8.8.1.3. *Dynamic version*

We only display here information relative to the users situated in proximity to the screen (figure 8.12). Let us note that it could occur that two users are searching for the same information (they are meant to take the same flight). In this case, in dynamic mode, the screen is even more loaded than in the previous experiment. The results are given by table 8.3.

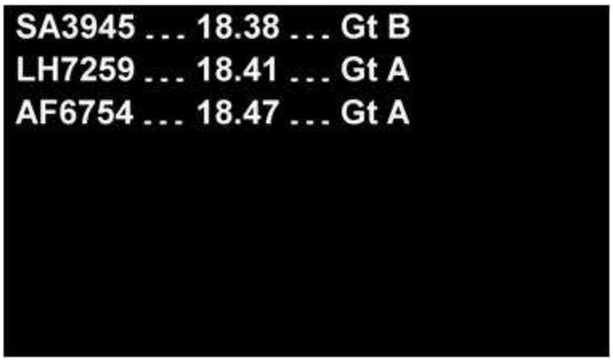

Figure 8.12. *Dynamic display of flights relative to users in proximity*

Number of people	Average time (s)	Standard deviation	Minimum time	Maximum time
1	1,50	0,50	1,00	2,00
2	2,75	1,92	1,00	6,00
3	2,83	0,69	2,00	4,00
4	3,31	1,49	0,00	6,00
5	3,00	1,73	0,00	6,00
6	2,82	1,85	1,00	7,00
7	3,29	1,94	0,00	7,00
8	4,06	2,34	1,00	10,00

Table 8.3. *Search time for a boarding gate on a dynamic screen*

These results lead to the following conclusion : the search for a piece of information is much quicker when only information relative to users in immediate proximity is presented (figure 8.13).

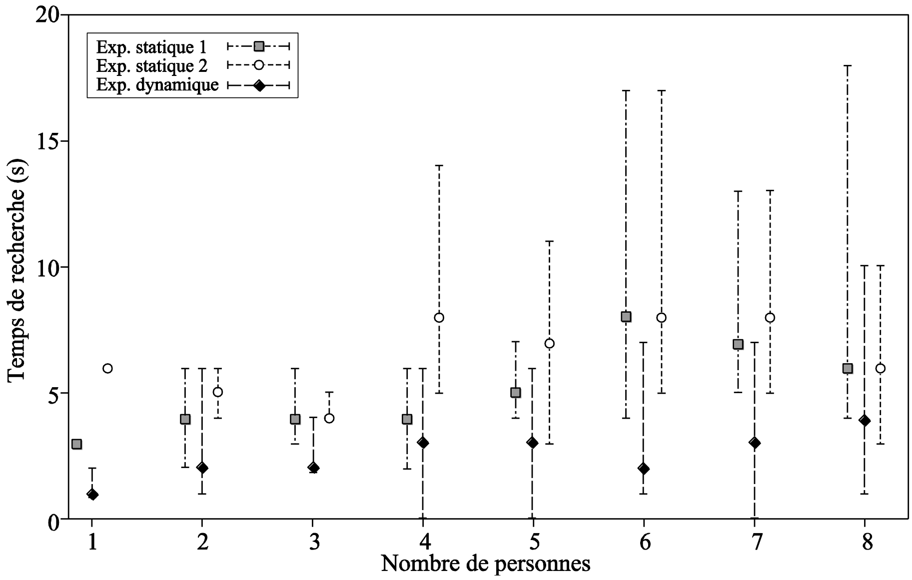

Figure 8.13. *Comparison of the search times of a flight in terms of the number of people simultaneously present. For each case studied, a segment figures on the graph : it indicates the minimum and maximum times. The point situated on the segment represents the average time. For legibility reasons, results of the static experiment n°1 are slightly staggered to the left, whereas those of static experiment n°2 are slightly staggered to the right. The results of the dynamic experiment are therefore between the results of these two static experiments*.

8.8.1.4. *Subjective perception of the experiement*

We handed our subjects a questionnaire in order to analyse their perception of this experiment. First of all, most of the users preferred the dynamic versions of these exercises : in general, they fond it « practical »,"easy », even "amusing". The search for information generally seems easier to them, as there are fewer items to scan over, so therefore less *noise* to drown out the information of interest. Let us note nonetheless that most of our subjects were around twenty years old, and so were definitely more receptive to the dynamic behaviours than the population average. Thus, a somewhat older person definitely prefered static displays, all the while defining themselves as being « lineary [5] ».

However, some people were troubled by an aspect of the dynamic display : the fact that the list is periodiclly reorganised (at each arrival or departure of a user in proximity to the display device). Indeed, a given line would sometimes move

5. This person appreciated the one-dimensional searches and narrations. For example, she does not like cartoons due to their lack of linearity, which she finds disturbing.

suddenly on the screen (due to the arrival of a new user and the permanent maintenance of the classification of lines), as the user is reading it These fluctuations give a *flashing* effect which is quite disruptive for users. In section 8.9 we introduce the outlines of the solution to solve this problem.

The implemented methods for information search were very typical. Most of the subjects started by looking for the time of departure, then checked it with the help of the flight number (or separated the flights leaving at the same time).

Most users think that this sytem can be useful in practice. However, they highlight the fact that its advantages are visible only when a small number of users are found in proximity to the screen. Indeed, if a large number of users are grouped together, the screens will generally display a great deal of information, and therefore the gain will be nil compared to a static system. In this vein, one of the subjects made us realise that it would be necessary to avoid passers by not interested by the information disrupting the display of the screens.

8.8.1.5. *Implementation notes*

We have seen up till now the global functionning of the information search experience in a list, carried out with the help of the PRIAM platform. In this section, we look more in detail at how this experiement was implemented in our platform, in particular in terms of agents. The presentation mechanism consisted of a simple computer with a big screen (17 inches). For simplicity reasons, and in particular inorder not to depend on a network connection for carrying out the experiment, all agents functioned on this laptop. The following agents were implemented :

– an informative agent tasked with attributing information to different users. Like all other PRIAM agents, this agent has a constructor capable of creating an instance based on a series of couples (attribute, value). The affectations of information can be transmitted to him by these means, in the end therefore, information can be stored in an XML file describing the experience. This informative agent provides their semantic units to all known user agents : its space of influence is therefore equal to the usage space of the system ;

– the potential users are simply each represented by a standard agent user of PRIAM. Eight of these agents are therefore instanced ;

– a presenter agent capable of displaying information. We have used a presentation device adapted to the presentation of tabbed data, called *DisplayPanel*.

We have also defined a class of semantic units meant to represent flight information. These semantic units are capable of generating a practical content intended for a textual presentation device, for example the *DisplayPanel*. In order for the user agents to detect the proximity of the screen, we have created a localisation service adapted to our badge system. As soon as the infrared receptor detects a badge in proximity, the agents corresponding the screen and to the user in question receive a proximity notification.

8.8.2. *Experiment « Finding ones way in a station»*

The previous experiment demonstrated the benefit of our system for the search of a piece of information in a list, including by several users simultaneously. We are now looking to evaluate how it can constitue an aid during the search for a direction. We use as an example the typical configuration of a train station (figure 8.14). A reception hall enables access to an underground pass (or a footbridge), which in turn gives access to different platforms via the intermediary of stairs. In the reception hall, a general display pannel indicates the departure times and platforms of all trains. Moreover, at each staircase, a monitor is situated in the underground passage: it recalls the list of departing trains on the corresponding platform.

This organisation can seem fairly complete, and perfectly able to guide the traveller. For example, when a user arrives in a train station, he starts by consulting the general display pannel, which gives him his platform number. He can then use the underground passage. At the staircase which leads to its platform, a monitor confirms his destination. However, this diagram does not take into account travellers in transit. Indeed the latter get off the train on one of the many tracks and must head for another track. Without additional information, they must therefore :

– either go to the hall, consult the general display panel, and then once again take the underground passage to go to their platform of destination ;

– either head to a random destination in the underground passage, at the risk of turning back to go and explore the other direction, if they were not going the right way. Indeed they have in this cas on average one chance in two of getting it wrong.

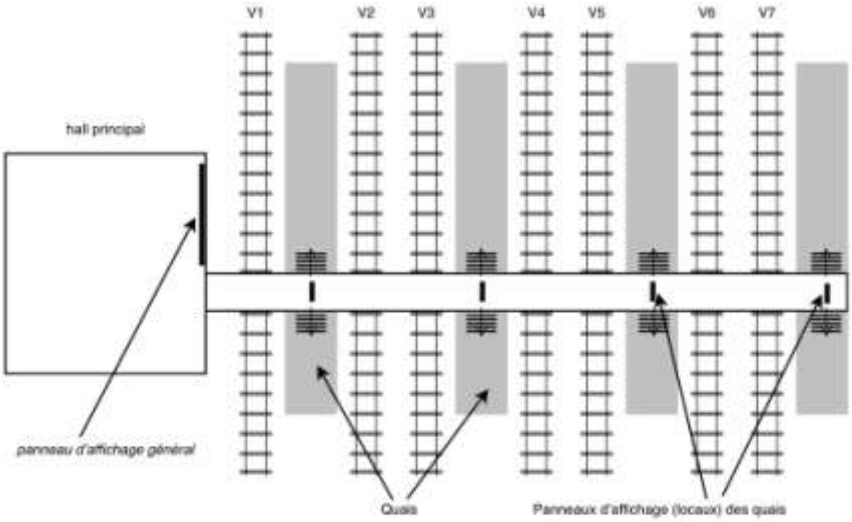

Figure 8.14. *typical layout of a train station*

In both cases, these strategies are not optimal, as usagers have to carry out unecessary movements. Not only are these movements tiring, especially when carrying luggage, but they are also *stressful* if the connection time is short. It would therefore be good to have an information system which indicates their destination platform from the start, wihtout them having to carry out unecessary trips. Amittedly, vocal messages about connections, broadcoast on arrival of trains in the station, are meant to accomplish this, but often they are not understood or not even heard by the travellers. We therefore propose to display on the screens of the underground passage, *in addition to the usual information* (departing trains on the corresponding platform), information relating to the trains of users who approach these screens.

8.8.2.1. *General description*

We have installed five screens (in reality laptops) in a corridor of our laboratory, according to the configuration of figure 8.15. Each of these screens corresponds to a platform, numbered from A to E. Users can go from one of the extremities of the corridor (landmark 0 and 2), or a « median » position (landmark 1). This median starting position is not found precisely in the middle of the corridor, but it is justified by the configuration of the place.

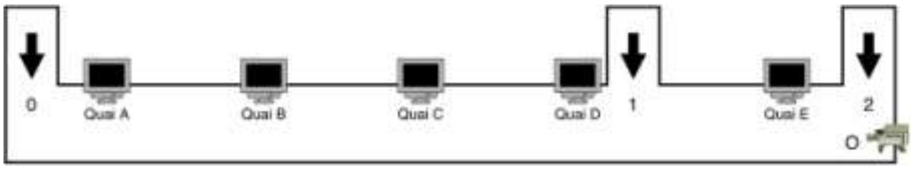

Figure 8.15. *Installation carried out for the direction search experiment. the underground passage of train station was figured in the corridor of our laboratory*

In two cases (static screens which only display the departing train on their platform, or dynamic screens which display personalized information), we wish to study the movement made by users to find their platform, according to the different possible starting points. As in the previous experiments, we filmed[6] the experimentations so as to later « segment » the movements of users (figure 8.16). During this segmentation, we have identified two kinds of elementary movements :

– advance from platform Q1 to platform Q_2. We denote this movement $Q_1 \rightarrow Q_2$. Example : $A \rightarrow B$;

– turn around at platform A. We denote this movement Q ↺. Exemple : C ↺.

These two types of movements enable the trajectory of users to be completely described. It seems to us much more relevant to carry out such a segmentation rather than measure the time taken by users to reach their destination platform, as this time can depend on how fast the user moves, which is absolutely not a relevant parameter for our study. Indeed, we do not want the measurements to be distorted by the subjects walking more or less quickly. In each experiment, the users had to search for the platform of the train for Lyon, starting from one of the three landmarks 0, 1 and 2. Once they had found it, they needed to stop in front of the corresponding screen and raise their hand. For the utilization of results, we first of all introduce the notion of the *length* of a path. The length of a path is equal to the number of elementary movements on this path. We can then define the *relative length* of the path travelled by a user as being equal to the division of the length L_U of the path actually travelled by the user by the length L_O of the optimal path[7]. For example, let us presume that the user goes from landmark 1 to platform B. The optimal path is :

$$1 \rightarrow C , C \rightarrow B$$

6 . the camera was situated at the observation position marked O in figure 9.15.
7 . The *optimal path* is that which has the least elementary movements.

Figure 8.16. *Extract from the film of the direction search experiment*

We therefore have L_O = 2. Let us now presume that the user travels the following path :

1 → C , C → D , D → E , D ↺ , E → D , D → C , C → B

In this case, L_U = 7. the relative length L_R of this path is therefore L_U/L_O = 7/2 = 3,5. This relative length enables any travelled path to be recognised in relation to the optimum, without the distance between the start and end points coming into play. We therefore judge that it is a matter of a good criteria for comparison between different experiments.

8.8.2.2. E*xperiments with a user*

In these experiments, a single user at a time is looking for his way. Control experiment. In this experiment, the screens only displayed information concerning the platform that corresponded to them (figure 8.17). The results are given in table 8.4. We can observe a great disparity in results :

– when the user goes from one of the extremities of the corridor (landmarks 0 or 2), the average relative length is 1, which shows that in this case, the journeys are optimal. Indeed, all that is necessary in this case is to go down the corridor in the only possible direction, and the user will inevitably end up at his platform of destination, without the risk of making a mistake ;

– however, when the user starts from the middle of the corridor (landmark 1), the average length in our experiments was 2.75 : the journeys are far from being optimal, as the user can choose either of both directions, and therefore has a one in two chance of making a mistake.

Figure 8.17. *Static display of a departing train on a given platform*

Subject	**Start**	**Dst**	**Movement**	L_U	L_O	L_R
a	2	E	2 → E	1	1	1,0
b	1	E	1 → D, D → C, C → B, B → A, A ↺, A → B, B → C, C → D, D → E	9	2	3,5
c	0	E	0 → A, A → B, B → C, C → D, D → E	5	5	1,0
d	1	E	A → D, D → C, C → B, B → A, A ↺, A → B , B → C, C → D, D → E	9	2	3,5
a	1	B	1 → D, D → E, E ↺, E → D, D → C, C → B	6	3	2,0
b	2	B	2 → E, E → D, D → C, C → B	4	4	1,0
c	1	B	1 → D, D → E, E ↺, E → D, D → C, C → B	6	3	2,0
d	0	B	0 → A, A → B	2	2	1,0
a	0	C	0 → A, A → B, B → C	3	3	1,0
b	0	C	0 → A, A → B, B → C	3	3	1,0
c	2	C	2 → E, E → D, D → C	3	3	1,0
d	2	C	2 → E, E → D, D → C	3	3	1,0

Table 8.4. *Results of the experiment of direction search with the help of static screens. The double horizontal lines are used to separate the different series of experiments*

Dynamic version. In this version, the screens display *in addition* information that concerns users situated in proximity (figure 8.18). The departure times of the trains of the latter, as well as their platform numbers and arrows that indicate the directions to follow complete the basic static display.

Figure 8.18. *Display of a train departing from a given platform, completed by dynamic information relative to users situated in proximity. This display is to be compared with that of figure 8.17*

Subject	**start**	**Dst**	**Movements**	L_U	L_O	L_R
a	1	B	1 → D, D → C, C → B	1	1	1,0
b	1	B	1 → D, D → C, C → B	1	1	1,0
c	1	B	1 → D, D → C, C → B	1	1	1,0
d	1	B	1 → D , D → C , C → B	1	1	1,0
e	1	B	1 → D , D → C , C → B	1	1	1,0
a	1	E	1 → D , D → E	1	1	1,0
b	1	E	1 → D , D → E	1	1	1,0
c	1	E	1 → D , D → E	1	1	1,0
f	1	E	1 → D , D → E	1	1	1,0

Table 8.5. *Results of the direction search experiment with the help of dynamic screens*

As in the previous experiment, users starting from the corridor extremities (landmarks 0 and 2) were already following optimal trajectories, we did not reiterate these experiments and we concentrated on the experiments in which subjects started from the middle of the corridor (landmark 1). The corresponding results are given in table 8.5. We can note that in all cases, the movements are optimal. On average, the use of a dynamic system brought the relative length of the journeys departing from landmark 1 from 2,75 to 1,00.

8.8.2.3 *Experiments with several users*

We have also studied the behaviour of this installation when several users simultaneously search for their respective platforms. Three users each had to search for a different direction, corresponding to a departing train on one of the five platforms. We started by carrying out a control experiment in which the screens were static, and only displayed the destination of the next train of their platform. The results are given in table 8.6.

Subject	**Start**	**Dst**	**Movements**	L_U	L_O	L_R
a	1	A	1 → D, D → E, E ↺, E → D, D → C, C → B, B → A	7	4	1,75

b	1	B	1 → D, D → C, C → B	3	3	1,00
c	1	E	A → D, D → C, C → B, B → A, A ↺, A → B, B → C, C → D, D → E	9	2	4,50

Table 8.6. *Results of the direction search experiment by several users with the help of static screens*

The average relative length for this experiment was 2.42, which once again shows that the journeys taken are less than optimal. Thus, subjects b and c went in the wrong direction from the offset. We then began the experiment again in dymamic mode. The results are given in table 8.7.

Subject	**Start**	**Dst**	**Movements**	L_U	L_O	L_R
a	1	A	1 → D, D → C, C → B, B → A	4	4	1,0
b	1	E	1 → D , D → E	2	2	1,0
c	1	B	1 → D , D → C , C → B	3	3	1,0

Table 8.7. *Results of the direction search experiment by several users with the help of dynamic screens*

In this case, all the journeys are optimal. Thus, even when several users are present, the use of PRIAM to provide users with dynamic and personalised information enables them to save precious time when they are on the move.

8.8.2.4. *Implementation notes*

The implementation followed the same principles as the flight search experiment. We have used the following agents :

– an informative agent tasked with providing each user with the semantic unit corresponding to their destination ;

– a few standard user agents : one is enough in the event where a single user travels the length of the underground passage ; for the experiment with three users, we have implemented three of these agents ;

– five presenter agents, each responsable for the corresponding screen.

During the practical realization of the experiment, we used five portable computers to represent the five screens, all the while keeping the same architecture.

However, in order to avoid problems related to network connections between computers[8], we prefered to duplicate the informative agent and the user agents *on each of the five portable computers*.

In summary, each computer therefore contained :

– a copy of the informative agent ;

– a copy of all the user agents linked to the infrared localisation system ;

– the corresponding presenter agent.

As a general rule, such a duplication of agents could pose a problem, as different *instances* of the same agent could be found in different states, which would be incoherent.

However, in the very restricted framework of our experimentation, this did not disrupt the global functionning of the system, as the user agents implemented did not have any particular *states*.

8.9. Conclusions and perspectives

We have preseted a conceptual model for the presentation of multimodal information to mobile users, the natural application of which is in train and bus stations. This model is accompanied by algorithms for the choice of modalities according to the abilities of the interactive devices and the users. This model and its algorithms were implemented in the PRIAM platform, which enabled us to conduct experiments in pseudo-real conditions. These experiments have shown the benefit of carrying out a selection as to what information is presented in public places, depending on the people situated in front of the presentation devices.

The people who participated in our experiments often told us that they had been unsettled by modifications in the content of the screen, which were too frequent. When it is necessary to reorganise the display of a screen, it will in consequence be necessary to anticipate transitions between the old organisation and the new one. For example, if it is necessary to add a new line between two previously displayed lines, it is possible to very slowly stream the lower part of the screen so as to carefully deal with the necessary space, rather than bluntly switch from one display to the next. Or also, if it is necessary to delete a line it is possible to progressively reduce its size. We will be able here to reuse animation techniques validated by the IHM. It would

8. Even though at the beginning of this chapter we formulated a hypothesis stating that all the entities would be realized by a wireless network, we preferred not to make our experimentations dependent on possible problems linked to the network.

be also be interesting to introduce priorites between the presented information. Thus, the information relative to the immediate departures or to the disapearance of people could appear first. Similarly priority could be given to users depending on what their subscription or their handicap is.

The display of selected information according to the people present can raise issues of respecting private life. We have seen that our system has the aim of carrying out a selction among many pieces of information. Consequently, if a single user is present in a given place, an individual hidden in proximity can infer private information based on a system's presentation, as he knows that it will only concern the user in question. Let us remark that this problem disappears when two or three users are present, if different information concerns them: it is then no longer possible to attribute the presented information to such and such a person.

For example, let us presume that a monitor displays the destinations of the travellers situated in proximity. If several people are present, the monitor will display a few destinations, and it is not possible to infer anything about anybody. But if a single person is present, then only their destination will be displayed, which could be a problem. To remedy this inconvenience, it is possible to introduce a « scrambling » of information. In the aforementionned case, we can for instance decide that below two or three relevant pieces of information to be presented, one or two additional pieces of information, which are random and non relevant, will also be presented. This way revealing information relative to a passenger who presents himself alone in front of a screen is avoided.

8.10. Bibliography

[BAS 92] BASS L., FANEUF R., LITTLE R., MAYER N., PELLEGRINO B., REED S., SEACORD R., SHEPPARD S., SZCZUR M., « A Metamodel for the Runtime Architecture of an Interactive System », *SIGCHI Bulletin*, vol. 24, n°1, p. 32-37, 1992, .

[BEL 95] BELLIK Y., Interfaces Multimodales : Concepts, Modèles et Architectures, Thèse de doctorat, Université Paris-Sud 11, Orsay, 1995.

[COU 87] COUTAZ J., « PAC, an Object-Oriented Model for Dialog Design », *Proceedings INTERACT 87 - 2nd IFIP International Conference on Human-Computer Interaction*, North-Holland, p. 431-436, 1987.

[DUC 01] DUCATEL K., BOGDANOWICZ M., SCAPOLO F., LEIJTEN J., BURGELMAN J-C., Scenarios for Ambient Intelligence in 2010. Final Report, Information Society Technologies Advisory Group (ISTAG), European Commission, 2001.

[EAG 05] EAGLE N., PENTLAND A., « Social Serendipity: Mobilizing Social Software », *IEEE Pervasive Computing*, vol. 4, n° 2, p. 28-34, 2005.

[EMI 05] EMILIANI P.-L., STEPHANIDIS C., « Universal access to ambient intelligence environments: Opportunities and challenges for people with disabilities », *IBM Systems Journal*, vol. 44, n° 3, p. 605-619, 2005.

[HUL 97] HULL R., NEAVES P., BEDFORD-ROBERTS J., « Towards Situated Computing », *Proceedings of ISWC '97*, IEEE Comp. Soc., p. 146, Washington, DC, Etats-Unis,1997.

[JAC 04] JACQUET C., BELLIK Y., BOURDA Y. « A Context-aware locomotion assistance device for the blind », *People and computers XVIII – design for life*, Springer-Verlag, p. 315-328, Londres, United Kingdom, 2004.

[JAC 06a] JACQUET C., BELLIK Y., BOURDA Y., « Dynamic Cooperative Information Display in Mobile Environments », *Proceedings of the 10th International Conference on Knowledge-Based & Intelligent Information & Engineering Systems, KES 2006*, p. 154-161, Bournemouth, United Kingdom, 2006,

[JAC 06b] JACQUET C., BELLIK Y., BOURDA Y., « KUP, un modèle pour la présentation multimodale et opportuniste d'informations en situation de mobilité », *Ingénierie des systèmes d'information (ISI), numéro spécial « Adaptation et gestion de contexte »*, vol. 11, n°5, p. 115-139, Hermès Lavoisier, Paris, 2006,

[JAC 07] JACQUET C., « IRIS : identification d'utilisateurs par badges infrarouges », *Actes d'IHM*, p. 287-290, ACM Press, 2007.

[JAC 09] JACQUET C., BELLIK Y., « Présentation ciblée d'informations dans les moyens de transport », *Génie Logiciel,* n° 91, p. 27-34, 2009.

[KIN 01] KINDBERG T., BARTON J., « A Web-based nomadic computing system », *Computer Networks*, vol. 35, n° 4, pp. 443-456, 2001.

[KRA 88] KRASNER G., POPE S., « A cookbook for using the model-view controller user interface paradigm in Smalltalk-80 », *Journal of Object Oriented Programming*, vol. 1, n° 3, p. 26-49, 1988.

[LON 96] LONG S., KOOPER R., ABOWD G., ATKESON C., « Rapid Prototyping of Mobile Context-Aware Applications: The Cyberguide Case Study », *Proceedings of the 2nd annual international conference on Mobile computing and networking*, ACM Press, p. 97-107, 1996.

[RAM 07] RAMOS C., « Ambient Intelligence – A State of the Art from Artificial Intelligence Perspective », *Progress in Artificial Intelligence*, Lecture Notes in Computer Science, n°4874, p. 285-295, 2007.

[RIS 05] RIST T., « Supporting Mobile Users Through Adaptive Information Presentation », *Multimodal Intelligent Information Presentation*, Springer, ch. 6, p. 113-141, 2005.

[ROU 06] ROUSSEAU C., BELLIK Y., VERNIER F., BAZALGETTE D., « A Framework for the Intelligent Multimodal Presentation of Information », *Signal Processing*, vol. 86, Issue 12, Elsevier, p. 3696-3713, 2006.