

PART II: RESEARCH PROGRAMME

1. OVERVIEW

We propose the investigation and evaluation of an alternative approach to the integration of physical and digital resources which we call *negotiated interaction* (NI). This framework draws on dynamic systems theory, probabilistic reasoning and multimodal feedback. We believe this ambitious project has wide-ranging implications for HCI in general, creating a new paradigm for analysis and design of interaction, and is especially important for the growing area of mobile computing.

The proposed probabilistic, dynamic framework allows us to make use of the continuous control actions humans have evolved to perform on the physical world (grasping, probing, tracking sounds), and culturally acquired ones (e.g. driving a vehicle) [8,28,32]. Now we can apply these to rich abstractions such as multidimensional, structured probability density functions as if they were tangible objects [30]. So, for instance, the likelihood of a route being interesting to users can be represented in a probabilistic manner, conditioned on their proximity to it, the route's attributes and the way users react to cues given by the system to suggest they might explore it (following or deviating from it) [27,24,31].

Multimodal techniques can be used to present the feedback the human needs to collaborate with the machine. A key part of this proposal will be the careful combination of audio, haptics and gestures in such a way as to give the user a sense of the uncertainty of states in the machine, and, through the continuous negotiation process, to refine the shared understanding of context [9,31,6,21]. The negotiated dynamic approach 'opens up' the machine's mechanism of pattern recognition, so that the user is progressively given feedback of the machine's interpretation of his/her sensed actions. This contrasts with predominant, discrete approaches whereby the system simply performs the response to its interpretation of a user's actions – a gesture for instance – once a 'match' is made. The project has three core aims, each led by one of the investigators:

1. *Develop the theory and mechanics of the dynamic systems approach to NI* (led by Murray-Smith);
2. *Design and evaluate multimodal interaction techniques for NI* (led by Brewster);
3. *Investigate and evaluate macro-level NI techniques in relation to realistic scenarios* (led by Jones).

The work carried out towards achieving these aims will provide insights into the sorts of situation and tasks to which the approach is best suited, and investigate the extent to which the approach may enable users to sense and make sense of digital information related to phenomena in their environments such as places, routes, events and people. This work will also lead to novel evaluation techniques with the purpose of assessing the impact of the approach on the user's experience of their environments.

The activities will be highly integrated, with the theoretical work of Murray-Smith being transferred into interface-level techniques by Brewster and then considered in realistic contexts by Jones. The scenario development work will both inform and be informed by findings arising from the theory, mechanics and multimodality efforts.

The proposed research is interdisciplinary, bringing together specialists in multimodal and mobile HCI and mathematical modelling. It is also adventurous, suggesting

a fresh approach to HCI, and is of key importance to the UK for it to maintain its strong position in the area of HCI and design for mobiles. The Government's Foresight Committee reports that in the near future the "... richness and diversity of both the input and the output channels will increase - multimodal input and output will become the norm. The senses of sight, hearing and touch will be seamlessly integrated, and exploited together to maximise the bandwidth of the psychological interface". We are therefore addressing problems that are directly relevant to the future of UK science and industry, especially mobile service and software companies.

The team's research provides solid foundations for this project. Murray-Smith has a background in modelling dynamic systems, human control behaviour [7,8] and the interface to statistics [29,30]. Brewster is an active researcher in multimodal interaction and mobile devices [4, 20, 21]. Joint work between Brewster and Murray-Smith in the EPSRC-funded AudioClouds project (rated "Outstanding") and an ongoing SFI project on Negotiated Interaction, at NUI Maynooth, laid the foundations for the current proposal, and the experience, software and hardware developed will form a unique basis for the efficient development and evaluation of the ideas in this project. Jones has a background in the research of innovative mobile interactive schemes (e.g., [10-13]). He has conducted pilot-studies related to the proposal [11, 25, 27]. He has just co-authored the most extensive book available on mobile HCI [13], and with strong experience in related areas provides invaluable experience to the team.

We are requesting 2 RAs and 1 RS, equipment and travel for a period of 3 years. Our progress will be measured against the following milestones:

Year 1: Hardware/software test-bed shared across both sites. Papers on: the theory and mechanics of dynamics approach underlying NI; the design and evaluation of basic multimodal interaction techniques to support NI; and on the scenario development work.

Year 2: Papers on: dynamic and probabilistic approaches to dealing with increased uncertainty and complexity in scenarios; dynamic multimodal interactions and multi-user interfaces; evaluation of effectiveness of NI in range of scenarios. Demonstrator and experimental-control systems for scenarios.

Year 3: Toolkit for building NI applications. Design guidelines for using new interaction techniques. Toolkit of evaluation methods. Final demonstrator applications. Papers on the efficacy of the approach in more complex scenarios including multi-user cases and browsing of structured content in the augmented reality. Host workshop to disseminate results.

2. BACKGROUND

Our proposal is to investigate an alternative means of allowing users to interact with content and services in their environment such that the actions they make – movements, gestures, etc. – and feedback they receive are continuous, with the user and system negotiating their interactions in a fluid, dynamic way. We believe the appropriate comparison would be *dancing*, rather than the current *command & control* metaphor. When someone dances with a partner there is a soft ebb and flow of control; sometimes one person leads, sometimes the other, this changing fluidly as they dance. We are proposing a