SEVENTH FRAMEWORK PROGRAMME
THEME 3
Information and Communication Technologies

Grant agreement for: Small or medium-scale focused research project

Annex I - "Description of Work"

Project acronym: ***NIW***
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PART A

A1. Budget breakdown and project summary

A.1.1 Overall budget breakdown for the project

A3.2:
What it costs

Project Number [1]	222107	Project Acronym [2]	NIW

One Form per Project

Participant number in this project [9]	Participant short name	Estimated eligible costs (whole duration of the project)					Total receipts	Requested EC contribution
		RTD / Innovation (A)	Demonstration (B)	Management (C)	Other (D)	Total A+B+C+D		
1	UNIVR	268,000.00	0.00	46,800.00	16,200.00	331,000.00	0.00	264,000.00
2	McGill University	292,000.00	0.00	4,000.00	2,400.00	298,400.00	298,400.00	0.00
3	AAU	348,000.00	0.00	7,000.00	8,200.00	363,200.00	0.00	276,200.00
4	INRIA	495,670.00	0.00	8,786.00	2,244.00	506,700.00	0.00	382,782.00
5	UPMC	320,000.00	0.00	7,000.00	4,400.00	331,400.00	0.00	251,400.00
TOTAL		1,723,670.00	0.00	73,586.00	33,444.00	1,830,700.00	298,400.00	1,174,382.00

A.1.2 Project summary

The simple act of walking in everyday environments exposes us to highly structured information about the ground. Its nature and composition are revealed, in part, through our footsteps, as they carry us along concrete city sidewalks, over gravel park walkways, or across tiled building lobbies. The sounds and haptic sensations we experience signify the spaces we traverse in an intuitive and familiar way, and communicate to us their characteristic, identifying features.

The Natural Interactive Walking (NIW) project aims to take advantage of this information to develop knowledge for designing walking experiences. This will be accomplished through the engineering and perceptual validation of human-computer interfaces conveying virtual cues of everyday ground attributes and events. Such cues may be conveyed by auditory, haptic, pseudo-haptic, and visual augmentation of otherwise neutral grounds. The project is focused on creating efficient and scalable display methods across these modalities that can be easily and cost-effectively reproduced, via augmented floors and footwear.

It is expected that the NIW project will contribute to scientific knowledge in two key areas. First, it will reinforce the understanding of how our feet interact with surfaces on which we walk. Second, it will inform the design of such interactions, by forging links with recent advances in the haptics of direct manipulation and in locomotion in real-world environments. The methods that will be created could impact a wide range of future applications that have been prominent in recently funded research within Europe and North America. Examples include floor-based navigational aids for airports or railway stations, guidance systems for the visually impaired, augmented reality training systems for search and rescue, interactive entertainment, and physical rehabilitation.

A.1.3 List of beneficiaries

Beneficiary Number *	Beneficiary name	Beneficiary short name	Country	Date enter project**	Date exit project**
1(coordinator)	Università di Verona	UNIVR	Italy	Month 1	Month 36
2	Royal Institution for the Advancement of Learning	McGill University	Canada	Month 1	Month 36
3	Aalborg University	AAU	Denmark	Month 1	Month 36
4	Institut National de Recherche en Informatique et en Automatique	INRIA	France	Month 1	Month 36
5	Université Pierre et Marie Curie – Paris 6	UPMC	France	Month 1	Month 36

* Please use the same beneficiary numbering as that used in the Grant Agreement Preparation Forms

** Normally insert “month 1 (start of project)” and “month n (end of project)”

PART B

B1. Concept and objectives, progress beyond state-of-the-art, S/T methodology and work plan

B.1.1 Concept and project objective(s)

In a 1939 paper, J. A. Hogan analyzes the incident in which Marcel Proust entered the courtyard of the Princess de Guermantes' residence in Paris when "his feet came to rest on two uneven flagstones, and as he balanced from one to the other a delicious sensation swept through his body" [Hogan, 1939]. The author relates that, "Proust continued to exploit this sensation which brought him so much joy; … he swayed back and forth on the two uneven flagstones, oblivious to his surroundings." He continues, "But what? Where? How came he by these sensations? … Then suddenly it was revealed to him. It was Venice. One day, long since past, he had stood in the baptistry of St. Mark's in Venice, balanced on two uneven flagstones. His present experience balancing on the stones in the Guermantes' courtyard was sufficiently like that one in the past to call up from within him that day in Venice, which he had for so long a time kept buried deep inside him."

The experience Proust felt upon walking into this courtyard is regarded as fundamental to the creation of his celebrated *Remembrance of Things Past* and to the aesthetic theory that pervades all his Recherche. Leaving the significance of this event to his aesthetic universe aside, it is worth noting the impact that the activity of exploring the flagstones with his foot had in awakening pieces of Proust's previously acquired experience. Significantly, the association he makes is strongly non-visual. It is moreover unlikely that the two flagstones he depresses in Paris are particularly similar in shape, size or configuration to those he earlier encountered at the baptistry of St. Mark's in Venice.

The Natural Interactive Walking project (NIW) will proceed from the hypothesis that walking, by enabling rich interactions with floor surfaces, consistently conveys enactive information that manifests itself predominantly through haptic and auditory cues. Vision will be regarded as playing an integrative role linking locomotion to obstacle avoidance, navigation, balance, and the understanding of details occurring at ground level. The ecological information we obtain from interaction with ground surfaces allows us to navigate and orient during everyday tasks in unfamiliar environments, by means of the invariant ecological meaning that we have learned through prior experience with walking tasks.

The project intends to define knowledge, methods and tools for the design of walking experiences through the auditory, haptic, and visual augmentation of otherwise perceptually neutral floors. This will be accomplished through the realization of human-computer walking interfaces conveying virtual ecological cues of ground attributes and floor events. NIW will focus on walking as an everyday experience in which to situate the sensing and display of rich haptic and acoustic information for simulation of basic floor properties, such as material, composition and texture. It will draw on vision in a complementary role, to communicate properties like deformation and the presence of objects through the animation of visually-rendered ground features and events.

NIW will link floor properties to physical, material attributes that are considered crucial for characterizing familiar contact interactions of the feet with ground surfaces. Taken together, such attributes permit the characterization of a broad spectrum of materials, including: uniform solids such as concrete and wood; textured surfaces such as carpeted floors; loose and aggregate materials such as gravel, sand, and snow. While the rendering of realistic surface textures and contact interactions has been a significant aim in manually operated virtual environments [Minsky, 1995; Pai et al., 2001], in interaction with ground surfaces, the additional material dimensions possessed by aggregate materials are also brought to the fore. Recent research indicates that the human haptic and auditory sensory channels are particularly sensitive to material properties explored during walking [Giordano et al., 2008], and earlier studies have demonstrated strong links between the physical attributes of the relevant sounding objects and the auditory percepts they generate [Rocchesso et al., 2003]. The project will select, among these attributes, those which evoke most salient perceptual cues in subjects.

With regard to events, the project will concentrate on basic dynamic effects such as impact, friction, and deformation, for the characterization of a simple but rich phenomenology of ecological foot-floor interaction events. Such effects account for normal and tangential contact interactions between feet and floors. They are elicited by diverse component actions undertaken during walking, such as the impact of a shoe against the floor, the deformation of the surface underfoot as weight is shifted on to it, the scraping of a shoe against the ground, the bouncing and rolling of a stone that is kicked. From the standpoint of auditory events, the three effects above, along with that of rolling [Stoelinga, 2007] constitute the four basic solid interaction types in Gaver's taxonomy of everyday sound [Gaver, 1993].

NIW is strongly aimed at developing approaches to interaction that are complementary to the costly and complex robotic walking interfaces that have been a main focus of prior research on virtual walking experiences (an overview of such devices is given in [Iwata, 2008]). The NIW project will develop knowledge toward the approximation of such experiences by means of simple, repeatable, and low-cost interaction methods and devices. Such experiences will be made effective through the careful application and validation of abstracted, illusory and cross-modal perceptual and perceptual-motor effects. As described below, walking interaction methods innovated in NIW will be applicable to closed VR environments, and readily exportable to many other unconstrained contexts that do not depend on the presence of VR display systems.

A wide range of haptic illusions is known [Hayward, in press], and many of them have been successfully used for the design of new haptic interactive devices. This includes some that depend on unusual features of cutaneous or proprioceptive haptic perception, and others simulate ecologically-based phenomena, such as the rolling of a stone along a manipulated rod [Yao and Hayward, 2006]. Such effects will be at the heart of the development effort in NIW.

In the area of auditory display, much has been recently accomplished in the interactive generation of everyday sounds by means of abstracted, lumped signal processing models [Rocchesso and Fontana, 2003], and these constitute another area of research of the project. Physically based sound synthesis models are capable of representing sustained and transient interactions between objects of different forms and material types, and such methods will be used in NIW in order to model and synthesize the sonic effects of basic interactions between feet and ground materials, including impacts, friction, or the rolling of loose materials.

The project will likewise explore unfamiliar effects that are capable of thrusting users into paradoxical situations, moving from the phenomenon of “pseudo-haptic feedback” [Lécuyer et al., 2000]. As an example, the impression of being absorbed into the ground, as if being stuck in a swamp or in the mud might be conveyed through visual feedback. As in previous examples of pseudo-haptic feedback (e.g., related to the texture of a manipulated object [Lécuyer et al., 2004]) the origin of the illusion and cross-modal transfer is the modification of the control/display ratio, i.e., the visual gain or ratio between the real physical movement of the user and the visual displacement on the screen [Dominjon et al., 2005].

Activities

To date, the generation and use of simplified but perceptually-salient ecological cues in walking, such as those noted above, has been missing. Such phenomena are nonetheless highly salient to current and emerging augmented and virtual environment applications for diverse contexts. The NIW project will innovate a number of methods for closed-loop interaction centred on phenomena and problems where multisensory feedback and sensory substitution can be exploited to create unitary multimodal percepts of the sort encountered in everyday walking tasks.

The S&T plan of the project is centred around three activities, devising a methodology that will lead to a progressive development of methods and prototypes. Two of these activities are mutually and tightly interconnected, and will both start at the beginning of the project:

i) The design and prototyping of haptic and auditory methods, devices, and computational models for the synthesis of virtual floor attributes of material, texture, and elasticity and for the facilitation of ecologically-based multimodal interaction in walking (leading to milestone M1)
ii) The systematic experimental validation of such devices and the measurement of the perceptual impact of cross- and multi-modal effects associated with different synthetic ground properties and floor events, via non-navigational walking tasks providing also visual information in addition to haptic and auditory cues (leading to milestone M2).

Since the success of the experiments depends largely on the quality of the interface and vice-versa, it is expected that the design and validation activities will be iterated to progressively lead to improved interface designs and more robust verifications of the experimental hypotheses.

Beginning in the second year, validated (in terms of perceptual saliency) walking interaction methods and prototypes will be progressively exported to an immersive and integrated setting also affording some freedom of navigation to users. This research will be presented in milestone M2, and will lead to milestone M3 through the following activity:

iii) The assessment of the interaction designs and prototypes delivered in milestone M1 and validated in milestone M2 into an integrated immersive multimodal floor installation capable of engaging users in realistic tasks of walking across grounds of different nature and in the presence of simple floor events.

Taken together, these activities constitute the three milestones of the project listed below:

M1 – Design, engineering, and prototyping of floor interaction technologies (month 12)
M2 – Validated set of ecological foot-based interaction methods, paradigms and prototypes, and designs for interactive scenarios using these paradigms (month 24)
M3 – Integration and usability testing of floor interaction technologies in immersive scenarios (month 36).

Objectives

From here we outline the project's two main objectives:

i) The production of a set of **foot-floor multimodal interaction methods**, for the virtual rendering of ground attributes, whose perceptual saliency has been validated
ii) The synthesis of an immersive floor installation displaying a **scenario of ground attributes and floor events** on which to perform walking tasks, designed in an effort to become of interest in areas such as rehabilitation and entertainment.

Due to the lack of fundamental knowledge in foot-floor interaction as opposed to the fairly large amount of existing know-how in locomotion interfaces and related tasks, the consortium envisions that achieving those two objectives will mark a significant breakthrough in the field of walking interfaces.

B.1.2 Progress beyond the state of the art

Virtual simulations typically engender a strong mismatch between what is seen, heard and felt. The mechanical simulation of the re-presented space is to-date limited to a fixed (say concrete or carpet surfaces for open-space-type simulators) or some unfamiliar compliant behavior typical of treadmill-type simulators such as the HapticWalker, Torus Treadmill, Virtual Perambulator, GaitMaster, CirculaFloor, BiPort [Iwata, 2008]. It rarely matches, even remotely, what is seen. The mismatch is due both to the content of the simulation and to the lack of visual resolution (virtual surfaces "do" look virtual). The multi-modal stimulus poses for the central nervous system an insurmountable fusion problem that can result in a variety of outcomes. The most common of these outcomes is to "block-out" complete sensory channels from conscious experience, resulting in the experience of intangibility mentioned earlier. Another typical outcome is to contribute to the impairment of the postural balance of the user, reinforced with possible additional mismatch with vestibular inputs.

Little research to date has been conducted on floors as receptors and conveyors of specifically ecological information. The few exceptions have been confined to specialized domains such as content creation for entertainment [Cook, 2002]. In spite of this underexploration, interaction with ground surfaces represents an exceptionally promising interaction scenario, which may leverage previously learned tasks and familiar contexts, and make considerable use of existing enactive knowledge.

Auditory and haptic information in manual tasks has been long studied. Significant attention has been devoted to measuring the physical interaction behavior of materials for the purpose of identifying surface properties [Pai and Rizun, 2003; Andrews and Lang, 2007], most frequently texture, for the purpose of simulating these properties in interactions with manually operated haptic virtual environments [eg. Minsky, 1995; Kry and Pai, 2006; Pai et al., 2001]. Early studies on texture perception demonstrated that auditory cues played a significant role in the perception of textures when haptic cues were not present, thus devising a cross-modal effect [Lederman, 1979]. Considerably less is known about the perception and display of ecological information in walking. Recent results [Giordano et al., 2008] suggest that the acuity of auditory and haptic sensory information processing channels to ecological information in walking is sufficient to enable fine discrimination between ground textures.

An acceleration to the use of auditory information in multimodal tasks has come from the introduction of physically-based sound synthesis models. Physically-based sound synthesis was applied beginning in the 1980s, to the design of musical instrument models [Smith, 1998]. As technology evolved, and with the increasing importance of multimodal interfaces, this paradigm was exported to an increasing number of interactive sonic designs [Van den Doel, 2001; Cook, 2002; Rocchesso et al., 2005; Rath and Rocchesso, 2005; De Witt and Bresin, 2007; Serafin et al., 2007; Delle Monache et al., 2007]. One milestone in the passage of physics-based modelling from the realm of electronic music to human-computer interaction was the IST-FET project "The Sounding Object" (*SOb*), coordinated by the University of Verona, which launched the design concept of ecological interactive sonification paradigms simulating the physics of prototype dynamical systems that are at the base of most everyday sounds generation [Rocchesso et al., 2003; Rocchesso and Fontana, 2003]. Initially simulating simple nonlinear elastic contacts [Avanzini et al., 2002], such objects have then embraced more sophisticated basic interactions, such as friction [Avanzini et al., 2005]. From there they have progressively moved to the rendering of higher level events, made by assembling basic models into computational structures simulating articulate sounds such as crushing [Fontana and Bresin, 2003], squeaking, or rolling [Rath, 2003]. The taxonomies of everyday sonic interactions, beginning with Gaver [Gaver, 1993] and continuing with the work of other researchers [Cook, 2002; Rath et al., 2003] have proved useful in organizing this knowledge.

As part of the research in cross-modality, *pseudo-haptics* has played a prominent role in relatively recent time. This sensory substitution paradigm is rooted in several types of simulations providing haptic sensation during the interaction with virtual environments. The most famous one relies on dedicated interaction devices, called haptic interfaces, which provide the user with dynamic haptic stimulation [Burdea, 1996]. A second solution consists in using "props", tangible interfaces which are "familiar real-world objects in the user's real environment to offer a physical manipulation with the virtual environment" [Hinckley et al., 1994]. A third possibility is that of sensory substitution [Lenay et al., 2003], which radically transposes one haptic stimulus into the stimulation of another sense (e.g. an audio beep to simulate contact with virtual objects). Finally, if haptic sensations are conveyed without using any of these previous methods then they give rise to pseudo-haptic feedback [Lécuyer et al., 2000].

Pseudo-haptic feedback was initially achieved through the combination of a passive input device with visual feedback, as a way to simulate the haptic sensation of friction. By coupling a slowing down visual object to the increasing reaction force coming from a haptic device gives users the illusion of a force feedback, as if a frictional force were applied [Lécuyer et al., 2000]. Thus, pseudo-haptic feedback provides illusory enactive haptic sensations through the display of proper visual feedback during manipulation tasks of a haptic device. To date, it has been demonstrated that pseudo-haptic feedback can be used to efficiently simulate haptic sensations over hands, such as the stiffness of a virtual spring, the texture of an image or the mass of a virtual object [Lécuyer et al., 2000; Lécuyer et al., 2004; Paljic et al., 2004; Dominjon et al., 2005].

Concerning vision more in general, visual effects have been shown to improve walking sensations in virtual environments. Artificial camera motions, for instance, can be calibrated to simulate the visual flow that takes place during motion [Lécuyer et al., 2006], and experiments have shown that such effects improve the virtual experience and the sensation of walking in a VE for users (video gamers) playing in front of a computer screen [Hillaire et al., 2008].

As opposed to the synthesis of multimodal ground cues, the research on sensing floors is at a more advanced development stage. Prior work on the computational understanding of walking-based information has focused on recognition tasks for areas such as biometrics/security and clinical movement analysis, or on style modeling by means of motion capture. Significant prior research and development of smart, sensate floors exists. Most of these rely on high-resolution force sensor arrays that in many cases do not necessarily pose a technological challenge today. Several companies, including TekScan Inc., offer sensor technologies tailor made for high-density force sensing floor applications. Examples of research artefacts employing such technologies include the ASU-AME sensing floor, the GaitMat, Lightfoot, Magic Carpet, Z-Tiles, FootSee, Ada, and several others, like the newly marketed Wii fit. Motivating applications for such floors have included entertainment spaces, artistic (dance and music) performances, and augmented dwelling or workspace environments. Applications of increasing relevance comprise navigation aids for impaired persons in unfamiliar or hostile environments, athletic equipment (such as the Nike+ system), or interactive public displays (like the Reactrix augmented flooring system). Likewise, relatively advanced force-sensing technologies for footwear are commercially available, with the largest markets to have emerged to date being concentrated within the medical industry. Primary applications include the rehabilitation of locomotion and balance-related disorders [Harry et al., 2005].

The growth in commercial development and ubiquity of mobile and location-aware information devices demonstrates the significant potential for new interaction paradigms to take hold. At the same time, the state-of-the-art in commercially deployed interactive systems presents a challenge and source of motivation for researchers in new interactive technologies, suggesting that they extend the contexts motivating their work to encompass non-laboratory environments. This brief review on the state of the art and development, that is of primary interest for NIW, forms the roots of the baseline explained below, from which the project will move.

Concerning physical actuators, the haptic rendering of floors is still a largely unexplored issue. Consequently, the baseline of actuation technologies the consortium can rely on are all at the research and development stage. Early tasks of NIW will involve advancement of prototype device concepts in parallel with the development of actuation technologies. McGill University has already made initial progress toward the actuated floor tiles, with plans for future tests in configurations of up to 10 square meters [Visell et al., 2008]. Prototype concepts for actuated shoe soles, along the lines described above, have begun to be explored by project personnel of UPMC: An ordinary shoe sole acts as a "filter" that couples the mechanical behavior of the surface being stepped on and the sensitive glabrous volar regions of the foot. Humans demonstrate ability to process the signals coming from soles to recover ground information, and show profound behavorial changes when this information is blocked. This effect may be readily exploited by an actuated floor surface or actuated shoe.

Aim of such devices is not to replace locomotion-oriented haptic interfaces, but to complement them. However, given the high complexity and cost of these machines, which must be capable of operating at very high force levels (on the order of 1000 Newtons) and large displacements (on the order of 1 meter), we also envisage that our designs could be sufficiently capable to create low cost virtual environments that could be implemented in a variety of locations such as hospitals, science museums, amusement parks, and perhaps homes. Performance indicator of the advancements NIW brings in the physical design of actuated floors will be every new device associated with its measurable degree of realism, either floor-located or shoe-embedded, that the consortium will be able to prototype within the project.

Besides taking haptics as an individual modality, another important component of the proposed project is to generate technologies which can complement potential limits of haptic inputs relying on today's most advanced actuation technologies. A possible strategy requires to leverage cross-modal transfer phenomena, in particular pseudo-haptic effects. Baseline to the application of this sensory substitution paradigm in NIW is the knowledge gained by INRIA, already mentioned in the previous paragraphs and put into concrete action especially during the conceptual and physical development of HOMERE [Lécuyer et al., 2003]. The HOMERE system was dedicated to enabling visually impaired people to walk in virtual environments. HOMERE provided users with force feedback from a virtual cane (to avoid obstacles and "feel" textures of the ground), thermal feedback from a virtual sun, and spatialized sound corresponding to the ambient atmosphere and specific events in the simulation. While its users lauded the design, they stressed that their perception of the ground would be more naturally achieved with the foot than with the cane.

NIW will study new generations of pseudo-haptic feedback, on two levels. First, we want to explore the existence of illusory haptic sensations elicited by auditory feedback generating at floor level, concerning the physical properties of the ground that are naturally sensed through our feet during contact, such as material, texture, elasticity. Second, we want to focus on visual, auditory, as well as audiovisual pseudo-haptic effects arising during walking tasks performed in immersive environments. In this case we want to assess perceived ecological properties such as those listed before, along with attempting to recreate physical states linked to balance and proprioceptive cues (sensation of fatigue, external forces, slope and viscosity of the floor).

As we are not aware of quantitative results dealing with the assessment of cross-modal illusions arising during walking tasks, any new systematic psychophysical measurement made by the consortium and validated through experiments will indicate an incremental step along this baseline. One example of pseudo-haptic experimentation in immersive virtual reality, obtained by superimposing appropriate visual effects and/or auditory cues that are synchronized with the motion of walking users, might deal with the simulation of a scenario in which users are being stuck in the mud. Another example of immersive pseudo-haptics would be a "King-Kong" floor effect: when the user walks in the virtual environment, the visual feedback "shakes the world" each time her feet touches the ground, so to give the impression of being heavier or more powerful. By reversing this simulation paradigm users may experience lighter gravity: this might have applications in the long term for instance in space and underwater sciences.

Simulations based on cross-modal effects will need a defined baseline embracing both sound and vision, from where to start. Concerning sound, the development of physically-based auditory models for contact interactions between the feet and the floor – events arising during walking, while tapping or scraping the foot, etc – have been comparatively neglected, with few notable exceptions some of those are part of the know-how of the Consortium [Cook, 2002b; Fontana and Bresin, 2003]. Likewise, the problem of how to display such stimuli in an ecologically plausible manner has been missing, despite some promising developments, such as [Nordahl, 2006], in which interactive auditory feedback based on physical models has been used to enhance the sense of presence in immersive photorealistic VEs.

The NIW project aims to improve upon this situation. By promoting the use of sound in floor interfaces, it will mark advancements in the development of physically-based synthesis models each time a model will be successfully adapted, or newly conceived to display realistic foot-floor contact sounds in the context of auditory only, audiovisual, or immersive multimodal scenarios.

Similarly to sound, the baseline for vision is centred around the interactive simulation of contact events by means of the synthesis of visual cues. Various kinds of simulation paradigms have been proposed for their use in virtual environments [Sreng et al., 2006; Sreng et al., 2007]. They display information of proximity, contact and effort between virtual objects using for instance glyphs (arrow, disk, or sphere) when the manipulated object is close or in contact with another element in the virtual environment. Light sources can also be added at the level of contact points. When an "event-based" approach is used, the contact events represent the different steps of two colliding objects: (1) the state of free motion, (2) the impact event at the moment of collision, (3) the friction state during the contact and (4) the detachment event at the end of the contact. The different events are used to improve the feedback by superimposing specific rendering techniques based on these events. For instance, visual rendering of impact, friction and detachment based on particle effects was developed by Sreng et al. [Sreng et al., 2007].

In the NIW project, visual feedback will be used to improve or generate sensations related to the walking motion. Camera motions and other changes in the motion or position of the user's viewpoint will be studied and used to augment or distort the walking sensations of the users. Ground textures and floor events will be projected to convey visual information of floor properties. These visual effects will be designed to support the manifestation of pseudo-haptic sensations, as described previously, as well to create immersive scenarios of ground floors. The performance of the research in floor-based visual displays must not be linked to the fidelity of projected images, as this goal has been already achieved for instance by the Reactrix systems. Rather, indicators of advancement of this part of the project research will be found in validated discoveries of visual effects contributing to form pseudo-haptic sensations, first in situated experiments making use of visual display only, then in audiovisually displayed settings, and finally in immersive multimodal settings in which visual information will have an integrative role in augmenting the sensations conveyed by the other modalities.

As the enactivity of the floor interface is part of the core concept of the project, sensing devices play a role of primary importance in NIW. Baseline, here, is the relatively little research which has investigated their use in the simulation or control of everyday ecological information in walking, [Cook, 2002; Nordahl, 2006; Visell et al., 2007]. In parallel to this research NIW wants to employ surface microphones recording in-solid acoustic waves, a technique that was investigated in the past IST project on Tangible Acoustic Interfaces for Computer-Human Interaction (*TAI-CHI*) as an alternative to the dense electronic networks that must be deployed to make use of force sensing methods. Such sensing method achieves locus-of-contact (foot) localization based on computations such as Time-difference-of-arrival (TDOA) [Crevoisier and Polotti, 2005]. The two approaches are substantially complementary, as force-sensing methods can more easily capture fine positional information, while acoustic sensing possesses an intrinsic high temporal resolution that is well suited to capturing nuanced aspects of foot-based gestures.

This work will be further extended in NIW through the combination of sensing with the novel display methods investigated in the project. Little work to date, primarily on the artistic side, has understood walking information as situated in a closed-loop setting, and virtually none of it in the context of ecological interactions. NIW will, in these respects, be in novel research territory. Force and acoustic sensors will be employed in NIW, and to the extent that they are used in tandem, their fusion will be addressed using currently state-of-the-art methods, including Bayesian machine learning models. The modeling and extraction of walking information from the fused sources will be accomplished with similar methods. This task will also be addressed via acoustic signal processing and pattern recognition models that have proven their worth in fields such as speech recognition and musical information processing. Such techniques may prove particularly suited to the novel acoustic sensing methods deployed here. Attention will be devoted to both positional information and to nuanced features, ranging from low-level actions (the click of the heel or scrape of the toe) to high-level correlates (expressive intentions or emotional attitudes). As smart floors making use of fused force and acoustic sensing have not been researched, new sensor designs as well as computational methods capable of interpreting positional and gestural information coming from these sensors will denote significant steps ahead from the baseline.

Finally, basic knowledge linking floor sensing and feedback has to be gained during the project. Priority will be given to forming abstract classifications (i.e. a taxonomy) of the sensed information, that can be readily exported to the synthesis paradigms in the diverse modalities. Although the notion of haptic rendering is relatively new [Salisbury et al., 1995], the decomposition of elementary haptic interactions according to physical interactions can be seen as essential to simulating haptic interactions with virtual objects. To date, most attention has been focused on elementary manual interactions, including rigid contact, friction, cutting, contact with deformable bodies, textural effects, and shocks. NIW will employ existing taxonomies in order to classify interaction events, and use such taxonomies as a baseline: specifically, the aforementioned Gaver's classification of auditory events, and methods for the simulation of physical phenomena such as impacts, friction, scraping, or rolling, that are being developed for manual haptic interaction in virtual environments [Hayward, in press].

To date, little attention has been devoted to the categorization of interactions in a multimodal setting, or in one that involves interactions between the feet and ground. Thus, the categorization activities that are planned for WP2 are seen as essential to the project. Novel taxonomies that can be effectively exported to foot-floor interaction will be counted up as performance indicators of the project, and consequently delivered.

B.1.3 S/T methodology and associated work plan

B.1.3.1 Overall strategy and general description

Besides WP1 (management), the workplan includes four work packages evolving in parallel: WP2 (haptic devices), WP3 (sensing), WP4 (feedback), and WP5 (evaluation). By touching at the same time issues of interaction design and psychophysical evaluation of the same designs, the project in fact will need to continuously iterate across these two issues in such a way that unavoidable mutual connections exist among the corresponding work packages. This fact also implies that the project will require a continuous and tight collaboration between all partners.

WP6 (integration) is more loosely connected. Since it deals with presence studies in an immersive virtual environment, that is more rich compared to the situations proposed by the previous work packages, it will start one year later. The usability experiments made upon the immersive environment will nevertheless affect the previous work packages. For this reason, and despite their delivery dates do not match with month 36, WP2, WP3, WP4 and WP5 cannot be concluded before WP6 ends, i.e. at month 36, when it should combine the tested technologies in a durable prototype.

WP7 (dissemination) will also take off one year after the project activity begins, i.e. at month 12. Even if some of its tasks such as the construction of the web site, the publication of the brochure, and the design of the official logo, will begin as soon as the project starts, the core activity of this work package embraces the second and third year of the project.

Work packages like WP4 and WP5 are particularly challenging given that they will respectively realize and validate novel interface designs and interaction paradigms. WP5 can only be profitably implemented in continuous loop with WP2, WP3, WP4, and later also with WP6. Together with the experimental design, the beginning of WP5 will be devoted to the system calibration via measurements and preliminary experimental tasks aimed at tuning the control maps, which make possible the continuous interaction between the user and the augmented floor.

A general description of the workplan, divided into research tasks, is given in the following paragraphs.

Physical engineering: actuated floors and shoes

Actuated programmable surfaces mounting simple, readily available, and relatively low-cost actuator technologies based on voice-coil motors have been recently shown to be effective in reproducing key aspects of the mechanical behaviors of a floor surface when loaded by a foot step. McGill University has matured a crucial know-how in the prototyping of such devices during the past twelve months, and NIW will contribute to fuel this research for the next three years.

The concept of actuated shoes is key in the project and the consortium is already nurturing their realizations based on some design principles. Consider the principal mechanical deformation undergone by a typical shoe sole when loaded by a foot step. There is overall sole bending, even minute, which presumably is be picked up by the foot. This global shoe deformation can be simulated using hopefully simple actuator techniques, even more so as it occurs in the low frequencies. For instance, the boot bottom of an actuated shoe could be split into two: a front and a back section. An actuator could displace the two sections relatively to each other according to the load sensed by the shoe. Such a mode of actuation could convey the compliant nature of a virtual ground being walked upon, such that the higher is the shoe deformation, the higher is the ground stiffness.

High frequency signals arise from two sources when walking with a shoe. The first category is the result of shocks between the rigid sole and the ground. It can be speculated that the foot can pin-point its epicenter from the wave patterns on the surface in contact with the foot: tapping with the toe isn't the same as tapping with the heel. Cues could include phase effects, intensity gradients and spectral attenuation. Appropriate vibrotactile transducers could be engineered to replicate these cues. A second category of high frequency signals arise during stance. In this respect, they may be further subcategorized into those vibrations arise during pressure application on the soil and those vibrations arising from generating traction. These signals may be conveniently produced by either voice-coil motors driving a rigid surface that is walked upon, or by compact inertial type electromagnetic actuators embedded in a multilayered compliant sole. In the latter case, an important engineering consideration will be to design the relative compliance of the layers so that vibratory wave energy generated by the actuators be reflected "upward" to the foot rather than to the ground. Similar wave propagation design problems have been successfully solved in many other contexts, so no major difficulty is anticipated. An alternate design would employ large piezoelectric bending bimorph or monomorph slabs. The piezoelectric approach may have energetic advantages opening paths toward an autonomous, personal system, eliminating the need for tethers and reducing the need for bulky batteries. It will be proposed to pit the two technological approaches in the corresponding work package.

Experimental campaign

The experimental campaign comprises three steps that will address progressively increasing levels of complexity in terms of both technologies and methods:

i) Fundamental perception of the novel NIW technologies

The objective of this first step is to measure the performance of the new auditory and haptic devices and rendering techniques that will be developed in the project, taken individually. This step does not consider the assessment of navigation tasks in experiments enabling locomotion.

We will conduct a series of psychological experiments to study users' perception of some floor properties as simulated through each novel device and/or each novel rendering technique. We will refer to psychophysical protocols that enable to characterize and quantify the perception of physical properties, such as differential and absolute perception thresholds [Gescheider, 1985; Lécuyer et al., 2000].

We intend here to evaluate, more specifically and in parallel:

- The floor interface, i.e., the capacity of the floor device and of its associated haptic actuators to simulate floor properties such as elasticity, texture, etc.
- The auditory interface, i.e., the capacity of the auditory rendering to simulate accurately contact information and ground properties such as also elasticity or texture.

ii) Pseudo-haptic effects and combination of multiple sensory stimulations

The objective of this second step is to measure the possibility to improve the user's perception of the ground properties using a combination of the sensory stimulations, i.e., an association of the various technologies developed in the project.

We will combine one or more devices, and one or more rendering techniques together and evaluate the resulting gain in terms of perceptual performance and/or subjective preference. Again, locomotion tasks will be not employed in this kind of evaluations. We will also study and evaluate the pseudo-haptic effects obtained by using auditory and visual cues. In both cases, the methods used will here again mainly refer to psychophysics.

Thus, we intend here to evaluate more specifically and in parallel:

- The multi-sensory rendering of ground-properties: is it more efficient or more appreciated by the users to have more than one modality for the rendering of floor attributes such as impact, elasticity, textures, etc?
- The pseudo-haptic effects (cross-modal effects or illusions) generated by the association of visual feedback and/or auditory cues during walking or when standing in the interactive floor.

iii) Usability studies: interacting with the VE using the NIW techniques

The objective of this third step is to measure the potential of the system to improve interaction, and thus in our case the navigation and the walking, inside the virtual world. Here we want to evaluate the influence of the various sensory stimulations offered by the system and their associated novel interaction techniques on the performance the users obtained when walking in a VE.

The novel techniques will thus be evaluated using higher level tasks that correspond less to the basic perception of floor attributes, but rather to the achievement of more complex operations. Psychophysical protocols will be abandoned here to the profit of classical 3DUI evaluation paradigms [Bowman et al., 2004]. We will also make use of acknowledged and classical methods to measure the level of presence of the user in the virtual world, i.e., the Presence questionnaires [Slater et al., 1994; Schubert et al., 2001; Witmer and Singer, 1998].

We intend here to evaluate, more specifically and in parallel:
- The presence and performance of the user when simply walking in the virtual world using the interactive floor and its associated interactive techniques: the performance of navigation (task completion time, positioning errors), the level of immersion and presence, etc.
- The performance of the user during a more concrete or even a "real-life" task. Such a task should involve the need for walking and interacting with the ground (examples: sport training or entertainment activity, rehabilitation or re-education task, etc). The whole NIW system must then be evaluated through looking at: improvement of performance (training performance, learning curves) or subjective preference (level of presence, fun, etc).

Interface development

i) Physically-based sound design tools

Research activity on physics-based sound synthesis models has been ongoing in UNIVR, and its results now comprise a unified corpus of everyday sounds. As a result of research and development within the *CLOSED* project, to which UNIVR and key personnel at McGill University are participating, the synthesis models have been organized into the Sound Design Tools (SDT) software library, which is published on the internet, regularly updated, and expanded in an ongoing way. So far, the SDT software library provides the following C++ modules running on Windows and Mac OS under the Max/MSP and PureData real time environment:
- *Low-level models*: impact between solid bodies, friction, liquid (bubble) events
- *High-level models*: bouncing, rolling, crumpling, bubble stream, splashing.

AAU has been involved in parallel research, including the development of a physically-based footstep synthesizer representing the actions of walking on snow, gravel, tiles, grass, bricks and metal [Nordahl, 2005]. Recently, it has been also shown that interactive auditory feedback based on physical models enhances sense of presence in a photorealistic virtual environment [Nordahl, 2006]. The synthesizer from the latter work will be adapted to be compatible with the SDT library, and models will be further developed for the aims of NIW, to let them dynamically sonify events characteristic of foot-floor interactions. The SDT library will be expanded by deriving from the low-level models of impact and friction, new models capable of rendering such effects as scraping, squeaking, dragging, sliding, crushing sounds on both dry and wet floor surfaces.

In summary, concerning physically based interactive sonification, the main tasks of the NIW project will be the extraction of meaningful parameters from real sounds representing the different situations described above, and the development of modular physically based algorithms which reproduce these sounds while maintaining realism and fidelity of interaction.

ii) Auditory display methods

Auditory displays of walking events in prototype, experimental, and demonstration devices will require attention to the selection of loudspeaker technologies, whether the interactive device is a sonic wearable footwear component or floor tile. Accurate near-field audio spatialization/positioning is needed to avoid potential conflicts between the multimodal walking cues that users will receive. For free movement, wireless transmission of audio must also be considered. Participating labs have experience on both embedded auditory displays [Susini et al., 2006; Franinovic et al., 2007; Delle Monache et al., 2007] and audio over wireless networks, through ongoing projects, such as *Mobile Audioscapes* (McGill University) and *CLOSED* (UNIVR). Devices trading off between fidelity and miniaturization may consist of conventional loudspeakers positioned near floor level, performing near-field spatialization of auditory events; miniaturized loudspeakers embedded in shoes; or audio-bandwidth actuators vibrating the surface of the flooring itself [Visell et al., 2007].

iii) Ecological calibration of haptic and auditory displays

Since the input device augments the user's experience by conveying virtual cues through a flat floor surface, an effort must be made to ensure that the physical setting does not convey any specific impression on subjects independent of these cues, haptically, sonically, and visually. A preliminary, fundamental problem consists of compensating the intrinsic structural dynamics of the device (shoe or floor tile), in order to overcome the limitations that the latter would otherwise pose – i.e. interaction with very stiff materials, such as metals, or materials with very different resonant characteristics from those of the device. This will be accomplished through mechanical and electronic means as part of the device design effort in WP2.

A strong interest in the project lies in matching display and rendering methods to the interactive behavior of real-world materials. The rendering methods which ultimately produce the driving signals for the actuators of the displays are parametrized by values such as mass, elasticity, resonant spectrum, or viscosity that possess physical interpretations, albeit ones that are idealized or approximate. Equally importantly, the structure of the interaction models themselves involve physical assumptions.

NIW aims to match the phenomena rendered and displayed by the devices to real-world measurements. Hence, a methodology is required for identifying models, interaction mappings (eg. sensed displacement-to-force profiles), and rendering parameter settings that best match the measured properties of materials. This activity will occur within the scope of WP2 research on data analysis.

In order to solve this calibration problem (Task 3.2), NIW will require: (1) Measurement techniques for characterizing walking-based interactions with the materials of interest, such as the displacement or force applied to the ground and the vibrational and acoustic responses that result; (2) An algorithm for determining the optimal rendering parameter settings given the data; (3) A method for determining the unknown control mapping function from sensor data to rendering parameters. Data will be obtained from recorded walking interactions with real-world materials using instrumented shoes or other measuring probes. Interactive rendering methods will be refined, and their respective control mappings matched to the acquired data. Similar techniques have been successfully applied to modelling the acoustic and haptic interactive behavior of manually probed objects [Pai et al., 2001; Pai and Rizun, 2003; Andrews and Lang, 2007].

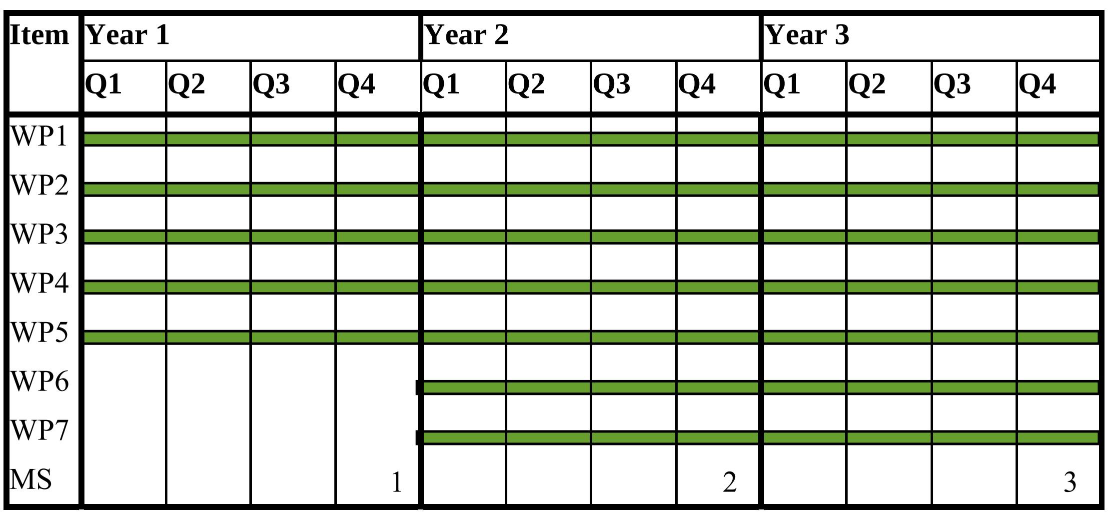
This approach also provides an analytic mean of validating the haptic and auditory displays on measured interactions. Such a validation will complement human-centred studies that will be performed as part of the experimental campaign of WP5.

iv) Visual display and rendering

The visual feedback will be provided using projection technologies ranging from head mounted displays (HMDs) to large screens in a six-sided CAVE, providing continuous projection into side walls, floor and ceiling. A virtual reality software platform will be selected and extended in order to facilitate the integration of the different sensors and actuators, as well as software elements involved in the project. The platform will support stereo visualization in the different display systems.

One further issue concerning control must be dealt with during tasks in which floor surface textures and simple dynamic events must be visualized to users. In this situation, NIW will adopt results from the *BENOGO* project, in which photo-realistic 3D real-time images of different places were rendered in real-time for a moving observer. NIW will utilize the results of the *BENOGO* project to visually render different floor surfaces in which the user can navigate, as well as ground-level events the user can interact with.

B.1.3.2 Timing of work packages and their components (Gantt chart)



B.1.3.3 Work package list /overview

Work package list

Work package No	Work package title	Type of activity	Lead partic. No	Lead partic. short name	Person-months	Start month	End month
WP 1	Management	MGT	1	UNIVR	14	1	36
WP 2	Haptic engineering	RTD	5	UPMC	51	1	36
WP 3	Multimodal sensing, analysis and integration	RTD	2	McGill University	53	1	36
WP 4	Auditory, haptic and visual feedback modelling	RTD	1	UNIVR	52	1	36
WP 5	Pseudo-haptics and perceptual evaluations	RTD	4	INRIA	52	1	36
WP 6	Iterative integration and presence studies	RTD	3	AAU	39	13	36
WP 7	Dissemination, Collaboration and Exploitation	RTD	3	AAU	10	13	36
	TOTAL				**271**		

B.1.3.4 Deliverables list

List of Deliverables – to be submitted for review to EC

Del. no. (WPx.Dy)	Deliverable name	Lead	Nature	Dissemination level	Estimated effort p/m	Delivery month
2.1	Initial device designs and prototypes for haptic interaction in walking	UPMC	R+P	PU	23	12
2.2	Reproducible haptic device prototypes for integration in multimodal contexts	UPMC	R+P	PU	28	24
3.1	Contact-based sensing methods for walking tasks	McGill University	R+P	PU	18	12
3.2	Sensor data fusion and gesture analysis tools	McGill University	R+P	PU	35	24
4.1	Auditory and haptic augmentation of floor surfaces	UNIVR	R+P	PU	22	12
4.2	Multimodal display of virtual attributes and floor events in walking interfaces	AAU	R+P	PU	30	24
5.1	Assessment of multi-modal and pseudo-haptic ground cues from augmented floors	INRIA	R	PU	52	24
6.1	Presence studies in multimodal augmented floors	AAU	R+P	PU	39	36
7.1	Project web site	UNIVR	O	PU	2	12,24,36
7.2	Panel on foot-based interfaces and interactions	AAU	R+O	PU	3	36
7.3	Book on ecological foot based interfaces and interactions	UNIVR	O	PU	5	36
				TOTAL	**257**	

B.1.3.5 Work package descriptions

WP1: Management – Lead UNIVR

This work package is needed to ensure technical and administrative management of the project. Major aims will be the development of a spirit of co-operation between the partners, the creation of consensus and circulation of the information among partners, the joint preparation of reporting documentation.

WP1 will create the interface with the Project Officer, especially by means of the following communication tools:
- Three periodic reports, one for each reporting period: 1-12, 13-24, and 25-36.
- One final report, at project end, comprehensive of the final plan for the use and dissemination of foreground and the report on wider societal implications of the project, in the terms stated by the General Conditions of the Grant Agreement.
- Project Web-Page (see Deliverable 7.1).

WP2: Haptic Engineering – Lead UPMC

The Haptic engineering work package will research the engineering of haptic interactive floor and shoe interfaces for the simulation of ecological phenomena in walking. As a preliminary to this work, and to that of WP4, the consortium will survey the relevant literature on physical interactions with ground materials during walking. Categories will be organized around material properties, including features like solid, carpeted, aggregate, or wet, and contact interaction types, such as rubbing, crushing, or impact. The resulting taxonomy may be well-characterized by changes in few basic attributes characterizing the floor interaction, such as texture, elasticity, viscosity, resistance.

The main research tasks within WP2 are to create new device designs using simple, compact, and relatively low cost mechanisms and actuator technologies, such as voice-coil (inertial) motors, piezoelectric bimorphs, or other devices. Relative to high-end robotic walking interfaces, such devices may be viewed as reproducing the haptic sensations experienced during walking "without the 'DC component'" [Yao et al., 2005]. A basic hypothesis to be later tested in coordination with WP6 is that even such simplified simulations can be designed to afford a degree of realism that allows their users to perform the same kinds of perceptual judgements as they would with natural stimuli.

The feet are well suited as a target for such stimulation methods, because of the high density of tactile mechanoreceptors in the sole of the foot. WP2 will employ low-cost high fidelity actuators that are to be selected to best match the devices and ecological phenomena under study. Even simple actuators such as those described above can be highly effective at the display of the subtle features characterizing realistic ecological signals [Yao and Hayward, 2006]. Attention will be devoted to the compensation of the structural dynamics of the actuator and mechanism, so that simulated physical properties (eg. material hardness) may be independently specified from those of the device. Considerable correspondence with WP4 on the physically-based synthesis of driving signals (using techniques from sound synthesis) will be needed. Tight coherence between the auditory and haptic informational channels is expected to positively impact realism.

However, the reduced time/frequency sensitivity of the tactile modality relative to that of audition can facilitate further simplifications to the haptic synthesis models that nonetheless preserve the invariant signature of the stimuli involved [Yao and Hayward, 2006]. Illusions that give rise to a haptic percept that is in conflict with the apparent properties of the stimulus have been a staple of haptic engineering since its inception [Hayward et al., 2007]. Such effects will form the basis for giving users impressions that they are walking on real-world materials despite the limitations of the actuation mechanisms that will be investigated. Visual-haptic, auditory-haptic, and finally full multimodal effects will be the subject of interactions with the other project working areas.

WP2 contributes to milestones 1 and 3, and culminates into the following deliverables:

2.1 *Initial device designs and prototypes for haptic interaction in walking*
Delivery: month 12
Lead: UPMC
Other contributors: McGill University
Object: report and prototypes of actuated floors and active shoes.

2.2 *Reproducible haptic device prototypes for integration in multimodal contexts*
Delivery: month 24
Lead: UPMC
Other contributors: McGill University
Object: report and prototype of multimodal floor interface, relying on validated physical designs (due to WP5) and informed by user experiences (made in WP6).

WP3: Multimodal sensing, analysis, and integration – Lead McGill University

While WP2 aims at enabling low-level haptic interactions in walking, WP3 will investigate the use of the relevant sensed information at higher levels of abstraction. It addresses the acquisition and analysis of sensor data from walking-based interactions, the computational integration of available sensed information sources, and the development of data-driven methods for controlling multimodal feedback synthesizers in response to sensed data.

Sensing will be achieved using sensors integrated within floor components or shoes, and from complementary sources. Sensing methods will be drawn from acoustic sensing techniques described earlier, shoe- or floor- based force sensing arrays, and inertial sensors from shoe-based sensor packs. Motion capture will be used to provide ground truth movement profiles in a subset of trials. The particular sensing configurations will be chosen so as to be later appropriate to the interaction scenario under study, in coordination with WP6.

In order to complement research within WP4 on the modelling of interactive ecological phenomena in walking, the work package WP3 will develop methods for identifying the physical interactive behavior of ground materials, for the purpose of refining haptic and auditory interaction in ways that optimally match the response profiles of real materials. Such mappings will be inferred from recordings of subjects walking on real ground surfaces using novel measurement techniques. The results will facilitate tuning the characteristics of the feedback synthesis models developed in WP4 in ways that best reproduce interactions with real materials.

Machine learning methods will be used to model the fusion of multimodal information sources from arrays of sensors, and to analyze user walking gestures and activities from this information. NIW will draw on modern Bayesian machine learning methods that have found considerable recent use in multimodal data fusion. Acoustic pattern recognition techniques that are well suited to the in-solid acoustic sensing methods innovated in NIW will also be employed.

Higher level inferences will involve the computational understanding of salient, evolving patterns of walking movement (walking styles) and the identification of high-level correlates such as intentionality, affect, activity type, and individual identity. This work will aim to build on recent research in areas like walking style modeling for motion capture [Ek et al., 2007]. The results will be exported to immersive interactive scenarios, in coordination with WP6.

WP3 contributes to milestones 1, 2, and 3, and includes deliverables 3.1 and 3.2:

3.1 *Contact-based sensing methods for walking tasks*
Delivery: month 12
Lead: McGill University
Other contributors: UNIVR, AAU
Object: report and prototype (sensing device and software) of the interface sensing part.

3.2 *Sensor data fusion and gesture analysis tools*
Delivery: month 24
Lead: McGill University
Other contributors: UNIVR
Object: report and prototype (software) of the computational model for the analysis and fusion of the input data.

WP4: Auditory, haptic and visual feedback modelling – Lead UNIVR

The main goal of this workpackage is to enable the interactive synthesis of multimodal cues required for the design of ecological walking experiences. Physically-based sound synthesis methods will be extended to better suit this setting, as an extension of methods previously researched by UNIVR, some of them jointly with AAU [Rocchesso et al., 2003; Avanzini et al., 2005]. Sound events including impact, walking, crumpling, crushing, friction, rolling will be synthesized in such a way as to be continuously controlled by foot-floor interactions. While the required synthesis models are sufficiently mature to generate credible walking sounds for certain materials and interactions, there is a need for walking sound design tools that offer a sufficiently broad palette and level of realism (or even of hyper-realism) to enable the design of high quality ecological walking experiences. Moreover, attention to the situated use of these synthesis tools in walking interfaces, based on floor- or foot-based sensing and acoustic actuation devices, is required so that interactive feet-floor interactions may be convincingly reproduced. These aims dictate a close exchange with the experimental program of WP5 and the measurement-driven identification activities of WP3.

Synthesis methods for acoustic phenomena associated to walking remain further developed than the corresponding haptic methods. Nonetheless, the fundamental approaches to many of the relevant phenomena can be inferred from existing work on haptic simulation, such as those related to impacts, friction, or textural effects. Within NIW, special considerations will arise from the need to develop interactive synthesis methods that are well-matched to the unusual nature of the shoe and floor–component devices being addressed in the project. At the same time, to the extent that auditory and haptic stimuli are attributable to the same physical pathway, considerable exchange of synthesis methods between the two modalities can be expected.

Since part of the experimental campaign undertaken by the project is devoted to study the impact of vision in the subjective evaluation of animated ground surfaces and floor events, then visual floor textures need to be synthesized in parallel to auditory and haptic cues at least for some experimental tasks, through static and dynamic projections of ground events based on existing techniques for virtual reality applicable to the facilities existing at AAU, INRIA, UPMC, and McGill University.

WP4 contributes to milestones 1, 2, and 3, and includes deliverables 4.1 and 4.2

4.1 *Auditory and haptic augmentation of floor surfaces*
Delivery: month 12
Lead: UNIVR
Other contributors: UPMC, McGill University, and AAU
Object: report and prototype (software) of the auditory and haptic feedback synthesis model.

4.2 *Multimodal display of virtual attributes and floor events in walking interfaces*
Delivery: month 24
Lead: AAU
Other contributors: UNIVR, INRIA, McGill University
Object: report and prototype (display device and software) of the multimodal feedback synthesis model.

WP5: Pseudo-haptics and perceptual evaluations – Lead INRIA

In this work package, experiments will be designed that measure the ecological validity of categories of commonly experienced floors, which can be described in terms of elementary attributes such as texture, elasticity, viscosity, resistance. These attributes will be rendered through displays initially exposing one, then two, and finally three modalities chosen between the auditory, haptic, and visual channel. Ground surfaces will be object of non-visual enactive explorations performed by subjects walking and scraping with the foot. Visual events will enable further interactions, providing additional information on the nature of the floor.

This workpackage will also cover the iterative developments and testing of novel pseudo-haptic concepts based on perceptual phenomena (cross-modal/illusory effects). The pseudo-haptic techniques will rely on the combination of haptic/visual/auditory cues for the simulation of ground properties sensed while walking and interacting with the feet. The workpackage focuses on pseudo-haptic feedback based either on the synthesis of augmented sounds to accompany users' foot gestures during contact with the floor (by means of interactive, physically-based sound synthesis models) and on the visual display of events involving presence of virtual artefacts or features on the floor surface.

A compact corpus of experimental tasks will be first determined at the beginning of WP5 upon a set of ground materials and properties, considered promising in terms of perceptual relevance and feasibility using the available technological baseline. This workpackage will investigate how elements in such a set, chosen among homogeneous, carpeted, loose, aggregate grounds, and the like, can be correlated to different configurations of the elementary attributes described above. Such grounds will be later tested in the presence of visual events creating more complex interactive walking scenarios, and ultimately affording locomotion.

The methods and tools used to conduct the experimental campaign at the level of this workpackage will mainly refer to classical experimental psychology and psychophysics. For instance, each device or each technique can be evaluated by computing its associated perceptual thresholds (absolute or differential threshold), for the simulation of one property or ground attribute, e.g., rugosity.

WP5 contributes to milestones 2 and 3, and includes deliverable

5.1 *Assessment of multi-modal and pseudo-haptic ground cues from augmented floors*
Delivery: month 24
Lead: INRIA
Other contributors: AAU, UNIVR, UPMC, McGill University
Object: report on the experiments (methodologies and results) carried out during the experimental campaign, plus outline of the presence studies planned for the third project year.

WP6: Iterative integration and presence studies – Lead AAU

This workpackage will integrate prototyping activities throughout the project. The different sensors and actuators developed in the previous work packages will be iteratively combined in a unique platform. A primary challenge in this integration will be the synchronization of auditory and haptic information with the visual modality. The technologies developed will be tested concerning their ability to maintain fidelity of interaction in the environment.

In parallel, the work package will investigate the role of multimodal integration in providing and enhancing sense of presence in virtual worlds, with specific concern to scenarios proving useful in fields such as rehabilitation and entertainment. To achieve this goal, a compact and coherent set of scenarios will be planned through discussions with experts coming from institutions as described in the section on Strategic impact. These experts will be invited to meetings and put in front of the interaction designers joining the project, both at the beginning of WP6, and later at project month 24, i.e. once robust experimental knowledge on basic foot-floor interaction methods will have been delivered by WP5.

Acknowledged and classical methods to measure the sense of presence such as presence questionnaires will be adapted [Slater et al., 1994]. The different combinations of modalities will be compared. For example, we will examine the role of pseudo-haptic feedback versus real haptic actuators in providing sense of presence. All experiments will be performed both when subjects simply walk in the virtual world, and when they are performing more complex tasks such as hitting objects with their feet.

The activities of WP6 will culminate on the realization of a final prototype used for demonstration and evaluation purposes, obtained by progressively introducing improvements to the interaction design and the experimental scenarios, until facing a pre-industrial design activity aiming at prototyping.

WP6 contributes to milestones 2 and 3, and culminates in deliverable

6.1 *Presence studies in multimodal augmented floors*
Delivery: month 36

Lead: AAU
Other contributors: INRIA, McGill University
Object: report on scenario design guidelines and presence studies (methodologies and results) plus prototype of VE.

WP7: Dissemination, Collaboration and Exploitation – Lead AAU

Raising interest for the project during its development will facilitate the exchange of ideas and solutions with human-computer interaction design groups external to the project. Further contacts with communities working in the bio-engineering, biometrics, clinical movement areas, some of those listed in the section on Strategic impact, might create mutual fertilization of fundamental importance for the project. Hence, this work package wants to create awareness of the project in academic, scientific, industrial and cultural communities as well as within the FET-Open programme. Furthermore it wants to create occasions and tools for cross fertilization with interaction design teams working in such communities, disseminate project achievements, and finally generate a joint edited book summarizing the results of the project.

WP7 will also tighten the consortium toward more cohesive joint work. Most of the publication activity in NIW will be the result of shared research and joint manuscript authorship. Concerning the book in particular, a cross-review methodology will be adopted which already proved successful during the editing process of a previous jointly authored multi-disciplinary book, which was edited also by the Coordinator [Rocchesso and Fontana, 2003]: according to this methodology, the authors of a selected chapter are asked to review parts of the book whose scientific merit is outside their primary research activities.

Dissemination, collaboration and exploitation as well as concertation at FET-Open level will be implemented according to the tasks described in the WP7 table below. The Consortium agrees to include the following reference in all project-related dissemination activities:

"The research leading to these results has received funding from the European Community's Seventh Framework Programme under *grant agreement* n° 222107",

as well as, concerning project presentations, activities and events:

"The project NIW acknowledges the financial support of the Future and Emerging Technologies (FET) programme within the Seventh Framework Programme for Research of the European Commission, under FET-Open grant number: 222107".

All dissemination activities (i.e. publication abstracts, reports from events and activities organized during the project) will be summarized within specific sections in the periodic reports project's. The Final plan for the use and dissemination of Foreground will be published in the final report.

WP7 contributes to milestone 3, and will issue deliverables 7.1, 7.2, and 7.3:

7.1 *Project web site*
Delivery: month 12, 24, 36
Lead: UNIVR
Other contributors: McGill University, AAU, INRIA, UPMC
Object: web exposition of the project progress, updated on a monthly basis.

7.2 *Panel on foot-based interfaces and interactions*

Delivery: month 36
Lead: AAU
Other contributors: UNIVR, McGill University, INRIA, UPMC
Object: report and publication material from a panel organized by the project.

7.3 *Book on ecological foot based interfaces and interactions*
Delivery: month 36
Lead: UNIVR
Other contributors: AAU, McGill University, INRIA, UPMC
Object: publication of a book supported by the project.

Workpackage number	**WP1**	**Start date or starting event:**		month 1
Workpackage title	**Management**			
Activity type	MGT			
Participant number	1	2	3	4	5
Participant short name	**UNIVR**	McGill University	AAU	INRIA	UPMC
Person-months per Participant	10	1	1	1	1

Objectives To ensure technical and administrative management of the project. To develop a spirit of co-operation between the partners. To create consensus and circulation of the information among partners. To prepare reporting documentation. To interface with the Project Officer. To stay within timeframes. To keep focus on the work plans. To ensure quality of management.

Description of work:
Task 1.1: Project management. To manage the communication inside the project consortium and toward the European Commission. To prepare and conduct project meetings and reviews. To prepare minutes. To manage fund transfers toward the partners.
Task 1.2: Technical and scientific co-ordination. To perform technical coordination between partners. To provide progress reports. To organize meetings on a regular basis. To ensure that the development process follows the quality rules for the project.
Task 1.3: Management of workpackages and tasks. To perform workpackage/task management. To monitor measurable success factors for all workpackages.

Deliverables
- Three periodic reports, one for each reporting period: 1-12, 13-24, and 25-36.
- One final report (at project end), containing also the final plan for the use and dissemination of foreground and the report on wider societal implications of the project.
- Project Web-Page (see Deliverable 7.1).

Expected results
- Efficient management.
- Kick-off meeting (Project Officer invited) and project meetings.
- Progress reports and reviews as per contract.
- Minutes of meetings.

Workpackage number	**WP2**	**Start date or starting event:**			month 1
Workpackage title	**Haptic Engineering**				
Activity type	RTD				
Participant number	1	2	3	4	5
Participant short name	UNIVR	McGill University	AAU	INRIA	**UPMC**
Person-months per Participant	2	9	2	2	36

Objectives To identify new methods for low-cost haptic interaction in walking, exploiting novel perceptual illusions and cross-modal effects where suitable. To create prototype interactive devices based on these methods. To enable simulations of realistic ecological phenomena, while compensating for structural properties of the input device. To design interactive devices capable of "transparently" representing perceptually salient haptic features of ecological walking grounds. To integrate driving signal simulations developed in WP4.

Description of work:
Tasks 2.2 and 2.3 below depend on an integrated development and evaluation cycle, in exchange with WP4 and WP5, aimed at producing interactive devices with a sufficient level of realism.
Task 2.1: Basic walking interactions. In the first task of WP2, the consortium will survey the relevant literature on physical interactions with ground materials during walking. This will facilitate identifying display methods appropriate for reproducing these phenomena.
Task 2.2: Haptic display methods. Project partners will identify methods for haptic interaction that are suited to representing ecological phenomena encountered in walking on familiar ground surfaces. Attention will be devoted to low-cost methods whose effectiveness depends on good exploitation of the available interaction modalities and physical device characteristics, rather than upon the volumetric simulation of three-dimensional walking surfaces and environments. Device designs will be generated, analyzed, and simple prototypes will be constructed to illustrate the principles involved, and to perform informal perceptual or use studies as appropriate.
Task 2.3: Prototype devices. The third task will focus on the creation of robust prototypes of a subset of the display methods from task 2.2. In coordination with WP4, it will furthermore carry out the implementation of unitary ecological interactions via these devices, as for example in the simulation of particular solid or aggregate surface types. These prototype demonstrators will provide the basis for a strong connection with the assessment efforts of WP5. Results from the assessments of WP5 will be fed back to this task to further refine the developments involved.
Task 2.4: Integration. The final task of WP2 will be supportive of the integrated design efforts of the project, in which different haptic interaction methods are to be combined with those of other modalities to enable implementation of immersive interaction scenarios and corresponding evaluations in WP6.

Deliverables
D 2.1: Initial device designs and prototypes for haptic interaction in walking.
D 2.2: Reproducible haptic device prototypes for integration in multimodal contexts.

Expected results [contributing to Milestones]
R2.1 [M1] Initial haptic prototype.
R2.2 [M3] Finished device designs, interaction methods.

Workpackage number	**WP3**	**Start date or starting event:**			month 1
Workpackage title	**Multimodal sensing, analysis, and integration**				
Activity type	RTD				
Participant number	1	2	3	4	5
Participant short name	UNIVR	**McGill University**	AAU	INRIA	UPMC
Person-months per Participant	12	27	10	4	0

Objectives To extract gait gesture information from the available (contact-based) sensor information sources, including in-solid acoustic wave signals, force sensing arrays, and inertial sensors. To extract activity-related information from these sensed signals. To perform measurements necessary to best match rendering models to real-world materials. To make higher level inferences as to user walking patterns.

Description of work:
Task 3.1: Contact-based sensing. Multimodal sensor data data will be acquired from walking-based interactions via contact-based sensor arrays, from the sensors of a haptic interactive device, or complementary sources. Sensing configurations will be chosen so as to best match the interaction scenarios under study, through coordination with other work packages. Primary sensing methods will be based on contact interactions. These may include in-solid or in-air acoustic sensing, shoe- or floor-based force sensing arrays, and wearable inertial sensor packs. Motion capture and video will be used to provide reference data sources in cases where a ground truth may be needed.
Task 3.2: Material interaction modelling. Data-driven methods will be used to optimally identify interactive behavior of real-world materials for the purpose of identifying rendering methods developed in WP4, and their respective sensor-to-control parameter mappings. The aim is to allow the interaction methods to best reproduce interactions with real-world materials. The necessary data will be obtained from measurement techniques for walking-based interactions on real ground surfaces, which must be innovated in the project.
Task 3.3: Multimodal data fusion. This task will focus on the fusion of information coming from multiple sensor data sources and from arrays of sensors, implemented in Task 3.1. Fusion will be accomplished in a probabilistically consistent way using machine learning methods. The result will be improving estimates as to the state of user interaction during walking.
Task 3.4: Walking pattern and gesture inference. Higher level inferences as to user activities and gait patterns or styles, and identification of high-level correlates such as intentionality, affect, activity type, and individual walker identity, will be accomplished using machine learning methods, including techniques extending those of Task 3.3, as well as specific acoustic pattern recognition methods matched to the acoustic sensing methods of Task 3.1.

Deliverables
D 3.1: Contact-based sensing methods for walking tasks.
D 3.2: Sensor data fusion and gesture analysis tools.

Expected results [contributing to Milestones]
R3.1 [M1] Design of interactive floor systems: sensing technologies and data analysis.
R3.2 [M2] Data analysis in experimental sensing floors.
R3.3 [M3] Intelligent analysis of walking interactions for immersive environment simulations.

Workpackage number	**WP4**	**Start date or starting event:**		month 1	
Workpackage title	**Auditory, haptic and visual feedback modelling**				
Activity type	RTD				
Participant number	1	2	3	4	5
Participant short name	**UNIVR**	McGill University	AAU	INRIA	UPMC
Person-months per Participant	21	6	12	4	9

Objectives To design auditory, haptic, and visual rendering algorithms. To adapt the synthesis models of the Sound Design Tool software library for the aims of interactive sonification of floors. To design rendering algorithms for the haptic synthesis of ground materials, suited to the devices developed in WP2. To provide interactive visual displays of floor and ground surfaces and events. To design maps for the continuous control of the synthesis models. To develop physical and digital communication layers from sensing to synthesis modules.

Description of work:
All the following tasks must be considered in loop with WP5 and WP2, hence repeatable until leading to an interface having the desired level of realism.
Task 4.1: Auditory, haptic, and visual synthesis. Synthesis models which take the constraint of continuous control into account will be designed. Sound synthesis will exploit, and further expand a class of models that simulate the physical generation of a broad spectrum of everyday sounds. Novel physically-based haptic rendering algorithms will be designed, matched to the capabilities of the input devices (actuated shoes or floor components). Interactive methods for the visual presentation of ground attributes and floor events will be developed.
Task 4.2: Real-time control mappings. Parametric and excitatory control mappings over the synthesized phenomena will be developed. They will be aimed at providing the tight level of control required for realistic interactive displays. The controls will allow the rendering methods to be integrated in the interactive devices via the sensors the latter provide. This task will be facilitated by the physically-based nature of the synthesis models.
Task 4.3: Communication protocol. Physical and digital communication layers mapping sensing to synthesis modules will be developed, so as to ensure a coherent and efficient exchange of data with the input interface. The communication protocols will encompass both low-level controllers, suitable for closed-loop haptic control within a device or low-latency auditory feedback, as well as higher level protocols aimed at modalities such as vision with less stringent requirements on latency or at slowly-varying features, such as dynamic material variation.

Deliverables
D 4.1: Auditory and haptic augmentation of floor surfaces.
D 4.2: Multimodal display of virtual attributes and floor events in walking interfaces.

Expected results [contributing to Milestones]
R4.1 [M1] Auditory and haptic feedback for floor augmentation.
R4.2 [M2] Controlled feedback in experimental floor settings.
R4.3 [M3] Design of interactive floor systems: multimodal actuation technologies and display.

Workpackage number	**WP5**	**Start date or starting event:**		month 1	
Workpackage title	**Pseudo-haptics and perceptual evaluations**				
Activity type	RTD				
Participant number	1	2	3	4	5
Participant short name	UNIVR	McGill University	AAU	**INRIA**	UPMC
Person-months per Participant	4	2	13	29	4

Objectives To select a coherent and compact corpus of experiments. To evaluate augmented floors and virtual ground attributes displayed using different (auditory, haptic, visual) modalities and their combinations. To iteratively develop pseudo-haptic techniques using a perception-based and user-centred approach. To perform experimental tasks with different categories of real and simulated surface materials as well as simulated feet-floor contact events, involving subjects belonging to different gender, culture, and ability.

Description of work:
Task 5.1: Design of experiments. This task will search experiments that can unveil, in the limit of the available technologies, floor attributes conveying prominent and realistic perceptual cues. A compact corpus of experimental tasks will be initially selected from a broad pool of possible foot-floor interactions. This corpus may be subjected to further refinement, to maximize the quality of the experiments in terms of expected results.
Task 5.2: Unimodal experiments. This task intends to measure the performance of the auditory and haptic devices and rendering algorithms, taken individually. We will conduct a series of psychological experiments to study users' perception, during non-navigational tasks, of floor properties of material, elasticity, and texture, using well-established psychophysical protocols such as differential and absolute perception thresholds.

Task 5.3: Cross-modal and pseudo-haptic techniques. In this task, novel concepts of cross-modal and pseudo-haptic feedback will be iteratively developed in strong conjunction with perceptual evaluations and testing. We want here to simulate, first: (1) physical properties that are naturally sensed through our feet during non-navigational tasks, such as ground material, elasticity, and texture, and then (2) the physical states and sensations involved when balancing with the feet or walking (sensation of fatigue, of external force, and perception of diverse floor attributes such as slope and viscosity). The task focuses on the pseudo-haptic perception based either on the synthesis of augmented sounds or on the visual display of events or features on the floor surface.

Task 5.4: Multimodal experiments. This task intends to measure possibilities to improve the user's perception of ground properties, by combining sensory stimulations validated in previous tasks 5.2 and 5.3. Different modalities will be rendered and evaluated together in terms of perceptual performance and/or subjective preference. We will also study and evaluate pseudo-haptic effects obtained by jointly using auditory and visual cues. In both cases, the methods used mainly refer to psychophysics, while extending also to walking tasks made on real ground materials.

Deliverables
D 5.1: Assessment of multi-modal and pseudo-haptic ground cues from augmented floors.

Expected results [contributing to Milestones]
R 5.1 [M2] User-centred design of auditory and haptic interactive floors
R 5.2 [M3] Evaluation of pseudo-haptic and multimodal interactive floors.

Workpackage number	**WP6**	**Start date or starting event:**			Month 13
Workpackage title	**Iterative integration and presence studies**				
Activity type	RTD				
Participant number	1	2	3	4	5
Participant short name	UNIVR	McGill University	**AAU**	INRIA	UPMC
Person-months per Participant	4	7	14	12	2

Objectives To combine the different methods and prototypes in a unique multimodal platform. To test the combined platform and its ability to provide sense of presence in a virtual environment. To design a final prototype for demonstrations, with specific concern on future applications in rehabilitation and entertainment.

Description of work:
Task 6.1: Design of scenarios. Specific attention will be devoted to scenarios having potential application in fields such as rehabilitation and entertainment. This task will be implemented through discussions with experts in such fields as described in the section on Strategic impact.
Task 6.2: Integration of technologies. The input and output techniques realized in WP2, WP3, WP4, and tested in WP5, will be combined in a unique platform affording also locomotion. The different methods developed in such workpackages will be iteratively selected and connected.
Task 6.3: Fidelity of interaction. In this task we will measure the potential of the system to improve navigation and walking in virtual environments. This task will be accomplished by evaluating the influence of the different sensory stimulations on users' performance when walking in virtual environments, and when interacting with different virtual objects with their feet, for example by kicking or hitting them.
Task 6.4: Presence studies. The combined platform will be tested regarding its ability to provide sense of presence in virtual environments. To achieve this goal, techniques already established in the presence research community such as presence questionnaires will be adapted and employed.
Sense of presence will be assessed both in simple tasks such as walking and navigating in the environment, and in more complex tasks such as when interacting with objects.
Task 6.5: Final prototype. The previous tasks will provide the necessary tools for finalizing the prototype of a scenario that will be demonstrated in the end of the project.

Deliverables:.
D 6.1: Presence studies in multimodal augmented floors.

Expected results [contributing to Milestones]
R 6.1 [M2] Multimodal augmented floor scenario designs.
R 6.2 [M3] Final prototype and presence studies.

Workpackage number	**WP7**	**Start date or starting event:**		Month 13
Workpackage title	**Dissemination, Collaboration and Exploitation**			
Activity type	RTD			
Participant number	1	2	3	4	5
Participant short name	UNIVR	McGill University	**AAU**	INRIA	UPMC
Person-months per Participant	2	2	2	2	2

Objectives: To create awareness of the project in academic, scientific, industrial and cultural communities. To create occasions and tools for cross fertilization with interaction design teams working in such communities. To disseminate project achievements. To produce a book summarizing the results of the project. To contribute to the FET-Open portfolio and concertation activities.

Description of work:
Dissemination, collaboration and exploitation will be implemented according to the following tasks covering FET-Open portfolio and concertation activities:
Task 7.1: **Website.** A website documenting the project's aims and publishing results and ongoing research on a monthly basis.
Task 7.2: **Publications.** A series of joint publications in widely accessible and, where available, openly accessible academic journals and conference presentations focused on interface design, realization, and evaluation, as well as on perception and psychophysics. Four press releases (every 12 months). Three brochures (every 18 months) for widespread dissemination during thematic events. Four web videos (every 12 months). Project logo.
Task 7.3: **Participation and organization of events**. Including those organized by FET. Key persons of NIW will regularly attend conferences and workshops, also to present NIW at separate sessions. NIW will cooperate to organize one international summer school. In the third year of the project, NIW will organize a panel on foot-based interfaces and interactions at an international HCI-related conference, where the achievements and ongoing works of the project will be presented and disseminated. NIW will be also presented off the academy (eg. hi-tech fairs).
Task 7.4: Edited book. NIW will produce a joint book on ecological interfaces and interactions for walking, compiling existing knowledge and state-of-the-art contributions developed within and outside the project.
Task 7.5: **Contribution to the FET-Open concertation activities.** NIW will promote cross-activities especially at the FET-Open level. At least one joint workshop and related press release will be organized together with one or more FET-Open projects (STREP or Coordination action).

Deliverables
D7.1 Project web site.
D7.2 Panel on foot-based interfaces and interactions.
D7.3 Book on ecological foot based interfaces and interactions.

Expected results [contributing to Milestones]
R7.1 [M3] Contribution to FET-Open portfolio and concertation activities.

B.1.3.6 Efforts for the full duration of the project

No.	**Beneficiary**	**WP1**	**WP2**	**WP3**	**WP4**	**WP5**	**WP6**	**WP7**	**Total person months**
1	UNIVR	**10**	2	12	**21**	4	4	2	55
2	McGill University	1	9	**27**	6	2	7	2	54
3	AAU	1	2	10	12	13	**14**	**2**	54
4	INRIA	1	2	4	4	**29**	12	2	54
5	UPMC	1	**36**	0	9	4	2	2	54
Total		14	51	53	52	52	39	10	**271**

Activity Type	UNIVR	McGill University	AAU	INRIA	UPMC	TOTAL ACTIVITIES
RTD/Innovation activities						
WP1	0	0	0	0	0	0
WP2	2	9	2	2	**36**	51
WP3	12	**27**	10	4	0	53
WP4	**21**	6	12	4	9	52
WP5	4	2	13	**29**	4	52
WP6	4	7	**14**	12	2	39
WP7	2	2	**2**	2	2	10
Total 'research'	45	53	53	53	53	257
Demonstration activities						
WP1	0	0	0	0	0	0
WP2	0	0	0	0	0	0
WP3	0	0	0	0	0	0
WP4	0	0	0	0	0	0
WP5	0	0	0	0	0	0
WP6	0	0	0	0	0	0
WP7	0	0	0	0	0	0
Total 'demonstration'	0	0	0	0	0	0
Consortium management activities						
WP1	10	1	1	1	1	14
WP2	0	0	0	0	0	0
WP3	0	0	0	0	0	0
WP4	0	0	0	0	0	0
WP5	0	0	0	0	0	0
WP6	0	0	0	0	0	0
WP7	0	0	0	0	0	0
Total 'management'	10	1	1	1	1	14
Other activities						
WP1	0	0	0	0	0	0
WP2	0	0	0	0	0	0
WP3	0	0	0	0	0	0
WP4	0	0	0	0	0	0
WP5	0	0	0	0	0	0
WP6	0	0	0	0	0	0
WP7	0	0	0	0	0	0
Total 'other'	0	0	0	0	0	0
TOTAL BENEFICIARIES	55	54	54	54	54	271

B.1.3.7 List of milestones and planning of reviews

M1 - Design, engineering, and prototyping of floor interaction technologies (month 12)

The first project milestone will be centred on the generation of new technologies and methods for foot-floor interaction, based upon uni-, cross- and multi-modal augmentations of ground surfaces and events. The milestone will mark the creation of new haptic interactive devices, sensing and analysis methods, and auditory and haptic synthesis models. Prototypes turning out from the overall design activity implied by this milestone will be made available.

Haptic interaction will be based on devices designed to provide the impression of interactions with everyday materials to the walker, by means of integrated sensing, actuation, and control hardware and algorithms. Low-cost techniques including vibrotactile actuation of shoe and floor tile devices will be pursued. Similar techniques have been exploited in prior research of project personnel [Yao and Hayward, 2006; Visell et al., 2007; Visell et al., 2008].

Sensing methods will be drawn from both standard force and position sensors that may be integrated within haptic devices, and from unconventional techniques, including the use of inexpensive contact microphone arrays for in-solid source localization for foot-based interaction with surfaces, as in prior research by project personnel [Crevoisier and Polotti, 2005]. Sensors will provide complementary sources of information accounting for the loci of interaction over time, as well as expressive information such as foot posture and gesture. These multimodal information sources will be fused and mined using machine learning methods (especially Bayesian models) that will be used to perform higher-level inferences and mappings.

Auditory and haptic stimuli will be generated by physically-based interactive synthesis models. These will simulate and modify the auditory and haptic appearance arising in physical interaction between physical objects (in the present setting, chiefly foot and floor), including friction and contact events, for display by means of the interactive devices noted above [Hayward and Armstrong, 2000; Avanzini et al., 2002; Avanzini et al., 2005; Yao and Hayward, 2006].

M2 - Validated set of ecological foot-based interaction methods, paradigms and prototypes, and designs for interactive scenarios using these paradigms (month 24)

The relevant technologies forming the core of Milestone M1 will be logically organized in relation to each other. The interaction methods enabled by these technologies will be evaluated, to uncover basic illusory effects of ground material and other perceived floor characteristics facilitating the simulation of ecological interactions relying on the devices under study.

Individual display modalities will be characterized according to their ability to present ecological properties – for example, the range of hardnesses that may be conveyed by a haptic device, or the ability of an auditory display to communicate a certain level of friction. Psychophysical and psychological experiments will be conducted based on non-navigation perceptual tasks, so that basic performances will be assessed in walkers. The evaluation of individual display modalities will be followed by experiments aimed at measuring cross-modal and pseudo-haptic effects involving the use of two modalities, eventually including the visual one. The multi-sensory rendering of ground properties will be assessed, furthermore compared with results obtained in the uni-modal experiments. Psychophysical protocols that enable to characterize and quantify the perception of physical properties, such as differential and absolute perception thresholds, will be employed in the experiments.

Together, such tasks will articulate an experimental campaign comprising the first level of systematic evaluation of the technology. This evaluation will be exploited to optimize the efficiency of the auditory and haptic devices, mainly via iterated refinement of the parameter maps driving their action, and possibly through further improvement of their physical engineering.

The measure of success of milestone M2 will be proportional to the assessed validity of the interactions enabled by the devices under study. Due to the tight mutual dependency of the two first project milestones, it is expected that M2 will be successful if and only if the success of M1 is achieved as well. In the end, a validated toolkit of interaction methods and devices is expected to mark the success of the milestone to an extent that will depend on the level of versatility of the same toolkit and the quality of the proposed prototypes.

In parallel to this achievement, M2 will also expose the first year of activity aimed at integrating the toolkit into a multimodal scenario. Hence the milestone will allow to check the state of advancement and quality of this scenario, as well as to optimize its design toward a correct implementation of milestone M3.

M3 - Integration and usability testing of floor interaction technologies in immersive scenarios (month 36)

In milestone three, the proposed scenarios made using the most promising interaction methods will be evaluated within an integrated immersive multi-modal virtual environment (VE), also capable of engaging users in simple navigation tasks. While the first milestone focuses on auditory and haptic feedback channels, the third will construct a setting in which visual display paradigms as those tested during M2 are provided, and play an integrative role aiding in the fusion of the other two modalities. The purpose of this embedding is twofold: First, it intends to test the usability of the methods from M1 in an enriched and ecologically valid, but controlled, setting; Second, it will demonstrate the utility of these methods for conventional immersive VE applications.

A floor area of sufficient size, that has been constructed using techniques created in M1 and validated by M2, will become object of user experiences and presence studies. Where interactive footwear is involved, shoes or other worn components will be integrated within the informational network intrinsic to the VE facility. These haptic and acoustic sensing and actuation devices will be used afford the experience of walking over grounds of different nature, and possessing different static or dynamic features (e.g. streams, rocks or branches), depending on the nature of the VE task that is to be negotiated with the users. Assessment will constitute a series of such environments, posing perceptual and control tasks such as material identification, navigation/path following, targeting or acquisition of static features and dynamic objects.

Higher-level cross-modal effects based on the combination of display methods from M1, whose psychophysical validity has been recognized, will be investigated. Greatest attention will be devoted to pseudo-haptic effects relying on vision and audition. User studies will be conducted to determine the extent to which combinations of different cues enhance perception, task completion, and the sense of presence in a virtual environment [Lombard, 1997; Slater et al., 1994; Schubert et al., 2001; Witmer and Singer, 1998].

Finally, M3 will result in a reference implementation intended to endure in form and influence beyond the end of the project. By providing a reliable and reproducible experience that may be exported to other investigations, particularly concerning rehabilitation and entertainment. Besides these investigations, the consortium has a strong interest in eventual follow up studies on the usability of such cues for tasks such as navigation, landmarking, and guidance to locations of interest by normally-able and impaired subjects. Moreover, it is intended that the reference platform may be adopted by architectural and design firms to aid in the interactive design of flooring components and/or intelligent footwear for everyday spaces.

The success of this milestone may be proportional to the levels of realism and engagement provided by the VE. Methods to assess these levels are based on presence measures, as detailed in the experimental campaign.

The milestone list is provided below, along with scheduling.

List and schedule of milestones

Milestone no.	Milestone name	WPs no's.	Lead beneficiary	Delivery date from Annex I	Comments
1	Design, engineering, and prototyping of floor interaction technologies	WP2, WP3, WP4	UPMC	12	Design of sensing and interaction methods: device designs, techniques, and initial haptic prototypes
2	Validated set of ecological foot-based interaction methods, paradigms and prototypes, and designs for interactive scenarios using these paradigms	WP3, WP4, WP5, WP6	INRIA	24	Validated multimodal (including visual) floor feedback and sensing: devices, techniques, and prototypes. Design and early prototype of immersive scenario or scenarios
3	Integration and usability testing of floor interaction technologies in immersive scenarios	WP2, WP3, WP4, WP5, WP6, WP7	AAU	36	Immersive multimodal floor interaction comprising ground properties and floor events, validated through presence studies

Each project review is linked to a respective milestone, in both logical and temporal terms. Hence, it is expected that:

1. after project month 12, the acoustic and haptic prototypes and methods developed by that date for both feedback and sensing will be physically accessible at the laboratory level, as well as sent to review in the form of a report;
2. after project month 24, a validated toolkit of interaction methods and devices will be demonstrated, also in the form of a preliminary immersive scenario. The results and prototypes coming out with the second milestone will be reported for review;
3. after project month 36, a scenario instantiated using the aforementioned toolkit will have been studied in sufficient detail, and its level of presence assessed quantitatively. The quality of this scenario will be object of review, through reported user experiences and by direct experience of a virtual reality installation.

The expected review plan is listed below.

Tentative schedule of project reviews

Review no.	Tentative timing, i.e. after month X = end of a reporting period	planned venue of review	Comments , if any
1	After project month: 12	Laboratory (Paris)	Check point on acoustic and haptic floor feedback and sensing devices, techniques, and prototypes
2	After project month: 24	Laboratory (Rennes)	Validated toolkit of devices, techniques, and prototypes for foot-floor interaction. Early prototype of the immersive scenario
3	After project month: 36	Laboratory (Copenhagen)	Immersive virtual environment in action

B2. Implementation

B.2.1 Management structure and procedures

UNIVR has considerable experience in the management of European projects. Despite its relatively small dimensions, to date it participates in five EU projects while coordinating two of them. Administrative, financial and scientific components will be implemented through appropriate, clear, consistent and efficient management of internal affairs as well as with transparent relationships with the European Commission and third parties. The following procedures will be implemented.
Administrative coordination — Periodic reporting to the EC is planned as follows: three reporting periods: months 1-12, 13-24, and 25-36. Final report.
Financial co-ordination — The distribution of funds will be managed by the European partners and the Canadian partner independently. An accounting will be maintained and left open for inspection. Periodic financial reports will be submitted to the Commission.
Scientific co-ordination — Meetings will be organized every four months, to keep the scientific project development on schedule.
Organization and Conflict Resolution — The management structure is headed by the Coordinator, who is ultimately responsible for the management of the whole project. The Coordinator will interact with the Workpackage Leaders, who are responsible for the coordination of each workpackage, and with the Local Coordinators, who are responsible for the work made by each beneficiary. The decision-making body of the Consortium is the General Assembly, whose authority to make decisions and resolve conflicts is established in the Consortium Agreement that will entry into force before the beginning of the project.

B.2.2 Beneficiaries

UNIVR - Dipartimento di Informatica of the Università di Verona - Vision, Image Processing, and Sound laboratory

The University of Verona is one of the largest universities in the North-East of Italy. The Department of Computer Science started in 2000 as a spin-off of a science and technology department, and has been ranked for three consecutive years as the best computer science department of Italy by an official analysis of CENSIS (the national centre for statistical analysis of the society). The department has more than 40 faculty members covering the principal subjects of computer science. The UNIVR group will benefit of the administrative support from the department, which has a strong record of participation in national and international projects. It will mainly involved in the design and realization of the technologies for auditory sensing and feedback.
Federico Fontana (Coordinator) is Assistant Professor in the Department of Computer Science, where he teaches sound processing and object-oriented programming. In 2001 he was visiting scholar at the Laboratory of Acoustics and Audio Signal Processing, Helsinki University of Technology (Espoo, Finland). In 2003 he received the PhD in computer science from the University of Verona. He was team member in the EU Project IST 2000-25287 *SOb*, and consulted for the EU Projects IST 2001-37117 *RACINE-S* and IST-2-511316-IP *RACINE-IP*. He has responsibility of a research group now counting 5 PhD students, 2 senior researchers, and 4 consulting researchers specialized in sound synthesis by physical modelling, auditory display, acoustic spatialization and reverberation, and sound design. He coordinates the project “Sound synthesis by physical models of the piano”, involving the

University of Verona and Viscount SpA. He is team member and local administrator of the EU Project FP6-NEST-29085 *CLOSED*, and of a EFSD-Novartis projects funded as part of the European Program for Clinical Research in Diabetes. His current interests are in sound synthesis and computational modelling of acoustic resonators and nonlinear systems.

Davide Rocchesso is with the Department of Art and Industrial Design of the IUAV University of Venice, as Associate Professor. He has been teaching several classes in the areas of sound processing, operating systems, computer graphics, interaction design, and programming. In 1994 and 1995 he was visiting scholar at the Center for Computer Research in Music and Acoustics (CCRMA) at Stanford University. Since 2006 he has been President of the AIMI (the Italian computer music association). He has been the coordinator of project IST 2000-25287 *SOb* and local coordinator of the project NEST 29085 *CLOSED* and of the Coordination Action IST-FET 2004-03773 *S2S²* "Sound-to-Sense; Sense-to-Sound". He is currently chairing the COST Action IC-0601 *SID* "Sonic Interaction Design". His main research interests are sound modelling for interaction design, sound synthesis by physical modelling, and design and evaluation of interactions.

Pietro Polotti is presently with UNIVR and with the Interaction Design group of the University IUAV of Venice, Italy. He is also associate professor of Electronic Music at the Academy "Giuseppe Tartini" of Trieste, Italy. From 1998 to 2002, he worked at the Ecole Polytechnique Fédérale de Lausanne (EPFL) in Switzerland. During that period, his research activity was mainly focused on sound synthesis and processing. From the EPFL, he obtained a Ph.D. in Communication Systems with a thesis on audio coding based on the wavelet transforms. From 2003 to 2004 he was with the Politecnico di Milano where, during 2004, he was the principal investigator for the EU FP6-IST project *TAI-CHI*. Recently, his research interests moved towards auditory display and sonic interaction design. With UNIVR, he has collaborated in the Coordination Action *S2S²* and collaborates in the *CLOSED* project.

Delphine Devallez is a PhD student at UNIVR. Her research work deals with auditory distance perception and rendering of auditory perspective effects. In 2002 she obtained a Diploma of Engineering from ENSIETA, a French Engineering School, and a Master of Science in Acoustics from Aalborg University, Denmark. From 2003 to 2005, she worked at Philips Research in Eindhoven, as a research scientist. In addition to auralization, her research interests include auditory human perception, auditory displays and multimodal interactions.

McGill University, Centre for Intelligent Machines – Shared Reality and Intelligent Environments Lab

McGill is the top research university in Canada (Macleans's 2005 and 2006 rankings) and is the only Canadian university to be ranked among the top 12 in the world (Times 2007 rankings). The Centre for Intelligent Machines (CIM) is an inter-departmental inter-faculty research group at McGill, formed to facilitate and promote research on intelligent systems. The members of CIM seek to advance the state of knowledge in such domains as robotics, design, artificial intelligence, computer vision, medical imaging, haptics, systems and control and ultra-videoconferencing. CIM faculty and students come from the Departments of Computer Science, Electrical and Computer Engineering, and Mechanical Engineering. Many of CIM's researchers are members of REPARTI, the Regroupement stratégique pour l'étude des Environnements PARTagés Intelligents répartis, which studies distributed intelligent shared environments.

CIRMMT is The Centre for Interdisciplinary Research in Music Media and Technology, a multi-disciplinary research group centred at McGill University. CIRMMT seeks to develop innovative approaches to the scientific study of music media and technology, to promote the application of newer technologies in science and the creative arts, and to provide an advanced

research training environment. Its researchers are active on the national and international stage and are implicated in six European networks (*S2S²*, Enactive Interfaces, Integra, Brain Tuning, COST *ConGAS*, COST *SID*), and one French network (*Consonnes*).
The Shared Reality Lab conducts research in Intelligent Environments and the communication of high-fidelity data between distributed users in such environments. The goal of Shared Reality is to achieve high-fidelity distributed interaction, with both real and virtual data, at levels of presence that support the most demanding applications, and to do so in spite of sensor and bandwidth limitations. The lab's research is currently supported primarily by grants and contracts from NSERC, FQRNT, and Canarie Inc. The involvement in NIW will deal with the computational understanding and haptic synthesis of multimodal information.
Jeremy Cooperstock (Ph.D., University of Toronto, 1996) is an associate professor in the department of Electrical and Computer Engineering, a member of the Centre for Intelligent Machines, and a founding member of the Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT) at McGill. He directs the Shared Reality Lab and leads technical development of the Ultra-Videoconferencing system, for which he was recognized by an award for Most Innovative Use of New Technology from ACM/IEEE Supercomputing and a Distinction Award from the Audio Engineering Society. His research interests focus on computer mediation to facilitate high-fidelity human communication. Cooperstock has worked with IBM at the Haifa Research Center, Israel, and the T.J. Watson Research Center in Yorktown Heights, NY. He was visiting researcher at the Sony Computer Science Laboratory in Tokyo, Japan. He chairs the Audio Engineering Society (AES) Technical Committee on Network Audio Systems and is an associate editor of the Journal of the AES.
Yon Visell is a PhD candidate in Electrical and Computer Engineering at McGill, affiliated with the Centre for Intelligent Machines and CIRMMT. His research concerns the design of new interactive systems that make use of bodily movement for interaction, through machine learning algorithms for movement, and new input devices. He serves as a key research staff member for the EU IST-FET research project *CLOSED*, and is national coordinator for Canada to the COST Action IC-0601 *SID* “Sonic Interaction Design”. He received the Master’s degree in Physics from the University of Texas. He has worked as a research scientist at Applied Research Labs in Austin and at Loquendo in San Francisco, on fundamental speech and acoustic recognition and signal processing research, funded under the aegis of DARPA. In Berlin, he led DSP development for the computer music platform Ableton Live, and in 2005 co-founded the art and technology research organization Zero-Th in Croatia.

AAU - Institute of Media technology and Engineering Studies (IMI) at Aalborg University

The IMI was inaugurated on September 1st, 2005. IMI is composed of several research groups that have been active in research for several decades. The head of the institute is Erik Granum. The Institute's laboratory which will take part to the NIW project is Medialogy. Medialogy, founded in September 2004, is active in research on sound synthesis for interactive media and VR, photo-realistic image based rendering, computer vision, human perception and evaluation techniques for interactive media. The group has 10 faculty members, 7 PhD students, and support from technical and administrative staff. Currently Medialogy is involved in the following EU projects: *Paco-Plus* (IST-FP6-IP-027657), Sound forum Oresund (Interreg III) and the COST Action IC-0601 *SID* “Sonic Interaction Design”. Previously it was involved in *BENOGO* (Being There Without Going), EU IST FET *PRESENCE* (2002-2005). IMI includes the VR Media Lab, the advanced virtual reality visualization center of the university, which has three different display arenas: 3D-auditorium

(8m wide screen, 80 seats), a Panorama (7.1 m diameter, 160 deg, 28 seats), and a 6-sided CAVE.
IMI will contribute to NIW by bringing technical skills in sound synthesis by physical models and sensors technology, and will provide expertise in designing, implementing and testing multimodal immersive systems. The VR facilities of IMI (CAVE, Panorama, 3D auditorium) will be extensively used during testing.
Erik Granum is a full professor of information systems (BScEE 1967, MSc 1973, PhD 1981). He has worked in industry, and done research on automated chromosome analysis and cytogenetics with Rigshospitalet, Copenhagen, and for the Medical Research Council in Edinburgh. Since 1983 he has been with Aalborg Universitet, where he founded a laboratory for research in image analysis, pattern recognition and computer vision. He has had and has numerous national and international grants for research in computer vision and AR/VR, and has been and is partner or coordinator of several EU projects and networks under ESPRIT and HCM/TMR (active vision, robotics, multimedia, and virtual reality). He is also the coordinator of *BENOGO*, an EU IST FET *PRESENCE I* project. He was one of the main actors in the establishment of a multimedia center and a large virtual reality center (1999) at Aalborg University, and he has taken much interest in interdisciplinary research, which characterizes many of his current projects. He is a frequent reviewer for national and international bodies, journals and conferences, and he has given or coauthored more than sixty scientific contributions.
Stefania Serafin is associate professor in Medialogy at Aalborg University in Copenhagen. She has been within Medialogy from 2003, and she was among the founders of the department in Copenhagen. She received a PhD in Computer Based Music Theory and Acoustics from Stanford University (2004) and a Master in Acoustics, Signal Processing and Computer Science applied to Music from IRCAM, Centre Pompidou in Paris (1999). She has been visiting researcher at Cambridge University (2002) and KTH in Stockholm (Summer 2003), and visiting professor at the University of Virginia (Spring 2003). She has published several papers on the field of sound synthesis by physical models and design of novel interfaces. She is currently Danish delegate for the COST Action IC-0601 *SID* “Sonic Interaction Design” and Medialogy representative of the Sound forum Oresund project (Interreg III). She is frequently reviewer for international journals and conferences, and she was paper chair of ICMC 2007 as well as appointed publication chair at NIME 2008.
Rolf Nordahl is a Ph.D. student in Medialogy at Aalborg University Copenhagen. He is Campus Coordinator of Basic Studies in Engineering, Science and Medicine at Aalborg University Copenhagen as well as Medialogy representative in the Danish National Academy of Digital Interactive Entertainment (Dadiu).

INRIA - French National Institute for Research in Computer Science and Control

INRIA operates under the dual authority of the French Ministry of Research and the Ministry of Industry, and is dedicated to fundamental and applied research in information and communication science and technology (ICST). Throughout its nine research units, INRIA has a workforce of 3,500 - 2,700 of whom are scientists from INRIA’s partner organizations such as CNRS (the French National Centre for Scientific Research) or universities and leading engineering schools.
BUNRAKU is the INRIA team involved more specifically in NIW. It involves more than 40 researchers and engineers, devoted to research and development in Virtual Reality, Multimodal Interaction, Behavioural Animation, and Computer Graphics. BUNRAKU is or was involved in numerous European or National projects. As an example, BUNRAKU was the co-leader of *PERF-RV*, the first French Platform on Virtual Reality, which federated more

than 15 industrial and academic partners interested by the field of Virtual Reality. BUNRAKU is the current scientific coordinator of *PERF-RV2*, the follow-up of *PERF-RV*, which gathers today more than 20 French partners. Furthermore, BUNRAKU (and INRIA) is currently in the core group of the European Network of Excellence on Virtual Reality *INTUITION* (IST-NMP-1-507248-2). Inside *INTUITION*, BUNRAKU is the leader of the working group on "Haptic Interaction", with more than 20 partners, in charge of promoting and developing the haptic activities of the network.

In the frame of NIW, INRIA is the leader of WP5, "Pseudo-Haptics and perceptual evaluations". INRIA is the co-inventor of the concept of "pseudo-haptic feedback" with a first publication at IEEE VR in 2000 [Lécuyer et al., 2000]. Since 2000, INRIA validated this concept through numerous experimental and perceptual studies. INRIA also promoted and developed applications of pseudo-haptics in various fields, such as for medical simulation, vocational training, or graphical user interfaces, etc. All these results were systematically published in numerous papers in reference conferences and journals (IEEE VR, ACM CHI, Presence, ACM TAP, Haptics symposium, Eurohaptics, etc). With this background in pseudo-haptics but also haptics and perceptual evaluations, INRIA will naturally be in charge of the development of novel pseudo-haptic techniques of the project as well as of the supervision of perceptual evaluations of other basic technologies.

Anatole Lécuyer is responsible for INRIA activities inside the NIW project. Anatole Lécuyer received his Ph.D. in Computer Science in 2001 from University of Paris XI, France, and since 2002 he is a senior researcher at INRIA in the BUNRAKU research team. He is currently the coordinator of the Open-ViBE National project on Brain-Computer Interfaces, and the leader of the Working Group on Haptic Interaction of *INTUITION* European Network of Excellence. He is or was an expert in Virtual Reality and haptics for national public bodies and a member of International Program Committees (World Haptics, Eurohaptics, etc). He is or was the organizer of tutorials on haptics (IEEE VR, Eurohaptics, etc) and is currently an associate editor of the ACM Transactions on Applied Perception. His main research interests include: virtual reality, 3D interaction, haptic feedback, pseudo-haptic feedback and brain-computer interfaces.

Role of INRIA in the consortium

As said in the section on Progress beyond the state-of-the-art, INRIA is the clear leader within this consortium of documented expertise on pseudo-haptic effects and cross-modal illusions. Furthermore, in the same section it has been said that this beneficiary has matured a significant know-how in the visual and haptic display of basic events through which we interact with our everyday environments: contact, friction, detachment. Specifically, in this project INRIA will lead as well as coordinate all the experimental campaign across its different stages:

i) by suggesting, to all beneficiaries involved in this campaign, subjective tasks having the best potential to uncover the existence of cross-modal and pseudo-haptic effects
ii) by distributing to the consortium quantitative methodologies for performing both psychophysical experiments and, later, presence studies
iii) by maintaining a critical point of view on the overall quality of the experiments generated across the project
iv) by steering the experimental roadmap in due course if necessary
v) by finally collecting into Deliverable 5.1 the experimental results coming out from the experiments
vi) by contributing to the multimodal experiments with visuo-haptic display methods.

UPMC - *Université Pierre et Marie Curie* - *Paris 6 – Institut des Systèmes Intelligents et de Robotique (ISIR)*

ISIR is a research lab of the UPMC, associated to the Centre National de la Recherche Scientifique (CNRS). It was created on the first of January, 2007 through the grouping of three teams at the UPMC: The Laboratoire de Robotique de Paris; the group Perception et Réseaux Connexionnistes (PRC) du Laboratoire des Instruments et Systèmes d'Ile de France (LISIF); and the AnimatLab team from the Laboratoire d'Informatique de Paris 6 (LIP6).
ISIR is a pluridisciplinary research laboratory, which gathers disciplines of Engineering and Computer Science including mechanics, automation, signal processing, and computer science. Research in the laboratory covers more specifically: Modeling and simulation of robotic systems and complex interactions; Robust control for systems, teleoperation and identification; Perceptual systems (vision, touch, speech) and signal processing; Techniques of artificial intelligence for the design of behaviors and their adaptation. Projects at the ISIR are organized around the activities of three teams of 20 to 30 personnel each: The team on Interactive Systems; The team on Human Perception and Movement; And the team on Integrated Mobile and Autonomous Systems.
Areas of participation of the ISIR in robotics at the international and national level include: The EU Network of Excellence on Robotics (*EURON*); The EU Platform for robotic industry (*EUROP*); The International advanced robotics program (IARP); The research group on robotics (GDR) at the CNRS (GDR-ROB). Concerning NIW, ISIR will chiefly take responsibility of the engineering of haptic devices for floor feedback.
Vincent Hayward will join the Institute des Systèmes Intelligents et de Robotique at UPMC as a professor beginning September 2008. He is responsible for UMPC activities within NIW. He received the Ing. Ecole Centrale de Nantes 1978, and the Ph.D. in Computer Science in 1981 from the University of Paris. He has been Professor of Electrical and Computer Engineering at McGill University, Visiting Assistant Professor, Purdue University (1982); Chargé de recherches at CNRS, France (1983-86), and Professeur invité, Université Pierre et Marie Curie (2006).
Hayward is interested in haptic device design and applications, perception, and robotics. He has led the Haptics Laboratory at McGill University and was the Director of the McGill Center for Intelligent Machines (2001-2004). Hayward co-founded spin-off companies: Haptech (1996), now Immersion Canada Inc. (2000), and RealContact (2002). He is a co-Founder of the Experimental Robotics Symposia, Program Vice-Chair 1998 IEEE Conference on Robotics and Automation, Program Vice-Chair ISR2000, past Associate Editor IEEE Transactions on Robotics and Automation, Governing board Haptics-e, Editorial board of the ACM Transaction on Applied Perception. Keynote Speaker of the IFAC Symposium on Robot Control (Bologna, Italy) 2006; Eurohaptics (Munich, Germany) 2004; Workshop on Advances in Interactive Multimodal Telepresence Systems (Munich, Germany) 2001; IEEE ICMA (Osaka, Japan) 2001; Distinguished Lecturer Series, Department of Computing Science, University of Alberta (2000). Hayward received several awards including the NASA Space Act Tech Brief Award (1991) and the E. (Ben) & Mary Hochhausen Award for Research in Adaptive Technology For Blind and Visually Impaired Persons (2002). He is a Fellow of the IEEE (2008).
Philippe Bidaud is the director of the Institute des Systèmes Intelligents et de Robotique at UPMC. He received his PhD degree in Mechanical Eng./ Robotics from the University of Poitiers (France) in 1984 and the habilitation for directing research from the University Paris 6 in 1996 for his work on “Design and Control of Complex Robotics Systems”. For 15 years he was as a researcher in the section of Physical Sciences for Engineers at CNRS (Centre National de la Recherche Scientifique), France. He became Full Professor at the University of

Paris Pierre et Marie Curie (UPMC) in 1998. Since 1981, his research interests are the field of the design of complex robotics systems, articulated hands, locomotion systems, assembly systems, haptic devices from the view point of modeling and analysis of mechanical systems and of their associated control. He also works in complex interaction control and modeling, control of smart materials, micro-robotics systems, design and optimization of compliant structures, and high mobility systems. in 1997-98, Philippe Bidaud was a Visiting Professor at the Field and Space Laboratory of the Department of Mechanical Engineering at MIT. He has published more than 150 papers including contributions to books, journals, international conferences. He holds several patents and has been very active in technology transfer and valorisation through the Centre de Robotique Intégrée Ile de France.

B.2.3 Consortium as a whole

The consortium comprises five participants each having a knowledge-base, institutional assets, and in-house facilities to facilitate inter-institutional connections, while avoiding excessive overlap between the capabilities of each. UPMC has joined the consortium after key personnel formerly based at McGill University have moved to UPMC. This inclusion has further increased the research potential of the consortium, by adding know-how in fundamental disciplines such as rehabilitation robotics, automation, tele-operation, and system control for robotics, all research strengths at UPMC.

The individual fields of expertise include:
- UNIVR: Acoustic sensing, sound design, sound synthesis and auditory display, perceptual evaluation of acoustic cues;
- McGill University: Interaction in immersive environments; Movement and gesture-based interfaces; HCI;
- AAU: sound synthesis, multimodal integration, presence studies, interaction;
- INRIA: Haptic interfaces, pseudo-haptic feedback, multimodal perception, 3D interaction techniques;
- UPMC: Haptic device design and applications, haptic perception, rehabilitation engineering, locomotion, robotics, control.

NIW has appointed lead institutions for each work package such that the mix of expertise and resources are best matched to the objectives of each. All workpackages entail the tight integration of diverse activities such that the successful completion of the tasks is strongly dependent on the level of collaboration achieved among participants. Common scientific bases shared by all partners, which provide a basis for a satisfactory level of collaboration, lie with their documented skills in human-machine interaction design and in their basic experience in conducting human factors and psychological experiments.

In addition to these two common bases, connecting knowledge exists which will simplify the birth of necessary synergies during the work package tasks. Such connections can be illustrated with a self-explanatory figure, which describes the balanced complementary role as well as the feasibility in terms of shared knowledge of the participants in NIW.

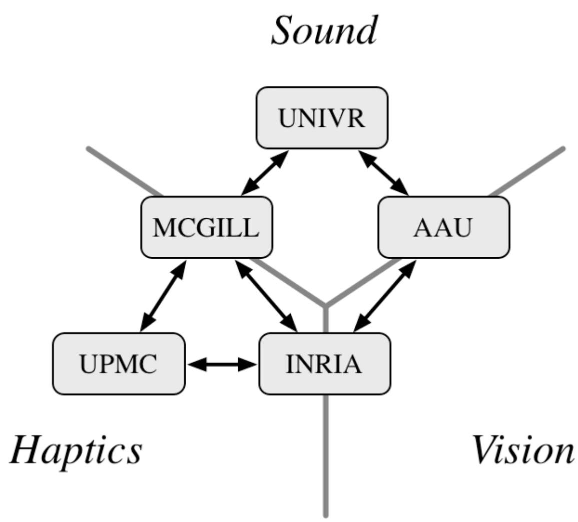


Figure 1: High-level map of areas of partner expertise with respect to the indicated modalities.

Such connections will translate in precise joint activities as foreseen by the project implementation. As a general rule, all beneficiaries will collaborate in the different stages of development, evaluation, and integration, and the intensity of the collaboration will increase as the project advances, until culminating in the shared design and making of a scenario in which to integrate the methods and technologies developed by the project. More in particular:

- UPMC and McGill University will collaborate on the design and implementation of the prototype haptic technologies; (Deliverables 2.1 and 2.2)
- McGill University, UNIVR, and AAU will collaborate on contact-based sensing methods; (Deliverable 3.1)
- McGill University and UNIVR will collaborate on the walking gesture analysis tools; (Deliverable 3.2)
- UNIVR, UPMC, McGill University, and AAU will collaborate on the design and implementation of the sound and haptic synthesis algorithms; (Deliverable 4.1)
- AAU, UNIVR, INRIA, and McGill University will collaborate on the multimodal display of virtual attributes and floor events; (Deliverable 4.2)
- INRIA will collaborate with AAU, UNIVR, UPMC, and McGill University on the assessment of multi-modal and pseudo-haptic ground cues; (Deliverable 5.1)
- AAU will collaborate with INRIA and McGill University to conducting presence studies in the multimodal augmented floor; (Deliverable 6.1).
- All beneficiaries will collaborate on the dissemination activities foreseen by WP7, particularly concerning the organization of a panel (Deliverable 7.2) and the production of a book (Deliverable 7.3).

Finally, all beneficiaries have experience in coordinating or participating in international projects. In particular, the Coordinator has currently local administrative responsibility and scientific co-responsibility of a European project, a joint industrial-academic project, and an international project funded by the European Foundation for the Study of Diabetes (EFSD) and Novartis.

B.2.3.1 Sub-contracting

The consortium will make use of the subcontracting tool for paying financial audits (costs ranging between 1500 and 3000 Euros per partner). UNIVR will outsource the design of the official NIW logo (estimated cost 250-500 Euros). The total cost of subcontracting is 8000 euros.

B.2.3.2 [Third parties]

No third parties will be involved in the project.

B.2.3.3 [Funding for beneficiaries from third countries]

Not planned.

B.2.3.4 [Additional beneficiaries / Competitive calls]

Not foreseen.

B.2.4 Resources to be committed

The descriptions in this proposal demonstrate a realistic assessment of the efforts necessary to effectively realise the project plans and an optimal distribution of the effort across the project partners. In particular, as summarised in the staff effort shown in Section 1.3.6, the project will require a total of 271 person months, distributed between the two principal kinds of activities as follows:
• RTD: 257 person months for research and innovation, and
• Management: 14 person months for project and consortium management.

Management

Resources for project management are adequate (5% of the total effort in PM). The project coordination and management will be carried out by the project coordinator with the help of the other members of the UNIVR research group and of the administrative infrastructure of UNIVR. The management costs have been kept to the minimum required for the smooth course of the project and the assessment of its scientific and administrative progress (via the required internal and external audits). The only subcontracting foreseen in the project is for auditing reasons, and thus very limited.

Personnel employed in research and technological development

As can be seen from form A3 of the proposal, the vast majority of the planned costs will cover personnel costs for RTD. The key staff listed in the individual participants descriptions in Section 2.2 will provide the backbone of the consortium, and we are planning to hire about ten new researchers at various levels ranging from Ph.D. students to senior researchers to support the development of the desired methodologies and technologies. The majority of the research and innovation (RTD) effort (95% of the total effort, i.e. all workpackages between WP2 and WP7) is focused on the development and experimental validation of the multimodal floor interface, and on the construction of a durable platform for the proof of concept and the subsequent dissemination and prospective industrial engineering. The effort allocated to these tasks is adequate for the achievement of the project goals because the NIW partners bring into the consortium documented expertise from previous research activity projects.

Ten person months (3,6% of the total effort) will be devoted to dissemination of the project results. Dissemination will take place through appropriate channels and in appropriate forums: in order to reach a wide academic audience, and also to tackle the industry, and ensure a take-up of the project results, all project partners will aim to publish project results in international journals, conferences, and symposia. In addition, activities oriented towards the general public are planned.

Travel

Travel will be fundamental not only for the dissemination of results but, most importantly, for ensuring the tight synergy between the consortium partners and the intense exchange and cross-fertilisation of ideas and results required by the project. Hence, all partners have requested substantial funding for travelling to external meetings (conferences, workshops, international fairs, etc.), where the project results will be presented, as well as to such project-internal technical meetings. Some of these meetings in particular will be devoted to perform joint working sessions, to which personnel belonging to more than one research group will participate.

Working sessions will be planned initially to assemble technologies independently developed by the partners, together into arrangements basically providing multimodal features. In the second part of the project, such sessions will be devoted to assist researchers making experiments combining multiple sensory stimulations (i.e., part 2 of the experimental campaign), as well as to work on the construction of the multimodal immersive environment. For this reason they will necessarily involve personnel from all the participants.

Equipment

Equipment plays a primary role in NIW. Novel hardware and software components will be acquired, which can be integrated to existing physical interfaces and computational infrastructures available to the partners. Major items of expense are listed in the following table:

UNIVR	Experimental workstation
	Lightweight computers and multimedia portable hardware
	Software licenses
	Acoustic sensing and reproduction equipment
McGill University	Prototyping workstation
	Device development equipment (including haptics and sensing)
	Software licenses
AAU	Personal computers
	Software licences
	Sensors and actuators
INRIA	Personal computers
	Experimental equipment (including haptic and sensing equipment)
UPMC	Device development equipment (including haptics and sensing)
	Prototyping and experimental workstation

	Software licenses

Budget allocation to the Coordinating institution

As it appears from the budget of the project, UNIVR employs a MGT-to-RTD person-month ratio that is notably higher compared to the other participants. This figure is not only consequence of the specific role UNIVR has in the project coordination, but also because the number of person-months UNIVR allocates to RTD activities is smaller (i.e., 85%) than those planned by the other participants. This proportionally minor effort is entirely motivated by the merit and type of the research UNIVR makes in the context of the project.

Addition of UPMC to the consortium

Since UPMC has drawn key personnel previously involved in McGill University, who are also leading experts in haptic engineering, its inclusion in the consortium has necessitated a reformulation of the budget of the project, with a corresponding increase in the EU funding request. In parallel, the increased overall expertise gained by the consortium thanks to the presence of UPMC has enabled the European partners to steer part of their research activity toward the new participant. In particular, UNIVR and AAU have been able to diminish their involvement in the project in terms of person-months. Hence, it has been possible to produce a planning effort aimed at minimizing the financial impact coming from the new participation. Overall, the requested funding to the EU has been increased from 979.628 to 1.174.382 Euros, i.e. by about 20%, due to a personnel involvement that now counts 11.5 person-months more than those accounted for in the short proposal.

Indirect costs

All beneficiaries rely on internal accounting systems which can explicitly quantify indirect costs.

INRIA determines real indirect costs, by isolating indirect from direct costs. At the beginning of every year, the indirect costs of the previous year are divided by the number of person/hours spent on research. Hence, the overhead of the costs per person/hour for the current year is calculated.

Other costs

All beneficiaries will collaborate in coordinating the management of the project concerning the local organization of management coordination meetings. Furthermore, the project includes dissemination activities that will be distributed across the consortium: in particular, all beneficiaries will present the project at international conferences.

In addition to the above shared coordination and dissemination work, UNIVR, AAU, and UPMC will employ part of their budget to cover costs for the following additional dissemination tasks:

- UNIVR: establishment of the website, publication of the book, payment of fees for publication in open-access journals, and management of the joint-event organization and concertation activities required by FET-Open
- AAU: organization of the conference panel

- UPMC: payment of fees for publication in open-access journals.

Resources complementary to EC contribution

In addition to the funding requested from the EC, all partners will bring their own resources to the project (for the budget complementary to the requested EC contribution) in the form of technical work to be provided by permanent scientific staff members and the administrative support from the local offices, as well as hardware and software necessary for the successful completion of the project, except for the equipment mentioned above.

Complementary resources for this work include the 2.5 cubic metre CAVE and the 71 metre cylindrical Panorama space, both at AAU; the Shared Reality immersive environment laboratory at McGill University; the six shared laboratories of McGill's Centre for Interdisciplinary Research in Music Media and Technologies (comprising a range of designed labs, including semi-anechoic, critical listening, immersive multimodal, and other facilities); and the constituent labs of the other project parners.

In addition to these resources, of particular interest to NIW is the complementary funding that is expected to be assigned to support participation by McGill University by the government granting agencies of Canada, should the project receive EU funding. Multiple sponsors, including the *Quebec Ministère de Développement Economique, Innovation et Exportation* (MDEIE) and the Canada *Natural Sciences Engineering Research Council* (NSERC), and the *Hexagram Institut de Recherche/Creation en Arts et Technologies Mediatiques* have expressed a strong interest in providing prompt support for Canadian participation in the project, if it goes forward. In the case of the MDEIE, support has been formally announced to the Commission through its *Programme de soutien à la recherche - Soutien à des initiatives internationales de recherche et d'innovation (PSR-SIIRI).* The latter has funded participation by Quebec institutions in 36 different European project, 12 of them in the ICT domain, including support for McGill University to participate in the current *ENACTIVE* NoE, the COST Action *ConGAS*, and a number of other projects. Coordination on these points is facilitated by McGill University's Office of International Research, which has extensive experience in cooperative research with Europe.

Canadian funding for the project would amount to 20.3% of the overall funding, or 25.4% of the grant request to the EU. Should unforeseen difficulties arise with regard to Canadian funding for McGill University's participation in the project, it is understood that the situation will be reported, and terms of the contract will be discussed and if necessary renegotiated with the EC, in accordance with the existing FP7 regulations governing changes to the consortium. Likewise, should McGill University be involved in any disputes with regard to research, IP, or similar issues, the relevant disputes will be handled through the mediation protocol to be specified in the Consortium Agreement, in accordance with FP7 rules.

B3. Potential impact

B.3.1 Strategic impact

Comparatively little is known about the relevance of multi-modal actuation in everyday foot-floor interactions, or about methods for generating cohesive and rich sensations of ground surfaces, materials and objects.

Despite this knowledge gap, there is an interdisciplinary set of recent and ongoing research programs on walking interfaces (notably within Europe) that have generated results that NIW may draw upon and complement. Among these, two current projects are especially relevant:
- *IMMERSENCE* aims at providing multimodal feedback to the users of new human-computer interfaces, through a program that has some affinities with that of NIW. The project is, however, focused upon manual manipulation of objects, with another component of its activity tied to computer-mediated interaction between people.
- The *HapticWalker* project [Schmidt et al., 2005] has innovated a locomotion interface that has been recognized for its applicability to application fields including clinical rehabilitation and task training, virtual reality and immersive games. Its features include the rendering of virtual ground shapes, like staircases and inclined planes, as well as ground conditions such as hard and soft surfaces. As with other robotic, force-reflecting foot interfaces, it constrains the user to move within a machine that integrates well with immersive visual VEs (with the caveats noted in section 2.2 above), but which cannot be readily exported to other walking settings.

NIW will aim to build on results from other current areas of research in interaction and interface design, as organized in research networks such as the *ENACTIVE* or the *INTUITION* NoEs. Recent results on self-motion simulation and spatial self-orientation will be adopted, where appropriate, from the body of documentation released by past IST projects such as FET *POEMS* and *WAYFINDING*.

As discussed in Section 1, much of the current research on interactive walking relies on the use of treadmills complemented by head mounted displays, to create accurate immersive visual environments where locomotion is enabled [Pelah and Koenderink, 2007]. One project that leads this way is *Cyberwalk*, which promotes the simulation of large-scale walking scenarios through an omni-directional treadmill, called *CyberCarpet*. As discussed in section 2, we regard NIW as research that is substantially complementary to projects like *Cyberwalk*. The successful creation of new ecological interaction methods, as explored in NIW, may result in the possibility for synergistic exchanges of technology with advanced locomotion platforms such as *CyberCarpet*, through new multimodal haptic, auditory, and visual ground properties, or to new methods of interaction with the modalities they already employ, leading to advancements in the state-of-the-art of walking interfaces.

By promoting novel uses of cross-modality and illusions as means to achieve realism in multimodal displays, NIW proposes new directions for the improvement of haptic floor technologies. The discovery of such effects in walking is likely to make affordable a wider range of applications, just as they have enabled the development of applications ranging from robotic surgery to mobile telephony [Hayward and MacLean, 2007]. The discovery of practical interaction techniques for walking may enable developments in smart tiles, mats, or other flooring components. By bringing psychophysics together with interaction design and technology, in the short term NIW will impact the way multimodal floor interfaces are designed, and will provide guidelines for their basic engineering.

The design of passive haptic characteristics of the ground for aesthetic or functional purposes (for example, as navigational aids for blind people) has been a staple of architectural design of urban space for some time. The synthesis of active haptic cues targeting the feet has largely been a niche research field, with the main application area being rehabilitation. Other industries, including the sports (eg. Nike+ system), entertainment (eg Nintendo Wii fit controller), automotive, and simulation industries have nonetheless taken notice of new opportunities for haptic interaction with the feet. Companies including Sarcos, Virtual Space Devices, Cybernet Systems, Reha-Stim, Afferent, and VR-Systems have begun to take notice of the possibilities as well. Taken as a whole, these developments testify to the large-scale financial impact that new technologies for interaction via floors and shoes may effect, provided these technologies can establish their economic viability.

The NIW consortium is not aware of competing interaction paradigms to those we propose to research, combining both the sensing of footsteps and multimodal actuation of responses to them in ways that can be readily exported to existing environments, without tethering their users to complex robotic structures. A project devoted to bridging this gap will necessarily require a strongly multidisciplinary approach, which cannot be easily achieved within the limits of the proposers' countries. Furthermore, the consortium is not aware of national funding schemes sponsoring pioneering research roadmaps such as that promoted by FET-Open.

If funded, NIW will maintain contact with a number of national and international research activities running in parallel with the project:

- The EU FP6 Network of Excellence on Enactive Interfaces, in which McGill CIRMMT is a partner (led by local PI Marcelo Wanderley). The Network is focused on the creation of a multidisciplinary research community with the aim of structuring the research on a new generation of human-computer interfaces called Enactive Interfaces. Enactive Interfaces are those devices that can use multisensory knowledge stored in the form of motor responses and acquired by the act of "doing". Those input devices to be researched in NIW fall strongly in this category, due to a basic emphasis on the use of existing sensory-motor capabilities. Moreover, NIW shares significant affinities with other interaction paradigms studied within the *ENACTIVE* NoE, As a result, significant synergies are expected to result.
- The EU Project FP6-NEST-29085 *CLOSED* Closing the Loop Of Sound Evaluation and Design under the initiative "Measuring the Impossible" (2006 to 2009), in which UNIVR is a partner, and in which two members of the research staff at McGill University participate, through an external affiliation with the University of the Arts in Zurich, Switzerland. The *CLOSED* project aims at providing new, perceptually-based design, analysis, and synthesis tools and technologies for interactive sound embedded in everyday objects. These tools include software measures that furnish easy-to-interpret indicators allowing for the improvement of everyday sounds aimed at existing contexts. NIW will make use of these tools, and contribute to their further development, as part of its effort to shape the quality of sonic interactions in walking.
- The COST Action IC-0601 *SID* "Sonic Interaction Design" (2007 to 2011), from which NIW welcomes the national coordinators of Denmark, Canada, and Croatia as key research personnel working at AAU and McGill University. The interaction with *SID* will constantly keep NIW synchronized with the most recent trends, results, as

well as organizations of international meetings in interactive sound synthesis and product sound design.

- The national industrial project *Sound synthesis by physical models of the piano*, a "Joint Project" between Viscount SpA and UNIVR (2007 to 2008) which is led by the NIW coordinator. This projects deals with the design, prototyping and preliminary engineering of a piano model simulating the behaviour of a real piano instrument. It makes use of sound synthesis models that are directly derived from those available from the SDT library maintained by UNIVR. This project provides state-of-the-art real time realizations of such models, that can be imported in NIW as initial, but already accurate, reliable and efficient real time sound synthesis software architectures written in C++.
- The NSERC/Canada Council for the Arts New Media Initiative *Mobile Soundscapes* project at McGill University SRE lab, which seeks to provide a compelling experience of immersive 3D audio for each individual in a group of users, located in a common physical space of arbitrary scale. Unlike other projects involving 3D audio space, our work is unique in supporting navigation within a continuous, modeled audio environment through the real world motion of users. Results on the mobile display of spatialized audio sources and augmented environment content are highly salient to NIW.
- The IST-FP6-IP-027657 Perception, Action and Cognition through learning of Object-Action Complexes (*Paco-Plus*) project, coordinated by Aalborg University, whose goal is to design cognitive systems which can perceive and interact with the environment. NIW and *Paco-Plus* will exchange ideas and results on sensors technology and multimodal interaction.
- The FP-2004-IST-4-27571 *IPCity* project, in which Aalborg University is a partner, which investigates analytical and theoretical approaches to presence in everyday settings. NIW will discuss with the members of *IPcity* novel evaluation techniques for measuring presence in virtual environments.
- The national French project *PERF-RV2* "Virtual Humans in the Numerical Factory of the Future" (2005-2009) is a 20-partner project led by CEA and focused on the use and development of interactive virtual humans in the digital factory for future industry. In this project, research actions are undertaken to study and model the walking of virtual humans. INRIA is a major actor of *PERF-RV2*, in charge with other partners of developing scale1 haptic feedback for operating manipulation, and studying navigation strategy and mental representations of virtual humans when walking in the factory. Natural interactions are thus expected with NIW through INRIA that could lead to the deployment of NIW outcomes in industrial applications and industrial partners envisioned by PERF-RV2.
- The European Network of Excellence IST-NMP-1-507248-2 *INTUITION* is led by ICCS-NTUA (2004-2008). It encloses more than 60 European laboratories and is devoted to the federation and development of the European VR community. In *INTUITION* INRIA leads one (out of the eleven) working group dedicated to the "haptic interaction" and which gathers more than 20 European haptic partners. The results of NIW could thus naturally be discussed and deployed as well through the "haptic interaction" working group of *INTUITION*, or of its possible follow-up association (the expected future European association for Virtual Reality).

Other research programs will be drawn on by NIW wherever they concern issues that are relevant for the project. The EU *MONAT* and *SynTex* projects, which are investigating the synthesis and evaluation of virtual material textures, are of current interest. NIW, *MONAT*, and *SynTex* researchers are in contact through the current NEST Measuring the Impossible network (*MONAT*, *SynTex*, and *CLOSED* are partners). These contacts will facilitate access to a forum of experts in measurement and novel assessment methodologies that may also be significant for the project.

Crucial for the correct planning of WP6 will be the interaction with expert groups in such fields as gait rehabilitation and entertainment. Such an interaction must be necessarily put into action during the beginning and half-way of this workpackage. Concerning rehabilitation and movement science, the Coordinator has optimal relationships with Prof. Paola Cesari (PhD in Kinesiology: Motor Control and Motor Learning at Penn State University U.S.A., and presently assistant professor at the University of Verona, Department of Neurological, Faculty of Movement Science). Within her LAP-LAB (Laboratory Action Perception), whose facilities include motion capture, eyes tracker, force platform, force cell, zero wire EMG and TMS (Transcranial Magnetic Stimulation) systems, prof. Cesari works on the visuo-motor imagery and recognition of actions and motor representation and performance in elite athletes. The overall goal of her work is to improve the basic scientific understanding of the learning and control mechanisms underlying skilled movement, and, additionally, to develop new, low-cost, non-intrusive, explanatory diagnostic methods for monitoring skill acquisition, as well as for clinical applications (e.g., for monitoring and characterizing neuro-pathologies). LAP-LAB is currently partner in the project "Inside shoes", in collaboration with the Faculty of Medicine and the Veneto association of shoes industries in Italy. The lab is in charge of analyzing dynamical patterns of gait and testing several materials to afford comfortable and correct locomotion in normal subjects and patients with specific pathologies. Prof. Cesari will join one or more project meetings when decisions on the scenario are taken, as an invited expert. Should the project proceed during the first year at a pace faster than envisioned in the workplan, then part of the UNIVR budget may be spent to fertilize the growing of common know-how with LAP-LAB (for instance, by co-tutoring a PhD or post-doc researcher) during the development of the immersive environment.

Furthermore, the experts in signal processing belonging to the Coordinator's research group participate to the project entitled "Genetic Bases of β-Cell Role in Glucose Homeostasis of Patients With Type 2 Diabetes: A Computational Biomedicine Study" granted by the European Foundation for the Study of Diabetes (EFSD) and Novartis as part of the European Program for Clinical Research in the Field of Pancreatic Islet Dysfunction (applicant Prof. Riccardo Bonadonna, of the Endocrinology Division at the Department of Biomedical and Surgical Sciences of the University of Verona): though largely orthogonal to NIW, nevertheless this project may provide access to subjects affected by Type 2 diabetes, hence possibly suffering also from reduced foot sensitivity. Aside of their collaboration in the EFSD project, such subjects may provide opinions and suggestions turning useful in making decisions as well as planning user experiences upon the scenario.

The same kind of interaction will be needed to raise awareness in groups interested in entertainment, about future opportunities to take advantage of the project's research outcome and prototypes. AAU participates in Dadiu, the National Academy of Digital and Interactive Entertainment, springing out as a collaboration between the University of Copenhagen, the National Film School of Denmark, the Animation Workshop at University College of Western Denmark, Danmarks Designskole, Denmark's Technical University, University of Aarhus, and the IT-University of Copenhagen. This body has specific commitment to educate to computer game design by developing a cross-language that can be shared by people having diverse backgrounds. NIW will establish contacts with Dadiu through AAU key person Rolf Nordahl.

While current research envisions floors as protagonists in a mosaic that will lead to the design of novel interfaces and virtual and augmented walkways, the good sensitivity of the haptic communication channel of the human feet lies nearly unaddressed by contemporary information technology. This has remained true even where exploiting this channel may have dramatic benefits to the user. By comparison, the creation of knowledge salient to auditory and haptic interactions mediated by interfaces for the human hands have weighed strongly in existing research, such as the already mentioned *IMMERSENCE* project, among many others.

Sensing floors and shoes providing multimodal ecological cues to users may give rise to novel interaction paradigms and devices that could prospectively become part of everyday experiences. The unravelling of ecological foot-floor interaction paradigms that are exportable to everyday settings may nurture new designs for floor components and shoes that fundamentally impact the way we get information from our surroundings. Some strong points in favour of this vision are: i) the ecological unity and intuitive nature of the information; ii) the exportability of the communication paradigms to diverse cultures and social systems; iii) the independence of the interface from identification/authentication services, such as those necessarily coming into play when information is for instance delivered to personal mobile devices; iv) the affordability of the walking interface not only to people gifted with normal abilities, but also to the visually or hearing impaired—as far as the haptic channel is not integrally substituted by illusory effects; v) the potentially ubiquitous, calm, non distracting character of the interface especially in cases where the display can avoid the use of the visual channel.

Points i), ii) and iii) envision the profitable use of such interfaces in functional spaces such as airports or railway stations, where cluttering, distraction and pressure prevent people from performing rapid navigation tasks even if they focus most of their attention on the visual information and auditory messages displayed to the public. Agreement might be shared among designers of functional spaces in encoding simple semantics of basic signals into floor cues, that intuitively account for signalling pieces of information coherently with their ecological meaning. Such cues may integrate or replace existing information channels. For instance: revealing an exit as a distinctive ground material (gravel walkway), increasing floor elasticity approaching gates or platforms, simulating carpeted floor in the proximity of a meeting room, or wet floor mats when near to a toilet. Of course, personalized support for navigation involving the encoding of directional signals and simple markers into corresponding cues may be delivered to travellers via intelligent shoes or floors as soon as their identity or route to destination may be disclosed to the information system.

Another arena where interactive shoes or floor interfaces may bring notable advantages is that of public urban spaces, whose navigation is frequently non-obvious, despite a long-standing tradition of visual and auditory signals, both passive and active, as well as passive haptic markers underfoot to denote everything from recreational trails, to pedestrian crosswalks, railway platforms, and subway entrances.

At a more abstract level, properly designed interactive floors implement, in principle, all the distinctive strategies of persuasive interfaces: ubiquity, opportunity of intervention, social acceptance, connectivity, facilitation, persistence, simplicity [Tscheligi and Reitberger, 2007]. Persuasive interfaces have recently been the subject of a special section of the September

2007 issue of the ACM *Interactions* magazine. Although not aimed at solving societal problems such as health, well-being and sustainability, interactive floors may naturally bring better public awareness about welcoming, as opposed to forbidden places or areas where one ought not to go [Tscheligi, 2007].

Point v) of the above items becomes particularly interesting when looking at shoes as two-way interfaces for the communication of personal information. Active shoes affording the kinds of interactions as those dealt with by NIW may enable non-intrusive and context-dependent information channels that would be applicable to virtually any space, either public or personal, based on extensions of existing location-based mobile communication infrastructures. As with any wearable device, their display and sensitivity to foot gesture may readily accommodate personal preferences or needs. The idea of accessing information via gestures, communication or information channels available through the feet, during normal activities, appears perhaps less speculative if we think of the complexity and subtlety of the Braille code or the visual language spoken and understood by hearing impaired people. For these people, finding communication tools that integrate with the most important parts of their human interface (i.e., ears and hands for the blind, as well as eyes and hands for the deaf) synergistically rather than obtrusively, is vital for their acceptability. Unlike existing sensory substitution devices, such as the TDU visual substitution system (a device that transcodes visual information into the stimulation of the tongue via a denture in the mouth), fewer obstacles to the acceptance of foot-based interaction methods exist [Upson, 2007].

Less common, but still significant, settings in which humans find themselves deprived of sensory information may also be impacted by this work. In the space sciences, there is a strong interest in technologies that can assist astronauts in settings in which they must operate under dangerous conditions without the normal sensory channels that are available to them. Examples of current interest include footwear for lunar explorers that may convey critical ecological information about the stability and dynamics of the ground material beneath their feet (for example, to prevent them from falling down the edge of a crater). Similar auditory and haptic interventions have been significant for manual work in sensory deprived settings (astronautical manual labor; undersea labor; teleoperation).

Finally, the accurate synthesis of specific floor cues may have clinical applications, in helping patients recover from strokes and incidents and in curing neurological dysfunctions. There is a growing body of research that investigates the relationships existing between sensory activity and the ability of the nervous system to repair itself following an injury [Harry et al., 2005]. So far, the study of these relationships has been restricted to so-called stochastic resonance techniques, particularly through a sub-threshold haptic foot stimulation, but the availability of floor devices enabling the fine control of the stimuli to the foot, in particular reinforcing the ecological connotation of the percepts conveyed to an otherwise insensitive injured system, may encourage clinical investigations aimed at creating specific or personalized rehabilitation therapies based on selective foot stimulation. Such methods could be significant for recovery from gait or vestibular disorders, for which interactive VR techniques have been increasingly applied. The availability of a flexible palette of ecological foot-floor interaction paradigms may also help the researchers working in this field to approach new frontiers of investigation, that anticipate the possibility that haptic stimulation technologies may accelerate the learning or re-learning of body gestures and activities [Harry et al., 2005].

B.3.2 Plan for the use and dissemination of foreground

NIW will disseminate its research achievements through workshops, national and international conferences, and high-impact scientific journals centered on the following disciplines: human-computer interfaces and interaction design, applied perception and psychophysics, intelligent systems, multimodal displays, interactive technology, robotic and haptic control and engineering, software and system modeling. Dissemination and communication of results will be also provided on the web, through the regular maintenance of content documenting the project's aims and ongoing research. All dissemination activities (i.e. publication abstracts, reports from events and activities organized during the project) will be summarized at the end of each reporting period within the periodic reports.

The deliverables and the Final plan for the use and dissemination of foreground contained in the final report will form a solid basis for further scientific development beyond the end of the project. In particular, D6.1 will document the design of a prototype installation realizing the most convincing interactive floor models developed during the project. When achieving a satisfactory degree of realism, this installation will be demonstrated at events organized off the academic circle, such as hi-tech fairs, to attract the interest of actors that, after the end of the project, would be involved in further development, engineering, and production of advanced interaction technologies based or inspired by the interaction designs researched by the project.

Key persons of the project will regularly attend international conferences, also with the aim of presenting NIW and disseminating its concept and results in separately organized panels. In the third year of the project, NIW will organize a panel on foot-based interfaces and interactions at an international HCI-related conference, where the achievements and ongoing activity of the project will be presented and disseminated.

The consortium will prepare a brochure in English with the objective of advertising the project in the context of events participated by delegates working in NIW. The brochure will be accessible to the non-specialist and will expose the project aims and activities using intuitive graphic tools. It will be published during month 1, and refreshed during month 18 and at the end of the project.

An edited book summarizing the most salient knowledge in the field, both developed within and outside NIW, will be produced by the end of the project.

In parallel to dissemination, it will be necessary to raise interest for the project during the three years of activity. Contacts with communities belonging to both the academy and industry, working on research topics that are considered interesting for the project, will be opened with the purpose of cross-fertilizing each other community with mutual exchange of know-how. In order to facilitate intellectual exchange and multidisciplinary discussions, not only groups whose interests can be closely assimilated to the activity of NIW will be contacted. For instance, the interdisciplinary forum created by the European *MINET* network represents a convincing ensemble of groups having diverse scientific cultures, which discuss together on themes which are central in the current development of the European research. It will be a central concern for NIW to open contacts with contexts like this, by actively participating to public meetings, and, if possible, by opening further collaboration agreements. By cooperating with such subjects the Consortium expects to co-organize an international summer school focusing on the theme of multimodal interfaces.

Since it receives economic support by public European and Canadian funds, the NIW project will disclose its results to the scientific community using the aforementioned tools. It will not protect any of its achievements through patenting or other forms of intellectual property. Consistently with this policy, it will build knowledge on top of publicly available know-how, furthermore avoiding to make use of technical recipes contained in patents or other protected documentation. If required to apply forms of copyright concerning the management of knowledge such as software code or technical specifications, the NIW project will adopt the Creative Commons licence, that provides a legal form for the protection of publicly available intellectual products.

B.3.2.1 [Contributions to standards]

NIW will not contribute to current international standardization activities.

B.3.2.2 Contribution to policy developments

Making public and private urban spaces more accessible to impaired persons is an issue to which the EU puts particular concern, by funding both research and development of solutions at several levels. Exploratory projects like that promoted by the European Union's Institute for the Protection and Security of the Citizen (IPSC) are testing RFID-based navigational system for blind residents and tourists in small town-scaled urban areas [Peck, 2008]. By using future versions of the haptically-marked walkways that already exist in the sidewalks of some cities, perhaps based on technologies that NIW will nurture, cues invisible to other people could be displayed so as to provide critical orientation, informational, and navigation services to the blind. Such an approach improves upon major obstructions to existing aids for the non-sighted: Namely, that such aids are of no help if they are not touched. Braille signs are of limited use for the reason that people do not grope at random for messages in such spaces. By comparison, everyone who is able to walk is in continuous contact with the floor.

A simple, unified floor-based “ecological” haptic code might be developed in the future, for example, to assist public transport companies in complying with the guidelines that the EU has set up to guarantee equal access to travelling information to disabled persons, who could otherwise be autonomous travellers [Raemy and Ruprecht, 2007].

B.3.2.3 Risk assessment and related communication strategy

NIW will make research upon floor-based interaction paradigms that, if established in future public information systems, in principle do not expose users to explicit identification as opposed to what happens using, for instance, RFID-based or cell phone-based communication. Nevertheless, human expression including foot gestures provides potential identification clues that may be decoded even accurately, as gesture recognition techniques become progressively able to capture subjective forms of expression.

Prospective users and providers of these systems should be acquainted with the risks connected to deliver, as well as acquire personal information which may be used for identification purposes. Even if the research plan of the project is limited in scope to the design of working prototypes, whose generalization into products is not going to happen in the short term, yet knowledge about these potential risks should be gained before planning any future use of such systems at societal level.

Concerning possible implementation risks arising during the project, a major source of uncertainty derives from the assumption that pseudo-haptics can compensate for lack of haptic information. Apparently, there exists a unique way to mitigate the risk that multisensory and pseudo-haptic techniques are not sufficient to compensate for the lack of dynamic information inherent in tactile, low-cost actuators. It consists in probing the maximum power of the haptic paradigms, irrespectively of the availability of other display modalities.

At the moment, only an estimate of the technological limits of the haptic devices can be attempted. We are looking at two approaches to provide haptic feedback through the feet during walking on a arbitrary floor. Both have already been prototyped up to various degree. The first is to divide a floor into tiles. Each tile has a load sensor and an actuator capable to vibrating the surface over a wide frequency range as a function of the load that is applied. From early working prototypes, this approach has been proven to be extremely effective so there is not worry to have as to its feasibility. Of course there is a concern as to its cost since cost is in direct proportion to the surface covered. The main cost component that scale up however is due to the electromagnetic transducers (they operate on the principle of inverted loudspeakers). These are in fact available at consumer electronic prices and are already mass produced. Since the tiles can sense the presence of a person standing on it, the more expensive power electronics need not to be duplicated and a small, fixed number of amplifiers can be multiplexed to activate only that tiles that need activation. So a significant surface of, say, 10x10 tiles with proper engineering would represent only a small cost fraction of the visual and audio components of a complete VR environment.

The second approach calls for designing special shoes with haptic transducers embedded in them. Here, the haptic engineering challenge is much greater. The actuators must be small enough to create significant stimulation in a small space and with a limited power budget. But also they must be engineered to resist the weight of a person and be embedded in the deformable medium that is a shoe. Here we are planning to experiment with two different sub-concepts. The first is based on a flexural design where the sole can deform laterally but is rigid in the vertical direction to resist the weight of the subject. There would be two types of electromagnetic transducers optimized to act in different frequency ranges. It is envisaged that piezoelectric transducers because of their small form factor, could be appropriate also for the high range. The second design is based on a shoe sole divided into compartments filled with a gel or a liquid with the acoustic impedance of the various regions designed to reflect vibrations upward into the foot of the subject rather than to the ground. This design concept is very exciting as it promises to essentially isolate the wearer from the ground interaction and expose her or him to the signals specified by a computer. The inherently flexible design would make these shoes very close to the design of modern sneakers but with an active component.

From this description it should be clear that the project, from a haptic engineering view point, is articulated around a hierarchy of increasingly challenging designs starting from an already proven approach that needs enhancement to a more risky approach with very high pay-off, with an intermediate level in-between. It is anticipated that these approaches all contain potentially very valuable IP that will be weighted in due time, by decoupling open research added value due to EU public funding from product development that may depend on different sources of financing.

Something should be said about the anticipated scientific contributions. If relatively little is known regarding how the hand perceived the various attributes of manipulated objects—although elements of a theory that could be compared to the theories that have already been proposed for vision and audition (say, Marr and Bergman) are currently coming in focus—even less is known about how the foot perceives the surfaces on which subjects are walking. For instance, the foot and the hand share the same basic design as far as the receptor populations are concerned. There is a slowly adapting population, a fast adapting one and a Pacinian system, plus channels of kinesthetic nature. In the foot, the current hypothesis is that the kinesthetic channel and the Pacinian system dominate as sources of information when perceiving surfaces. In addition, there are very fundamental questions regarding how vision and audition combine with haptics during walking. The haptic engineering effort that we propose to conduct is expected to provide us with unique experimental paradigms not available today. Another outcome of this project is therefore concerned with providing the means to address very fundamental scientific questions of high value to the applications described in the proposal.

The success of the project can be put in direct relationship with its outcome in terms of validity of the proposed prototypes, utility and efficiency of the foot-floor interaction methods, number of successful experiments, and degree of realism of the immersive scenarios. As a result, there are clear indicators available to weigh this success, hence no need to elaborate specific communication strategies in the case the project may be unsuccessful. The consortium will in any case document accurately its research efforts (either successful or unsuccessful) made toward the achievement of the project objectives.

B4. Ethical issues

The NIW project involves psychological experiments, within the scope of WP5. These experiments will take place in Canada, Denmark, France, and Italy. Subjects will be involved in natural walking tasks along floors, and using shoes that must not impede the task. Such experiments are needed to evaluate from a perceptual point of view the floor interface systems developed during the project. The kind of stimuli dealt with by the project (i.e., multimodal floor cues) must be ecological by definition, hence of no physical or psychological consequence for the subjects. Conversely, care must be taken to respect the privacy of subjects, by avoiding to disclose their personal as well location data.

All subjects for the experiments will be adult healthy volunteers, gifted with normal abilities. In specific cases where subjects may be visually, hearing or sensory-motor impaired in a way that he or she cannot perform a walking task as the subject were gifted with normal locomotion ability, it will be partner's responsibility that of preliminary taking all possible measures to ensure the subject's safety during the walking task, as well as to take the needed consideration to make the subject fully aware of the experimental task. More generally, all necessary cautions will be taken to ensure as safest experimental condition to all participating subjects, in compliance with the rules and guidelines affecting the participating institutions. The experiments will take place in normal environmental conditions and will in any case avoid the display of stimuli beyond acceptable subjective thresholds of illumination, sound pressure and haptic stimulation.

Personal data will be retained only for possible recalls to further experimental sessions. Such data will be eliminated after the end of the project, in compliance with the rules and guidelines affecting the participating institutions. Some experiments involve the use of wearable devices (i.e., interactive sole shoes) interfaced with a PC via wired or wireless communication systems. Such systems will be not connected to any public network, nor associations will exist between a wearable device and a subject, so as to avoid potential personal identification and location outside the experimental environment.

Ethical issues table

Informed Consent	**YES**	**PAGE**
Does the proposal involve children?		
Does the proposal involve patients or persons not able to give consent?		
Does the proposal involve adult healthy volunteers?	X	62
Does the proposal involve Human Genetic Material?		
Does the proposal involve Human biological samples?		
Does the proposal involve Human data collection?	X	62
Research on Human embryo/foetus		
Does the proposal involve Human Embryos?		
Does the proposal involve Human Foetal Tissue / Cells?		
Does the proposal involve Human Embryonic Stem Cells?		
Privacy		
Does the proposal involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)		
Does the proposal involve tracking the location or observation of people?	X	62
Research on Animals		
Does the proposal involve research on animals?		
Are those animals transgenic small laboratory animals?		
Are those animals transgenic farm animals?		
Are those animals cloned farm animals?		
Are those animals non-human primates?		
Research Involving Developing Countries		
Use of local resources (genetic, animal, plant etc)		
Benefit to local community (capacity building i.e. access to healthcare, education etc)		
Dual Use		
Research having direct military application		
Research having the potential for terrorist abuse		
ICT Implants		
Does the proposal involve clinical trials of ICT implants?		

Informed Consent	YES	PAGE
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL		

B5. Consideration of gender aspects

The activity of NIW ultimately wants to generate better and more scalable product design in the actual niche of interactive floors. Also in accordance with the European policy of equal opportunities between men and women, the project will avoid to specify prototypes establishing gender differences. For this reasons, involving both normally gifted and impaired female as well as male users in the design and experience of such prototypes will substantially enrich the body of knowledge NIW wants to gain through interaction with users. Hence, in the limits of the project dimension, a specific effort will be made to attract in the design and evaluation cycle of the project users belonging to different gender, culture, and ability.

All the beneficiary institutions promote parity of gender opportunities in their recruiting activity. Under the supervision of the Coordinator, the Local Coordinators will constantly check that such opportunities are guaranteed concerning the employment of persons in the project. Considering the unbalanced gender distribution of jobs affecting the field of ICT worldwide, all efforts will be made to hire female candidates who are qualified to work in the project.

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