PROJECT PERIODIC REPORT

Grant Agreement number: **222107**

Project acronym: **NIW**

Project title: **Natural Interactive Walking**

Funding Scheme: **Small or medium-scale focused research project**

STREP - CP - FP - INFSO

Date of latest version of Annex I against which the assessment will be made: July 1, 2010

Periodic report: 1st ☐ 2nd √ 3rd ☐

Period covered: from October 1st, 2009

to September 30th, 2010

Name, title and organisation of the scientific representative of the project's coordinator[1]:

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1 Usually the contact person of the coordinator as specified in Art. 8.1. of the grant agreement

2 The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm ; logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

Declaration by the scientific representative of the project coordinator1

I, as scientific representative of the coordinator1 of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):

  √ has fully achieved its objectives and technical goals for the period;

  ☐ has achieved most of its objectives and technical goals for the period with relatively minor deviations[3];

  ☐ has failed to achieve critical objectives and/or is not at all on schedule[4].
- The public website is up to date, if applicable.
- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 6) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 5 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator1: **Federico Fontana**

Date: ..../ ..../ ....

Signature of scientific representative of the Coordinator1: ....

3 If either of these boxes is ticked, the report should reflect these and any remedial actions taken.

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NIW natural interactive walking

1. Publishable summary

The simple act of walking in everyday environments exposes us to highly structured information about the ground. 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 NIW project aims to take advantage of this information to develop knowledge for designing walking experiences involving touch, hearing, and vision. This aim is being accomplished through the engineering and perceptual validation of human-computer interfaces providing virtual cues of everyday ground attributes and events. Such cues are conveyed across a continuous perception and action loop, by haptic, auditory, and visual augmentation of otherwise neutral grounds.

The realism of multimodal feedback must be assessed from a user's perceptual standpoint. For this reason the project explores effects that are capable of thrusting users into illusory situations, with special attention on so-called pseudo-haptic feedback.

1.1 Project objectives

The project is focused on creating efficient and scalable multimodal display methods that can be easily and cost-effectively reproduced, via augmented floors and footwear.

These two interface components contribute to provide substantial content to the main objectives that, overall, form the core goal of NIW:

1. The production of a set of **foot-floor multimodal interaction methods**, for the virtual rendering of ground attributes, whose perceptual saliency has been validated;
2. 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.

1.2 Description of work since the beginning of the project

Work at McGill University, UPMC, UNIVR, AAU, and INRIA, has moved mainly along the design, engineering, and validation of floor- and shoe-based interface components, capable of acquiring foot gesture information as well as providing auditory, haptic, and visual feedback accounting for information at ground level and, more in general, to drive one's walking activity.

McGill University has directed its effort to the further development of a situated interface based on the active tiles, and to its validation in an empirical investigation devoted to comparing the perception of real and virtual ground surfaces. Relying on a previously existing concept for the force sensing and interactive vibro-tactile feedback of ecological grounds such as snow and gravel, that had been nurtured at the same institution immediately before the beginning of the project, in these two years the active floor surface has been further characterized and hence optimized in terms of mechanical compliance, as well as integrated into a multimodal sensing/actuated floor provided also with interactive visual information. A number of interaction techniques have been developed based on the judicious use and analysis of sensor data acquired through the floor interface. To date such tiles represent a reference in the state of the art of foot-based interaction. Such a recognition has been made possible especially thanks to Canadian resources drawn by McGill University through affiliation to the NIW project.

Work done at UMPC has been oriented toward engineering, and subjecting to validation a new type of electromagnetic actuators sufficiently small and powerful for use in wearable haptic interfaces subjected to heavy loads as it is the case when employed in shoes. UPMC has furthermore delivered equipment to AAU and UNIVR, that was used to support a number of studies.

UNIVR, AAU, and INRIA have proficiently drawn tools from the above two participants, and created a mutual exchange of experiences both between them and with the other institutions. UNIVR and AAU started the design of actuated shoes, capable of sensing the user's force during walking and consequently responding with auditory and tactile cues of ground, in an aim to ecologically augment otherwise neutral floors. Both participants had preliminary knowledge in sonic interaction design, and possessed real time software capable of rendering everyday sounds based on the excitation of physically-inspired synthesis algorithms. Conversely the physical design of actuated shoes started largely from scratch and, hence, it required to face problems of accuracy of the acquisition, communication between components, latency and fidelity of the feedback. Two years of research activity have allowed the partners to come up with validated versions of the different components forming the shoe interface, in which all the aforementioned problems have been solved albeit in the limits of unavoidable current technological constraints affecting the wearable prototype, particularly concerning the power needed to provide tactile stimuli and the frequency bands of the multimodal feedback.

Work done at INRIA has been oriented towards the visual modality, and the design of novel visual rendering and interaction techniques for navigating virtual worlds. Novel pseudo-haptic techniques based on visual camera motions have been created for simulating walking on uneven relieves. Novel graphic and haptic rendering techniques have been proposed for interaction and walking on liquid/fluid media. A "walking-in-place" technique called Shake-Your-Head has been introduced for desktop virtual reality. The "Magic Barrier Tape" technique was also introduced to enable walking in infinite virtual worlds, when being physically constrained by a limited workspace in reality. Furthermore INRIA has coordinated the overall project's experimental campaign, by both leading psychological tests in which the visual component was prominent, and performing multi-sensory experiments jointly with other participants.

In parallel to the role of INRIA, all participants have conducted experiments in their own domains related to the NIW project. Besides such individual activities, the experimental campaign culminating during the second year of the project has fertilized the movement across the participating institutions of a notable number of (especially young) researchers, carrying with them precious knowledge about various interaction design and validation methods held by the respective institutions. As expected, this cross-fertilization has brought a substantial acceleration in the overall design-validation cycle, to which all the consortium was called to participate.

Important dissemination results have been achieved not only within the consortium, but also at the foreground of the most important related scientific fora. Different media including the television have covered NIW in these two years, and almost all the major conferences in the interaction design, virtual reality, and device engineering scientific fields have been joined with submitted papers, demos, and thematic keynotes. Furthermore, the project has co-sponsored its own events in synergy with other EU-funded actions.

In the light of the milestone expected for the third year, all participants are now working at consolidating the main existing prototypes toward a final integrative demonstrator. In parallel, they are going on developing components that are potentially expected to play a meaningful role in this demonstrator: UNIVR and AAU are continuing the research activity on sensing pavements based on arrays of accelerometers; UNIVR is conducting an experiment in its LapLab, a laboratory of motor sciences involving the use of active tiles along with the measurement of biomechanical data. AAU is conducting multi-sensory experiments in which subjects perform evaluation tasks such as balancing on a virtual rope. INRIA is conducting research on multi-sensory rendering of rich media and simulated walking on multiple states of matter. McGill is investigating further sensing designs, perceptual effects of simulated compliance, and variable friction control. At UPMC, work is being carried out to investigate the effect of vibrotactile stimuli on posture, furthermore a new sole-based stimulation principle based on the circulation of fluids in cavities is being investigated. All such activities are expected to yield results during the next project year.

The new participant UNIUD has entered the project in its role of coordinator on July 1, 2010, yet with no substantial research contribution.

1.3 Main results achieved since the beginning of the project

The work made on the active (tiled) floor surfaces has led to new results on the contribution of vibrotactile information to the perception of mechanical properties of floor surfaces. The specific results, related to a robust vibration-induced compliance illusion, may also have applications to the movement sciences and perhaps, in the future, to gait rehabilitation or orthotics. Other key results in this area concern the development of sensing and interaction techniques that facilitate the development of rich interactive applications via the multimodal floor surface.

At UPMC, the first engineering cycle aimed at miniaturizing, speeding up manufacturing and lowering the cost of electromagnetic actuators is now nearly completed.

UNIVR and AAU have realized a set of components for the multimodal augmentation of shoes in contexts of continuous interaction. This set includes acoustic as well as force acquisition methods, physically-inspired real time synthesis algorithms, and shoe-based interfaces providing audio-tactile feedback. All components have been or are being validated, at different levels: the acquisition system has been characterized in electro-mechanical terms; the data processing and synthesis algorithms optimized in their performance, and their acoustic quality validated; the multimodal feedback psychophysically tested under different interaction contexts. An early prototype of sensing pavement is being developed jointly by UNIVR and AAU, based on arrays of accelerometers.

Work done at INRIA has developed a set of novel visual techniques and multi-sensory rendering approaches. This set includes pseudo-haptic simulations of slopes based on visual changes in camera motions, and multi-sensory rendering techniques for liquid and fluid media. INRIA has also designed novel walking paradigms, first for Walking-in-Place with the “Shake-Your-Head” based on head movements, and the “Magic Barrier Tape” for walking infinitely in virtual worlds when in a limited workspace in reality.

1.4 Expected final results and their potential impact and use

The methods that will be created by NIW are expected to find application as floor-based navigational aids in functional spaces, guidance systems for the visually impaired, augmented reality training systems for search and rescue, in interactive entertainment, and for physical rehabilitation.

Tiles are envisioned to provide seamless cues mainly for guidance and virtual reality purposes. Compact worn shoe-like devices, additionally, are expected to deliver a variety of haptic and auditory signals for use in sports training and rehabilitation.

At the end of the second reporting period, there is strong expectation that both the active tiles and actuated shoes will together translate into a final demonstrator accounting for at least some of the already validated interactions, and integrating one or more application scenarios such as those listed above. The conclusive form of this demonstrator will certainly put the emphasis on the most interesting kinesthetic and cross-modal illusions found so far. Its precise characterization is under discussion within the consortium.

1.5 Notes on this report

The latest version of this report is downloadable from the project public web site `www.niwproject.eu`.

2. Project objectives for the period

As by the Annex I of the project, the objectives for the second year are summarized as "The systematic experimental validation of [haptic and auditory] 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".

Together, the above objectives have led to the milestone no. 2, scheduled for the end of this period: "Validated set of ecological foot-based interaction methods, paradigms and prototypes, and designs for interactive scenarios using these paradigms."

2.1 Summary of the recommendations from the first review, and how they have been dealt with

The board of reviewers has expressed the following main recommendation: *The overall feeling was the need for more intensive cooperation between subprojects and focusing on specific goals.*

The main concern of the reviewers, by all means shared by the consortium, has been dealt with conceptually, by trying to wrap up a common research core, and pragmatically, by making the largest use of inter-project research missions, a tool that is believed to be in practice the most useful for achieving shared goals.

About the concept, the consortium figured out soon after the beginning of the second period that all participants had already, or anyway maturing a specific interest in working on possibilities to create kinesthetic and proprioceptive illusions by means of psychophysical (vibro-tactile, auditory and visual) cues, either conveyed through isolated (i.e., monomodal) or in synergistic (i.e., multimodal) sensory stimulations. This concept, hence, has driven many (but not all) of the subsequent experimental activities.

Concerning the implementation, the consortium can exhibit a number of collaborations that, together, demonstrate a genuine and factual desire to share the individual know-how and the respective prototypes and technologies, once reached their sufficient point of stability and reliability, and provided the possibility to make them physically available to personnel outside the home institution. In particular, a specific effort has been made in maximizing the level of networking of INRIA with the rest of the consortium in ways to integrate its visual paradigms with the other display modalities (in particular the auditory one, in an aim to meet one specific recommendation coming from the reviewers).

Point-by-point recommendations have been made explicit as well. The consortium has kept developing both the floor- and shoe-based interface paradigm, with general good success. Still, a common evaluation scenario has not been outlined. In spite of this gap, there are strong evidences suggesting that the consortium is not far from figuring out this scenario. In particular, experiments conducted on the active tiles and the actuated shoes, whose results are fresh and still unpublished, meanwhile in part presented in Deliverable 5.1, suggest that both such interface concepts lead to salient changes in the perceived foot-floor compliance when the acousto-tactile feedback is varied accordingly. Holding this evidence, the consortium expects to benchmark both concepts over a common scenario that must be designed as part of the activity planned for the third year – refer to project milestone M3.

Concerning the panel's suggestion to concentrate resources on the most promising hardware and software prototypes, the consortium has certainly implemented it: concerning the hardware, both the tiles and the shoes have been significantly improved across the second year, while for instance the sensing pavement has been partially (but not completely) left in stand-by, for possible (and not necessarily validated) use on the final demonstrator; concerning the software, the experiments have further cleared out that floor augmentation is at reach of prototypes based on low cost devices such as those targeted by the project, whereas floor substitution is nowadays a potential, still largely unexplored domain of only more powerful virtual reality systems. For this reason, the consortium has focused across the second year on software models capable of virtually displaying floor layers such as gravel, snowy, muddy, and more in general aggregate instead of solid grounds.

3. Work progress and achievements during the period

The activities made during the first year have led to achievements that are aligned with the project work plan described in the Annex I. Concisely summarizing, the consortium has:

a) improved the physical engineering of actuated floors and shoes;
b) better characterized the tile- and shoe-based analysis techniques and components, conceived during the first period;
c) validated several physically-based models in walking scenarios, this year including not only the auditory or vibro-tactile, but also the auditory *and* vibro-tactile sensory modalities, with diverse ground attributes;
d) substantially carried on the experimental campaign, by performing mono- and bi-modal experiments ranging across vision, hearing, and touch, meanwhile subjecting the project interface designs to multiple types of tests.

Detailed descriptions of such achievements follow for each work package:

WP 2 – Haptic Engineering

The workpackage has seen most of its activity happening at UPMC. This participant, in fact, has designed, engineered, and prototyped several pairs of haptic shoes capable of providing vibrotactile stimulation. Such shoes have been imported by AAU and UNIVR. Furthermore, a "hapticized" balance board based on the structural suspension presented in Deliverable 2.1 has been put available to AAU.

In addition to the above realizations, UPMC has made significant steps in conceiving as well as preliminary prototyping radically new subminiature actuators characterized by low production cost, extended response in the low range, crush resistance, and high efficiency. Alternative advanced designs whose prototyping is under way consist in a fluid-based actuator concept. Finally, UPMC has constructed and tested an electronic system driving 2x700 tactors from a single Arduino microcontroller. The mechanical assembly of this system is under way.

Concerning the work package tasks:

- Task 2.3 is now at a good point in terms of number of validations that have been conducted during the second period using the available force-feedback devices, both equipping the tiles and, this year, also onboard the shoes.
- Task 2.4 has made a fundamental step ahead in the second period, once the haptic actuators have been delivered for use inside the interactive shoes.

At the end of this reporting period, the consortium does not see deviations from the research plan as by that outlined in the Annex I of the project, given that R2.2 [M3] is expected later on the third period.

The resources used for this WP are in line with the project workplan as by the Annex I. Quantitative information on the use of human and equipment resources is reported in section c) on Explanation of the use of the resources.

WP3 – Multimodal sensing, analysis, and integration

Research at McGill focused on two main tasks, both subserving the goal of enabling the development of rich applications based on interacting with augmented floor surfaces in virtual reality or human-computer interaction. The first concerns the analysis and fusion of sensor data acquired through a distributed array of in-floor force sensors and via motion capture, and the development of a modular client-server architecture for supporting application development using this data. The second concerns the recognition of specific foot or body gestures from in-floor force measurements, and the continuous tracking of pedestrian locations from similar data. A byproduct of the latter is that it is possible to coherently track the identity (i.e., left vs. right) of individual feet of a person even when they are lifted from the floor surface. This is expected to be beneficial to applications that assign different actions or different responses to the feet. Additional research has been devoted to developing a dynamic model of the tile-user system that can be identified in real-time from in-floor force-measurements. These developments are fully described in Deliverable 3.2.

In addition to work made at McGill University on their active floor surfaces, UNIVR has characterized the electro-mechanical behavior of the force sensors mounted on the shoes, as well as substantially improved the performance of the input data acquisition board. This work has allowed to optimize the sensing components of the shoe interface.

Concerning the work package tasks:

- Task 3.1 has been completed to a large extent, thanks to substantial improvements in the accuracy and latency control of the shoe sensing components, as well as in the mechanical characterization of the tiles. As already mentioned in Section 2.1 of this report, the sensing floor has been left standing by during this second year.
- Task 3.2 has substantially advanced: interactions with several floor materials have been tested, and the most promising ones (typically the models of aggregate grounds) have been evaluated, both in tile- and shoe-based test scenarios. For such interactions, sensor-to-control maps have been developed and fine-tuned as to provide sufficiently accurate information about walking to the rendering software, meanwhile maintaining the needed simplicity for execution in real time.
- Task 3.3 has been accomplished to a good extent: both the shoes and the active tiles have been almost completely optimized to make the best possible use of the force sensing devices available to the project. Fusion of data from a distributed array of sensors and from motion capture measurements has been addressed using the methods described above, which are fully elaborated in Deliverable 3.2. Acoustic sensing has been set aside for the moment, since the acoustic sensing floor surface has been temporarily put in stand-by for reasons explained in Section 2.1.
- Task 3.4 has led to impressive results in the distributed floor interface. In one scenario, users are enabled to browse geographical information presented via floor and wall displays

using intuitive gestures with their feet. These developments may be extended further during the third period, in the context of an integrative demonstration scenario.

At the end of this reporting period, in the consortium's opinion there is no major discrepancy with the research plan described in the Annex I, particularly with respect to the result R3.2 [M2]. Some further advancement that was planned for the analysis of foot gestures through contact-microphones arrays onboard the acoustic sensing floor surface is expected for the third period.

The resources used for this WP are in line with the project workplan as by the Annex I. Quantitative information on the use of human and equipment resources is reported in section c) on Explanation of the use of the resources.

WP4 – Auditory, haptic and visual feedback modeling

This period has seen the integration of the auditory and haptic modality in the shoe interface. Compared to the huge effort made in the first period by the consortium in modeling feedback in separate modalities, the work done in this work package during the second year has been smaller. Further research, with specific attention to the integration of the visual modality in walking scenarios, is expected to happen during the third period. Similarly to what happened during the first project year, McGill University's active tiles have maintained a fast pace also during this period, and anticipated effective scenarios in which the visual modality is already enabled and integrated in an acoustic-tactile context.

The physics-based software models which had been either designed or adapted, during the first period, to simulate floor-based feedback, have confirmed their versatility in synthesizing ground information suitable to both the auditory and tactile sense. Issues of stability have been understood better in the models, and an effort has been made to work only with such impact models that provide, if not even more accurate, at least a more realistic feedback. By just filtering their outputs in ways to avoid the injection of unnecessary, potentially distorting power into the respective actuators (i.e., speakers or haptic devices), such models have been employed in different real time implementations to convey cues accounting for diverse ground properties and materials. In conclusion, similarly to what had happened with the interface based on tiles, the tactile feedback was straightforward to integrate into the shoes thanks to the physics-based nature of the synthesis algorithms. At least when displaying aggregate grounds such as gravel and snow, subjects found the experience credible and generally acceptable.

The use of friction models has proven to be harder, also in connection to the inherently complicated question of detecting sliding gestures at ground level using microphones or other types of sensors. However, creaking phenomena simulated with the friction model have proven to significantly enhance the realism of the simulation.

McGill University has continued research on modeling and simulation of interactions with complex heterogeneous materials, focusing in particular on fracture processes in granular media and dynamically fracturing solids (e.g., ice). McGill has hosted research missions by personnel from UNIVR and INRIA devoted to rendering interactions with virtual solid floors and liquids, as detailed separately in this report.

Concerning visual feedback, INRIA has a novel model and approach for multimodal rendering of fluids, which notably enables to enhance ground-level feedback covered with liquids. This technique has been integrated in the McGill environment equipped with tactile tiles. There, users could experience walking on a sandy beach and feeling waves touching the feet by means of tactile and visual rendering.

INRIA has also designed a novel Walking-In-Place technique for desktop virtual reality based on head movements: the "Shake-Your-Head" technique. This technique enables to walk by moving heads in front of a webcam, i.e., with very low-cost VR equipment. The user is left with the possibility to sit down, and to use small screens and standard input devices such as a basic webcam for tracking. The locomotion simulation can compute various motions such as turning, jumping and crawling, using the head movements of the user as sole input. Experiments show a high subjective preference and efficient navigations compared to standard desktop inputs (joystick and game pad).

Concerning the work package tasks:

- Task 4.1, already at good point at the end of the first period, has received further information after the experiments. To date a number of interactive synthesis methods have been developed for use in the project, working in the auditory, tactile, and visual modalities.
- Task 4.2 has reached a mature point of development as well, especially after the tactile display has been enabled in the shoe-based interface. Similarly to the experience that had been made with the tiles, including the haptic feedback in the shoes has empowered sense of continuous interaction and tight feedback loop between users and the augmented (now multimodal) display. The haptic devices have not introduced interferences and loopbacks with the force sensors: this fact has greatly simplified the design of the physical shoe interface.
- Task 4.3 has took advantage from brilliant solutions coming from several young researchers working in the project, who had worked out software solutions capable of minimizing the system latencies in both tiles and shoes meanwhile improving the characterization of their mechanics, hence the accuracy of data acquisition as well as feedback presentation in both such interfaces. Further issues that should occur during the integration of the components forming the experimental situations and the final demonstrator will be dealt with in the third reporting period.

At the end of this reporting period, the consortium does not see deviations from the research plan as by that outlined in the Annex I of the project, particularly with respect to the result R4.2 [M2].

The resources used for this WP are in line with the project workplan as by the Annex I. Quantitative information on the use of human and equipment resources is reported in section c) on Explanation of the use of the resources.

WP 5 – Pseudo-Haptics and Perceptual Evaluations

WP5 has seen activity by all participants, INRIA leading the coordination of this work package.

Various experiments have been conducted to evaluate the different elementary technologies developed in the NIW Project. These experiments assessed the potential and limits of each technology and each mono-modal cue alone (visual, haptic, and auditory). Work has been carried out individually by each laboratory and each partner in which the technology has been developed. An overview of the different studies conducted in the NIW project on mono-modal ground cues is given in Table 1. The table provides evidence that all the sensory modalities (visual, auditory, haptic) were addressed, using various experimental protocols and complementary approaches.

Furthermore, numerous experiments have been conducted by participants to evaluate various combinations of the different technologies developed in the project. These experiments assessed the potential and limits of each subsequent combination of multi-modal cues (visual+haptic, visual+auditory, haptic+auditory). This work has resulted by lots of collaborations and exchanges between the partners who put together, assembled, and combined the elementary technologies, and then had to define and set up the corresponding experiments.

Modality	Participant	Technology	Type of experiment(s)	Reference/Additional material
Visual	*INRIA*	Oscillating visual camera motions	Perception of traveled distance	Paper published at IEEE VR 2009 (Terziman et al., 2009)
Haptic	*McGILL*	Vibratory feedback of tiles	Perception of ground compliance	Paper in progress
Haptic	*UPMC*	Vibratory feedback of shoes	Perception of self-motion	Paper in progress
Auditory	*AAU*	Sound of footsteps	Identification of ground type (various grounds: snow, leaves, wood, etc)	Paper published at IEEE VR 2010 (Nordahl et al., 2010)
Auditory	*AAU*	Sound of footsteps	Perception of bumps and holes	Paper submitted at Digital Audio Effects Conference 2010 (Serafin et al., 2010)
Auditory	*AAU*	Sound of footsteps plus soundscape	Role of soundscape to enhance recognition	Paper published at SMC 2010 (Turchet et. Al, 2010a)
Auditory	*UNIVR+ INRIA*	Sound of contact with ground	Identification of ground type (aggregate vs. solid material, influence of temporal vs. spectral cues of sound)	Paper to be submitted at ICAD (Fontana et al., 2011)

Table 1: Overview of the studies on mono-modal ground cues conducted in the NIW Project

Modalities	Partners	Technology	Type of experiment(s)	Reference/Additional material
Haptic+Visual	INRIA+UPMC	Visual camera motion + Force in hands	Perception of self-motion (vection illusion)	Patent (Ouarti et al., 2009), Paper submitted at IEEE ToH (Ouarti et al., 2010)
Haptic+Visual	UPMC	Visual motion + Vibrations	Perception of self-motion	Paper in progress
Visual+Audio	AAU+INRIA	Visual camera motion + Footstep sounds	Perception of bumps and holes (with or without sensory conflict)	Paper published at ACM VRST 2010 (Turchet et al., 2010b)
Audio+Haptic	AAU+UPMC	Footstep sounds (ears/helmet)+ Vibratory shoes	Identification of ground type (various grounds: snow, leaves, wood, etc; with or without sensory conflict)	Paper published at Eurohaptics 2010 (Nordahl et al, 2010b) and (Serafin et al, 2010a) and HAID 2010 (Turchet et al, 2010c)
Audio+Haptic	UNIVR+INRIA	Footstep sounds (loudspeakers)+ Vibratory shoes	Illusory vibrotactile changes induced by variable acoustic energy in the low-frequency	Paper in preparation for ACM TAP (Papetti et al., 2010b)

Table 2: Overview of multi-modal studies conducted in the NIW Project

An overview of the different studies on multi-modal ground cues conducted so far in the NIW project is given in Table 2. Again, this table shows the variety of sensory combinations, and the large number of studies using various experimental protocols and complementary approaches.

Finally, INRIA has continued to evaluate a novel psychological aspect of virtual ground perception: the perception of postural affordances in VR (with visual feedback). Taken together, our results show quantitatively that the perception of affordances can be effective in virtual environments, and influenced by both environmental and subjective properties. Such a perceptual evaluation of affordances in VR could guide VE designers to improve their concepts and to better understand the effect of their designs on VE users.

Concerning the work package tasks:

- Task 5.1 has advanced a lot. By providing several experimental designs, some of which had already started during the first period, the consortium (in particular AAU) has validated a set of floor attributes conveying prominent and realistic perceptual cues.
- Task 5.2 has been substantially carried out. All unimodal experiments have been concluded, and their results reported on Deliverable 5.1 (see related table in this section).
- Task 5.3, chief in the context of the NIW experimental campaign, has brought highly satisfactory results. Besides, novel kinetic illusions in the form of subjective compliance adaptations have been discovered either working with the active tiles and the shoes. Further cross-modal experiments are foreseen to be performed during the third reporting period.
- Task 5.4 has produced significant experimental results during the second period by means of numerous collaborations and experiments (see related table in this section). Further evaluations will be performed using the final demonstrator, in particular by making use of all (i.e., visual, auditory, and tactile) modalities.

At the end of this reporting period, the consortium does not see deviations from the research plan as by that outlined in the Annex I of the project, particularly with respect to the result R5.1 [M2].

The resources used for this WP are in line with the project workplan as by the Annex I. Quantitative information on the use of human and equipment resources is reported in section c) on Explanation of the use of the resources.

WP6 – Iterative Integration and Presence Studies

The consortium has successfully made some integrations, resulting in insightful bi-modal experiments that are documented in Deliverable 5.1. Among the scenarios conceived for such experiments, AAU has performed some presence studies, mainly concerned with the role of soundscape design to provide a context and therefore enhance the recognition of the simulated footsteps.

At the end of this reporting period, the consortium does not see deviations from the research plan as by that outlined in the Annex I of the project, particularly with respect to the result R6.1 [M2].

The resources used for this WP are in line with the project workplan as by the Annex I. Quantitative information on the use of human and equipment resources is reported in section c) on Explanation of the use of the resources.

No deliverables were planned for this work package by the end of the second period.

WP7 – Dissemination, Collaboration and Exploitation

The consortium started a number of activities related to this work package already during the first reporting period. The second period has seen such activities to grow, culminating with the organization of a scientific conference in collaboration with an academic institution and a EU COST action. A detailed list of WP7 activities follows here below.

WP7.1 Dissemination

While the first year was employed for disseminating at conferences using especially the demonstration tool, during the second year more oral presentations have been given, including keynotes.

NIW personnel has participated, at various levels, to the following events:

- the iSon conference in Stockholm (March 2010)
- IEEE Virtual Reality 2010 in Boston (March 2010)
- IEEE Symposium on 3D User Interfaces (March 2010)
- IEEE Haptics Symposium in Boston (March 2010)
- the 7th Canadian Conference on Computer and Robot Vision in Ottawa (May 2010)
- the Sound and Music Computing Conference in Barcelona (July 2010)
- the Eurohaptic conference in Amsterdam (July 2010)
- the Digital Audio Effects Conference in Graz (September 2010)
- the HAID 10 Conference in Copenhagen (September 2010)
- the (EGVE/EuroVR) Joint Virtual Reality Conference in Fellbach (September 2010).

At the IEEE Haptics Symposium in Boston (March 2010), NIW project researchers won a Best Paper award for work undertaken in the project.

Stefania Serafin has been invited as keynote speaker to the Eurohaptic workshop on Haptic and Audio-Visual stimuli, where she was asked to present the activities of the NIW project.

An important dissemination occasion has been the 2010 IEEE VR Conference, in which NIW co-chaired a tutorial (March 20th, 2010) on "Walking through Virtual Worlds: One Virtual Step for Man, one Giant Leap for VR?". This tutorial was organized by A. Lécuyer (INRIA), F. Steinicke (University of Münster, Germany), Marc O. Ernst (MPI for Biological Cybernetics, Germany).

The same tutorial and chairs were invited also at the (EGVE/EuroVR) Joint Virtual Reality Conference.

Press releases have been appeared citing NIW-related products during this year:

- New Scientist, 13.04.2010
- MIT Technology Review, 28.04.2010
- Boing Boing, 29.04.2010
- Wired, 29.04.2010 (article by Bruce Sterling)
- KTIRIO (a Greek journal of Architecture), September 2010.

Finally, NIW has organized the HAID10 Conference in Copenhagen, in co-sponsorship with Aalborg University in Copenhagen and the EU Cost action IC-0601 on Sonic Interaction Design

(SID). The conference has been a complete success in terms of number of paper and poster submissions, as well as demo presentations. A morning session entitled "Walking and navigation interfaces", in which some results springing out from the NIW project have been presented, has been included in the conference. Furthermore, Prof. Vincent Hayward from UPMC has given a keynote lecture.

The list of publications in which the project support is acknowledged is maintained in the project website, `www.niwproject.eu`, under the menu item "NIW publications".

WP7.2 Collaboration with other projects and programmes

NIW has profitably collaborated with several other funded projects.

- Pietro Polotti and Carlo Drioli (both from UNIVR) have collaborated with personnel of the (now over) FP6-NEST-29085 EU project CLOSED, and performed research that has led to NIW-acknowledged conference papers, respectively presented at the 2010 AudioMostly and DAFx conferences.
- Federico Fontana has obtained, in October 2009, resources for a short-term mission from the (now over) MINET NoE, funded by FP6 under the NEST call "Measuring the Impossible". Thanks to these resources, a presentation of NIW has been given in Stockholm at the KTH School of Computer Science and Communication, Dept. of Speech Music and Hearing. In that occasion, a joint research activity with personnel from the same department has been initiated, finally leading to an iSon 2010 conference paper.
- AAU and INRIA have used funds from the COST action IC-0601 SID to support a research exchange of Luca Turchet from AAU to INRIA in May 2010.
- Pietro Polotti is also in EGGS, a national project coordinated by the Conservatorio di Musica (Italian school of music) "G. Tartini" in Trieste. Together with Maurizio Goina, they have set up Sonic Walking, an interactive installation for the perception of self-identity in walking by an auditory representation of one's action and movement through the space. The concept has encountered good public success at the Researchers' Night organized in Trieste on September 24, 2010 with the support of the STAR national project. Further information available at http://www.conservatorio.trieste.it and http://visualsonic.eu.
- UNIVR and AAU have used NIW funds synergistically with Aalborg University in Copenhagen and the EU COST action IC-0601 SID, to support the September 2010 HAID Conference in Copenhagen.

At the end of this reporting period, the consortium does not see deviations from the research plan as by that outlined in the Annex I of the project. Result R6.1 [M3] will be reported at the end of the third period.

The resources used for this WP are in line with the project workplan as by the Annex I. Quantitative information on the use of human and equipment resources is reported in section c) on Explanation of the use of the resources.

Deliverable 7.1 on the project web site, first published at the end of the first period, has been updated with web statistics accounting for the second period (see also the related section below). No further deliverables were planned for this work package at the end of the second period.

a) Deliverables and milestones tables

TABLE 1. DELIVERABLES[5]									
Del. no.	**Deliverable name**	**WP no.**	**Lead beneficiary**	**Nature**	**Dissemination level**	**Delivery date from Annex I (PM)**	**Delivered Yes/No**	**Actual / Forecast delivery date**	**Comments**
2.2	Reproducible haptic device prototypes for integration in multimodal contexts	2	UPMC	R+P	PU	24	Yes	Oct. 14, 2010	Deferred, for health problems of the leader of this deliverable
3.2	Sensor data fusion and gesture analysis tools	3	McGill University	R+P	PU	24	Yes		
4.2	Multimodal display of virtual attributes and floor events in walking interfaces	4	AAU	R+P	PU	24	Yes		
5.1	Assessment of multi-modal and pseudo-haptic ground cues from augmented floors	5	INRIA	R	PU	24	Yes		
7.1	NIW web infrastructure	7	UNIVR	O	PU	12, 24	Yes	13, 24	

a.1 Brief report on delivered prototypes

- Prototype 1 (lead McGill University): The sensor analysis and fusion infrastructure is integrated with a distributed floor interface installed at McGill University, as described in Deliverable 3.2. Data acquired from multiple sources (force data streamed from networked acquisition boxes in the floor, and motion capture data) is received by the server application, which analyses the data and provides streams, upon request, to client applications on the network. A complete description is provided in the deliverable.
- Prototype 2 (lead UPMC): subminiature actuators, described in Deliverable 2.2.

[5] For Security Projects the template for the deliverables list in Annex A1 has to be used.

- Prototype 3 (lead UNIVR and AAU): A pair of sandals provided with force sensing resistors, speakers, and haptic actuators made by UPMC. The sensors register a walking activity, and are connected to an Arduino USB-based acquisition board. The sensed data drive a set of physics-based synthesis models running in real time on a laptop under the Puredata platform. The speakers and actuators are connected to an RME Hammerfall 800 sound card, in its turn picking up the output from the real-time synthesis algorithms. In the AAU version, the shoes are tracked in a 3D space by using reflective markers (3 markers for each shoe) and an Optitrack motion capture system. The prototype is described in Deliverable 4.2.

Milestones

TABLE 2. MILESTONES							
Milestone no.	Milestone name	Work package no	Lead beneficiary	Delivery date from Annex I	Achieved Yes/No	Actual / Forecast achievement date	Comments
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	Yes		

b) Project management

Management tasks

The coordinator has administered the Community financial contribution regarding its allocation between beneficiaries and activities, in accordance with the project grant agreement and the decisions taken by the consortium. All the payments for the first period to the other beneficiaries have been done without unjustified delay.

The coordinator has kept the records and financial accounts for the second period. He is in condition to inform the Commission of the distribution of the Community financial contribution and the date of transfers to the beneficiaries, if and when required by the Commission.

The coordinator has reviewed the reports to verify consistency with the project tasks before transmitting them to the Commission. He constantly monitors the compliance by beneficiaries with their obligations under the project grant agreement.

The coordinator has ensured the maintenance of the consortium agreement. He has verified the overall production of legal, ethical, financial and administrative management for the second period.

Besides ensuring the technical and administrative management of the project, during the second period the Coordinator has intensively worked to consolidate the spirit of co-operation between participants that was sown in the first period. Consensus and open spirit has been constantly pursued, mainly by ensuring a constant circulation of information and young people among the participants.

Interaction with the Commission has been productive, through the mutual exchange of substantial information mainly communicated by email and, when strictly necessary, by phone calls. In particular, the coordinator recognizes the Project financial officer and her collaborators for their prompt and effective actions in occasion of the change of the coordinator, whose processing and status is reported below.

As already mentioned above in Section 2 (see section WP7.2 above on collaborations), NIW has proficiently collaborated with other funded projects: the EU Cost action IC-0601 on Sonic Interaction Design (SID), and the MINET NoE.

Federico Fontana required two amendments to the Grant agreement, whose motivations and status are reported below.

The project planning and status is in line with the scientific and administrative plan as foreseen by the Annex I for the end of the first period.

Delay in the submission of the Periodic report for the first period

Though in final shape immediately after the first review meeting (Paris, October 13, 2009), the first Periodic report could not be submitted to the Commission since a discussion started with the administration at McGill University, about the necessity for this participant to provide the Table 3.2 on financial data for the period. The case was definitely cleared out on January 15, 2010, when the Project officer confirmed that the Commission had included special clause 9 in the grant agreement, which exempts McGill from sending Form C's and related financial data in the periodic report.

The final periodic report for the first year was delivered on January 18, 2010.

Amendments to Grant agreement: no. 1

On February 4, 2010, the Project officer started the payment process. Somehow unbelievably, the same day Federico Fontana was communicated by the UNIVR administration that the NIW dedicated bank account coordinates were to be changed. A decision on how to proceed was taken together with the Project officer, also involving issues that led to the request of amendment no. 2 described below.

The coordinator launched a request for amendment of the bank account coordinates in the Grant agreement in March, 2010. The amendment was approved. On May 5th the payment was finalized by the Commission, using the new coordinates.

Amendments to Grant agreement: no. 2

On February 3, 2010, Federico Fontana was affiliated to the Department of Mathematics and Computer Science of the University of Udine, Italy, acronym UNIUD. Immediately after his affiliation, UNIVR and UNIUD sent respective official requests for opening a procedure of coordinator change. This procedure inevitably intertwined with the change of bank account at UNIVR, and the consequent (to that date unpredictable) delay in the payment, with the ultimate consequence of invalidating the request for obsolescence of the proposed date of change.

Immediately after receiving the payment of the first period, both UNIVR and UNIUD sent another request for opening a procedure of coordinator change. The respective requests agreed in the coordination change to take effect starting from July 1, 2010.

This time there were no formal obstacles to be worked around. The letter, along with the corpus of supporting documents also in electronic form, was filed on August 5, 2010.

After one last request for further clarifications, on August 26 the project contact person was notified that the amendment was ready to be launched for validation and signature. On Oct. 5 the Project officer communicated to new coordinator that the amendment had been accepted. The same day, the project contact person forwarded this information to all participants.

Consequences of the amendments for the consortium

The coordinator has made any possible effort to minimize discomfort to the consortium during the amending processes. The European participants have not lamented problems of any kind in consequence of the delay in the first payment.

The change of coordinator caused no problems of any type to the participants. While waiting for amendment no. 2 to enter into action, personnel working at the new coordinator implemented creative solutions to anticipate the financial funding necessary to carry on the project.

Project meetings

The reporting documentation for the second period has been prepared. It includes five deliverables (D2.2, D3.2, D4.2, D5.1, D7.1 update, all to be delivered at month 24), this periodic report (delivery date September 29, 2010), and two minutes from the project meetings that are listed below:

- University of Verona, Verona (IT), February 17-18, 2010.
- McGill University, Center for Intelligent Machines, Montreal (CA), June 9-10, 2010.

Personnel exchanges

The second period has seen an especially growing number of exchanges, especially of young personnel. Periods, objectives, and names of the persons as well as hosting and hosted participating institutions are constantly maintained in the project website, under the menu item `Misc`.

Changes in legal status

The project is coordinated by UNIUD with effect from July 1, 2010. All financial and administrative changes in the project status following by the amendment no. 2 can be retrieved by the Grant Preparation Forms compiled through NEF. The new Annex I, version 4.2 dated July 1, 2010, contains sufficient information for the reviewers concerning all significant changes in the management and scientific workplan following by this amendment.

Ms. Ella Bouquet has substituted the former Person in charge of administrative, legal and financial aspects in this project at UPMC. Her record is:

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Position in the organization: European Affairs Officer
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Fax : +33 1 44277484
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Project website

The project website `www.niwproject.eu` has proved to be a precious resource for the communication among partners as well as the public dissemination of foreground. Furthermore, it provides a selected area to subscribers, enabling to share official and draft material for internal use.

The consortium strongly believes in the dissemination of the project foreground through all possible communication means, including the internet. For this reason, all beneficiaries are making their best effort to keep the website up-to-date especially concerning the availability of multimedia documentation.

The status of the website is monitored through Deliverable 7.1, that is updated every 12 months. Unfortunately, at mid August the project web server has been object of a malicious attack from hackers. In consequence of this attack, the server has been disconnected from the internet until a complete disinfection and restoration of the data has been performed on it. The server was up again on mid September.

The web statistics that have been measured during the second reporting period are satisfactory, and confirm a constant worldwide interest in the project activity. Figures on number and type of web access can be retrieved from supplementary material accompanying Deliverable 7.1 on the web site. Drops in the number of visits occurred in August and September are consequence of the interruption of the web service caused by the hacking.

Use of foreground and dissemination activities

Direct use of project foreground has been discussed by participants during the second period, for possible exposition to the industry of the most interesting realizable outcomes of the project.

Technologies developed by UPMC have attracted interest from a major corporation, and proper intellectual property protection steps have been taken. A whole-sole distributed actuator with 700 hundred tactors has been developed and is now under construction. Two patents are being prepared in collaboration with the industrial relations office at UMPC.

Concerning dissemination, all events in which NIW has taken part are listed in Chapter 2 of this report.

c) Explanation of the use of the resources

Costs for personnel are limited to RTD and management activities. Involvement of personnel during the second reporting period can be evinced by the table below, reporting figures of person/months for each work package and for every beneficiary:

	wp1	Wp2	Wp3	wp4	wp5	Wp6	wp7
UNIUD	1.00	0	0	0	0	0	0.20
McGill University	0	5.00	13.00	2.00	2.00	0	0
AAU	0	0	3.00	5.00	7.00	3.00	2.00
INRIA	0.40	1.73	3.68	0.17	14.98	1.04	1.32
UPMC	0.00	18.50	0.00	4.00	1.00	1.00	2.00
UNIVR	3.80	2.00	5.00	2.00	2.00	2.00	1.00
TOTAL	**5.20**	**27.23**	**24.68**	**13.17**	**26.98**	**7.04**	**6.52**

Overall, the table gives account of an homogeneous development of the scientific work packages overall. At the end of the second period, UNIVR exposes a slight overhead of person-months in WP3 and WP4, that is motivated by research activity reasons.

Personnel costs for the same period are exposed on Tables 3.1-3.6 at the end of this section.

Major direct cost items

None of the participants claims either major cost items, or deviations in planned costs.

TABLE 3.1 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 1 UNIUD FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
1, 2, 3, 4, 5, 6, 7	Personnel costs	4.734,55 €	Salary of Research staff (Federico Fontana) July, August, September
1, 3, 4	Travel	579,07 €	Travelling to conference and scientific project meeting
1, 3, 4, 5	Equipment		
1, 3, 4, 5	Other direct costs		
TOTAL DIRECT COSTS		5.313,62 €	

TABLE 3.2 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 2 MCGILL UNIVERSITY FOR THE PERIOD(**)			
Work Package	Item description	Amount	Explanations
NOT DECLARED	NOT DECLARED	NOT DECLARED	NOT DECLARED
TOTAL DIRECT COSTS		**NOT DECLARED**	

(**) special clause 9 of the list dated 22/04/2009 (v.4) included in the Grant Agreement, exempting McGill from sending financial reports

TABLE 3.3 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 3 AAU FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
4,5,6	Personnel costs	48.228,31 €	Salary of one research assistant (Luca Turchet) for 12 months.
4,5,6	Travel costs	20.124,34 €	Travelling to conferences and project meetings
4,5,6	Other direct costs	8.496,83 €	Equipment and consumable items
TOTAL DIRECT COSTS		**76.849,48 €**	

TABLE 3.4 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 4 INRIA FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
1, 2,3,4,5,6,7	Personnel costs	78.469,66€	Salary of Research staff and PhD Students 23.32PM
1,5	Travel costs	6.848,38€	Mission expenses: project meetings and related research activities
TOTAL DIRECT COSTS		**85.318,04€**	

TABLE 3.5 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 5 UPMC FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
2,4,5,6,7	Personnel costs	94.938,91 €	Salary of research engineer, post-doc and interns
2,4,5,6,7	Consumables and other	24.016,82 €	Material and manufacturing expenses for prototypes
2,4,5,6,7	Travel	2.766,36 €	Conferences and project meetings
TOTAL DIRECT COSTS		**121.722,09 €**	

TABLE 3.6 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 6 UNIVR FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
1, 2, 3, 4, 5, 6, 7	Personnel costs	48.098,52 €	Salaries of Papetti Stefano for 6 p/m, De Sena Antonio for 3 p/m, Polotti Pietro for 4 p/m, Civolani Marco for 2 p/m, Morreale Fabio for 1 p/m. Salaries of UNIVR own staff: Federico Fontana 0.8 p/m and Cesari Paola for 1 p/m
1, 3, 4	Travel	5.011,54 €	Mission expenses: project meetings and related research activities
1, 3, 4, 5	Equipment	3.336,42 €	Depreciations for the 2nd period and other durable purchases
1, 3, 4, 5	Other direct costs	1.183,11 €	Consumable purchases and other expenses
TOTAL DIRECT COSTS		**57.629,59 €**	

d) Financial statements – Form C and Summary financial report

All Form C's and related Summary financial report come along with a paper copy of the final version of this Periodic report, furthermore in the form of supplementary material that can be found on the web site along with the final PDF version of this report.

e) Certificates

List of Certificates which are due for this period, in accordance with Article II.4.4 of the Grant Agreement.

Beneficiary	Organisation short name	Certificate on the financial statements provided?	Any useful comment, in particular if a certificate is not provided
1	UNIUD	No	Expenditure threshold not reached
2	McGill University	No	Not to be taken into consideration (Art. 7.2 of GA)
3	AAU	No	Expenditure threshold not reached
4	INRIA	No	Expenditure threshold not reached
5	UPMC	No	Expenditure threshold not reached
6	UNIVR	No	Expenditure threshold not reached