Towards an Advanced Framework for Whole Body Interaction

David England, Martin Randles, Paul Fergus, and A. Taleb-Bendiab

School of Computing and Maths, Liverpool John Moores University,
Liverpool L3 3AF, UK
`{d.england,m.j.randles,p.fergus,A.TalebBendiab}@ljmu.ac.uk`

Abstract. Whole Body Interaction has emerged in recent years as a discipline that integrates the physical, physiological, cognitive and emotional aspects of a person's complete interaction with a digital environment. In this paper we present a framework to handle the integration of the complex of input signals and the feedback required to support such interaction. The framework is based on the principles of Autonomic Computing and aims to provide adaption and robustness in the management of whole body interaction. Finally we present some example case studies of how such a framework could be used.

Keywords: Whole Body Interaction, Motion Capture, Autonomic Computing.

1 Introduction

Bill Buxton [1] mused on what future archaeologist would make of today's humans extrapolating from our current computer technology and came up with a being with one eye, a dominant hand and two ears but lacking legs, and a sense of smell or touch. He argued for greater involvement in the whole person and their senses in human-computer interaction. Researchers and artists have responded to this challenge by exploiting the various technologies that fall under the general banner of virtual reality, and support whole body interaction. In our own work with artists [2] we have seen how they use camera vision and motion capture in novel interactions.

However, despite the technological and methodological advances we are still some way off from a completely integrated approach to Whole Body Interaction. Let us give a definition of Whole Body Interaction:

The integrated capture and processing of human signals from physical, physiological, cognitive and emotional sources to generate feedback to those sources for interaction in a digital environment.

From this definition we can see that some approaches to HCI do not give us an integrated view of interaction. For example, Ubiquitous Computing [3] is more concerned with the notion of 'Place' rather than capturing the full range of actions. Physical Computing [4] is more concerned with artifacts than the physical nature of humans. Of course it is the nature of research to focus on certain, measurable aspects of interaction within the scope of a research project. However, in doing so we can loose sight of the larger, richer picture and the possibilities of Whole Body

R. Shumaker (Ed.): Virtual and Mixed Reality, LNCS 5622, pp. 32–40, 2009.

Interaction. For Whole Body Interaction to succeed requires an interdisciplinary approach and interactions between the following disciplines

- Physical – we need interaction with Sports, Movement Science and Artists on the physical capabilities and limitations human being
- Physiological – sharing with clinicians and psychologists on the reading and interpretation of physiological signals
- Cognitive – the long history interaction between cognitive psychologists and computer science has been the bedrock of HCI
- Emotional – Psychologists, Artists and Game Designers have sought to understand and introduce knowledge of human emotions into interaction design

From this collection of disciplines we can see there is quite a rich interplay of knowledge required before we can begin to support a truly integrated Whole Body Interaction system. It would also be the case that as further research is carried out in the contributing disciplines, our understanding of how can support Whole Body Interaction would evolve. Furthermore, there are a vast range of possible applications areas for Whole Body Interaction including, Games and Entertainment, Medical, Military, Education, Sports, Household, the Arts and so forth and each application area would have its own requirements as to accuracy of movement, the nature of any feedback and robustness of the system. And within each area individuals will learn and evolve their physical skills as they interact.

From this opening set of requirements we can see that we may need a complex system to manage Whole Body Interaction. However, if we are to allow domain experts to exploit Whole Body Interaction then we need an approach which allows them to express their domain knowledge; in movement, cognition, physiology, in their own terms.

The rest of the paper is structured as followed. In section 2 we explain Autonomic Computing as a basis for managing complex Interaction. In section 3 we present our framework based on Autonomic Computing. In section 4 we present some illustrative case studies, and final in section 5 we discuss our conclusions and the future implications of our work.

2 Autonomic Computing and Interaction

Autonomic Computing systems [5] were proposed by IBM as a way of managing the configuration and management of complex systems without continuing user human involvement. Such systems could include farms of servers, monitoring equipment in the field, Cloud-like distributed systems of services, wireless sensor networks and autonomous robots. Autonomic Computing systems borrow and adapt ideas from biological systems in order to support their on-going self-management. Thus such systems try to take care of:

- Reconfiguration in the event that one or more components fail or go off line
- Real-time service selection: as circumstances change new services may be selected to cope with them
- Self-Monitoring of the status of the whole system supporting self-repair

Though originally envisaged as supporting embedded or autonomous systems without much human involvement, the principles of Autonomic Computing have been used in complex interactive systems. Here the requirement is to support characteristics such as adaptability, robustness, self-repair and monitoring of the interaction. We require the system to be able to cope with emerging complex issues after it has been released to the end users without further monitoring or maintenance by the original development team. Ideally we would like the end users to provide their own on-going systems configuration based on their expert domain knowledge.

In our own work on post-operative Breast Cancer decision support [6] we used the mechanisms of Autonomic Computing to support the integration of components in a complex decision making process. The key challenges to such a system were:

- The modeling of clinical decision-making processes – these processes could evolve over time and vary from hospital to hospital
- The governance of adherence to guidelines and patient safety
- Integration of rule-based guidelines modeling with the data mining of historical treatments data to provide a cross-cutting approach to decision support
- Providing multiple views of decision data
- Generating user interface(s) to the above

The chief mechanism for our Autonomic User Interface Engine is the Situation Calculus. The Situation Calculus provides an extensible representation of system knowledge, ideal states and action sequences [7, 8] is used as a User Interface Description Language to provide the major specification formalism and reasoning mechanisms. Firstly the action-based semantics of the language provide an in-built description for every available user interactive action and system-generated event; unpredictable environmental events are also expressible in the formalism, at runtime, through action histories. Secondly the effects of user interactions are predictable through the use of successor state axioms; providing a context and prediction for the consequences of action choices: Uniquely, counterfactual reasoning with branching timelines is permitted, thus reasoning may proceed, completely automatically, based on "what-if" scenarios. Thirdly, there is no requirement for a complete state enumeration and transition model; rather what is true in the system can be logically stated reasoned upon and updated whilst behaviour follows by logical consequence: The Current circumstance (situation), for the production of a user interface, is conceived as a causal action (event) history. Fourthly, properties of the specification can be proved entirely within the logic, whereas other formalisms require a separate mechanism to prove correctness properties of the interface deployment. Fifthly, the user interface, described in Situation Calculus, is directly implementable through Neptune scripts, which are runtime generable and adaptable; allowing rapid uptake and updating of decision models with runtime reasoning to incorporate current application knowledge with historical data in an integrated, fully audited and provably correct manner.

We can learn general lessons about supporting the requirements for rich and complex interaction scenarios where we need to support evolving processes, quality criteria, the integration and cross-working of components and the engineering of the final user interface. These can be expressed in the Situation Calculus to support a wide range of complex interactions.

2.1 Autonomic Computing and Whole Body Interaction

From the opportunities and challenges posed by both Whole Body Interaction and Autonomic Computing we can see how the latter can support the former. For example, in using multiple sensors for motion capture (accelerometers, 3/5 axis gyroscopes, ultrasonic transducers etc) we face potential problems of the sensors malfunctioning, temporarily dropping signals or giving error-prone signals. So we need a sensor management layer to ensure the robustness of the input data. We can triangulate this data with data from, say, markerless camera-based motion capture or stored kinematics models to smooth and correct the data.

Our stored kinematics model may give us a generic model of possible and allowed motions that can be used to ensure the safety of the human operator. However, we may also wish to model an individual's patterns of motion to either compare them with some norm or adapt the responses of the system to the individual. So there would be a machine-learning layer to capture and analyse the individual's performance.

Equally, if we are considering the emotional state of the person, we may wish to collect patterns of psycho-physiological data in an attempt to infer emotional states. Again we would need the appropriate machine-learning component in our framework and a means to integrate the data from that component with the other components. So we could combine signals from the physical and physiological states adjust the responses of the system to the user, e.g. to recognize they are under stress and change the nature of the feedback given.

3 An Advanced Framework for Whole Body Interaction

The full details of the implementation are outside the scope of this paper, and further details are available in the given references. To summarize, the implementation is executed through the Cloud architecture; the federation of services (component agents) and resources, with appropriately derived user interface descriptions. It is defined to enable the autonomic framework to function as a User Interface production module using the specially developed language, Neptune that allows management objects to be compiled and inspected at runtime. A system space provides persistent data storage for service registration and state information giving the means to coordinate the application service activities into an object model and associated User Interfaces based on the recorded interaction model and functional requirements. Reasoning can then proceed based on the Situation Calculus model, whereby the user interface descriptions are derived, inferred or adapted. Neptune exposes policies and decision models for system governance, derived from the Situation Calculus/Extensible Decision model, as compiled objects that can be inspected, modified and executed at runtime. Thus the system can evolve as modelled by the logical specification in a safe and predictable manner giving the adjustable self-management required. Neptune objects are executed on demand through an event model exposed by the Cloud architecture.

The system controller with an associated Observation System controls access to and from the individual services and resources within the Cloud. It brokers requests

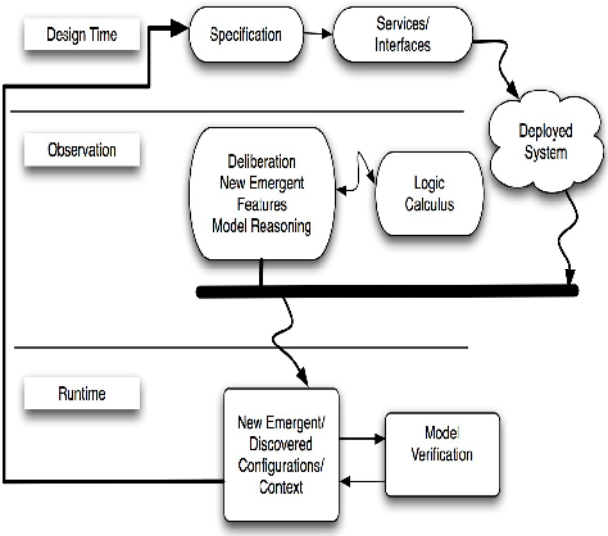

Fig. 1. The Observation system

to the system, through the contrived User Interface, based on system status and governance rules, in Neptune objects, derived from the deliberative process as stated above. An overview of the Observation system is shown in Figure 1.

Each service and resource when it first registers itself to the Cloud sends a meta-object serialized from an XML definition file. This meta-object contains the properties and state data of the service it is describing and is stored within the System Space at registration. Each service maintains its own meta-object and updates the System Space when changes in state occur. The XML definition file contains all information required for the Cloud to discover the service through registration contained in the service element and prepare the appropriate User Interface. In addition to the meta-objects exposing properties of a service within the Cloud, they also describe the interface events that can be fired, caught and handled, allowing multi-modal interfaces to be composed. The event model begins by the service informing the System Controller when an event is fired, which itself marshals this event to the System Space to provide the appropriate scope. It should be noted however, that the event model is abstracted from the components within the system, and is controlled by the Neptune scripting language that sends and receives the appropriate event calls to the controller. The Neptune scripting language is structured in terms of rules, conditional statements and variable assignments that are translated from the Situation Calculus specification to software system objects, encapsulating all the logical inference processes and variable instantiations for the production of the most relevant interaction model and associated interface. An overview of this process is shown in Figure 2.

In this way the base rules for deliberation to control the Cloud architecture, through enhanced user interaction, have been transcribed, from the Situation Calculus reasoned representation, into Neptune objects that can be modified as a result of Observation System deliberation on system events.

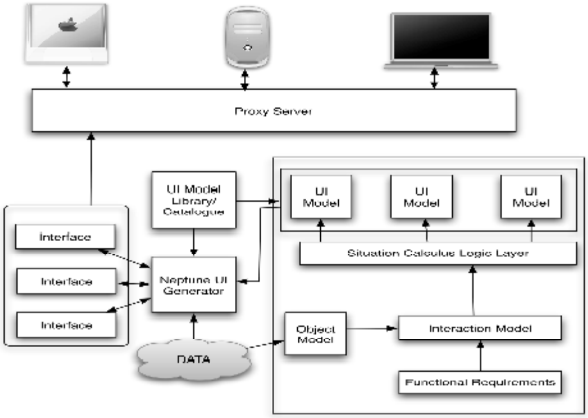

Fig. 2. User Interface Production at Runtime

4 Case Studies

To demonstrate the validity of the framework we present 3 case studies from current research work at Liverpool John Moores University.

4.1 Assessment of Risk of Falling in Older People

As the population in the more advanced countries ages there is an increasing burden on health services and budgets, not to mention personal risks and frustrations for older people. One of the major risks for older people is falling. Due to brittle bones, as a result of a fall, elderly people are more likely to break a major bone such as a hip or femur. They will then become bed-bound and loose their mobility and independence. The risk of premature death after a fall increases. These risks may be exacerbated by other factors such as diabetes, balance problems, Parkinson's disease and so on. At Liverpool John Moores the Caren platform [9] has been used to help measure issues or gait and balance. However, such platforms are large and expensive and thus not available to most clinicians who are diagnosing and caring for elderly people. It is also difficult to bring elderly people to such a facility. Ideally we would like a mobile system that would support:

- Research and Investigation of the general factors promoting the risks of falls
- A clinical diagnostic system that would help clinicians to identify at-risk individuals
- A personal mobile device that would warn elderly people that they were developing a fall risk

In the research system we are required to capture as much data as possible and compare it with existing models of potential fall situations and look for correlations with our clinical data, such as evidence of other diseases. We would need tools to visualize the data and help us refine our understanding of fall risks. For the diagnostic and alert models we would require a simplified physical model but a more robust management of the sensors to both ensure that risks were captured and that false positives were avoided.

4.2 Sports Excellence

In sporting academies it has long been a goal to discover next generation sporting champions. With the rising costs associated with their training and the potential loss of such talent due to poor management, attention has been drawn to scientific methods for talent prediction, training and programme development. Current methods are ad hoc in nature and rely heavily on human expert judgment including metrics and benchmarks. Whilst, research into scientific methods and test beds for sport science is not new and has already produced and/or enriched the talent of many world class names such as Lance Armstrong (cycling) and Amir Khan (boxing) to name but a few. Due to cost and time constraints often such laboratory based facilities are only available to the very few, and the techniques used are either intrusive or laboratory based, hence limiting their applicability to those sports that require mobile performance measurement (telemetry).

Using our framework we adopt a multidisciplinary approach where results from world-class research expertise in gait analysis for sportsmen, and advanced wireless body-area sensor networks and high-stream data analysis and visualisation are combined [10]. The framework aims to develop a fundamental understanding into full-motion modelling and analysis methods including associated test beds to support the prediction and follow up of potential sporting champions. Rather than utilising both marker and markerless motion capturing techniques we utilise advances in Micro-electromechanical systems that when connected to the body and switched on form an ad hoc peer-to-peer body area network. Ultrasonic transducer pairs, 3/5-axis gyroscopes, and accelerometers allow fully body motion to be captured. The challenge is to collect information from these data sources in real-time and perform predictive analysis of movements for the intended purpose of detecting movements, reactions and techniques typically associated with current and past world champions.

Using our novice and world champion martial arts collaborators we aim to evaluate the framework. Martial artists are equipped with body area sensor networks that dynamically connect to sub-networks in the gymnasium, such as gloves, footwear and the floor, including the sensors attached to the opponent. The sensors in one body area network form a coupling with another indicating that they are in combat mode. This allows attacks given by one subject to be compared against the defence techniques of the other. Building on techniques from artificial intelligence (neural networks) and autonomic computing a predictive module will collect information in real-time and rank the potential of new students using data from existing world champions.

4.3 Operator Performance in Simulators

Operators of complex systems, from automobiles, to aircraft to nuclear plants face they possibility of errors and mistakes when they become over-loaded or stressed. We can put operators in stressful but risk-free situations in simulators to assess people's reactions to stress and propose avoiding or alerting actions. Work on

Bio-cybernetic Control [11] has looked at the collection of physiological data such as heart rate, breathing rate and galvanic skin response to look for patterns in the data in moments of stress. However, such data does not always correlate with actual stress and potentially dangerous changes in operator behaviour in stressful scenarios. We would need to look for other factors such as body posture, head tilt and eye gazed to assess the alertness of the operator; have their physical responses to the controls changed, has their head titled forward due to fatigue or have their patterns of eye gazed changed from normal?

Once again we are looking at the integration of two types of input data with a view to discovering rich patterns of interaction, and our knowledge of both areas improves we would wish to update any stress monitoring and alerting system without re-writing the whole system.

5 Conclusions and Future Work

We have presented the beginnings of an advanced framework for whole body interaction. Having learned lessons from other domains we have applied the principles of Autonomic Computing to provide a framework that supports the requirements for system evolution, robustness and self-monitoring which are necessary in the complex field of Whole Body Interaction. Our illustrative case studies show such a framework could be used in a number of areas. These demonstrate the requirements for robustness in the use of sensor, pattern discovery and adaptability.

There are of course many challenges to the wider development and use of Whole Body Interaction systems. We need further investigation of the physical capabilities and limitations of humans in full body interaction. As Buxton [13] more recently observed we still only have a good knowledge of interaction involving the hands and arms but little beyond that. We are still at the early stages of understanding emotion in interaction let alone whole body interaction [12]. However, without a rich and evolvable framework, developments in these supporting areas will fail to provide the expected potential benefits.

Acknowledgements. The authors have benefit from discussions and presentations at the series of Whole Body Interaction workshops. The position papers for these workshops can be found here: http://lister.cms.livjm.ac.uk/homepage/staff/cmsdengl/WBI2009/.

References

1. Buxton, W.: There's More to Interaction than Meets the Eye: Some Issues in Manual Input. In: Norman, D.A., Draper, S.W. (eds.) User Centered System Design: New Perspectives on Human-Computer Interaction, pp. 319–337. Lawrence Erlbaum Associates, Hillsdale, New Jersey (1986)
2. England, D., Ruperez, M., Botto, C., Nimoy, J., Poulter, S.: Creative Technology and HCI. In: Proceedings of HCI 2007, Aveiro, Portugal (2007)
3. Weisner, M.: Some Computer Science Issues in Ubiquitous Computing. Communications of the ACM 36(7), 75–84 (1993)

4. Igoe, T.: Physical Computing: Sensing and Controlling the Physical World with Computers (Paperback), Course Technology PTR (2004)
5. Kephart, J., Chess, D.M.: A Vision of Autonomic Computing. IEEE Computing (January 2003)
6. Miseldine, P., Taleb-Bendiab, A., England, D., Randles, M.: Addressing the Need for Adaptable Decision Processes in Healthcare. In: Medical Informatics and the Internet in Medicine, March 2007, vol. 37, pp. 1–7. Taylor and Francis, Abington (2007)
7. Randles, M., Taleb-Bendiab, A., Miseldine, P., Laws, A.: Adjustable Deliberation of Self-Managing Systems. In: Proceedings of the 12th IEEE International Conference and Workshops on the Engineering of Computer-Based Systems (ECBS 2005), pp. 449–456 (2005)
8. Reiter, R.: Knowledge in Action. MIT Press, Cambridge (2001)
9. Lees, A., Vanrenterghem, J., Barton, G., Lake, M.: Kinematic response characteristics of the CAREN moving platform system for use in posture and balance research. Medical Engineering and Physics 29(5), 629–635 (2007)
10. Fergus, P., Merabti, M., El Rhalibi, A., Taleb-Bendiab, A., England, D.: Body Area Sensor Networks for Predicting Potential Champions. In: HCI 2008 Workshop on Whole Body Interaction, Liverpool John Moores University (September 2008)
11. Fairclough, S., Taleb-Bendiab, A., Tattersall, A.: Biocybernetic Control of Adaptive Automation, EPSRC Project (2002)
12. Crane, E., Gross, M.: Motion Capture and Emotion: Affect Detection in Whole Body Movement. Affective Computing and Intelligent Interaction, pp. 95–101 (2007)
13. Buxton, B.: Closing Keynote Talk. In: SIGCHI 2008, Florence, Italy (2008)