LNCS 4129

David McGookin
Stephen Brewster (Eds.)

Haptic and Audio Interaction Design

First International Workshop, HAID 2006
Glasgow, UK, August/September 2006
Proceedings

Springer

David McGookin Stephen Brewster (Eds.)

Haptic and Audio Interaction Design

First International Workshop, HAID 2006
Glasgow, UK, August 31 – September 1, 2006
Proceedings

Springer

Volume Editors

David McGookin
Stephen Brewster
University of Glasgow
Department of Computing Science
Glasgow G12 8QQ, UK
E-mail: {mcgookdk, stephen}@dcs.gla.ac.uk

Library of Congress Control Number: 2006930675

CR Subject Classification (1998): H.5.2, H.5, H.3, H.4, K.4, K.3

LNCS Sublibrary: SL 3 – Information Systems and Application, incl. Internet/Web and HCI

ISSN 0302-9743
ISBN-10 3-540-37595-3 Springer Berlin Heidelberg New York
ISBN-13 978-3-540-37595-1 Springer Berlin Heidelberg New York

Springer is a part of Springer Science+Business Media

springer.com

Printed in Germany

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India
Printed on acid-free paper SPIN: 11821731 06/3142 5 4 3 2 1 0

Lecture Notes in Computer Science 4129

Preface

Overview

The International Workshop on Haptic and Audio Interaction Design was organized as part of the EPSRC-funded MultiVis project. The main focus of the workshop was to investigate how the modalities of sound and haptics (touch) could be used together in interaction, and what novel interfaces could be provided when they are used in conjunction. What are the relative advantages of each of the modalities when used alone and together? Are there reasons why haptic-based information is more useful in certain situations than equivalent audio information? How can different modalities be used together to create compelling and useful interaction with computer-based systems? We posed these questions to researchers around the world, asking them to submit novel work which sought to discover answers. Thirty papers were submitted of which 15 were accepted. Each paper was peer reviewed at least twice using an esteemed set of leading international figures from both academia and industry, to whom we are grateful for the quality of their reviews, time, patience and responding within our tight schedule.

The papers presented at the workshop come from a wide variety of disciplines ranging from psychology to art, showcasing how haptics and sound can improve user interaction with computers; challenging us to move beyond simple mouse and keyboard metaphors to produce interfaces for devices and applications that allow for the full range of human interactivity. Below the papers are categorized and summarized based on their application and focus.

Visual Impairment

Much of the benefit of haptic and audio interaction is in situations where users may be unable to use a visual display. In such situations the haptic and audio modalities must shoulder responsibility that would otherwise be undertaken by the visual sense; requiring that the bandwidth of this modality is used efficiently. Magnusson *et al.* investigate how sound can be used in haptic navigation tasks to improve target location in non-visual environments. McAllister *et al.* consider how sound and haptics can be combined to improve access to image-based graphs. Both Winberg and Sallnäs *et al.* show how sound and haptics can create rich environments that allow for collaboration between sighted and visually impaired people. Rassmus-Gröhn *et al.* investigate how haptics can be used to support non-visual drawing activities amongst visually impaired children. These papers show us how much, when used together, the haptic and audio modalities can overcome the loss of vision creating rich and engaging user experiences.

Research Approaches

An additional approach in considering how to use haptic and audio interaction effectively is from the more theoretical perspective, with existing design approaches being adapted to fit with new modalities. Murphy *et al.* consider how semiotics can be applied to the design of non-speech audio to make the resulting audio cues more easily learnable and understandable by the users. Coleman *et al.* discuss how the existing approaches of ethnography can be adapted to investigate new areas where sound can be used. O'Sullivan and Chang propose a new descriptive language for vibration that should allow for more effective use. Vickers argues that by considering the relationship between haptics and sound in musical terms, we can create more effective and richer interactions.

Psychophysics

Whilst applications showing how to improve haptic and audio interaction design are of vital importance, it is also important to consider how audio and haptic stimuli interact at a more basic level to provide clues as to where future effort should be focused, as well as where it should not! Avanzini and Crossato investigate the contribution of audio and haptics on the perception of contact stiffness. Tikka and Laitinen uncover design principles to successfully use vibration in conjunction with touch screen technology.

Mobile Applications

As with visual impairment, mobile devices restrict the user's ability to interact with a visual display. Crossan and Murray-Smith investigate how haptic input can overcome the problems of selection in mobile environments. Using gesture-based interaction their system allows selection of songs by rhythmic tapping. Vanacken *et al.* identify how sound and haptics can improve selection in virtual environments.

Art and Leisure

Whilst many of the interactions discussed by authors involve measured performance improvements and "work" style applications, there has been some consideration as to how effective haptic and audio interaction design can make more engaging or entertaining experiences for the user. Martens and Walker investigate how low-frequency vibrations delivered both through sound and directly via a haptic "platform" can improve the sensation of presence and realism within a movie. Barras discusses how the use of haptic and audio interaction can create an engaging interactive experience to communicate historical stories. Barras describes the development of a haptic and audio-based interactive art exhibit that describes the imminent extinction of the great apes.

Through the work contained in these papers we can begin to see the potential of using complementary haptic and audio modalities in interaction design, as well as the initial results that show us how to do so effectively.

August 2006 David McGookin and Stephen Brewster

Organization

The International Workshop on Haptic and Audio Interaction Design 2006 was organized by the Department of Computing Science, University of Glasgow, UK.

Workshop Chairs: David McGookin and Stephen Brewster (University of Glasgow, UK).
Organization: Andrew Crossan, Eve Hoggan and Johan Kildal (University of Glasgow, UK).

Referees

Stephen Barrass, University of Canberra, Australia
Graeme Coleman, University of Dundee, UK
Mikael Fernström, University of Limerick, Ireland
Christopher Frauenberger, Queen Mary, University of London, UK
Antonio Frisoli, Scuola Superiore Sant'Anna, Italy
Stephen Furner, BT, UK
Matti Gröhn, CSC Scientific Computing, Finland
Matthias Harders, ETH, Switzerland
William Harwin, University of Reading, UK
Andy Hunt, University of York, UK
Gunnar Jansson, Uppsala University, Sweden
Roberta Klatzky, Carnegie-Mellon University, USA
Jukka Linjama, Nokia, Finland
Charlotte Magnusson, University of Lund, Sweden
Graham McAllister, Queen's University Belfast, UK
Margaret McLaughlin, University of Southern California, USA
Sile O'Modhrain, Queen's University Belfast, UK
Connor O'Sullivan, Motorola, USA
Antti Pirhonen, University of Jyväskylä, Finland
David Prytherch, University of Central England, UK
Roope Raisamo, University of Tampere, Finland
Chris Raymaekers, Limburg University, Belgium
Jonathan Roberts, University of Kent, UK
Gabriel Robles-de-la-Torre, International Society for Haptics, Mexico
Tony Stockman, Queen Mary, University of London, UK
Paul Vickers, University of Northumbria, UK
Bruce Walker, Georgia Institute of Technology, USA
Tamar Weiss, University of Haifa, Israel
Fredrik Winberg, KTH, Sweden
Mark Wright, Edinburgh School of Art, UK
Wai Yu, Queen's University Belfast, UK
Hong Z. Tan, Purdue University, USA

Sponsors

The workshop was supported by the EPSRC-funded Multivis project (GR/S86150/01) and Advanced Research Fellowship (GR/S53244/01) and the EU FP6 IST MICOLE project. We are grateful for the support of the Glasgow Interactive Systems Group. For more details on the workshop see www.multivis.org.

multivis.org

EPSRC
Engineering and Physical Sciences Research Council

UNIVERSITY OF STRATHCLYDE

GIST
GLASGOW INTERACTIVE SYSTEMS GROUP

UNIVERSITY of GLASGOW

Lecture Notes in Computer Science

For information about Vols. 1–4027

please contact your bookseller or Springer

Vol. 4146: J.C. Rajapakse, L. Wong, R. Acharya (Eds.), Pattern Recognition in Bioinformatics. XIV, 186 pages. 2006. (Sublibrary LNBI).

Vol. 4144: T. Ball, R.B. Jones (Eds.), Computer Aided Verification. XV, 564 pages. 2006.

Vol. 4139: T. Salakoski, F. Ginter, S. Pyysalo, T. Pahikkala (Eds.), Advances in Natural Language Processing. XIV, 771 pages. 2006. (Sublibrary LNAI).

Vol. 4138: X. Cheng, W. Li, T. Znati (Eds.), Wireless Algorithms, Systems, and Applications. XVI, 709 pages. 2006.

Vol. 4137: C. Baier, H. Hermanns (Eds.), CONCUR 2006 – Concurrency Theory. XIII, 525 pages. 2006.

Vol. 4133: J. Gratch, M. Young, R. Aylett, D. Ballin, P. Olivier (Eds.), Intelligent Virtual Agents. XIV, 472 pages. 2006. (Sublibrary LNAI).

Vol. 4130: U. Furbach, N. Shankar (Eds.), Automated Reasoning. XV, 680 pages. 2006. (Sublibrary LNAI).

Vol. 4129: D. McGookin, S. Brewster (Eds.), Haptic and Audio Interaction Design. XII, 167 pages. 2006.

Vol. 4127: E. Damiani, P. Liu (Eds.), Data and Applications Security XX. X, 319 pages. 2006.

Vol. 4121: A. Biere, C.P. Gomes (Eds.), Theory and Applications of Satisfiability Testing - SAT 2006. XII, 438 pages. 2006.

Vol. 4117: C. Dwork (Ed.), Advances in Cryptology - Crypto 2006. XIII, 621 pages. 2006.

Vol. 4115: D.-S. Huang, K. Li, G.W. Irwin (Eds.), Computational Intelligence and Bioinformatics, Part III. XXI, 803 pages. 2006. (Sublibrary LNBI).

Vol. 4114: D.-S. Huang, K. Li, G.W. Irwin (Eds.), Computational Intelligence, Part II. XXVII, 1337 pages. 2006. (Sublibrary LNAI).

Vol. 4113: D.-S. Huang, K. Li, G.W. Irwin (Eds.), Intelligent Computing, Part I. XXVII, 1331 pages. 2006.

Vol. 4112: D.Z. Chen, D. T. Lee (Eds.), Computing and Combinatorics. XIV, 528 pages. 2006.

Vol. 4111: F.S. de Boer, M.M. Bonsangue, S. Graf, W.-P. de Roever (Eds.), Formal Methods for Components and Objects. VIII, 447 pages. 2006.

Vol. 4109: D.-Y. Yeung, J.T. Kwok, A. Fred, F. Roli, D. de Ridder (Eds.), Structural, Syntactic, and Statistical Pattern Recognition. XXI, 939 pages. 2006.

Vol. 4108: J.M. Borwein, W.M. Farmer (Eds.), Mathematical Knowledge Management. VIII, 295 pages. 2006. (Sublibrary LNAI).

Vol. 4106: T.R. Roth-Berghofer, M.H. Göker, H. A. Güvenir (Eds.), Advances in Case-Based Reasoning. XIV, 566 pages. 2006. (Sublibrary LNAI).

Vol. 4104: T. Kunz, S.S. Ravi (Eds.), Ad-Hoc, Mobile, and Wireless Networks. XII, 474 pages. 2006.

Vol. 4099: Q. Yang, G. Webb (Eds.), PRICAI 2006: Trends in Artificial Intelligence. XXVIII, 1263 pages. 2006. (Sublibrary LNAI).

Vol. 4098: F. Pfenning (Ed.), Term Rewriting and Applications. XIII, 415 pages. 2006.

Vol. 4097: X. Zhou, O. Sokolsky, L. Yan, E.-S. Jung, Z. Shao, Y. Mu, D.C. Lee, D. Kim, Y.-S. Jeong, C.-Z. Xu (Eds.), Emerging Directions in Embedded and Ubiquitous Computing. XXVII, 1034 pages. 2006.

Vol. 4096: E. Sha, S.-K. Han, C.-Z. Xu, M.H. Kim, L.T. Yang, B. Xiao (Eds.), Embedded and Ubiquitous Computing. XXIV, 1170 pages. 2006.

Vol. 4094: O. H. Ibarra, H.-C. Yen (Eds.), Implementation and Application of Automata. XIII, 291 pages. 2006.

Vol. 4093: X. Li, O.R. Zaïane, Z. Li (Eds.), Advanced Data Mining and Applications. XXI, 1110 pages. 2006. (Sublibrary LNAI).

Vol. 4092: J. Lang, F. Lin, J. Wang (Eds.), Knowledge Science, Engineering and Management. XV, 664 pages. 2006. (Sublibrary LNAI).

Vol. 4091: G.-Z. Yang, T. Jiang, D. Shen, L. Gu, J. Yang (Eds.), Medical Imaging and Augmented Reality. XIII, 399 pages. 2006.

Vol. 4090: S. Spaccapietra, K. Aberer, P. Cudré-Mauroux (Eds.), Journal on Data Semantics VI. XI, 211 pages. 2006.

Vol. 4088: Z.-Z. Shi, R. Sadananda (Eds.), Agent Computing and Multi-Agent Systems. XVII, 827 pages. 2006. (Sublibrary LNAI).

Vol. 4085: J. Misra, T. Nipkow, E. Sekerinski (Eds.), FM 2006: Formal Methods. XV, 620 pages. 2006.

Vol. 4079: S. Etalle, M. Truszczyński (Eds.), Logic Programming. XIV, 474 pages. 2006.

Vol. 4077: M.-S. Kim, K. Shimada (Eds.), Advances in Geometric Modeling and Processing. XVI, 696 pages. 2006.

Vol. 4076: F. Hess, S. Pauli, M. Pohst (Eds.), Algorithmic Number Theory. X, 599 pages. 2006.

Vol. 4075: U. Leser, F. Naumann, B. Eckman (Eds.), Data Integration in the Life Sciences. XI, 298 pages. 2006. (Sublibrary LNBI).

Vol. 4074: M. Burmester, A. Yasinsac (Eds.), Secure Mobile Ad-hoc Networks and Sensors. X, 193 pages. 2006.

Vol. 4073: A. Butz, B. Fisher, A. Krüger, P. Olivier (Eds.), Smart Graphics. XI, 263 pages. 2006.

Vol. 4072: M. Harders, G. Székely (Eds.), Biomedical Simulation. XI, 216 pages. 2006.

Vol. 4071: H. Sundaram, M. Naphade, J.R. Smith, Y. Rui (Eds.), Image and Video Retrieval. XII, 547 pages. 2006.

Vol. 4070: C. Priami, X. Hu, Y. Pan, T.Y. Lin (Eds.), Transactions on Computational Systems Biology V. IX, 129 pages. 2006. (Sublibrary LNBI).

Vol. 4069: F.J. Perales, R.B. Fisher (Eds.), Articulated Motion and Deformable Objects. XV, 526 pages. 2006.

Vol. 4068: H. Schärfe, P. Hitzler, P. Øhrstrøm (Eds.), Conceptual Structures: Inspiration and Application. XI, 455 pages. 2006. (Sublibrary LNAI).

Vol. 4067: D. Thomas (Ed.), ECOOP 2006 – Object-Oriented Programming. XIV, 527 pages. 2006.

Vol. 4066: A. Rensink, J. Warmer (Eds.), Model Driven Architecture – Foundations and Applications. XII, 392 pages. 2006.

Vol. 4065: P. Perner (Ed.), Advances in Data Mining. XI, 592 pages. 2006. (Sublibrary LNAI).

Vol. 4064: R. Büschkes, P. Laskov (Eds.), Detection of Intrusions and Malware & Vulnerability Assessment. X, 195 pages. 2006.

Vol. 4063: I. Gorton, G.T. Heineman, I. Crnkovic, H.W. Schmidt, J.A. Stafford, C.A. Szyperski, K. Wallnau (Eds.), Component-Based Software Engineering. XI, 394 pages. 2006.

Vol. 4062: G. Wang, J.F. Peters, A. Skowron, Y. Yao (Eds.), Rough Sets and Knowledge Technology. XX, 810 pages. 2006. (Sublibrary LNAI).

Vol. 4061: K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer (Eds.), Computers Helping People with Special Needs. XXIX, 1356 pages. 2006.

Vol. 4060: K. Futatsugi, J.-P. Jouannaud, J. Meseguer (Eds.), Algebra, Meaning, and Computation. XXXVIII, 643 pages. 2006.

Vol. 4059: L. Arge, R. Freivalds (Eds.), Algorithm Theory – SWAT 2006. XII, 436 pages. 2006.

Vol. 4058: L.M. Batten, R. Safavi-Naini (Eds.), Information Security and Privacy. XII, 446 pages. 2006.

Vol. 4057: J.P.W. Pluim, B. Likar, F.A. Gerritsen (Eds.), Biomedical Image Registration. XII, 324 pages. 2006.

Vol. 4056: P. Flocchini, L. Gąsieniec (Eds.), Structural Information and Communication Complexity. X, 357 pages. 2006.

Vol. 4055: J. Lee, J. Shim, S.-g. Lee, C. Bussler, S. Shim (Eds.), Data Engineering Issues in E-Commerce and Services. IX, 290 pages. 2006.

Vol. 4054: A. Horváth, M. Telek (Eds.), Formal Methods and Stochastic Models for Performance Evaluation. VIII, 239 pages. 2006.

Vol. 4053: M. Ikeda, K.D. Ashley, T.-W. Chan (Eds.), Intelligent Tutoring Systems. XXVI, 821 pages. 2006.

Vol. 4052: M. Bugliesi, B. Preneel, V. Sassone, I. Wegener (Eds.), Automata, Languages and Programming, Part II. XXIV, 603 pages. 2006.

Vol. 4051: M. Bugliesi, B. Preneel, V. Sassone, I. Wegener (Eds.), Automata, Languages and Programming, Part I. XXIII, 729 pages. 2006.

Vol. 4049: S. Parsons, N. Maudet, P. Moraitis, I. Rahwan (Eds.), Argumentation in Multi-Agent Systems. XIV, 313 pages. 2006. (Sublibrary LNAI).

Vol. 4048: L. Goble, J.-J.C.. Meyer (Eds.), Deontic Logic and Artificial Normative Systems. X, 273 pages. 2006. (Sublibrary LNAI).

Vol. 4047: M. Robshaw (Ed.), Fast Software Encryption. XI, 434 pages. 2006.

Vol. 4046: S.M. Astley, M. Brady, C. Rose, R. Zwiggelaar (Eds.), Digital Mammography. XVI, 654 pages. 2006.

Vol. 4045: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), Diagrammatic Representation and Inference. XII, 301 pages. 2006. (Sublibrary LNAI).

Vol. 4044: P. Abrahamsson, M. Marchesi, G. Succi (Eds.), Extreme Programming and Agile Processes in Software Engineering. XII, 230 pages. 2006.

Vol. 4043: A.S. Atzeni, A. Lioy (Eds.), Public Key Infrastructure. XI, 261 pages. 2006.

Vol. 4042: D. Bell, J. Hong (Eds.), Flexible and Efficient Information Handling. XVI, 296 pages. 2006.

Vol. 4041: S.-W. Cheng, C.K. Poon (Eds.), Algorithmic Aspects in Information and Management. XI, 395 pages. 2006.

Vol. 4040: R. Reulke, U. Eckardt, B. Flach, U. Knauer, K. Polthier (Eds.), Combinatorial Image Analysis. XII, 482 pages. 2006.

Vol. 4039: M. Morisio (Ed.), Reuse of Off-the-Shelf Components. XIII, 444 pages. 2006.

Vol. 4038: P. Ciancarini, H. Wiklicky (Eds.), Coordination Models and Languages. VIII, 299 pages. 2006.

Vol. 4037: R. Gorrieri, H. Wehrheim (Eds.), Formal Methods for Open Object-Based Distributed Systems. XVII, 474 pages. 2006.

Vol. 4036: O. H. Ibarra, Z. Dang (Eds.), Developments in Language Theory. XII, 456 pages. 2006.

Vol. 4035: T. Nishita, Q. Peng, H.-P. Seidel (Eds.), Advances in Computer Graphics. XX, 771 pages. 2006.

Vol. 4034: J. Münch, M. Vierimaa (Eds.), Product-Focused Software Process Improvement. XVII, 474 pages. 2006.

Vol. 4033: B. Stiller, P. Reichl, B. Tuffin (Eds.), Performability Has its Price. X, 103 pages. 2006.

Vol. 4032: O. Etzion, T. Kuflik, A. Motro (Eds.), Next Generation Information Technologies and Systems. XIII, 365 pages. 2006.

Vol. 4031: M. Ali, R. Dapoigny (Eds.), Advances in Applied Artificial Intelligence. XXIII, 1353 pages. 2006. (Sublibrary LNAI).

Vol. 4029: L. Rutkowski, R. Tadeusiewicz, L.A. Zadeh, J.M. Zurada (Eds.), Artificial Intelligence and Soft Computing – ICAISC 2006. XXI, 1235 pages. 2006. (Sublibrary LNAI).

Vol. 4028: J. Kohlas, B. Meyer, A. Schiper (Eds.), Dependable Systems: Software, Computing, Networks. XII, 295 pages. 2006.

¥359.00元

Table of Contents

Session: Design I

Session: Design II

Perception of Audio-Generated and Custom Motion Programs in Multimedia Display of Action-Oriented DVD Films

Kent Walker and William L. Martens

Sound Recording Area, Department of Theory, Schulich School of Music, McGill University, 555 Rue Sherbrooke Ouest, Montréal, QC, H3A 1E9, Canada
kent.walker@mail.mcgill.ca
http://www.music.mcgill.ca/~kentw/

Abstract. This paper addresses a practical problem associated with multimedia display systems which utilize motion-platforms or chairs. Given audio-visual content for which motion data is not available, motion may be automatically generated from multichannel audio, usually from a Low-Frequency Effects channel (LFE) such as that distributed on Digital Versatile Discs (DVDs). Alternatively, custom motion programs may be created to accompany multimedia content. This paper presents the results of a study designed to test the sense of realism, sense of presence, and global preference for multimedia playback in these two distinct cases of platform accompaniment: motion which has been generated automatically from audio, and motion which has been designed expressly for the purpose of stimulating appropriate haptic and vestibular sensations.

1 Introduction

1.1 Research Context and Research Questions

Since the advent of the Digital Versatile Disc (DVD), affordable advances in multimedia display technology have evolved which offer consumers opportunities for enhanced experience in the form of devices capable of haptic stimulation and motion accompaniment (whole-body vibration). These devices are many and fall into several categories but generally may be described as platforms and chairs which are capable of moving and shaking observers. Given the variety of devices available and the absence of standardized practice, multimedia content providers such as Hollywood film houses have yet to supply this niche market with motion programs for home entertainment use.

As a result developers of haptic technology are faced with the question of how to generate motion programs for their customers. Two main options exist: the first is to generate motion programs automatically using existing content; the second is for hardware manufacturers to employ programmers to create custom-coded motion from scratch for content from media houses. Depending on the program material or the multimedia scene presented to the observer, either method of generating whole-body vibration may be sufficient in terms of enhancing an

D. McGookin and S. Brewster (Eds.): HAID 2006, LNCS 4129, pp. 1–11, 2006.

observer's experience. For example, previous investigations by the authors [15] and others [3] have indicated that for music-only material, generation of whole-body vibration using existing audio signals is sufficient for the enhancement of experience provided that the systems are properly coordinated. In other words, for music programs separate vibration recordings or custom motion programs are generally not required. However, in the case of more action-oriented program material this may not be the case. Though there is a significant body of research on how to create motion-cues for users of flight simulation technology via vestibular stimulation [18], there has been relatively little work done on the most effective integration of motion platforms into home entertainment oriented audiovisual content display. Different multimedia scenes may require different kinds of motion programs in order to create within observers the greatest suspension of disbelief.

The experiments described herein investigated multimedia display of commercially available DVD film titles. Motion data generated from audio Low Frequency Effects channels (the *.1* channel on a *5.1* channel disc) was compared to motion generated specifically for individual DVD titles by a human designer. Experiments were designed to determine if existing information present in LFE channels is sufficient for the enhancement of presence and realism, if observers prefer custom-coded motion when watching DVD titles, and if the extra costs involved in the creation of custom motion programs is perceptually justifiable. The tested hypothesis was: for action-oriented DVD titles is custom-coded motion more likely to be preferred over audio-generated motion, and is this preference linked to an observers sense of presence and sense of realism for a displayed multimedia scene?

Before further explaining the experiments conducted, background on the technology for motion-based display and human sensitivity to vibration is presented.

1.2 Enhancing Presence in Multimedia Display

In recent research and development of advanced multimedia display technology, great emphasis has been placed upon multichannel sound and the enhanced consumer experience associated with coordinated display of visuals and spatial audio content. The potential for user immersion in the presented virtual world is one benefit of such multimedia display which is most properly called *television-type telesensation* [13]. Compared to more conventional media, such immersive audio-visual content produces a higher proportion of user responses indicating higher *sense of presence* or "sense of being transported to the electronically-mediated space" [7]; consumers can forget that the virtual world presented to their eyes and ears is an electronic reproduction, and imagine instead that they are experiencing the virtual world first hand. However, this suspension of disbelief is weakened considerably by one factor that has often been ignored in the development of advanced multimedia displays: observers visiting these virtual worlds are *not* disembodied minds. Regardless of where observers' eyes and ears take them, their bodies most often stay put in the physical display space. On the other hand, if simulation includes touch and motion sensations which are consistent with what is seen and heard, a heightened sense of presence is to be expected.

There has been a small but growing interest in providing a means for creating such high-quality *multimodal* experiences for consumers in home theater and computer gaming applications, typically in the form of moving seats or motion platforms. Such multimodal content has the potential to not only enhance experience, but to spawn new markets for both entertainment and electronics corporations in a commercial age fraught with the terror of economic uncertainly, caused largely by the real threat of entertainment piracy. To date, the film industry's reaction to piracy has mostly been the so-called *high-definition* technological revolution of home-theater, resulting most recently in an emerging format war between High-Definition Digital Versatile Disc (HD-DVD) and Blu-Ray Disc (BD). Nevertheless, experts in these new formats question the ability of these systems to offer extra value over what's currently available to consumers via existing popular DVD standards, as many consumers have lesser quality sound reproduction systems and televisions that will benefit perhaps only marginally from these higher-definition media [12]. However, if DVD houses embrace and promote haptic and motion transducer technology together with their new formats, they may have a greater degree of success with the high-definition revolution: the addition of a mode of display is more immediately gratifying to consumers than just-noticeable differences in display quality for audio and video alone.

1.3 Haptics and Motion Sensation

Haptic comes from the Greek *hapt esthai* which may be literally translated as *feel sense* [1]. Haptic sensation can result from many forms of stimulation, ranging from local vibrations on the skin to whole-body movement, and relies on a variety of sense organs and receptors from multiple sensory systems. Cutaneous sensory organs such as *Meissner's Corpuscles* (used for the sensation of vibration below approximately 40 Hz), *Pacinian Corpuscles* (used above 40 Hz), and *Merkel Discs* (used for the sensation of pressure on the skin) [4]. The haptic senses also include the organs of human kinesthesia such as muscles, tendons, and joints (used for the sensation of movement below 30 Hz), although such vibration-related stimulation is distinguished from the stimuli for the vestibular organs of the inner-ear, namely the *semi-circular canals* (used for detection of angular acceleration of the head), and the *otoliths* (used for detection of linear acceleration). It is important to note that there is a great deal of overlap in our sensory systems with regards to vibration, as our hearing sensitivity extends down to approximately 20 Hz, while our vibration sensitivity grows with frequency to peak at approximately 250-300 Hz; therefore, low-frequency sound sources are often *both heard and felt.*

1.4 Motion Degrees of Freedom (DOF)

In control of motion platforms, it is necessary to distinguish how freely the platform may be made to move through space. Complete freedom of motion in space admits Six Degrees of Freedom (6DOF), which include the possibility of three directions of displacement and three angular gyrations. The terms that are used in the technical literature to describe an object or observer's motion through space are not in such popular use, and so these terms are related to more common language in this section. To begin with, there are three terms that are used to describe the rotation of an observer whose spatial position does not change: yaw, roll, and pitch. If a person who is standing upright rotates to the left or right about the vertical axis through their body, this rotation is termed yaw. If an airplane were to dive forward, the rotation about the left/right axis would be termed pitch, and if the airplane were to tilt to one side, the rotation about the front/rear axis would be termed roll (not to be confused with the acrobatic maneuver termed a *barrel roll* in which an airplane not only rotates along its longitudinal axis, but also follows a trajectory along the surface of a cylinder or barrel). The remaining set of three terms is used to describe the spatial translation of an observer whose orientation in space does not change. These three translational motion terms, describing movement leftward, forward, or upward, are respectively: sway, surge, and heave.

2 Methods

2.1 The Loudspeaker Array

The current study used a calibrated multichannel stereophonic sound system compliant with ITU standards [6] yet with full range capabilities at all standard angles (in degrees relative to the median plane the angles were -110, -30, 0, 30, and 110). Five low-frequency drivers (ranging from 35 Hz to 300 Hz) and five higher-frequency drivers (ranging from 300 Hz to well over 20,000 Hz). The low-frequency drivers were Mini-Mammoth subwoofers manufactured by Quebec-based D-BOX Technology, which were placed at standard locations for the 5 main speakers in surround sound reproduction. The higher-frequency drivers were dipole radiating, full range transducers featuring the Planar Focus Technology of Level 9 Sound Designs of British Columbia. These speakers were placed at the same azimuth angles as the 5 low-frequency drivers, but in a ring positioned 15 degrees above the observer's ear level. All listening tests were conducted in a treated room [11].

2.2 The Visual Display

A Panasonic model TH-50PHD6UY HDTV 50-inch plasma display with a resolution of 1366 x 768 and contrast ratio of 3000:1 was used to display the video portion of all DVD titles. A Pioneer model DV 563A DVD player was also used. Titles were of the widescreen variety and observers sat at a distance of 2 meters from the screen.

2.3 The Motion Platform

The research presented here used a commercially available motion platform, the Odyssée system from the Quebec based company D-BOX Technology [9]. This