Negotiation Models for Mobile Tactile Interaction

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Abstract. With the recent introduction of mass-market mobile phones with touch-sensitive displays, location, bearing and motion sensing, we are on the cusp of significant progress in a highly interactive mobile social networking. We propose that such systems must work in various contexts, levels of uncertainties and utilize different types of human senses. In order to explore the feasibility of such a system we describe an experiment with a multimodal implementation which allows users to engage in a continuous interaction with each other by using capacitive touch input, visual and/or vibro-tactile feedback and perform a goal-oriented collaborative task of target acquisition. Initial user study found the approach to be interesting and engaging despite the constraints imposed by the interaction method.

Keywords: Mobile social interaction, multi-modal, mobile, touch, tactile, human communication.

1 Introduction

With the recent introduction of mass-market mobile phones with touch-sensitive displays, location, bearing and motion sensing, we are on the cusp of significant progress in a highly interactive mobile social networking [5]. Strachan and Murray-Smith [13] described bearing-based interaction with content and services, and in linked work Robinson et al. [11] describe its use for GeoBlogging. It is also an obvious step to couple this with social networking applications, where users can probe and point at and engage with nearby friends [12]. The richness of the sensing, and the context-sensitivity and person-specific nature of such communications suggest that designers should beware of implementing overly prescriptive mechanisms for allowing individuals to interact in such systems. Currently capacitive touch displays are primarily used for human-computer interaction, i.e. for navigating through the user interface of the device, however they have the potential to be used for a much more exciting range of interaction styles including dynamic human-human interaction. We present in this paper such an interaction style and explore its potential also for eyes-free mobile context. We introduce and describe a system, with an initial user study, which examines the interaction between human users using embodied touch-based interaction, exploring whether it is possible for users to track each other and locate objects in the virtual environment with realistic sensing conditions.

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2 Mobile Social Interaction

Mobile Social Interaction enables users to interact with each other via a hybrid physical/virtual environment using their mobile device. Users can remotely touch each other in a mediated environment and in an eyes-free manner and scan the space for objects using finger touch.

A fluid and unrestricted collaboration between two or more people connected remotely via a computer has long been a goal in the fields of virtual and augmented reality. Collaborative Virtual Environments [1] enable a sense of shared space and physical presence in the virtual world. The increasing power and ubiquity of continually connected and continuously sensing mobile devices enables us to generalise down to the mobile realm with the development of Mobile Collaborative Virtual Environment (MCVE). In this paper we present an approach enabling the creation of a hybrid 'eyes-free' physical/virtual world in which users can interact using their mobile device as a probe for objects or for other users, while receiving vibro-tactile feedback dependent on the nature of their probing. A key aspect to the success of this kind of interaction is the provision of a sense of embodiment or presence in the virtual environment. Greenhalgh and Benford [7] tackle this with the DIVE and MASSIVE systems by providing a number of graphical representations of embodied participants. The major advantage that these systems have is that they are highly visual and significant emphasis is placed on the provision of visual feedback to the user. Oakley et al. [10] presented a mechanism for haptic collaboration in synchronous shared editors and a study where haptic communication appeared to facilitate collaboration and improve usability.

One of the major functions of social cognition in humans is to allow the creation of a shared world in which interaction can take place. Communication between two or more people is greatly enhanced by the adoption of a shared vocabulary that enables us to share goals, so that we can engage in joint activity. For successful interactions to take place it is necessary that the interactors achieve the same perception of the world, referred to as 'common ground' [2]. This is slightly easier to achieve in a hybrid virtual/physical environment than in a completely abstracted space. Since an MCVE is located in the real world the user is not completely immersed in the virtual world, they have access to real-world visual cues and some of this natural intuition regarding the interaction with the physical world may be transferred into the virtual world. Espinoza et al. [3] describe their GeoNotes system that allows users to leave virtual messages linked to specific geographical positions. They strive to socially enhance digital space by blurring its boundary with the physical space. However little has been achieved in terms of active interaction or collaboration between two or more users in such environments and it still remains a challenge. The starting point for this kind of active and collaborative interaction is to align the focus of our attention in the environment, typically achieved in real life by pointing at an object or watching bodily movements that can give us some idea about the intentions of the other person [4]. Our bodies are used to provide continuous and fine-grained social cognitive signals about our psychological state, our presence, activity and our attention via gestures, facial expressions or general body posture. It is important that this kind of information is not lost completely in the virtual environment. Lenay et al. [9] show in their studies of perceptual crossing and reciprocal tactile perception how the feeling of sharing a common space with another intentional being can emerge by switching between two kinds of perception: perceiving the other as part of environment, versus perceiving the activity of other perceiving me. They also present a theoretical framework and models for assisting the conception of tactile communication devices.

Most experimental research on human communication relies on methods that entail the use of pre-established natural or artificial languages, which tap into the processes leading to the emergence of communication systems only indirectly. Galantucci [6], however, described a method introducing the complexity of human behavior into a controlled experimental setting, in the absence of pre-established human communication systems. The scientific understanding of such complex processes would greatly benefit from experiments that elucidate how these systems emerge and develop in the context of joint human activities.

The motivation for our experiment was to explore the feasibility of the presented new interaction method and investigate questions related to performance, cognitive load, user experience and in particular to sense of engagement and togetherness. The future outlook of the proposed method includes ‘in-pocket’ interaction, where simple tasks could be performed in an eyes-free manner.

3 Experimental System

Imagine the following scenario. Andy is in a meeting room with other colleagues while his friend John is walking on a busy street. They certainly cannot have a phone conversation at the moment, but would like to agree on a specific time for a call. Since they are not aware of each other’s schedule they would have to negotiate. Ringing each other up intrusively is not an option; texting extensively is not too convenient either. Instead they could work this out in a more dynamic and fluid manner by probing each other on their shared membrane and agreeing on the time. In this situation one important concern is privacy. They would not like the other one to have full visibility of their schedule, which makes it more complicated than if they would have shared calendars (Fig. 1a). Instead they will have to negotiate a common time slot suitable for both of them without revealing too much private information.

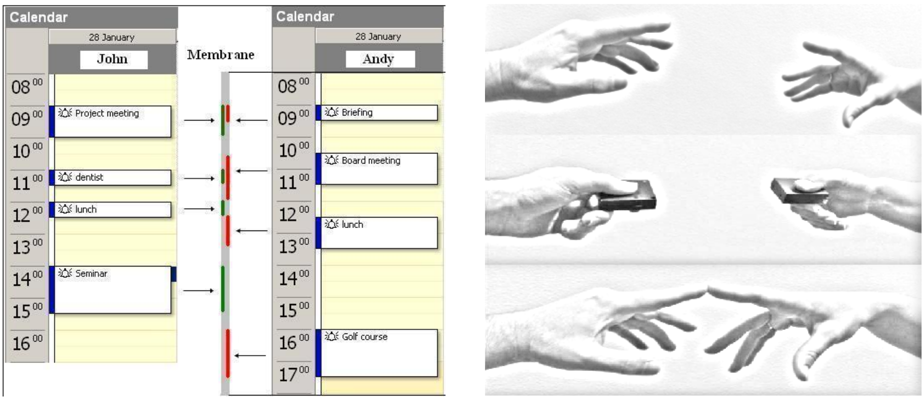

Fig. 1. (a) Membrane concept for diary alignment, (b) Remote touch using SHAKEs

Our interaction mechanism takes the concept of an abstract membrane as a medium to convey the sense of touch. The metaphor of the membrane dynamic system could facilitate and enrich interaction in scenarios as described above. It enables people to touch each other remotely and engage in a continuous dynamic interaction by sliding their fingers and pushing gently on both sides of the membrane. The feedback is visual and tactile, and provides rendering of the internal states of the simulated dynamic system. Allowing users to perceive the changing physical characteristics of the modeled system can be used to convey much richer information about the current state of the person they are interacting with, via continuous interaction and rich feedback, than a static event-based technique would.

The system is intended to illustrate an example of how shared environments can be created with low-latency multimodal feedback and capacitive sensing. It builds on the membrane concept of touch at a distance utilizing mobile tactile devices (Fig. 1b). In this case the membrane has certain number of holes on both sides. The interaction concept includes two users exploring simultaneously the membrane from their side respectively and trying to find a hole through which they could touch each other. In order to explore the effect different modalities have on this kind of interaction we have designed both visual and tactile feedback while trying to keep in mind results in crossmodal interaction research [8]. The main goal of the design was to present the same information in both modalities in a consistent and logical way. We designed the feedback displays so as to allow users to sense each other whenever their fingers meet on the shared membrane and to sense the holes in their side of the membrane whenever they locate one. We display the membrane in a section as a vertical gray-colored stripe (Fig. 2a). The visual representation of the finger is a bell-shaped pointer, while the tactile one is a fast and sharp vibration. The visual shape of a hole is a black square and the tactile one is a slow pulsing vibration.

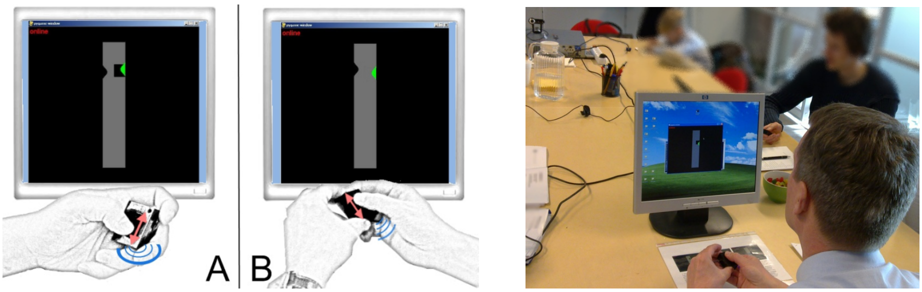

Fig. 2. (a) User A (in green on his display) has found a hole presented by black square and slow pulsing vibration. He can also see and feel his partner (in black) on the other side of the membrane. User B (in green on his display) feels and sees only his partner (in black), since there is no hole on his side of the membrane in this location, (b) Study participants familiarizing with the system.

The system uses capacitive sensing devices for finger touch input, a dual vibro-tactile engine and a visual display. With the input device the user can probe the membrane up and down, in the vertical direction and search for holes and for the remote partner. Holes and the remote partner can be sensed only when the user gets in their close proximity (Fig. 2a), otherwise they are hidden. The user can obtain information only by sensing for impact events, whenever their pointer collides with objects in the shared environment. The task requires users' active exploration of the membrane and locating a hole which is common for both sides. The hole is acquired only when both users locate it simultaneously and hold on still for 0.5 sec, which eliminates incidental acquisitions. Both sides have three holes each, sensible only from their respective side, of which only one is common.

The prototype system consisted of two laptops and two SHAKE SK7 sensor packs. The SHAKE provides 8-bit resolution capacitive sensing from 12 square pads in a 4x3 configuration at 100Hz. It also provides a dual vibro-tactile feedback display - a pager-style vibration motor and a pulsed resonant actuator. The former provides good low frequency while the latter provides excellent high frequency actuation. We use the former for representing the holes and the latter for representing the fingers. The system is implemented in Python and uses WiFi link between the laptops at 100Hz, which in turn are connected to the respective SK7 over Bluetooth.

4 User Study

In this exploratory study our aim was to examine the feasibility of the presented human collaborative task given the restricted modes for communication. We were interested in the limits of these unusual interaction methods in terms of performance and cognitive load and especially in how people cope with the tactile-only system. In our study participants performed a collaborative task in pairs via shared environment, while sitting in separate rooms. Performance depended on their cooperation, which in turn required some sort of communication. Since use of standard communication systems as speaking, writing and body language was prevented, in order to succeed participants were enforced to converge onto a way of using the available resources for interaction.

The experiment consisted of three phases, each 5 minutes long, corresponding to the three different conditions – Visual, Tactile, and Combined (visual&tactile). In each phase the pairs had to complete a set of tasks, where a new task started automatically 5 seconds after the previous task was completed successfully. The location of holes in different tasks was randomized and all pairs had to perform the same list of tasks in the same order, however the order of the three conditions varied for different pairs.

Twenty-six people, 18 males and 8 females participated in the study. Four pairs knew each other well (friends, couple), two pairs were colleagues, and five pairs did not know each other well previously.

Participants were first given an introduction to the system, before being allowed to practice the Combined version for up to 10 minutes, while still sitting in the same room (Fig. 2b) and being allowed and encouraged to discuss.

After completing each phase of the experiment, the participants filled out a section in the questionnaire including extended NASA-TLX, and a set of questions created especially for this experiment. In addition to this they defined 3-5 positive and negative words reflecting the positive and negative aspects of the interaction method they just tried out. At the end the participants answered a set of questions surveying the experience, preferences and game strategies used.

5 Results

The NASA-TLX results revealed that overall workload was significantly higher in Tactile condition ($p<0.001$). This was the trend in Mental ($p<0.001$) and Physical demand ($p<0.05$), Time pressure ($p<0.03$), Frustration and Effort ($p<0.001$). Combined had significantly higher performance level than Tactile ($p<0.03$). The majority of the subjective preferences ranked Combined the highest. Visual was considered unhurried and slow, while Combined was described as more responsive and active. Tactile was linked to words as 'togetherness', 'collaboration' and 'connection'. According to the questionnaires participants believed this technology could encourage communication with people.

The total number of holes acquired by all 13 pairs in different conditions shows a difference between Tactile (32) and the other two, Visual (135) and Combined (122). On the pair level differences between Visual and Combined seem to be due to the execution order, the first one being lower. The learning effect in the visual conditions shows an increase of 50% for most pairs in the subsequent phases. Top scoring pairs had a consistent strategy, executed relatively well in the Visual and Combined and less successfully in Tactile. Even when certain strategies failed to materialize some pairs tried and succeeded in creating new ones that eventually worked.

Some pairs performed surprisingly well in Tactile, even though the scores were lower than in the other conditions, which shows the potential in this approach. Tactile was considered challenging, novel, emphasizing the contact between the partners and the sense of togetherness and collaboration as suggested in [9].

One of the pairs who admitted having a working strategy described it as moving 'together from the top down' (Fig. 3). Fig. 4 shows parts of their time series in more detail. Fig. 3 reveals that this pair did not have clearly defined leader and follower roles. Instead they implemented a sort of turn-taking leadership, which resembles more to a smooth dance than a command-and-control behavior. After the experiment they commented that it was 'interesting', 'fun' and 'surprisingly social experience'.

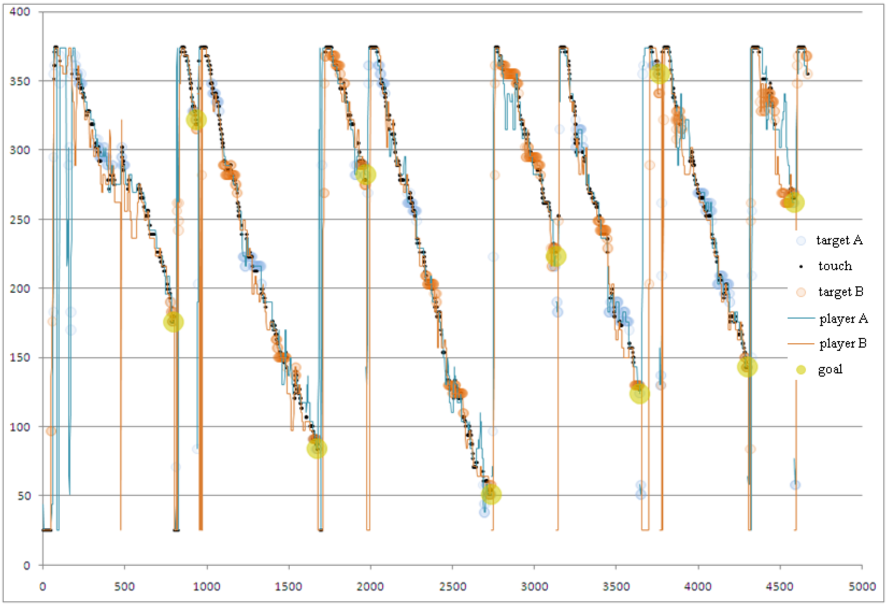

Fig. 3. Time series of a top performing pair

Another pair (Fig. 5), who admittedly did not have a strategy – or as one of the partners put it 'at least not a common one' – achieved only a fraction of the top performers' results. Although they claimed that it was easy to learn the technique and to find the holes and the partner, they found that the most difficult was 'to get the other to move to the same direction'. Since our system provided only limited means for exercising a command-and-control style behavior, this pair was unable to interact successfully (Fig. 6b). They could not literally drag or control, but only perceive each other and exactly this minimalistic kind of interaction was the purpose of our feasibility study.

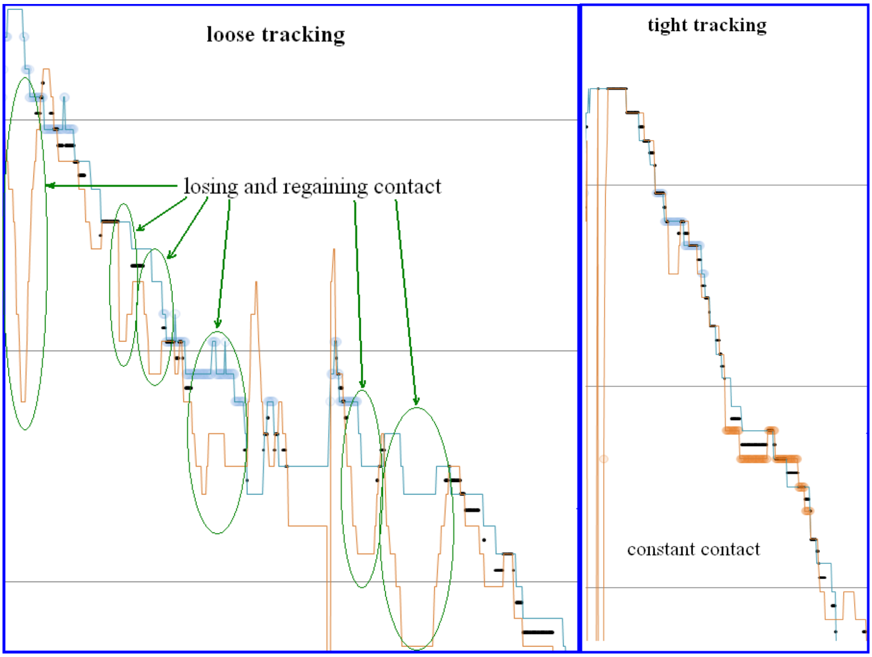

Fig. 4. Consistent strategies - (a) loose tracking, (b) tight tracking

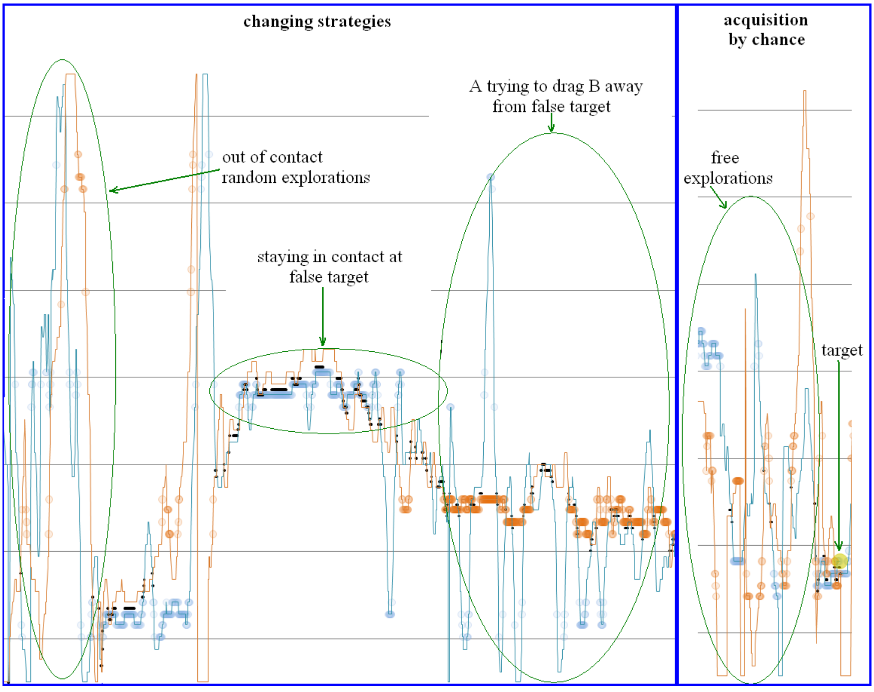

Fig. 5. Random strategies

The phase plot of a successful strategy (Fig. 6a) shows that after the pair managed to ‘get in touch’ they successfully executed their strategy while staying close (in touch) until they reached the target.

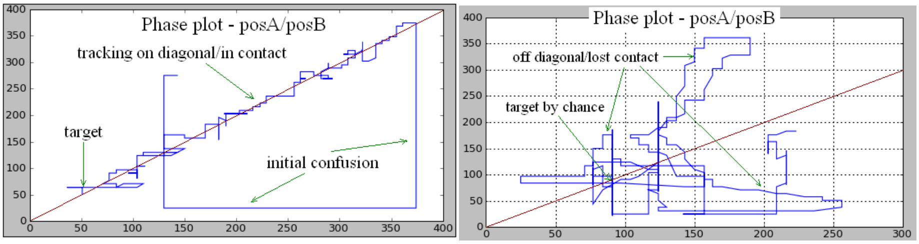

Fig. 6. Phase plots of (a) tight tracking and (b) random strategy.

Further successful strategies are shown in Fig. 7.

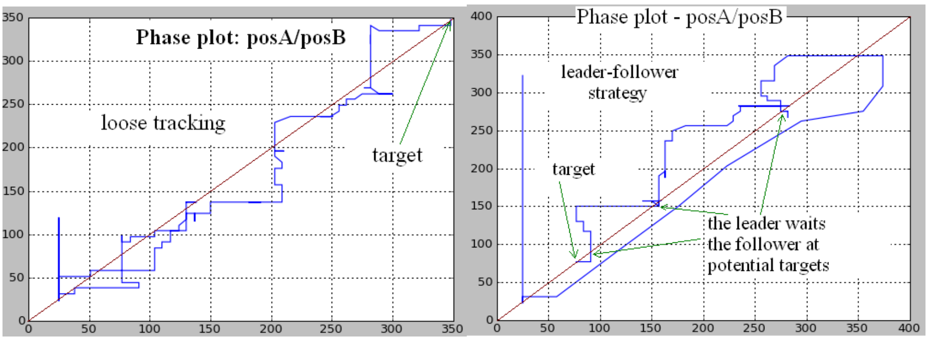

Fig. 7. Phase plots of (a) loose tracking and (b) leader-follower pair

6 Conclusion and Future Work

This paper introduced a new form of embodied social interaction using current technology and demonstrated its potential via an initial user study. It was found that pairs, with limited level of training, succeeded in their tasks to different degrees – the main discriminating factor being the existence or the lack of negotiating strategy. The participants found this new form of interaction interesting and engaging, and believed it could encourage communication with people, which opens new possibilities for the development of richer social interactions. The limited potential of the tactile-only version, shown by significant increase in overall workload and decrease in performance, however brings new research topics for future ‘in pocket’ interaction studies – namely by incorporating other eyes-free modalities like audio. The experiment in this paper involved human users interacting in pairs, from which an extensive amount of data was collected. One next step is to build models of human behavior fitting the collected data. Future experiments using simulated agents and human users would give us more control of the activity levels and would improve repeatability. This would give us firmer ground for observing the detailed interactions that evolve as people engage and disengage from remote contact with each other.

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