Kinetic User Interfaces for unobtrusive interaction with mobile and ubiquitous systems

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Abstract. Unobtrusiveness is a key factor in usability of mobile and ubiquitous computing systems made of several ambient and mobile devices intended to support users' activities in everyday life and supposed to not interfere with them. We intend to address this topic by proposing a new kind of user interface that captures motion as an input modality, and by assessing its impact on unobtrusiveness. The Kinetic User Interface is a new interaction paradigm for ubiquitous computing and mobile systems where input is provided through coordinated motion of objects and people in the physical space. Typically, people are capable of moving objects and themselves with low attention and consciousness while performing even complex tasks. Nevertheless, motion carries lot of information about their intentions and might signal abnormal situations when they are not following expected patterns.

1 Introduction

During the last ten years much research has been carried out in Ubiquitous Computing (Ubicomp) and Human Computer Interaction (HCI) to address the usability problems arisen by adapting old-style interaction models to new emergent interaction paradigms (see for instance, [1]). When HCI intersects Ubicomp, many assumptions made when designing for interaction with ordinary computing devices are no longer valid. In Ubicomp, computers exist in different forms and only in minimal portion as ordinary desktop computers (i.e. where interaction is performed through screens, keyboards, mice). Ubicomp and mobile computing systems enable new kinds of user interfaces that rely on different metaphors and interaction patterns than those on which classical Desktop and Web interfaces are designed. Now the interface is distributed in space. Motion of objects and people can be used to interact with physical places enriched with digital appliances. Moreover, these interfaces include modalities that are typically not under the conscious control of the user such as motion, gesture, heartbeat, temperature, and sweat. Through wearable sensor and smart objects technology, all these inputs can be easily collected and used for interaction with computers.

As pointed out by [2], interacting with a Ubicomp system should be realized through *unobtrusive interfaces*, more precisely, interfaces that, when used, do not capture the full attention of the user who can still use the system while performing other foreground tasks. One term for a system with this type of interface is "Calm Technology" so to stress the importance of adapting the computers and their interfaces to human pace rather that the other way around. In this vision, computers should follow users in their daily activity and be ready to provide information or assistance on demand.

As proposed by [3], Ubicomp user interfaces must provide a support for *implicit input*. By implicit input we mean input obtained from users by just observing their behaviour or sensing the interaction space (i.e. sensing the status of objects the user is supposed to interact with). Differently than explicit input, implicit input does not necessarily require the conscious supervision of the user and might trigger what Alan Dix calls *incidental interactions* with the environment [4]. Incidental interaction presupposes neither a precise user's goal nor conscious attention. Rather, it happens when the environment reacts to one or more ongoing user activities. Users may become aware of the effects of incidental interactions like when the courtesy lights are switched on when getting into a car, or they can be hidden and reflected only at system level like when a highway transit payment is made by driving through an electronic toll collection station.

1.1 Kinetic User Interfaces

We define here a new interaction paradigm that we called the *Kinetic User Interface* (KUI) model [5]. KUIs are expected to be unobtrusive in the sense that user's *activities* (rather than user's tasks and goals) are taken into account for interaction. In this type of interfaces, users' behaviour is observed by the system, which is then capable of inferring what are their goals and intentions as well as their level of attention. The KUI model extends in some way the notion of location-awareness in mobile Ubicomp systems by introducing the concept of *motion* (or *kinetic*) *awareness*. Motion, considered as a form of context-change, is an instance of the more general paradigm that Alan Dix defines as *context-aware computing* in [6]. In KUIs, motion and motion properties trigger actions and constitute events. Moreover, motion patterns can be recognized as meaningful activities and exploited to infer users (implicit or explicit) intentions.

The interpretation of a motion pattern does not necessarily relate to a single task, it is often part of a larger interpretation process where the user is trying to achieve a long-term goal such as experiencing some good feeling in playing a game or expressing emotions during a conversation. *Kinetic interaction* is thus about exploiting the motion properties of objects used in a mediated human-computer interaction in order to unobtrusively capture users' intentions (i.e. without a requiring heavy user's attention or cognitive load).

The role of the context in kinetic interaction is essential because the beforehand determination of the actual situation can guide the system in capturing specific expected (and unexpected) motion patterns and thus reducing the search space. Moreover, situations can be learned from historical data and provide a measure of deviancy from the expected behavior, thus triggering the appropriate reactions of the system (e.g. an unusual behavior in a well-know situation might signal an anomalous condition).

1.2 Related Work

The most known instantiation of KUIs is Tangible User Interfaces [7], tangible interaction is intended to replace desktop GUI's interaction and elements with operations on physical objects. The motion of objects in physical space determines the execution of actions on the user interface, such as items selection (by means of what in TUI are called “phycons”), service requests, database updates, etc. In [8] an extension of the Drag&Drop pattern, namely the Pick&Drop pattern has been proposed to move items across computers. Fitzmaurice in his work on Graspable User Interfaces [9] proposes to extend the interaction with classical GUI by means of physical objects (e.g. LEGO bricks) over an augmented desktop surface. Tangible and Graspable Interfaces are undoubtedly a great achievement in HCI. They are, however, still strongly biased by GUIs interfaces: nearly no new types of interaction induced by the nature of the physical space and objects have been proposed other than replicating those available on ordinary desktop GUIs. In these interaction paradigms, real objects replace input devices and visual feedback is typically obtained through *augmented reality*. In Augmented Reality [10], three-dimensional graphical elements of the user interface are superimposed to video streams of the real world, beamed on physical surfaces or directly projected to the user’s retina through head-mounted displays. Wearable Interfaces [11] feature some of characteristics of KUIs. Bodily motion is certainly one of the types of input provided by the worn computer whose main goal is providing a mobile computer embedded in ordinary clothes.

One project that almost fully exemplifies the features of KUIs is the Sonic City project [12] conducted at the Viktoria Institute in Sweden, which exploits motion in the urban landscape as a way for interactively creating musical experience. The user motion is tracked, as well as the current position over the city map. Motion and location contexts are combined with other contexts obtained through wearable sensors in order to influence composition of music content in real-time. Users of the Sonic City interface can hear themselves the result of musical composition during their walking activity through a headset. The synthesized music depends on motion patterns (crossing a street, walking straight, standing, running, etc.), contextual city information (busy street, traffic, etc.) and the user body activity (arm motion, heart rate). This system uses a large number of different motion capture devices embedded in a wearable prototype and used to retrieve activity and contextual information.

In October 2008, I co-organized a workshop on Mobile and Kinetic User Interfaces (MobiKUI’08) [13]. MobiKUI’08 was aimed at gathering researchers and practitioners interested in interaction with mobile and pervasive computer systems through motion of people and everyday objects. Since we typically move entities in physical space, we consider important that these entities be capable of location and motion awareness. Several scenarios where showcased where networked moving entities were exploited at different spatial scales, from tabletops, to rooms, buildings, cities, and even larger spaces. In these scenarios, interaction takes places by either triggering system’s reaction from the recognition of selected motion patterns of objects and people in structured spaces (e.g. tables, rooms, cities) or by observing longer-term activities.

The topics of the workshop were also related to a new trends in mobile and Ubicomp systems, such as Activity-Oriented Interaction Design, the new interaction patterns that are enabled by the availability of traceable objects for performing actions on computer systems.

1.3 KUI affordances

Moving a real object in the space is not the same thing as moving a virtual object in a virtual space. First of all, real objects themselves provide a visual feedback of the successful motion while visual feedback is required on a display in order to monitor the virtual object's reaction to the virtual motion stimulus obtained through an external device (e.g. a mouse). On the one and, depending on the type of object, real objects and the physical space provide fewer mechanical constraints than virtual spaces and can afford rather complex interaction patterns. On the other hand, virtual motion includes motion of virtual objects (e.g. documents) in virtual spaces (e.g. over the Internet).

Kinetic or motion awareness is a step beyond first-generation location-based mobile systems [14]. Sensing motion can be added to location-awareness in order to unleash more powerful interaction with mobile and ambient devices. In ordinary location-based system, the current location information is used as a context for applications running on mobile device. The location context is typically used for visualizing the user's current position or for providing the location parameters to the running application. The interaction with the mobile device remains the same.

In contrast in KUIs, location-awareness tells the interface the place where the kinetic interaction is happening. For instance, the same motion pattern (e.g. a gesture) can be interpreted differently depending where it is executed (e.g. indoor or outdoor).

Motion can be also used as a context for applications, which in turn could also afford kinetic actions. As a first case, let's consider a situation where motion is taken as a context and the interaction is not made through motion. For example, consider a car's computer system that switches output modality from GUI's dialog boxes to text-to-speech when the speed is over 70 Kmh. The second case is when motion awareness is combined with kinetic input. An example could be interpreting the action of shaking the cell phone while the user is walking or not.

As in GUIs, an important issue in designing KUI's interaction patterns is feedback management. Due to the different nature of physical space with respect to GUI's graphical space, feedback cannot be given in the same way as in GUIs. As one of the goals of KUI is to enable the calm computing paradigm, we give back to users only the minimal amount of information required to inform them that their interaction with the physical space has been successfully recognized. In turn, the system should avoid interfering too much with user's current activity if the effects of the recognized action have only a peripheral importance with their current activity, i.e. if they affect objects that are not in the current focus of attention of the user. Moreover, since the physical space already affords for direct manipulation of real objects, feedback should inform users only about those effects produced in the computing space to affected virtual objects. A feedback control mechanism is also necessary for other reasons, such as privacy: to grant a certain level of protection, users must be notified somehow when their presence and motion is being currently tracked. As a consequence, they must always be given the possibility to stop the tracking of a mobile device and to be allowed using an alternative interaction modality.

2 Unobtrusive interfaces

The main topic we would like to address in this paper is how kinetic awareness helps in designing mobile and Ubicomp unobtrusive interfaces. We identify two main use cases:

1. Users want to perform actions by moving themselves or objects in the physical space. In this case, unobtrusiveness is achieved by hiding the effects of the actions until something relevant happens in the system according to the current context. Only a minimal amount of feedback is provided in order to let users know that the input has been captured;

2. Users perform an activity that is monitored by the system. In this case, the system silently observes users activity and triggers a more attention-demanding interaction only when an abnormal behavior is detected, or when contextually relevant information is available.

Interaction with Ubicomp and mobile applications can thus benefit of KUIs. Being an input modality, motion can be used to explicitly communicate intentions to the system. For instance, if a dialog is started by the system on a mobile device (e.g. a cell phone) while the user is walking, keeping walking at the same (or higher) speed can be interpreted as an implicit "cancel". This pattern is illustrated in a KUI-based application for collaborative mobile workflow [15].

2.1 Continuous interaction

The above concerns highlight another important aspect of interaction in Ubicomp and mobile systems: *continuous interaction*. Continuous interaction is a shift of focus in designing computer interfaces from tasks to activities. In standard personal computing users intend to achieve well-defined goals by starting a suitable set of interrelated tasks and by following a precise workflow. While this type of interaction seems rather natural when sitting in front of a desktop PC or using handheld devices, it does not fit well with the assumptions of Ubicomp discussed earlier. In Ubicomp systems the users should have more freedom and, as it happens for other ordinary non-computing situations, they might focus more on the overall ongoing activity than on the individual detailed tasks. Typically, activities can be interrupted and resumed at any time and they can be made of several, loosely coordinated activities running at the same time. This means that designers of Ubicomp systems cannot assume a clear begin or end of applications that needs, in turn, to be highly responsive and interruptible. Moreover, an Ubicomp system should be able to recognize when the user is starting an activity without being explicitly notified of that and, most of all, without engaging an attention-demanding interaction with the user. Conversely, the system should show up in the foreground when something abnormal has been detected and only in this case it should capture the full user's attention.

Another important aspect addressed by kinetic-aware interfaces is how to infer the current focus and various degrees attention from user's kinetic activity. In certain situations it is pretty easy to infer the focus of the user. For example, when using an electronic tourist guide as in [16], the system might detect that the user is interested in getting information when stopping in front of a monument. Absence of motion is interpreted as a focus shift from looking around to observing an object. When this event is detected, then the system can start the interaction with the user. After providing the contextual information, the tourist guide might ask if the user need further information. If no explicit answer is given and the user starts moving away from the monument, then the system will interpret this motion pattern as an implicit negative answer.

2.2 The role of Activity Theory

The principles underlying this new interaction paradigm of continuous interaction have been developed in the framework of *Activity Theory* [17, 18]. Activity Theory (AT) is a model of human cognition that has been used to inform human-centred design of (possibly computational) artefacts. Within this theory, human activity is decomposed along the dimension of consciousness, from high to low, in three main categories: Goals, Actions, and Operations. In AT, goals set high-level activities and they correspond to either desired states of the environment (e.g. furnishing a room) or internal cognitive states (e.g. being happy). Operations are the most unconscious, routinely activities that require almost no explicit attention. Operations “implement” actions and are typically executed by “operating” artefacts through their "interfaces". More than one (possibly coordinated) operation is typically needed to carry out one action and the same operation could be used to support different types of action. By executing operations, humans (agents, more generally) are able to change the observable state of the operated artefacts. The state of an artefact can indeed be observed by other agents and thus serves as a coordination/communication device.

As pointed out by [19], AT represents a potential framework for HCI research. We share this belief especially because it can support the analysis and the decomposition of user interaction with Ubicomp systems. AT goes beyond the classical GOMS (Goals, Operators, Methods, and Selection rules) analysis [20] since it describes the *dynamic movement* between the levels of activity (i.e. in term of levels of consciousness) rather than taking a crystallised view on user’s tasks.

Interpreting user’s activities is a new direction in research in interaction design started at Washinghton University and Intel research in Seattle [21]. Activity-Oriented Design (AOD) is still in its early stage of development. It stems from the research started in Berkeley by Anind Dey on context-aware computing [22] and heads towards a new reconsideration of what it is Ubicomp and the type of interaction it will support. In their work, activities are first-class objects that are constructed and interpreted by looking at long-lasting observation of user’s behavior. They propose a conceptual framework that derives from Activity Theory and where users are engaged in *activities* having long-term goals (e.g. stay fit, stay safe, have fun, win a game, take a decision). They can perform *actions* that are short-term goal achieving, have multiple roles (can serve multiple activities), and require high-level of consciousness. Actions are implemented through (possibly reusable) *operations*. These are immediate goal achieving, require low-level of consciousness, have limited scope and are typically stateless. In AOD, there are three categories: *Themes*, a new term for activity, which is a collection of scenes. A *scene* is made of an action and a given situation (contextualized). Multiple scenes contribute to the advancement of the theme and *situations* represent the context in which an action has a particular role in a theme.

In activity-based Ubicomp, multiple sensors provide the event streams on which a certain number of "observers" are able to detect the presence of a given situation (with a certain degree of confidence). Within a spotted situation, the application focuses on the recognition of a smaller subset of actions that are relevant to the ongoing activity (the theme).

In KUIs, the theme corresponds to a high-level description of an interactive session (e.g. a game, a meeting, an artistic performance). The theme has a certain number of pre-defined (possibly learned) scenes that are possible in certain situations of the theme. For instance, being in a certain room of the house, let's say the kitchen, at a given hour of the day, let's say around lunchtime, enables a certain number of possible situations such as preparing a meal or getting a snack. Of course, it is not just entering in the kitchen that enables the situation, but a number of (correlated) events that occur in a given place (not in a strict order and interleaved by other unrelated events). Situations are not then "sufficient conditions" to be tested; they are rather "necessary conditions" that have to be verified if the situation holds. In other words, situations provide more focus in identifying the user's intentions. Intuitively, user's intentions can be recognized only after the observation of their behavior over time. Hypothesis on what the user is trying to achieve can be made and revised if not accurate after further observations.

2.3 Assessing the Interface's Unobtrusiveness

For the analysis of unobtrusiveness of interfaces, the Activity Theory model is adopted in the following way: we assume that users are performing a foreground activity and the system monitors that operations are executed correctly. In such a case, the users are likely to be able to interact with the system because operations typically require a low level of attention. When an abnormal (or relevant) situation is detected, the system expects that the user will now focus on the operation recognized as problematic or relevant to the current context. Now the system should act as a real assistant and provide real help for the situation. It is crucial at this time that the interface is as unobtrusive as possible, requiring minimal (unnecessary) interaction with the user. Conversely, the system should be pro-active and take unsupervised decisions that might solve the actual problems.

We argue that ordinary GUIs for ambient and mobile devices are minimally unobtrusive in the sense we just explained. Even in the case of augmented reality or wearable interface, unobtrusiveness is not guaranteed. The main reason is that ordinary user interfaces often rely on direct manipulation. Direct manipulation of the interface's elements requires immediate feedback in order to verify the success of the operation. The user is almost always forced to look at the manipulated interface's elements. If this is acceptable in using a desktop application, it is not when using a computing system in mobile environments (e.g. while driving a car or interacting with ambient devices).

We believe that current interaction models that are based on the interpretation of a single event stream within a single locus of attention are not adequate to model situations where multiple streams of events must be taken into account. Additionally, interaction with physical objects already provides a feedback of their direct manipulation. This means that the challenge here is to provide adequate feedback for extended manipulations of multiple real and virtual objects in a coordinated manner. For instance, in a kids play room made of networked smart objects such as the Bobick's KidsRoom [23], the game interface could provide a sort of reinforcement (e.g. a nice background song) when it is observing a "correct" or "progressing" behavior of the baby playing with the objects.

2.4 Evaluation framework for unobtrusiveness

In order to understand the essential characteristics of the KUI paradigm and its differences from GUIs we adopt the descriptive model offered by the Beaudouin-Lafon's Instrumental Interaction framework [24]. In this framework, a distinction is made between *direct* and *indirect manipulation* of domain objects through appropriate *instruments*. For instance, in GUIs whenever an action is made on highly interactive widgets (such as scrollbars or handles) the effects of actions are almost immediately perceivable through both the visual component of the widget and of the domain object. This means that in most cases, GUI provides nearly direct manipulation of the domain object through an appropriate instrument.

In KUIs the situation is different because of the different nature of the instruments and the domain objects being the former physical objects and the latter virtual entities. (e.g. sweeping a credit card trigger a payment transaction).

This framework will help us in evaluating at design time the KUI interface's elements along four measurable dimensions:

1. *Activation cost*. Some of the instruments available in KUIs will need to be activated following a procedure (e.g. by performing an action through another input modality) or they will be always available. The activation cost measures the cognitive load required to users to activate KUI's elements for their subsequent interaction.

2. *Degree of indirection*. It measures the physical (spatial, temporal) distance between the instrument and the domain object. With this feature we intend to evaluate how well the feedback is perceived by the user when executing actions on virtual objects using KUIs. Degree of indirection describes a continuum between direct manipulation and indirect manipulation.

3. *Degree of integration*. This dimension is defined as the ratio between the degrees of freedom (DOF) provided by the logical part of the instrument and the DOF captured by the input device. In KUI we will almost always have a very high DOF in the input. We will have to

ensure that only the easily controllable spatio-temporal dimensions of the KUI will be connected to in a given situation to corresponding controls of the instrument. For instance, if the environment affords only horizontal movement (e.g. there are no stairs or elevators), the height spatial dimension will simply not be taken into account.

4. *Degree of compatibility*. In the original definition, the degree of compatibility measures the similarity between the physical actions of the users on the instrument and the feedback of the domain object. In GUIs, dragging an object has a high degree of compatibility since the object follows the movements of the mouse. Scrolling with a scrollbar has a low degree of compatibility because moving the thumb downwards moves the document upwards. Measuring compatibility in KUI is difficult because of the intrinsic different nature of KUI interaction in the physical space (i.e. motion) and the actions on virtual objects of the computational space.

Among these four dimensions, we consider that the most relevant for assessing unobtrusiveness are the first twos. It is apparent that low activation cost and high degree of indirection substantially contribute to the interface's unobtrusiveness.

2.5 Unobtrusiveness in KUIs

KUIs are a special case of activity-based interfaces where actions and activities are realized through motion patterns. KUIs maximize unobtrusiveness in mobile and Ubicomp systems. We defend this position by looking at three case studies explicitly based on a specific framework for kinetic user interface. These cases exemplify how the KUI paradigm can help in making mobile and ubiquitous system more unobtrusive.

2.5.1 Smart Heating System.

The first case we examine is a system for the automatic adjustment of heating and cooling parameters in a household. Many existing systems only provide fancy interfaces for manual controlling the temperature settings. We consider instead intelligent systems that detect inhabitants' location and motion for automatically adjusting the temperature of individual rooms according to recognized activities.

The Mozer's Adaptive House is an experimental personal research project in Boulder Colorado and it is, as far as we know, the only system that observes and learns people's occupancy (i.e. at home or away), preferences (e.g. room's ideal temperature) and usage pattern (e.g. turn on/off, change thermostat levels), and tries to continuously adjust the temperature accordingly [25]. Basically, the Adaptive House uses people's schedules, preferences and occupancy to save energy by anticipating inhabitant needs. This system uses a rudimentary form of KUI because only detects people occupancy for automatically selecting learned temperature settings. We proposed an extension of this model in [26] where KUIs is fully exploited for maximizing both energy saving and user's comfort. Here unobtrusiveness is a key feature because users implicitly select different temperature preferences associated to their behavioral patterns. Also, the displacement of certain objects (e.g. a remote control) from one room to another can signal the intention of transferring the same ongoing activity from one place to another (e.g. watching TV). As a reaction, the system will transfer the current temperature setting from one room to another and will reset the "unoccupied" room setting to the left one.

According to the evaluation schema proposed, we consider that this type of interface would have a very low activation cost and a sufficiently high level of indirection, thus making this interface fairly unobtrusive.

2.5.2 Smart Flight Assistance.

Another scenario for which KUIs are essential for maximizing unobtrusiveness is navigation assistance. We designed and implemented a system for paragliding flight assistance [27]. During normal flight, the assistant shows flight parameters. When the pilot performs a potentially dangerous manoeuvre such as approaching an airfield or a no-fly zone, the system warns her with an audio-visual alarm. The user is shown with the flashing zone on the map so that she can steer and move away from it. Thus the user's focus is captured by the application only in cases where a danger is approaching and only by showing relevant information about the danger. The warned user can now take measures to exit from the dangerous situation and the return to normality is signalled by the application that shows ordinary flight parameters.

Here we have again low activation cost combined with a medium degree of indirection. However, it must be noted that the interface shows current flight parameters on a dashboard that can be ignored during normal conditions of the flight. When the application switches to "alert" mode, then the interaction changes and the degree of indirection becomes higher. In fact the system no longer show all flight parameters but forces the pilot to focus on the physical piloting for re-establishing safe flight conditions.

2.5.3 Mobile collaborative workflow.

The third case is about mobile collaborative workflow. Here we have workers connected through a mobile proxy who continuously signal their location and motion to a back-end application. This application assigns tasks from a geo-referenced task list according to the workers' location and motion. An example of this scenario is implemented by the UbiShop prototype which is manages shopping list reminder [15]. UbiShop alerts the user when he/she happen to be close to a grocery shop that sells one or more items in the current shopping list. Here unobtrusiveness is achieved by detecting the user's motion for interacting with the system. In case the user's location is nearby a targeted grocery store but the user's speed is high (e.g. driving), the system decides not to bother the user. Otherwise, if the user is just walking, the system sends the purchase request and waits for the user's response. In this situation the user can keep interacting through motion because keeping walking or moving away from the targeted place will be interpreted by the system as a rejection.

In evaluating unobtrusiveness, we note that the activation cost is low and degree of indirection is high. The indirection is reduced only when task request is sent to the users, who can in turn decide to keep interacting trough motion or use the mobile GUI. In the former case, the indirection degree is lowered. This case shows how the interface chooses to maximize unobtrusiveness by default, and only becomes more attention demanding when users decide to switch their focus to the application.

3 Conclusion

In this paper we have reviewed the main principles of kinetic user interfaces and outlined a conceptual framework for assessing and evaluating unobtrusiveness for mobile and ubiquitous computing systems' interfaces. We argued that unobtrusiveness is a key feature of certain mobile and ubiquitous systems for which user's attention should not fully captured by the interface. Since many mobile and Ubicomp system simply reproduced scaled down desktop GUIs, unobtrusiveness is hard to achieve. Only through a redesign of the user interface that takes into account user's implicit action this goal can be pursued. We applied the evaluation framework to three existing kinetic-aware applications and evaluated their interface's unobtrusiveness.

We recommend that interaction designers consider KUI as a design principle for all those cases where applications support users in performing a foreground task, which does not directly involve the computing device. In particular, we believe that if a mobile device is just a proxy for communicating with a back-end system, then the interface should be kept minimal with respect to the communication of user's activities. Moreover, if neither the direct manipulation of virtual objects is required nor the effects of user's action require direct feedback, then this is the right place for KUIs. In fact, as exemplified by the three cases, we argued that KUI support unobtrusiveness in intelligent task assistance.

We believe that unobtrusiveness is a key factor in the usability of new generation mobile and Ubicomp interfaces as pointed out by [28] and that kinetic-awareness can play an essential role in achieving this goal.

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