Chapter 11

Transport: a Fertile Ground for the Plasticity of User Interfaces

11.1. Introduction

Until the first decade of the 21st century, User Interfaces (UIs) were designed for a predetermined context of use, i.e. for a specific class of users, using a given platform (generally a workstation), in a fixed physical and social environment (e.g. at a desk). The UI was rigid, created for this specific context of use (<user, platform, environment>). This context was presumed to be fixed, known from the design stage, and intervened at the entry point of design methods [ISO 99], see Figure 11.1. Ambient intelligence creates a new paradigm: henceforth, the user is thought of as mobile, evolving in a dynamic environment consisting of heterogeneous interaction resources and being able to opportunistically target new goals. From this point on, the hypothesis of fixed context of use is no longer valid and the rigidity of the UI is no longer acceptable.

Comment [AS1]: Je mettrai plutôt "computer" puisqu'on utilize HCI dans la suite

This chapter deals with the plasticity of UIs in ambient intelligence. Plasticity denotes the ability of UIs to adapt to the context of use while respecting the user-centered properties. Two viewpoints are developed: on the one hand, the point of view of the user, and the system; on the other, for engineering plastic UIs. Both viewpoints are illustrated in the field of transport.

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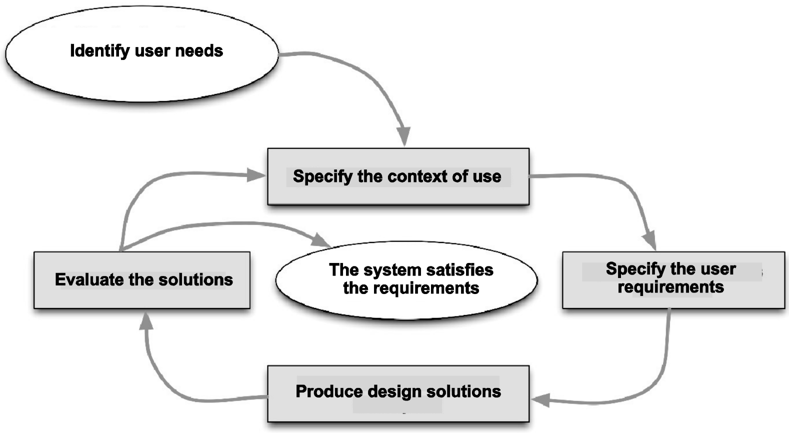


Figure 11.1. *User-centered design for a context of use specified before the design process takes place: ISO norm 13407 (figure translated from [ISO 99])*

The following section structures the key elements of UI evolution in ambient intelligence [CAL 06], [CAL 07a], [CAL 07b]. Section 11.3 shows how UI plasticity acts as an integrator for these evolutions from a user's perspective. Plasticity is then illustrated in the field of transport, which proves to be an extremely fertile application framework. Section 11.4 adopts the system viewpoint. Section 11.5 presents a problem space that covers both the user's and system's viewpoints. A number of questions remain open, giving rise to numerous issues for further research.

11.2. Evolution of human-machine interaction

Calvary *et al*. [CAL 06] identified the key elements for the metamorphosis of human-machine interactions in ambient intelligence. This section proposes a review of this and organizes its dimensions according to three factors: the diversity of interaction resources, their dynamicity and human control.

11.2.1. *Diversity of interaction resources*

Lyytinen and Yoo [LYY 02] structure the evolution of information technology (IT) according to two axes (see Figure 11.2a): *mobility* and *integration* into the physical world. *Mobility* refers to the success of pocket computers (personal assistants, smart phones, games consoles, etc.). *Integration* into the environment designates the progressive evanescence of the computer in the physical world: our everyday objects are augmented with digital properties, and take part in the interaction [THE 07]. For example, the vehicle, depending on the situation, is informed of or signals an accident (see Figure 11.2b), and then sends this information to other vehicles [DEL 09], [DEL 10]; or newspapers (see Figure 11.2c) complement textual information with video on demand [MAE 09].

Mobility and integration into the environment can be combined. Thus, the European GLOSS (*GLObal Smart Spaces*, 2001-2004) project imagined the coupling of a personal digital assistant (PDA) with an augmented wall to display information to the individual relating to his[1] journey (see Figure 11.3b): the PDA contained road information; the public wall, connected to the PDA, displayed additional information about the weather forecast and the transport strike at the destination. More recently, Maes and Mistry [MAE 09] envisioned the possibility for the traveler who is late, going to the airport by taxi, to project information in real time relating to his flight onto his boarding pass (see Figure 11.3a).

Such prototypes hypothesize a software and material infrastructure for perception, information and/or action. This information can be public and/or personal, offered by the current location and/or carried by the user. Borkowski [BOR 04] uses the control between a video projector, on one hand, and a camera fixed to the ceiling, on the other, to make every piece of paper an interactive display surface. Conversely, the SixthSense wearable motion interface [MAE 09] is based on a pico-video projector and a camera worn as a necklace. This principle of wearable IT was conceived by [ANT 02], who proposed the display of tabular information on the fingers of a hand, in this case information relating to hotels (see Figure 11.3c). Today, this idea is implemented in the Skinput system [HAR 10].

The variety of display surfaces (in size, width, transparency, etc.), the existence of other output modalities (audio, for example) and at the same time the diversity of input modalities make the *morphology of the interaction* a subject of utmost importance. UIs are no longer reduced to classical intermediate players and are no longer necessarily centralized in a single PC. They go:

– *from graphics to multimodal* form, involving other human senses than sight and touch, for example;

– *from WIMP (Windows, Icons, Menus, Pointing device) to post-WIMP*, going beyond the WIMP: windows can be round, directly handled by a finger;

1 In this chapter, he, him or his refers also to she, her and hers.

– *from centralized to distributed*, where components of the UI are spread over several surfaces: for example, a remote control on a PDA and content displayed on a wall [MYE 01].

The combination of this diversity with temporal relationships gives the study an additional complexity: that of the variability of interaction resources.

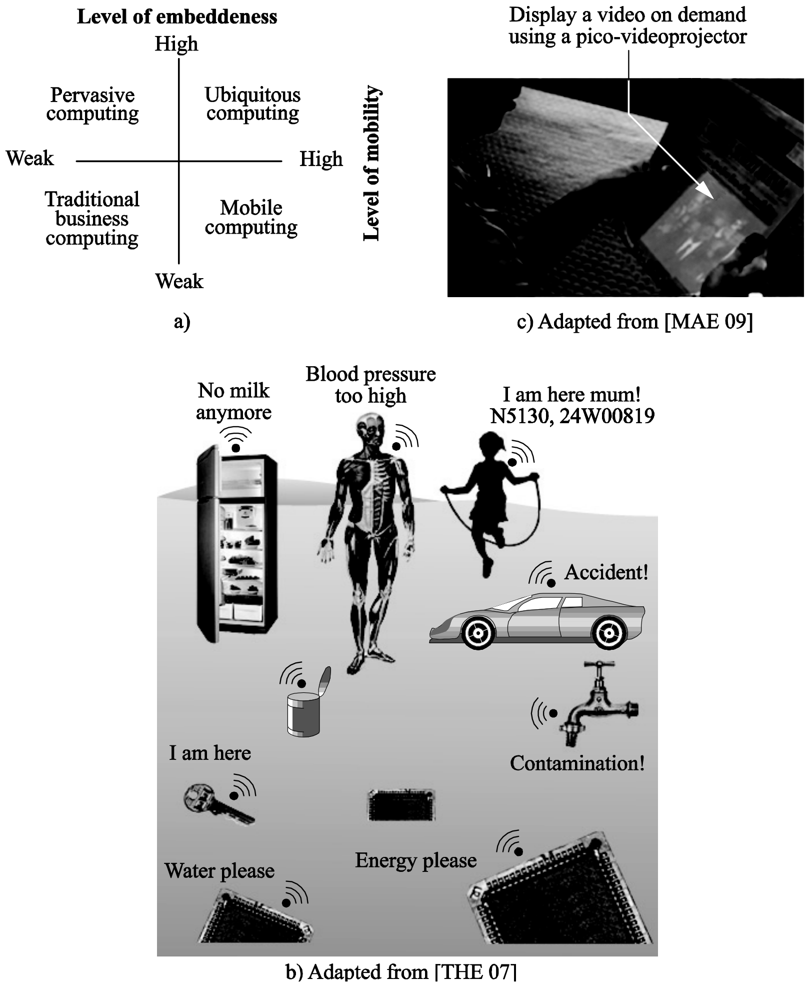


Figure 11.2. *From the evolution of IT to that of the interaction media*

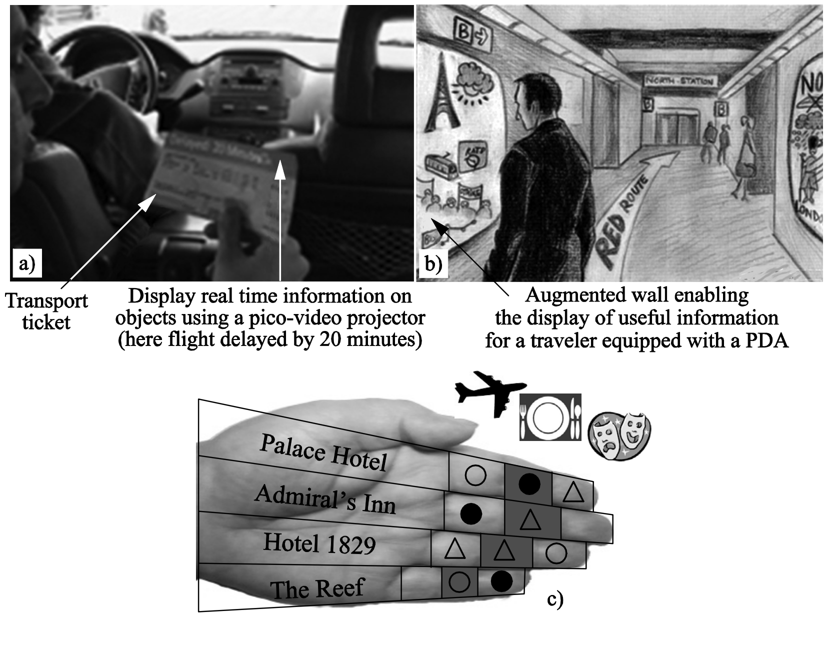
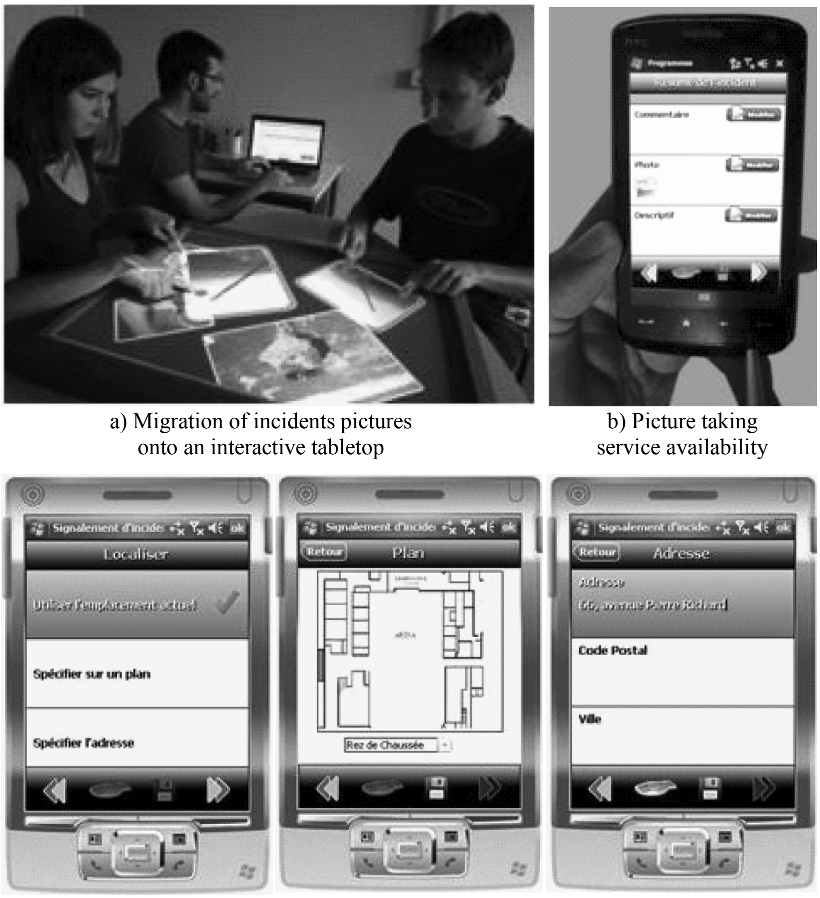


Figure 11.3. *Evolution of IT: combination of the mobility and integration axes: a) taken from [SIX] and adapted; b) project GLOSS; and c) according to [ANT 02]*

11.2.2. *Dynamicity of interaction resources*

In conventional IT, turning a computer on or off results in starting or stopping applications. In ambient IT, processing is more subtle: the interactive space of the user changes as soon as a computation, interaction or communication resource appears or disappears. Such a change can be an opportunity to redistribute applications across the available resources. UIs thus go from *sedentary to nomadic* [CAL 06]; the migration of applications, whether it be partial or total, being placed under the *explicit or implicit* user control, and this at various levels of granularity.

For example, Ubiloop [SER 09], see Figure 11.4, enables a person to report incidents (a broken bus shelter, a damaged self-service bicycle, etc.), and enables the communities to deal with them. Depending on the interaction device used by the person, a photo of the damage can be taken and attached to the notification of the incident. The local administration receives the notifications. For easier public decision making, the photos can be moved to an interactive table that will facilitate the grouping of incidents according to their level of priority, see Figure 11.4a. Moving the PC towards the table is explicitly asked for by the user (administrative member of staff), consequently leading to *redistribution* of the UI.



a) Migration of incidents pictures onto an interactive tabletop

b) Picture taking service availability

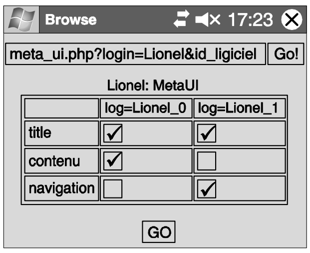
c) GPS localization

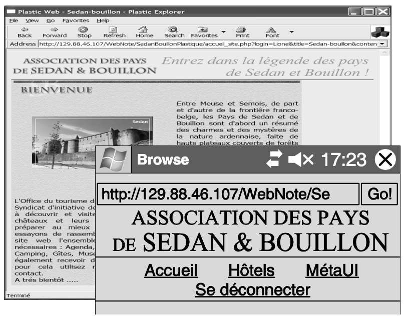
d) Localization on a map

e) Manual localization

Figure 11.4. *Ubiloop, an example of UI redistribution and remodeling*

(a) Sedan-Bouillon as a centralized version on PC: the UI is comprised of a title, a navigation bar and content.





(b) Meta-UI that proposes redistribution of the UI between the PC and PDA (identifiers: log_Lionel_0 or log_Lionel_1)

(c) After redistribution, the navigation bar has disappeared from the PC. It appears remodeled on the PDA and it is displayed horizontally (instead of vertically) below the title

Figure 11.5. *Sedan-Bouillon, a plastic website [BAL 04]*

For the individual, UI adaptation to the interaction device is performed automatically: photo taking is only proposed to the person if his cell phone is equipped with a camera, see Figure 11.4b. The localization of the incident is automatic when the cell phone has a GPS, see Figure 11.4c. Otherwise it is manually done by checking on a map whether the cell phone has a map of the place, see Figure 11.4d or, if not, by specifying the address of the place, see Figure 11.4e.

Comment [IPA2]: location?

If after connecting his PC to Sedan-Bouillon, Lionel connects to this same site from a PDA, then this double connection is detected and a redistribution proposal is made to him: a *negotiation* UI pops up that explains to Lionel that he can distribute the site, as he sees fit, between the PC and the PDA, see Figure 11.5b. The redistribution is done according to workspaces (the zones). By ticking the appropriate check boxes, Lionel specifies the allocation of the various workspaces to the different platforms. This additional UI enables the dynamicity to be placed under human control. These supervision UIs, which enable users to program their ambient spaces, are called "meta-UIs" by [COU 06]. The redistribution then proceeds, recomposing the UI under the control of the user, see Figure 11.5c.

In addition to dynamic adaptation triggered by the dynamic discovery of interaction resources, two other variables need to be considered:

– the variability of *information* provided by services that appear and disappear opportunistically; and

– the variability of the user's *intention* as the result of a change of place or the arrival of a particular information.

11.2.3. *User control*

It can be important for the user to have control of the UI adaptation process. One possible approach is so-called end-user programming, which makes it possible for "non-IT specialists" to develop their own services and systems. Although end-user programming was initiated 30 years ago [SMI 77], this area of research is being rediscovered in the context of ambient intelligence.

Research in end-user programming first sought to define simplified notations: scripting textual (*HyperTalk*) or graphical languages (*Visual AgenTalk*) [REP 04], programming by demonstration and by example [CYP 93], as well as the construction of macros (similar to emacs). These techniques were essentially applied to targeted areas such as CAO [GIR 92], spreadsheets [BUR 03], bio-informatics [LET 05] or, like Alice [CON 97] and HANDS [PAN 02], to the learning of programming. Recently, research has opened up to the web, with the possibility for users to build macros: with Koala, a user saves his actions on a webpage (for

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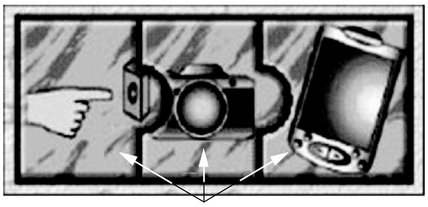
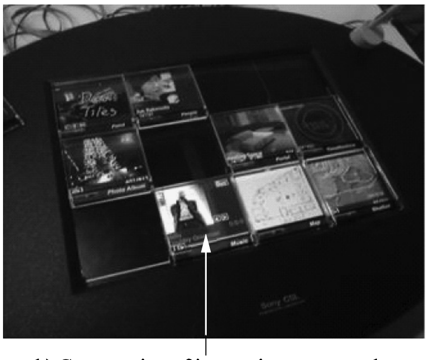
example, the input for the field of a form). He can replay these actions and publish them on a wiki to share them with members of his community (who can then reuse the pre-filled in forms) [LIT 07].

Works on the programming of ambient spaces by the final user are still in the early stages. In Speakeasy, the user can build queries for searching interaction resources (devices, services, etc.), filtering them based on the specification of the type of information they provide, with the objective of combining these resources in ways that had not been anticipated by the developers of the system [NEW 02]. With Jigsaw, users build simple programs by assembling pieces of a puzzle, such as "if someone rings the doorbell, take a photo and transfer it to the PDA" [ROD 04], see Figure 11.6a. It seems to be possible to extrapolate this principle to the world of transport or mobility, with assemblies such as: "provide a warning when passing an interesting site; take photos and send them to grandpa and grandma so that they can follow the journeys of their grandchild(ren) almost in real time". This extrapolation is broader than the adaptation to interaction resources: it also adapts to informational content.



a) Construction of interactive programs
by assembly of three digital components or services



b) Construction of interactive programs by
assembly of physical tablets indentifiable by RFID

Figure 11.6. *Two examples of programming by the end-user: a) Jigsaw [ROD 04]; and b) DataTiles [REK 01]*

The media-cubes [BLA 01], ICAP [SOH 06] and CAPella [DEY 04] tackle similar problems regarding combining interaction resources, with the difficulty of creating a productive alliance between the physical and digital worlds. Whereas in Jigsaw the user manipulates the digital world, in other approaches, such as [HIN 04] and DataTiles [REK 01] (see Figure 11.6b), the physical world comes first: for example, in DataTiles, the composition of physical tiles enables the user to express complex commands. The tiles are equipped with a radiofrequency identification (RFID) sensor that enables them to be identified in a unique way, as in [KUB 09]. They are augmented with the display of numerical data. In [TAY 09], motion defines the function of the object: the bar of soap becomes a telephone or a screen depending on how it is held. However none of them includes a Whyline-like development tool to support debugging [MYE 06].

UI adaptation to variability for the good of the human while supporting human control is a challenging issue for UI plasticity.

11.3. User interface plasticity: user viewpoint

This section adopts the viewpoint of the user. It defines the property of plasticity from the point of view of use and illustrates it in the field of transport.

11.3.1. *Definition*

Generally speaking, the property of plasticity refers to the ability of an entity for adaptation as the result of a change that has occurred in this entity or its environment. In human-computer interaction (HCI), plasticity is defined as the ability for *adaptation* of a UI to *a change in context of use* while respecting the *value* expected by the user [DAA 07]. Three key words structure this definition: the notions of adaptation, context of use and value.

Context is a set of information. This set is structured. It is shared, evolves, and serves interpretation [WIN 01]. The nature of the information, and how it is interpreted, depend on the finality. For UI plasticity, the finality is UI adaptation. As a result, the *context of use* is defined as the <user, platform, environment > triplet where:

– the user denotes the user of the interactive system. He can be described by his skills in the application domain, IT, etc., as well as by general data (age, size, etc.);

– the platform captures the hardware and software necessary for the interaction. Typically, the input and output devices are to be considered;

– the environment refers to the physical space where the interaction takes place. It can be described by light, sound, social, etc. conditions.

The *value* refers to a set of user-centered properties. In HCI, this notion of value is put forward by Cockton [COC 04], [COC 05]. He believes that usability is not sufficient: it must be confronted with the true expectations of the user. The example that he gives is that of heating management [COC 04]. The systems are possibly usable in the sense that they are easy to use and learn but none really meets the true desire of the user, which is to make a saving. The user does not program his heating system for fun. It is to reduce his bill. A good system should therefore show him how much he has saved. By extrapolation to the domain of transport, the incentive to use a mode of public transport or a combination of several personal and/or public modes (for example, take ones car to go to the station, then the train, then the tram, then walk) to go from point A to point B (refer on this subject to Chapter 1) can rest on a number of value criteria. These criteria can be those related to savings, time gained, or the possibility of traveling, or not, in connected mode during the trip. All of this must take into account the possible handicaps of the user, with the desire to be informed of the possible delays in the network, of the weather forecast (if it is raining, I'm not going to take my bicycle) etc. in real time.

In economy, value is defined as a unit that increases when the user's satisfaction increases or total spending decreases. Here, no judgment of value is established, consequently leaving the possibility of:

– whether or not to integrate the notion of cost;

– whether or not to support it with existing reference sources in the field of HCI, or in that of software ergonomics, whether normalized or not (for example ISO/IEC 9126), general references, attributing special attention to acceptability, utility and usability (e.g., typical reference sources such as [ABO 92], [BAS 93], [BRA 03], [CON 99], [DIX 93], [COC 96], [NIE 94], [PRE 94], [SCH 97], [SHA 91], [STE 09], [VAN 99] or specific references (such as [MON 04], [NOG 08] for the web or [LOP 04] for adaptation).

For choosing the appropriate properties, the domain-dependent functions as well as the adaptation process need to be considered. For example, observability [COC 6] is a criterion of general value. It applies to both the application domain and the adaptation process (and therefore successively to the UI and possibly to its meta-UI). In contrast, interaction continuity [TRE 03] measured, for example, by the number of physical actions the user has to repeat after UI adaptation, or inter-usability (i.e. "the facility with which users can transfer and adapt what they have learnt from their previous uses of a service when they access it with a new medium") [KAR 05] – also called horizontal usability [SEF 04] – are value criteria specific to the adaptation process.

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As illustrated in Ubiloop (section 11.2.2), adaptation can consist of a remodeling and/or a redistribution of the UI. The remodeling can be more or less deep, affecting the task of the user (his objective or the procedure) or be limited to surface modifications (restructuring or restyling). The redistribution can be total or partial, leading to a centralized or distributed UI.

The following section illustrates the plasticity in the domain of transport in a scenario that suggests an ensemble of research perspectives in this field.

11.3.2. *Illustration in transport*

Prelude: Pierre, who lives and works in Grenoble, must go on a business trip in the countryside near Toulouse for a company seminar. He must travel with Christine, a work colleague. They must take a train and then a bus to reach the location of the seminar. On his smart phone, Pierre has a very complete personal space, particularly for his trips: he stores all the information necessary for his journey (electronic train ticket, electronic bus ticket, hotel reservation, address of the seminar, etc.).

Moment No. 1: Pierre and Christine are in the augmented compartment of the train. Whereas some people are playing chess on the interactive table placed in front of their seats, Christine prefers to work on a project she is writing. She has already started filling in the description form: title, summary, number of hours, project manager, etc. She gets out her laptop computer. She begins by rereading the text and decides to show it to Pierre to get his opinion. As they are working, the battery of Christine's PC runs low. The form is then switched to the interactive table located in front of them. They can thus continue to work.

Analysis: a change occurred in the user platform (her battery was running out). This change caused a redistribution of the UI to enable the user to continue her task (expected value).

Moment No. 2: Pierre and Christine arrive in Valence, where they have to change trains. When they arrive on the platform, they learn that their connecting train will be late. Using his smart phone, Pierre consults the times of the next trains. There is a long wait so they will not arrive in time to take their bus to Toulouse. They must find an alternative solution. They head towards the station's augmented lounge and sit down at an interactive table. The system suggests keeping the actions linked to personal data on the smart phone and to carry out actions concerning the journey on the table. Pierre accepts. Information regarding the different stages of their journey is displayed on the table. By pressing on "Toulouse", they can consult the solutions available to get to the seminar. The system suggests renting a car

Comment [IPA5]: do you mean 'business lounge with computer facilities'? In England, access to the internet is usually referred to as 'wi-fi enabled' rather than taking the bus. Using his smart phone, Pierre drags and deposits personal information to fill in the car hire form. The presentation adapts itself to the platform.

Analysis: as the display surfaces of the platforms are heterogeneous, moving data requires a remodeling of the UI.

Moment No. 3: Pierre and Christine finally get onto their connecting train. Pierre consults his smart phone to see their seat numbers. They are in the augmented compartment; an interactive table is available to users. Pierre goes towards it. The system suggests moving information to the table. Virtual scissors then appear on Pierre’s smart phone that enable him to cut out the information he wishes to move to the interactive table. He chooses to display information relating to their journey on the table. A 3D view of the compartment of the train is displayed. Pierre can navigate through the compartment by tilting and turning his smart phone. He locates the seat numbers. Pierre takes advantage of this to visualize a map of the route. Christine and Pierre can interact at the same time: Pierre consults information regarding Toulouse station whereas Christine looks at where the seminar is and locates the hotel they have reserved.

Analysis: it is the proximity of the user to the table that triggers the adaptation.

Moment No. 4: once in Toulouse, Pierre and Christine collect the hire car. Pierre connects his smart phone to the vehicle system. The vehicle system asks him if he wants his “car preferences” to be transmitted to the hire car. Pierre chooses two options when he is driving: on one hand, the display of text messages on the dashboard and on the other hand, the oral transmission of road information. Pierre and Christine take the fast lane. The car system orally transmits the authorized speed to them. They have been going for about half an hour when Pierre receives a text message. The message is displayed on the dashboard: it is their colleagues from Grenoble telling them that they have stopped a bit further on to visit a farm with local products. Pierre and Christine decide to join them.

Analysis: the display of text messages adapts itself to the available platforms.

11.4. User interface plasticity: system viewpoint

This section is concerned with engineering UI plasticity. It recalls the key periods illustrated in the field of transport.

11.4.1. *Retrospective*

Since its definition in 1999 [THE 99], plasticity is explored incrementally, in three phases.

First stage: in the first decade of the 21st century, adaptation was studied in terms of multi-targeting: it consisted, at the design stage, of generating different versions of the UI for the different targeted contexts of use (typically, large screens *versus* small screens). This work was stimulated by:

– development and maintenance costs induced by the production of as many UI versions as contexts of use anticipated before the design stage; and

– the difficulty in ensuring ergonomic consistency between versions when developments are carried out in a partitioned manner.

This sales pitch was in answer to the *varied* nature of the context of use according to a system viewpoint: that of the designer confronted with multi target UI engineering [THE 01]. We label these works as the passage from *mono-targeting* to *multi-targeting.*

Second, the *variable* nature of the context of use is integrated into the research agenda, thus making the leap from *multi-targeting* to *plasticity:* designing for several key contexts of use identified in the phase before the design stage is not enough. Changes in context of use must be addressed. The European CAMELEON project (2001–2004)[2] covers these two increments (from mono-targeting to plasticity) with a bary centre nonetheless on multi-targeting. In particular, user-centered properties are not considered. The contexts of use and the changes in contexts of use are identified at the early phases. As a result, UIs are prefabricated, as for the Sedan-Bouillon demonstrator (section 11.2.2).

Third, the *unpredictable* nature of the context of use is integrated into the research agenda. From then on, it is no longer just a matter of perceiving the context of use and switching to the most appropriate prefabricated UI but generating, if necessary, an appropriate UI. The adaptation process then becomes more prominent. It can be based on approaches from artificial intelligence, including automatic symbolic learning techniques for decision modeling as in [HAR 08], [HAR 09]. The following section illustrates this viewpoint in a scenario linked to the field of transport[3].

2 http://giove.isti.cnr.it/cameleon.html.
3 This scenario could be extended to be linked with elements of personalization, as described in Chapter 3.

11.4.2. *Illustration in transport*

Prelude: Nathan, living in Grenoble, is on a business trip to Montpellier. Despite his tiredness, he decides to take his car rather than public transport. On his smart phone, Nathan has a very complete personal space, particularly for his trips (according to the same principle as Pierre in the illustration in section 11.3.2).

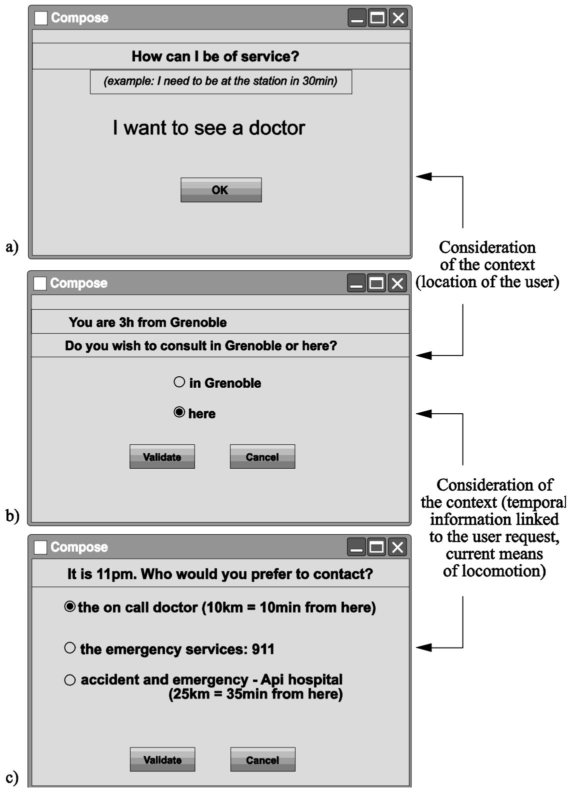


Figure 11.7. *Dynamic generation of HCI by taking into account information linked to the context of use (adapted from [GAB 09])*

Moment No. 1: Nathan is not very far from Montpellier. He is at the steering wheel and feels faint. He must see a doctor. He uses his smart phone (see Figure 11.7a) to express his needs.

Analysis: the plastic system takes into account contextual information to progressively provide Nathan with a reasonable solution (see Figures 11.7b and 11.7c).

Moment No. 2: Nathan has arrived in Montpellier. His feeling of illness is now more intense. He prefers to park and go by foot or by any other means available (bus, tram, etc., depending on the possibilities due to the late hour) to get to the on-call doctor's. Once again, he uses his smart phone to express his query.

Analysis: the plastic system takes contextual information into account in order to suggest the most appropriate route to Nathan (see Figure 11.8).

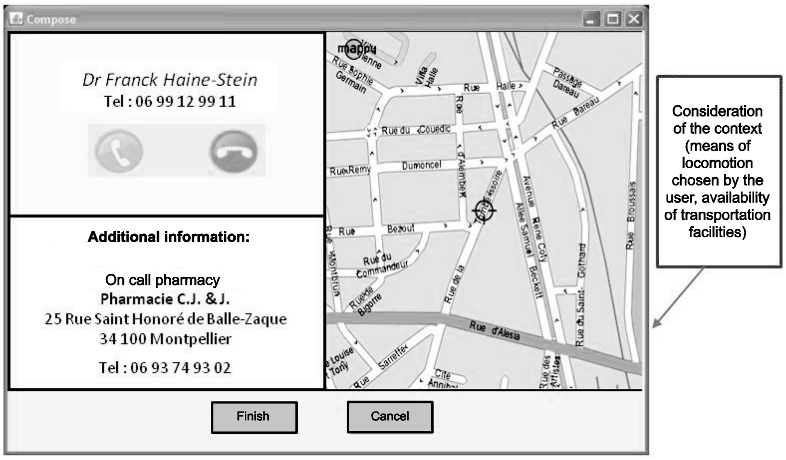


Figure 11.8. *Anoher example of dynamic generation of HCI by taking into account information linked to the context of interaction (adapted from [GAB 09])*

11.5. Towards a problem space for the implementation of plastic user interfaces

Several problem spaces have been proposed for UI plasticity [CAL 07a]. These spaces identify the key dimensions for supporting the analysis, design, implementation and/or evaluation of plastic UIs. Figure 11.9 proposes a simplified version of [CAL 07a]. This version is intended for UI designers. The objective is two-fold: to help them to imagine innovative solutions; and to think about the engineering. If this space does not claim to be exhaustive, it nonetheless compiles a number of questions that have been explored in the literature or that are to be investigated. Its originality is to attribute a semantic to point 0 and to the form of the diagram obtained by the characterization of a plastic UI in this space: the greater the distance to the centre, the more subtle the plasticity, making it potentially complex to implement. Our problem space is organized into sectors according to the external or internal properties under consideration.

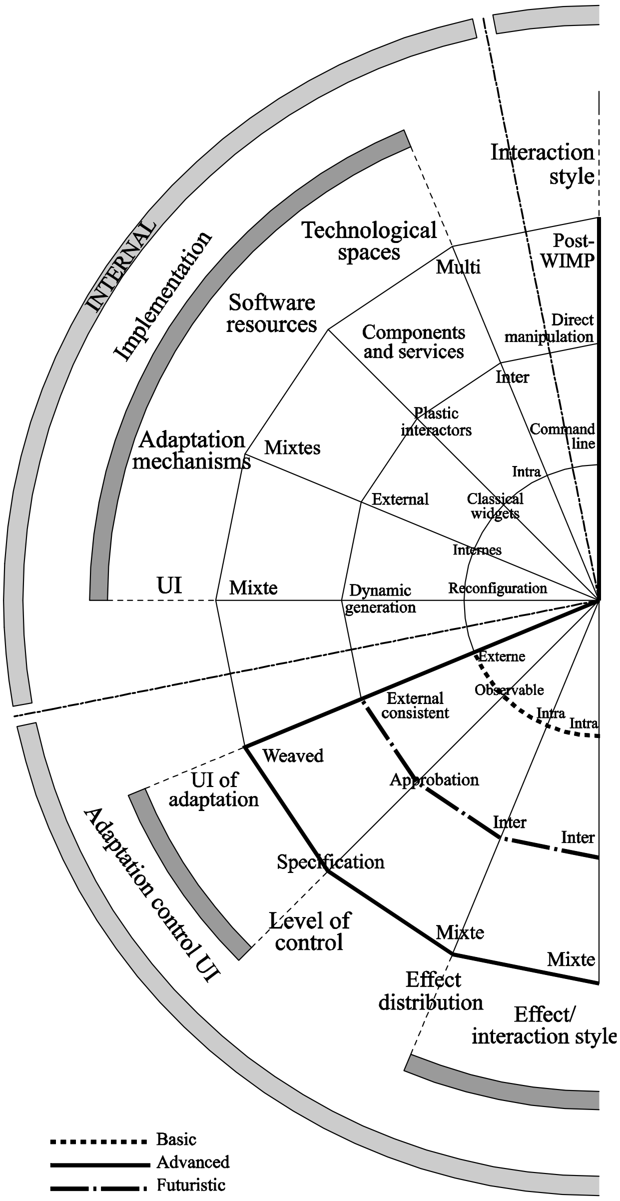
11.5.1. *User viewpoint: external properties*

External properties are organized into four sectors according to: the nature of the domain-dependent UI with which the user interacts; the change of context at the origin of the adaptation; the changes instigated in the UI; and the control given to the user regarding to the adaptation process (see Figure 11.9).

Domain-dependent UI: In general, the UIs that are considered for plasticity are simple, such as forms. The problem space makes a clear distinction, in terms of complexity, between the adaptation of form-based and command lines UIs and the adaptation of direct manipulation and post-WIMP UIs. This axis is concerned with UI remodeling. The second axis refers to UI distribution. It distinguishes the adaptation of centralized *versus* distributed UIs, the distribution being coarse grained (inter-task) *versus* fine grained (intra-task). Coarse grain means that a task is entirely carried out on a given platform. Conversely, fine grain implies that a same task requires the use of several interaction devices (for example in Ubiloop where part of the UI is on the PC and the other part is on an interactive table).

Context: in line with the definition of context of use, three axes make up this sector. The user dimension specifies whether the adaptation is done in relation to an archetypal model of the targeted user *versus* the effective interaction the user or, even more generally, his activity. The platform distinguishes simple configurations composed of a single entity (e.g. a PC) *versus* homogeneous (e.g. two PCs) or heterogeneous platform assemblies (e.g. a PC and an interactive table, as in Ubiloop). The environment, which goes beyond open environments (e.g. a street), and closed spaces (e.g. an office), covers some potential complexity related to users' mobility.

Effects of the adaptation: the occurrence analyses the moment when the adaptation happens. With coarse grain, it can intervene between two sessions. It can also occur between two user tasks or even, with smaller grain, between two physical actions on interaction devices. The task dimension defines the range of the adaptation in terms of the user's task: is it limited to the user's task?


INTERNAL
Implementation
Interaction style
Technological spaces
Post-WIMP
Multi
Software resources
Components and services
Direct manipulation
Inter
Plastic interactors
Command line
Adaptation mechanisms
Mixtes
Intra
External
Classical widgets
Internes
UI
Mixte
Dynamic generation
Reconfiguration
Externe
External consistent
Observable
Intra
Intra
Weaved
UI of adaptation
Approbation
Inter
Inter
Adaptation control UI
Specification
Level of control
Mixte
Mixte
Effect distribution
Effect/ interaction style
Basic
Advanced
Futuristic

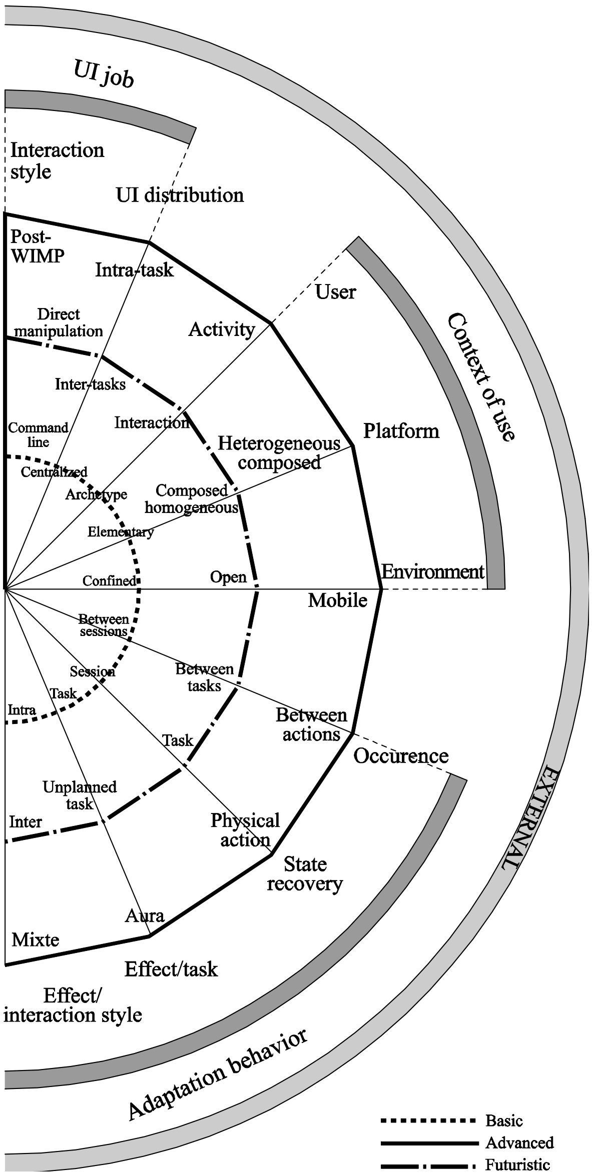


Figure 11.9. *Space problem of plasticity*

Does it consist of enabling an unplanned task as in section 11.4.2 or does it extend to the full personal information space? In terms of remodeling, does adaptation preserve the UI interaction style (command lines, direct manipulation *versus* post-WIMP)? If so, the adaptation is said to be intra-style. Inter-style refers to a change in style (e.g. from post-WIMP to direct manipulation). More complexly, styles can be combined (one post-WIMP part on the table; one command line part on the PC). In terms of distribution, the state of the UI (centralized, distributed inter-task *versus* intra-task) can be maintained (intra) or modified. The modification can be the passage from one state to another (inter) or to the combination of states (mixed). The repeat grain refers to the eventual loss of physical actions during the adaptation process. At the session grain, the user must repeat all of his past actions. The action grain saves and restores any physical action. whether the task is achieved or not.

Control of the adaptation: as a minimum, according to software ergonomic rules the user must be able to observe the adaptation process. For example, in Ubiloop the council staff member sees the photos move progressively from the PC to the interactive table. A more subtle degree of control anticipates that the system will propose adaptation (here, the moving of photos) to the user. The latter approves the proposition or not. In a more controlled manner, as in Sedan-Bouillon, the user can specify the adaptation and control the UI that is consequently fabricated or reused. Whatever the degree of control, a UI (and a meta-UI if it exists) therefore make the adaptation process observable and possibly controllable by the user. The meta-UI, which makes the domain-dependent UI observable and controllable, may be external to this domain-dependent UI, with no interaction style constraint, as is the case in Sedan-Bouillon: it is a window in its own right, heterogeneous in style. Alternatively, the meta-UI may be external and consistent in interaction style with the domain-dependent UI, or it can be woven into the domain-dependent UI, e.g., integrated into the window (in the case of graphical UI) of the domain-dependent UI, possibly requiring the plasticity of the domain-dependent UI!

If the dimensions described in this section are perceivable to the user, they all translate into software requirements. These requirements are not necessarily perceived by the user. These internal properties are discussed next.

11.5.2. *System viewpoint: internal properties*

Internal properties are organized along four dimensions, see Figure 11.9. First is the UI: is this subject to adaptation, reconfigured or is another UI generated or even a hybrid configuration produced? In the latter case, the UI is the assembly of components from the original UI and of generated parts. Second, are the adaptation mechanisms embedded in the source code of the UI? If not, are they external to the

UI and taken care of by a middleware? Or is it a hybrid configuration that inter-operates internal and external parts?

Third, do the generated UI instantiate classical *widgets* provided by the usual toolboxes (e.g. Swing) or do they resort to specialized *widgets* for plasticity (e.g. COMET [DEM 07])? It is worth noting that the software components of larger grain size can also be dynamically recruited to serve as a basis for the composition of UIs [BAL 08].

Finally, from a technological point of view, are the technological spaces conserved? Intra means that the pre- and post-adaptation UIs are implemented within the same technological spaces (e.g. HTML). Inter refers to a change in technological spaces (e.g. from HTML to OpenGL). Mixed would denote a combination of technological spaces.

11.6. Conclusion and perspectives

In the rich, complex domain of interactive systems, UI plasticity is a particularly promising and challenging research area. This chapter has given a representative overview of UI plasticity while showing that transport is a fertile ground for its application. The chapter opened with the evolution of HCI in relation to the diversity and dynamicity of interaction resources, including their control by humans. Where possible, these different aspects have been illustrated with transport applications, and more generally with users' mobility.

The concept of UI plasticity was defined from the perspectives of the user and the system. Two voluntarily restricted, but representative, scenarios related to transport have been explored to illustrate the potentials of UI plasticity. Both show the central role of context.

A problem space was outlined to provide designers, developers and evaluators with an overview of aspects of UI plasticity that should be considered and combined for the development of future interactive systems.

Numerous research issues have been identified. UI composition by end-users is one of the foremost challenges. If keeping the user in the loop seems reasonable from the point of view of software ergonomics, the approach seems equally reasonable from the point of view of engineering. The automation of evaluation of the quality of a UI requires the formalization of ergonomic criteria, the definition of metrics and the implementation of evaluation functions. These challenges are at the foreground of plasticity, but more generally are also at the cutting edge of teaching and practice of HCI in business. Indeed, [SER 10] shows that thinking plasticity can

Comment [IPA6]: is this interpretation correct?

improve the quality of even rigid UIs. Plasticity is clearly a challenge of growing impact that has yet to reveal its full importance.

11.7. Acknowledgements

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