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: May 30, 2008

Periodic report: **1st √ 2nd ☐ 3rd ☐**

Period covered: **from October 1st, 2008**

to September 30th, 2009

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

Federico Fontana (Dr.) **Università di Verona**

Tel: **+39 045 802 7032**

Fax: **+ 39 045 802 7068**

E-mail: **federico.fontana@univr.it**

Project website[2] address: **www.niwproject.eu**

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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: ....

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.

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

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 will be assessed from a user's perceptual standpoint. For this reason the project will also explore 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 will 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 UNIVR, McGill University, AAU, and UPMC, has moved mainly along the design and engineering of floor- and shoe-based interface components, capable of acquiring foot gesture information as well as providing auditory and haptic feedback at ground level. While the work made over the tiles, performed mainly at McGill University, could rely on some previously existing knowledge and early prototyping activity at least concerning individual tile designs, conversely the shoe-based interface started substantially from scratch.

As results of a fortunate and well managed research track, work on tiles at McGill University has proceeded with integration of the prototypes into a multimodal sensing/actuated floor, in which several tiles are networked together. Integrated work on the multimodal synthesis of audio, tactile, and visual responses from interaction on foot with virtual grounds enabled by active tiles has been performed.

Research activity made on the shoes (mainly a UNIVR, AAU, and UPMC topic) had to face a number of unsolved questions. To cite some: the sensors choice and positioning, the design and engineering of vibrotactile actuators, the design of the auditory display, and the communication between the interface components. On top of these questions, unavoidable issues descending from the wearability and mobility of these components had to be managed, such as ways to make it minimally obtrusive and to supply energy to the system. All such aspects have been considered, and solutions have been achieved at various levels.

Most notably among these solutions, at UMPC design work has been directed at producing prototypes for electromagnetic actuators sufficiently small to be embedded in force feedback shoes that can be worn by participants in virtual-reality scenarios. Also, force-feedback shoe concepts have been investigated as well as a distributed tactile sole concept with an array of 800 tactile sites. Put together these system provide haptically enabled shoe designs with combined high temporal and spatial resolution capability.

Besides physical design, UNIVR and AAU have made research on software models for the synthesis of feedback in real time. This activity has tackled both the theoretical development of existing physical models, and the design of simpler parametric models for the generation of walking sounds over different materials, resulting in a consistent palette of diverse feedbacks.

UNIVR and AAU have also initiated a research activity on the design and engineering of a sensing pavement, based on an array of 1-D accelerometers.

In parallel with the aforementioned tasks, experiments on the use of the visual feedback for the improvement and control of human navigation in virtual worlds have immediately been started at INRIA by making use of existing facilities and expertise: novel techniques for the simulation of walking sensations and ground properties have been tested; a visuo-haptic technique for improving self-walking in a virtual world has been pointed out; finally, a novel interaction paradigm enabling navigation in infinite virtual worlds on a finite enclosure has been resented.

Further experimental research focusing on foundational aspects of perception at different levels has been started: at McGill University, aimed at psychologically assessing and explaining compliance illusions via a rigid, vibrating surface; at INRIA, about perception of postural affordances in visual virtual environments.

1.3 Main results achieved since the beginning of the project

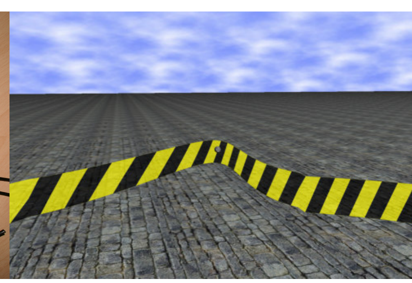
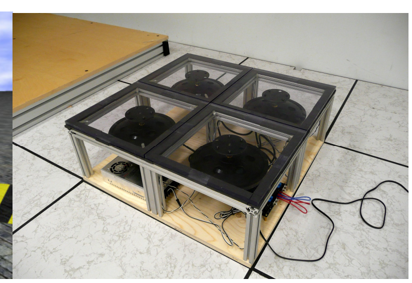
The work made on the active tiles has led to rich immersive multimodal simulation of brittle ground surface materials. Users can walk over a sensing floor meanwhile providing audio, tactile, and visual responses from interaction on foot with virtual brittle ground surface materials.

UPMC has produced two types of electromagnetic actuators, one with a small form factor (13 X 25 mm) that can be embedded in off the self shoes and that can produce 3 to 5 G of acceleration from 60 to 10,000 Hz and the other, larger and more powerful (15 x 85 mm) that can produce up to 10 G of acceleration for a bandwidth of 30 to 10,000 Hz. Using this equipment, a new perceptual phenomenon involving the stimulation of the feet by specific vibration patterns was discovered and early experiments piloted.

UNIVR and AAU have produced a number of methods for the real time synthesis of feedback. Such methods have found application in sonic (i.e. loudspeaker enabled) shoe prototypes using different sensing devices and strategies, in which the UPMC active insoles will be integrated in the short term.

An early prototype of sensing pavement has been engineered jointly by UNIVR and AAU, based on arrays of accelerometers. Though promising in terms of accuracy of positional and foot gesture detection, its responsiveness must be evolved toward achieving the real time, without sacrificing on detection accuracy.

INRIA has performed Virtual Reality experiments, evaluating: perceived travelled distance from camera motions techniques; pseudo-haptic simulations of slopes for the visual display of virtual ground shapes; sensation of self-motion by haptic motion techniques; the performance of a novel “Magic Barrier Tape” in comparison to existing techniques enabling infinite walking; perception of postural affordances at ground level.

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 be capable of delivering a wide variety of haptic and auditory signals for use in sports training and rehabilitation.

At the end of the first reporting period, there is strong expectation that validated versions of at least some of the designs developed during this period will translate into a final demonstrator, concretely pointing to one or more application scenarios such as those listed above. The conclusive form of this demonstrator will obviously depend on results from the same validations, most of which are scheduled for the next period.

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 first year are summarized as "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".

Together, the above objectives have led to the milestone no. 1, scheduled for the end of this period: "The design, engineering, and prototyping of floor interaction technologies."

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) generated novel physical engineering of actuated floors and shoes;
b) designed and tested sensor-based analysis techniques for the acquisition of exerted forces over floor tiles and shoes, and the localization of walking activity over pavements;
c) incremented results in physically-based sound models and their application to walking sounds, as well as in the parametric modelling of floor-based interaction with diverse ground attributes;
d) designed and implemented novel techniques based on visual and haptic feedback for the simulation of ground properties, the improvement of walking sensations, the control of human navigation in virtual worlds;
e) initiated the experimental campaign, by starting the evaluation of the techniques summarized in d), and by checking the validity of fundamental concepts in the psychology of perception through walking experiments.

Detailed descriptions of such achievements follow for each work package:

WP 2 – Haptic Engineering

This work package has moved along two lines: the realization of active floors, and the design of actuated shoe insoles.

The former line has moved its steps from an early design developed at McGill University, which has been further developed during this year into an optimized redesign of a vibrotactile display integrated in a rigid floor tile. This design is currently being analyzed in rigorous physical terms by the same beneficiary, concerning in particular its motion transmission properties from the actuator to the tile surface, and its mechanical response to forces exerted by the foot.

For its novel concept, the latter line had to face largely unknown design issues and challenging engineering aspects since the very beginning, with a notable contingent risk that was clear from the beginning of the project, and, for this reason, thoroughly documented in the Annex I. Despite the poor prior art, the consortium has been able to honour the work planned for the first period by working out a first design and early prototyping of shoe insoles, capable of providing haptic feedback.

In fact, the haptic design effort at UPMC has produced two types of electromagnetic actuators, one with a small form factor (13x25 mm) that can be embedded in off the self shoes and that can produce 3 to 5 G of acceleration from 60 to 10,000 Hz and the other, larger and more powerful (15 x 85 mm), that can produce up to 10 G of acceleration for a bandwidth of 30 to 10,000 Hz. Using this equipment, a new perceptual phenomenon involving the stimulation of the feet by specific vibration patterns was discovered and early experiments piloted.

- Tasks 2.1 and 2.2 can be considered completed.
- Task 2.3 has achieved an overall sufficient maturity level thanks to the feedback coming from initial iterations with WP5, to date yet not formalized by rigorous experiments. More precisely, this level is relatively advanced concerning the tile prototype, conversely it has to be moved ahead in the case of the shoes, for which few informal experiences have been done limitedly to their auditory feedback.
- Task 2.4 will proceed in connection with integration activities planned for the next periods.

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 R2.1 [M1].

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

As for dependencies with the previous work package, and in accordance with the project work plan, the activity for the first year has mainly consisted in the integration of affordable sensing technologies into innovative floor and shoe components. In addition, issues related to the analysis and understanding of the sensed data have been dealt with already at this stage in connection with work made using the tiles: to date, the platform whose sensing components perform most reliably.

The consortium has moved along three research lines, each synthetically described below.

a) Design and implementation of a tile-based multimodal floor interface, whose sensing component is based on force sensors.
b) Design and implementation of sensing shoes, currently enabled by force sensing resistors.
c) Design and implementation of a sensing pavement through an array of accelerometers.

Components a), b), and c) exhibit a level of development proportional to their position in the above list.

Design a) is largely integrated in an immersive environment, and is already object of experimentation at McGill University. It consists of an array of sensing and electronically augmented floor tiles in an immersive, CAVE-like virtual environment simulator. The involved interaction techniques utilize intrinsic force sensing for contact localization, via a distributed array of floor tiles. A study of the man-machine interface loop is in due course, involving issues of physical design and control of the system due to a mathematical abstraction of its components, in the fashion of classical control theory.

Design b) has started almost from scratch at project beginning, by testing early mock-ups based on rubber clogs and sandals mounting force sensing resistors and microphones located in different places. The design has progressively evolved into more stable and reliable prototypes, now based on sneakers provided with couples of force sensing resistors (one for the toe, one for the heel) and small trackballs (one at the center of the sole), as well as shoes mounting contact microphones detecting the ground reaction force during walking.

Design c) is largely based on results obtained during a previous European project, called TAI-CHI. This design makes use of 1D accelerometers, specific for the detection of surface effects of in-solid wave propagation. As shown by the TAI-CHI project, in-solid acoustics is a complex and tangled subject. By forming an array with a set of such accelerometers, and positioning it over a pavement, localization and "footprint detection" tasks have been experimented obtaining encouraging results in relatively short time. Key during the advancement of this research will be the finding of methods and processing algorithms capable of extracting sufficiently accurate localization and footprint information within or close to the real time, without requiring exaggerate computational power. UNIVR and AAU are currently being involved in this task before attempting an integration of the current array design with the rest of the NIW prototypes.

Concerning the work package tasks:

- Task 3.1 has required much work concerning the design, material construction, and early refinement of the physical sensing devices. This work has been occasionally delayed by apparently unavoidable latencies in the acquisition of technology and material from manufacturers and resellers, who often claim delivery times that in practice are hardly respected by most of them. While being on average at a very good stage, once getting into the details of the above listed points a), b), and c), it implies different levels of achievement of Task 3.2, as described here below.
- Task 3.2, key to the creation of a successful walking perception and action loop, must create strong dependencies with results from WP4. As we told in the above point, the current strength of such dependencies has been influenced by the completion time of the different components forming the task 3.1—refer to the list above: a) concerning the tiles, task 3.2 has been completed to a very large extent; b) concerning the shoes, the task may have been linked more tightly to the available results of WP4 on feedback synthesis; c) concerning the sensing pavement, research work on real-time methods and algorithms for localization and footprint detection is still needed before linking the prototype to results from other WP's. In conclusion, in spite of a slight delay of b) and c), the state of advancement of Task 3.2 overall satisfies the consortium. The research direction is in line with the annex plan, and there is full expectation to evolve the state of components b) and c) along this line without making corrective actions.

- Task 3.3 will be object of research during the remaining periods. Yet, tangible results have been already achieved with the tile prototypes. In particular, a general-purpose control strategy for the simulation of textured response from granular ground materials, such as sand or soil, is currently researched at McGill University. It will be reported in the future.
- Task 3.4 will be object of research during the remaining periods.

At the end of this reporting period, in the consortium opinion there is no major discrepancy with the research plan described in the Annex I, particularly with respect to the result R3.1 [M1]. Some more advancement was expected concerning the issue of data analysis for the reasons explained above. The consortium expects to fill this minor gap in the advancement by using the same resources and methodologies implemented so far. On the contrary, there are components (i.e. the tiles) whose state of advancement is anticipating the schedule of this reporting period. This result can have merit to counterbalance the relatively minor advancement of other components in this WP.

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

As the integration between modalities will mostly touch the second and especially third period, the main achievements of WP4 will be listed separately for each modality. McGill University's active tiles represent an exception of an already successful integration merging auditory, haptic, and visual feedback.

WP4.1 Auditory feedback

Auditory feedback modeling has proceeded along several lines, in an effort to meet both medium and long term research issues, and the need of having usable new models, ready for exploitation during the second and third period of the project.

Medium- and long term-oriented research has carried on traditionally hard investigations in the field of physical modeling, with a focus on the synthesis of impact, friction, and liquid sounds. These investigations are part of the theoretical research made at UNIVR and AAU. They present challenging questions that make their simulation in the discrete time especially compelling:

- the discrete-time simulation of nonlinear impacts, although forming a fundamental building block in the physically-based synthesis paradigm, still presents unsolved issues of stability and accuracy;
- friction models, by continuously making transitions among different dynamic regimes, have a multifaceted behavior that not always corresponds to satisfactory sounds. In this sense, one of the common research questions concerning friction models is about how to improve their sonic quality;
- liquid sounds have been traditionally under-explored, due to the inherent difficulty to wrap up the countless interactions occurring between liquid particles, also in presence of a macroscopic resonating body, into a coherent simulation preserving the physical (hence sonic) accuracy of the phenomenon.

The consortium has given an answer to some of these questions respectively i) by providing novel results on the simulation accuracy of nonlinear impacts, that noticeably improve their performance especially in contexts where the propagation of errors make them unrealistic and prone to instabilities (for instance in rolling or densely repeated bouncing events); ii) by complementing

state-of-the-art friction models with fractal noise, in an effort to improve the quality of crackling sounds; iii) by developing an efficient model for the synthesis of liquid sounds through physical interaction of the drops forming the liquid mass with a large resonant body.
The consortium believes that physical modeling is prospectively the most promising paradigm for use in walking interfaces and, in general, wherever the synthesis of ecological feedback is required. Concerning the field of walking interactions, accurate and reliable impact and friction models are considered crucial for the virtual representation of solid surfaces, upon which a foot can exert a vertical as well as horizontal force. Liquid sound synthesis has potential to be applied to the interaction with wet floors.

On the other hand, the need for more flexible models has clearly emerged once a systematic series of informal tests was performed, in an attempt to fit the physics-based models by tuning their parameters in order to obtain walking sounds. Such tests, made by UNIVR and AAU over the SDT library, have shown that this fitting is prospectively satisfactory limitedly to some types of aggregate materials (see below). For these materials, the related SDT real time software has been evolved and re-implemented to efficiently interact with the foot-based interfaces and methods, available to date through WP2 and WP3. Conversely, for other floor materials, in particular when the floor is homogeneous, the use of physical models is far from being obvious.

For this reason the consortium (particularly UNIVR and AAU) has focused its attention to alternative, so-called physically informed parametric models that promise to broaden the available sonic palette substantially in the short term. Although this research has started late on the first period, some preliminary but already promising results have come out leading, along with the physical models in use, to the following summary of currently available sounds:

Floor type	Modeling paradigm
Snow	Physical & Parametric
Iced snow	Parametric
Dry leaves	Parametric
Wood	Physical & Parametric
Creaking wood	Physical
Metal	Physical & Parametric
Gravel	Physical & Parametric
Sand	Parametric
Forest underbrush	Parametric
Dirt plus pebbles	Parametric
High grass	Parametric

A general consideration, which is substantiated by informal user experiences that took place while demonstrating the tile and shoe prototypes at projects meetings and during workshops and conferences, is that when the auditory ecological augmentation displays virtual solid floors upon physical solid floors, then a sort of “transparent” experience takes place unless the loudness is turned up, hence pushing, in this case, the auditory experience toward unnatural levels. This consideration becomes especially true when the environment is noisy: under such a condition, users hardly hear a virtual layer, accounting for a solid and homogeneous material, that is superimposed to a real floor: this happens, for instance, during a public demo made upon a conventional homogenous floor such as those commonly found in inner spaces.

Similar considerations are also expected to hold for the tactile modality: even if accurate cues of homogeneous material can be provided to users walking on a solid artificial floor, the question is whether the ecological display of these cues will translate into helpful information to these users.

For this reason, to date the virtual display of aggregate floors is considered much more promising in terms of potential impact on perception in many everyday situations, not only for their distinct character when they are displayed over an homogeneous floor, but also because it is inherently easier to superimpose an aggregate ground layer over a solid, regular floor, rather than virtually compensate an irregular ground to make it feel homogeneous.

WP4.2 Haptic feedback

This part of WP4 is totally dependent on results achieved in WP2. It descends that achievements on haptic feedback exhibit different level, depending on the interface components:

- active tiles provide a realistic palette of ground-dependent interactive feedback through the haptic channel. This palette includes a range of brittle materials, such as snow and gravel. This feedback will be object of more speculative research in the consortium, aiming at investigating the existence of illusory effects related to the interactive generation of vibrotactile cues;
- augmented shoes still need to be integrated with responsive insoles. The reasons why the shoe-based vibrotactile technology is ready but not yet integrated has been explained in the Section reporting about WP2, furthermore accounted for by the Annex I. Fortunately, the repeatable experience the consortium has already matured by making research over the tiles will turn extremely useful, to integrate the responsive insoles into the existing shoe-based interface.

WP4.3 Visual feedback

As opposed to the auditory and haptic modality, visual feedback relies on a more mature scientific background. Thanks to this different level of maturity, the consortium (with a polarization toward INRIA, see below and appendix) has already started to make experiments in which walking activities are analyzed and controlled when users navigate in virtual environments displaying boundaries and obstacles, as well as affordances at floor level. In parallel, an advanced interactive projection system has been implemented at McGill University for the projection of snowy and iced floors.

INRIA has developed:

- novel techniques for the simulation of walking sensations and ground properties using visual feedback. These techniques use subjective camera motions for simulating walking up and down in virtual worlds (see Marchal et al. in the Appendix). These techniques promise to result in novel pseudo-haptic paradigms with expected impact to WP5;
- a novel visuo-haptic technique for the improvement of sensation of self-motion when walking and navigating in virtual worlds. This technique, called “haptic motion”, applies to situations when the user is standing, and thus not walking, in the real physical workspace. “Haptic motion” makes use of a force feedback that is sent to the hands of the user and synchronized with visual feedback (and with acceleration of user’s virtual vehicle in the VE) to generate an improved sensation of self-motion (see Ouarti et al. in the Appendix);
- a novel interaction paradigm that enables users to navigate in infinite virtual worlds even though walking in a restricted-size workspace in the real VR setup. The technique is called “Magic Barrier Tape” as it uses a virtual (visual) barrier tape delimitating the physical

walking workspace in the VE. The user can interact with "Magic Barrier Tape" so to navigate at will in the virtual world (see Cirio et al. in the Appendix).

Concerning the projection system, see below Section WP4.4 on integration.

WP4.4 Integration

The consortium has demonstrated a product that already shows a strong level of integration and overall coherency. In fact, McGill University has implemented work on multimodal synthesis of audio, tactile, and visual responses from interaction on foot with virtual brittle ground surface materials.

Concerning the work package tasks:

- Task 4.1 is completed concerning sound and vision. Of course, both channels will receive substantial feedback from WP5 during the next periods, in a way to further improve the quality of the synthesis for these modalities. Concerning the haptic modality, satisfactory results exist for the active floor technology. In parallel, a great expectation exists for the haptic insoles: similarly to what has been done for the tiles, as soon as possible they will be coupled with the synthesis algorithms available to date for the sonic shoe prototypes, to understand the potential, limits, and opportunities that are currently offered by the resulting foot interface design. Overall, the task in on track with respect to the roadmap foreseen by Annex I.
- Task 4.2 has been object of intensive research during this period. The broad sonic palette of ground materials and corresponding wide range of synthesis methods provides the necessary flexibility for a successful connection with the sensor-to-control maps being developed as part of Task 3.2, as well as for the production of multimodal stimuli for current and future experiments in WP5. This task is mostly completed concerning the tile-based interface. The potential of the NIW synthesis methods in providing tactile cues of different materials through the shoe-based interface has to be checked out as soon as possible, by following the fast research roadmap outlined above.
- Task 4.3, that is mainly technical, has gained success in ensuring efficient, low latency communication between the diverse physical components forming both the tile- and shoe-based interface. In the former case there is an already effective communication among synthesis modules in different modalities. The consortium does not envision short-term major obstacles in this sense, when the active insoles will be integrated in the shoe-based interface. 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 future.

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 R4.1 [M1].

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 prominent activity by INRIA and McGill University, respectively concerning experiments on recently developed feedback techniques for WP4 and by investigating on the perception of floors of different nature.

INRIA has evaluated:

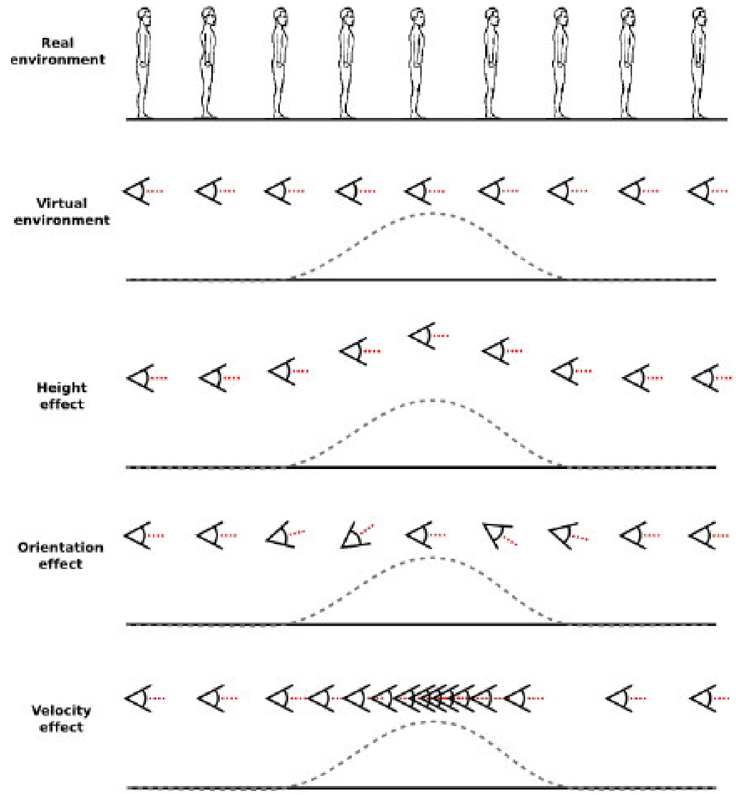
- the camera motions technique in terms of perception of travelled distance (see Terziman et al. in the Appendix);
- the pseudo-haptic simulation of slope for the simulation of simple shapes (bumps and holes) located on virtual ground (see Marchal et al. in the Appendix);
- the haptic motion technique in terms of sensation of self-motion in VR (see Ouarti et al. in the Appendix);
- the “Magic Barrier Tape”, in comparison to other classical techniques enabling infinite walking in VR in terms of performance and preference (see Cirio et al. in the Appendix);
- a novel psychological aspect of virtual ground perception: the perception of postural affordances in VR with visual feedback (see Regia-Corte et al. in the Appendix).

McGill University is currently investigating on the design and perceptual validation of a compliance illusion via a rigid, vibrating surface. Results from this investigation will be reported in the future.

As WP5 does not plan any deliverable until month 24 (end of the second period), an extension is included here below, containing more detailed information about the activities made so far in this work package, through notices drawn by related publication activity.

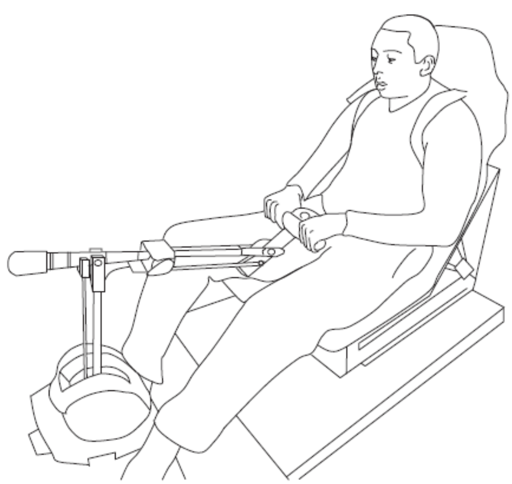
a) Simulation of Walking Up and Down in Virtual Worlds: Novel Interaction Techniques Based on Visual Feedback [Marchal et al., *submitted*]

We have developed novel interactive techniques to simulate the sensation of walking up and down in virtual worlds based on visual feedback. Our method consists in modifying the motion of the virtual subjective camera as function of the variations in the height of the ground. Three effects are proposed: (1) a straightforward modification of the camera’s height, (2) a modification of the camera’s navigation velocity, (3) a modification of the camera’s orientation. They were tested in an immersive virtual reality setup in which the user is really walking and in a desktop configuration where the user is seated and controls input devices. Experimental results show that our visual techniques are very efficient for the simulation of two canonical shapes: bumps and holes located on the ground. Interestingly, a strong ”orientation-height illusion” is found, as changes in viewing orientation produce perception of height changes (although camera’s height remains strictly the same in this case). Thus, our visual effects could be applied to simulate walking on uneven grounds in various virtual reality applications such as urban or architectural project reviews or training, as well as in videogames.



Principle of the three different effects: the user is walking on a flat environment while the virtual environment is composed of bump. The camera motion is modified in three different ways: height variation (the camera moves parallel to the slope), orientation variation (the camera is oriented following the curvature of the slope), velocity variation (the camera velocity decreases as the user is going up a virtual bump and increases as the user is going down with a run up at the end of the bump).

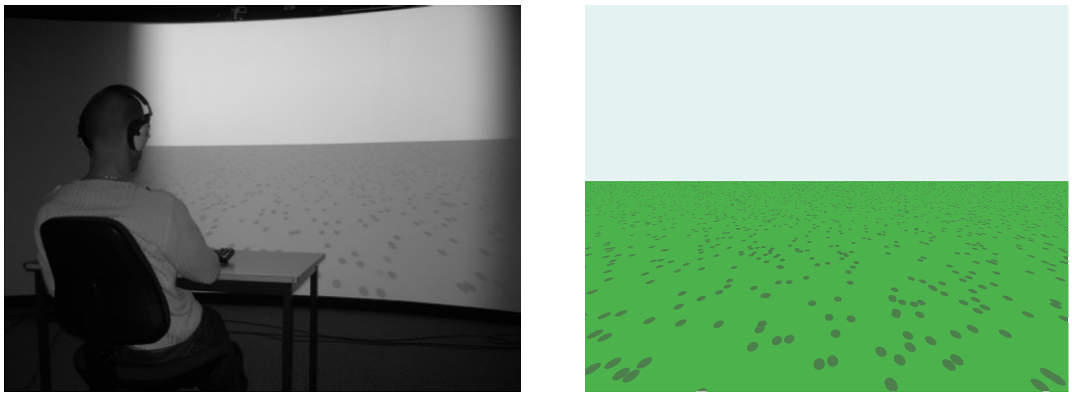
b) Haptic motion: Improving Sensation of Self-Motion with Force Feedback [Ouarti et al., *submitted*]



Experimental Apparatus used in [Ouarti et al., *submitted*]

We have developed a new visuo-haptic method for user interaction with virtual worlds called haptic motion. It allows the user to feel an important sensation of displacement of his body by applying a force in his hands. This force is coherently produced together with a visual 3D environment. We have designed two different experiments that evaluated haptic motion. Results demonstrate that haptic motion significantly improves the sensation of self-motion and the realism of the virtual experience.

c) Influence of Camera Motions on Perception of Traveled Distance in Virtual Environments? [Terziman et al., 2009]

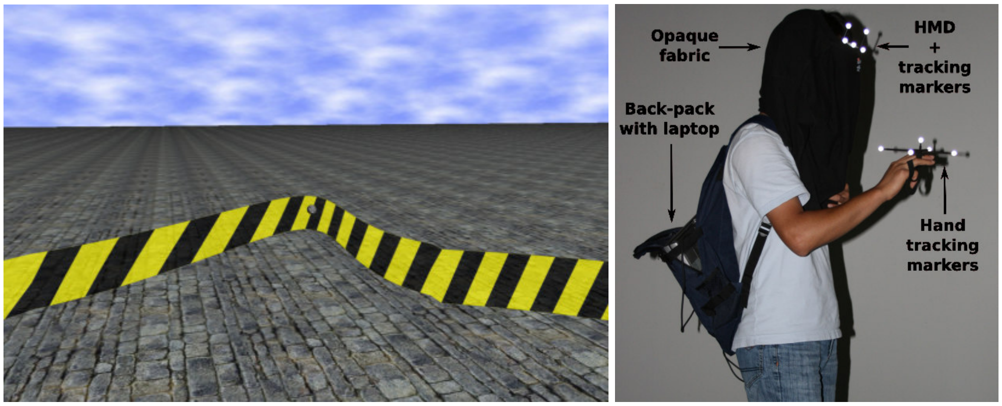


Experimental apparatus used in [Terziman et al., 2009]

We have conducted one experiment to evaluate the influence of oscillating camera motions on the perception of traveled distances in virtual environments. In the experiment, participants viewed visual projections of translations along straight paths. They were then asked to reproduce the traveled distance during a navigation phase using keyboard keys. Each participant had to complete the task (1) with linear camera motion, and (2) with oscillating camera motion that simulates the visual flow generated by natural human walking. Taken together, our results suggest that oscillating camera motions allow a more accurate distance reproduction for short traveled distances.

d) Magic Barrier Tape : a Novel Metaphor for Infinite Navigation in Virtual Worlds with a Restricted Walking Workspace [Cirio et al., 2009]

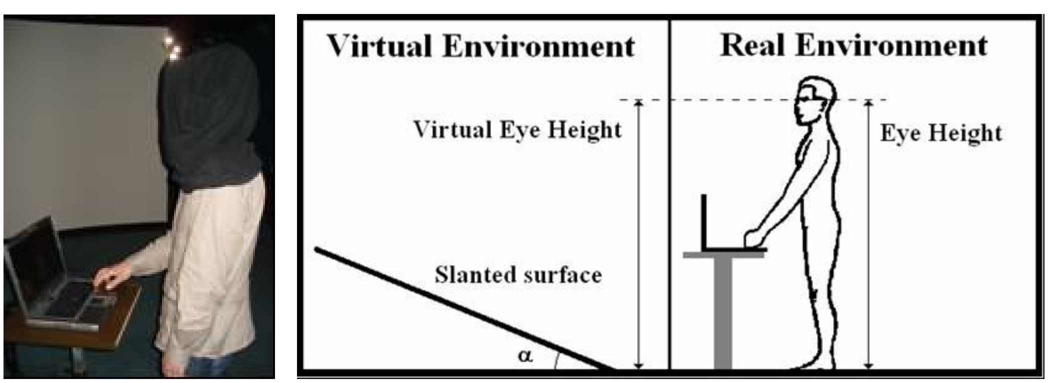
In most virtual reality simulations the virtual world is larger than the real walking workspace. The workspace is often bounded by the tracking area or the display devices. We have developed a novel interaction metaphor called the Magic Barrier Tape, which allows a user to navigate in a potentially infinite virtual scene while confined to a restricted walking workspace. The technique relies on the barrier tape metaphor and its “do not cross” implicit message by surrounding the walking workspace with a virtual barrier tape in the scene. Therefore, the technique informs the user about the boundaries of his walking workspace, providing an environment safe from collisions and tracking problems. It uses a hybrid position/rate control mechanism to enable real walking inside the workspace and rate control navigation to move beyond the boundaries by “pushing” on the virtual barrier tape. It provides an easy, intuitive and safe way of navigating in a virtual scene, without break of immersion. Two experiments were conducted in order to evaluate the Magic Barrier Tape by comparing it to two state-of-the-art navigation techniques. Results showed that the Magic Barrier Tape was faster and more appreciated than the compared techniques, while being more natural and less tiring. Considering it can be used in many different virtual reality systems, it is an interaction metaphor suitable for many different applications, from the entertainment field to training simulations scenarios.



(Left) User "pushes" on the Magic Barrier Tape – (right) Experimental conditions for the subjects participating in the evaluation

e) Can You Stand on Virtual Grounds? A Study on Postural Affordances in Virtual Reality [Regia-Corte et al., *submitted*]

The concept of affordance, introduced by the psychologist James Gibson, can be defined as the functional utility of an object, a surface or an event. The purpose of this study was to evaluate the perception of affordances in virtual environments (VE). In order to test this perception, we considered the affordances for standing on a virtual slanted surface. The participants were asked to judge whether a virtual slanted surface supported upright stance. Two dimensions were considered for this perception: (a) the properties of the *virtual environment* and (b) the properties of the *avatar* in the VE. The first dimension (environment) was investigated in a first experiment by manipulating the texture of the slanted surface (Wooden texture vs. Ice texture). The second dimension (avatar) was investigated in a second experiment by manipulating the participant's virtual eye height.
Regarding Experiment 1, results showed an effect of the texture: the perceptual boundary (or critical angle) with the Ice texture was significantly lower than with the Wooden texture. Regarding Experiment 2, results showed an effect of virtual eye height manipulations: participants overestimated their ability to stand on the slanted surface when their virtual eye height was reduced. Taken together, these results reveal that perception of affordances for standing on a slanted surface in virtual reality is possible and comparable to previous studies conducted in real environments. More interestingly, it appears that virtual information about friction can be detected and used in VE and that the virtual eye height seems to be an important factor involved in the perception of affordances for standing on virtual grounds.



Experimental apparatus in [Regia-Corte et al., *submitted*]

Tasks:

- Task 5.1 is continuously fertilized by experimental design ideas coming from the beneficiaries, but it has to be focused into a stable and systematic set of experiments. This activity will be object of a brainstorming that will take place before, along with, and after the review, based on the currently developed set of interfaces and analysis/synthesis techniques.
- Task 5.2 has started concerning the experimentation using the visual modality. Ideas and components exist to start unimodal auditory and haptic experiments immediately
- Task 5.3 relies an a set of ideas that is gradually focusing on specific experimental tasks using the NIW components. Cross-modal and pseudo-haptic experiments will start during the next period.
- Task 5.4 is also maturing ideas, that will find experimental applicability later on the second period and along the third period, based on evolved multimodal floor interface available at that time.

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

Starting at the beginning of the second period.

WP7 – Dissemination, Collaboration and Exploitation

Although this work package officially starts at the beginning of the second period, the consortium has already put the related activities in action. This anticipation has been warmly fostered by the European Commission itself, especially through diffusion of calls for participation to events such as FET09, to which NIW has participated with success. In consequence of this early start, available demo material has been brought also to other scientific fora. A more detailed list of WP7 activities follows here below.

WP7.1 Dissemination

The project during the first period has mainly generated novel interface prototypes. For this reason its foreground has been used especially for demos, that have been positively released at some of the most important scientific events worldwide, in particular:

- the FET09 conference "Science beyond Fiction" in Prague (March 2009), where the project prototypes have been object of a press release from the BBC;
- the World Haptics symposium in Salt Lake City (April 2009);
- the ACM SIGGRAPH 2009 in New Orleans (August 2009);
- the Audio Mostly conference in Glasgow (September 2009);
- the HAID 09 Conference in Dresden (September 2009).

An important dissemination occasion has been the 2009 Sound and Music Computing (SMC'09) Summer School in Porto (July 2009), where Stefania Serafin (AAU) and Federico Fontana (UNIVR) have tutored a group of students in a project entitled Natural Interactive Walking in Porto, selected among several project proposals under the main theme of the summer school, "Sounds of Porto". This experience has provided preliminary, precious feedback about the quality and performance of the prototypes available in Porto, coming from students and young researchers active in diverse disciplines under the umbrella of the sound and music computing field. At the same conference, the augmented shoe prototype has been demonstrated and discussed at the special session organized by Karmen Franinovic of the EU Cost action IC-0601 on Sonic Interaction Design (SID).

The list of publications in which the project support is acknowledged is maintained in the project website, `www.niwproject.eu`.

WP7.2 Collaboration with other projects and programmes

NIW has profitably collaborated with several other funded projects.

- The partial overlap with the FP6-NEST-29085 EU project CLOSED in terms of resources and scientific purposes has made possible to organize some joint meetings (in particular the NIW-CLOSED afternoon in Venice on March 4, 2009) and exhibits (such as the desks nearby at the FET09 conference), which turned to be particularly useful to exchange experiences as well as implement a smooth migration of some products made by UNIVR for that project to the NIW activities.
- Stefano Papetti and Federico Fontana have obtained, respectively in December 2008 and October 2009, resources for a short-term mission from the MINET NoE, funded by FP6 under the NEST call “Measuring the Impossible”. This network provides an especially fertile ground for the design of novel measurement techniques and experiments, that is vital for NIW while entering the core period of experimental evaluations.

WP7.3 Exploitation

INRIA has filed a N. Ouarti, A. Lécuyer, A. Berthoz, « PROCEDE DE SIMULATION DE MOUVEMENTS PROPRES PAR RETOUR HAPTIQUE ET DISPOSITIF METTANT EN OEUVRE LE PROCEDE », French Patent, N° 09 56406, 17/09/2009.

Some resources have been used for this WP, that are not in line with the project workplan. This use has been already motivated in the beginning of this section, as by an earlier start of the dissemination activities as opposed to what the Annex I foresaw. This fact should be considered positively, being a further sign of vitality of the research made by the project. Indeed, the used resources represent a small fraction of the available ones. Quantitative information on the use of human and equipment resources is reported in section c) on Explanation of the use of the resources.

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
2.1	Initial device designs and prototypes for haptic interaction in walking	2	UPMC	R+P	PU	12	Yes	PM 13	First version rejected. Update delivered Oct. 30, 2009
3.1	Contact-based sensing methods for walking tasks	3	McGill University	R+P	PU	12	Yes		
4.1	Auditory and haptic augmentation of floor surfaces	4	UNIVR	R+P	PU	12	Yes		
7.1	NIW web infrastructure	7	UNIVR	O	PU	12	Yes	PM 13	Delivered Oct. 30, 2009

a.1 Brief report on delivered prototypes

- Prototype 1 (lead McGill University): A high fidelity vibrotactile display integrated in a floor tile. This prototype resulted from an extensive optimization of the response of our existing floor tile interface designed to guarantee perceptual transparency. Engineering analyses (both lumped parameter system models and FEM models) were used to specify the structural components to assure a perceptually compatible passband, and physical measurements of the prototype were performed in order to design a digital compensating filter to ensure transparency. The device is described in Deliverable 2.1. The prototype has been demonstrated at the review meeting.
- Prototype 2 (lead UPMC): A recoil-type moving actuator, acting on a band ranging 40 Hz to 10 kHz, consuming less than 10 W and producing thrust up to 7 N. Currently embedded on Birkenstock-like shoes, to date used in the lab to carry out initial characterizations of floor-based haptic feedback and its consequences on users ‘posture. The prototype has been demonstrated at the review meeting.
- Prototype 3 (lead McGill University): A laboratory scale installation involving a distributed system of tiles of the type addressed in Prototype 1. The installation includes in addition a spatialized auditory display, and immersive video display capabilities, as described in Deliverable 3.1. The prototype is not mobile, it has not been demonstrated at the review meeting.

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

- Prototype 4 (lead AAU): A set of non-contact microphones placed on the floor was used, able to capture the footsteps sounds. The resonances corresponding to the impact of the shoe on the floor are removed, in order to extract the Ground Reaction Force. This force is used as input to different sound synthesis algorithms. Such algorithms have been implemented in real-time as an extension to the Pure data platform. The protoype is described in Deliverable 3.1 and 4.1. It has been demonstrated at the review meeting.
- Prototype 5 (lead UNIVR): A backpack hosts a laptop and an Arduino USB-based acquisition board which senses data from force sensing resistors. These sensors are embedded in shoe soles, and register a walking activity. The sensed data drive a set of real-time physics-based models running on the laptop under the Pure data platform, and providing low-latency audio feedback through the shoe-mounted speakers The protoype is described in Deliverable 3.1 and 4.1. It has been demonstrated at the review meeting.

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
1	Design, engineering, and prototyping of floor interaction technologies	WP2, WP3, WP4	UPMC	12	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. He has made all the payment for the first period to the other beneficiaries without unjustified delay.

The Coordinator has kept the records and financial accounts for the first 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 first period.

Besides ensuring the technical and administrative management of the project, during the first period the Coordinator has made a specific effort in developing a spirit of co-operation between the partners. Consensus and open spirit has been constantly pursued, mainly by ensuring a constant circulation of the information among partners.

Interaction with the Project Officer has been especially effective, through the mutual exchange of timely, substantial information mainly communicated by email and, when necessary, by phone calls.

As already mentioned above in Section 2 (see section WP7.2 above on collaborations), NIW has proficiently collaborated with several other funded projects: the FP6-NEST-29085 EU CLOSED STREP, and the MINET NoE.

Federico Fontana has participated to the Coordinators Day, organized by the European Commission in Brussels on June 10, 2009. He has repeatedly participated to meetings internal to the University of Verona in his role of contact person in the NIW project. He has been invited to an APRE (Agenzia per la Promozione della Ricerca Europea) workshop focusing on the dissemination of experiences by young European project coordinators.

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.

Project meetings

The planned reporting documentation for the first period has been prepared. It included four deliverables (delivery month 12, two deliveries postponed to month 13), this periodic report (delivery date November 30, 2009), and three minutes from the project meetings that are listed below:

- Aalborg University of Copenhagen, Copenhagen (DK), October 8-9 2008.
- Laboratorio di Acustica Musicale e Architettonica, Fondazione Scuola di San Giorgio, Isola di San Giorgio, Venezia (IT), March 2-4, 2009.
- INRIA, Rennes (FR), July 15-16, 2009.

Changes in legal status

Olga Naiberguer has replaced François Carrier as the McGill University contact person for any administrative, commercial and legal matters related to the NIW project. Her record is:

Olga Naiberguer
Associate Director, International Programs
Office of the Vice-Principal (Research and International Relations)
McGill University
1555 Peel Street, 11th Floor
Montreal, Quebec H3A 3L8 Canada
Telephone: +1-514-398-3488
Facsimile: +1-514-398-6878
E-mail: olga.naiberguer@mcgill.ca

Ms. Naiberguer does not have signing authority on behalf of the beneficiary, so any legal documents required for the project will from now on be signed by Sandra Crocker, Assistant Vice-Principal (Research Operations).

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. It is designed to provide a selected area to subscribed visitors, enabling to share material for internal use and draft documents.

The consortium strongly believes in the dissemination of the project foreground through all convenient 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 website is connected to three mailing lists:

- niw-research@niwproject.eu
- niw-management@niwproject.eu
- niw-atlarge@niwproject.eu

allowing subscribers to exchange information respectively concerning project research, management, and other, broader issues.

The web statistics that have been measured during the first reporting period are encouraging. They suggest a constantly increasing interest for the project. Figures on amount and type of web access can be retrieved from supplementary material accompanying Deliverable 7.1 on the web site.

Use of foreground and dissemination activities

WP7 on dissemination has not started yet, hence considerations on use of foreground are not mature. In spite of this, occasions for demonstration and dissemination have already been exploited by the project—refer to Section WP7 on dissemination.

c) Explanation of the use of the resources

Costs for personnel are limited to RTD and management activities. Involvement of personnel during the first 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
UNIVR	2.93	0	8.13	14.81	1.0	0	0
McGill University	0	5.0	13.0	2.0	2.0	0	0
AAU	0	0	5.0	7.0	2.0	0	0
INRIA	0.29	0	0	3.85	15.13	0	0.69
UPMC	0	16.0	0	2.0	0	0	0
TOTAL	**3.22**	**21.0**	**26.13**	**29.66**	**20.13**	**0**	**0.69**

Overall, the table gives account of an homogeneous development of the scientific work packages overall. In parallel to management, resources for the scientific and technological development during the second and third period, in fact, will be mainly used for non visual experimentation (WP5) and consequent iterated refinement of the prototypes (WP2, WP3, and WP4) as well as for the design and, later, implementation of the final demonstrator (WP6).

Personnel costs are exposed on Tables 3.1-3.5 at the end of this section.

Major direct cost items

UNIVR - Costs for subcontracting have deviated at UNIVR concerning the design of the NIW logo (see Table 3.1), for which a smaller cost had been foreseen in the Annex I. Another notable major direct cost (3297,77 €) has incurred for the support of a long research mission joined by Stefano Papetti at AAU during the project beginning (Oct. 23 – Dec. 17, 2008), aimed at reinforcing links and common technological background between the two beneficiaries in the joint design of some sound synthesis models (WP4). No expensive equipment or large consumable items have been acquired by UNIVR.

McGill University – Neither major cost items, nor deviations in planned costs are claimed.

AAU – Neither major cost items, nor deviations in planned costs are claimed.

INRIA – Neither major cost items, nor deviations in planned costs are claimed.

UPMC – Neither major cost items, nor deviations in planned costs are claimed.

TABLE 3.1 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 1 UNIVR FOR THE PERIOD

Work Package	Item description	Amount	Explanations
1, 3, 4, 5	Personnel costs	75.012,79 €	Salaries of Papetti Stefano for 6,10 person months, Drioli Carlo for 5,04 person months, De Sena Antonio for 2,49 person months, Polotti Pietro for 1,49 person months, Civolani Marco for 5,67 person months, Borin Gianpaolo for 1,09 person months. Salaries of UNIVR own staff: Federico Fontana 3 person months and Cesari Paola 2 person months
7	Subcontracting	1.500,00 €	Design of the official NIW logo
1, 3, 4, 7	Travel	14.980,15 €	Mission expenses: project meetings and related research activities
1, 3, 4	Equipment	2.804,88 €	Depreciation for the 1st period for personal computers and other durables purchases
1, 3, 4, 7	Other direct costs	6.147,01 €	Consumable purchases and expenses for organization of project meetings
TOTAL DIRECT COSTS		**100.444,83 €**	

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
1, 2, 3, 4, 5	Personnel costs	22.390 €	Salaries and benefits (Research staff and Graduate Students)
2, 3, 4, 5	Fellowships	4.280 €	Graduate student fellowships
2, 3	Consumable material and other hardware	19.010 €	Components, tooling, materials
1, 2, 3, 4, 5, 7	Travel	7.950 €	Travel to research meetings (Copenhagen, Paris, Venice, Rennes); Travel for research missions (Paris, Rennes, Verona)
TOTAL DIRECT COSTS		**53.630 €**	

(*) Accounts for paid or reimbursed costs during the first year, but excludes costs incurred that have not yet been paid or reimbursed during the reporting period. Amounts rounded to euro.

TABLE 3.3 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 3 AAU FOR THE PERIOD

Work Package	Item description	Amount	Explanations
3, 4, 5	Personnel costs	29.672,89 €	Salary of one research assistant (Luca Turchet) for 7 months.
	Travel costs	8.307,74 €	Travelling to conferences and project meetings
	Other direct costs	21.783,65 €	Equipment and consumable items
TOTAL DIRECT COSTS		**59.764,28 €**	

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	Personnel costs	1.558,10 €	Salary of Anatole LECUYER: 0.29PM
4	Personnel costs	11.350,64 €	Salaries of Gabriel CIRIO and Tony REGIA CORTE (2 PhD students) : 3.85PM
5	Personnel costs	48.755,54 €	Salaries of Anatole LECUYER (INRIA staff) and Gabriel CIRIO and Tony REGIA CORTE (2 PhD students): 15.13PM
7	Personnel costs	2.436,60 €	Salaries of Anatole LECUYER (INRIA staff) and Gabriel CIRIO and Tony REGIA CORTE (2 PhD students) : 0.69PM
1	Travel costs	2.378,36 €	Travel costs
4	Travel costs	105,15 €	Travel costs
5	Travel costs	2.970,14 €	Travel costs
TOTAL DIRECT COSTS		**69.554,53 €**	

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	Personnel costs	31.618,13 €	Salaries of one research engineer for 6 months, one graduate student for 3 months and two master student for 9 months
2, 4	Consumables	10.284,33 €	Components, tooling, materials, machining time
2, 1, 7	Travel	7.554,78 €	Project meetings
TOTAL DIRECT COSTS		**49.457,24 €**	

d) Financial statements – Form C and Summary financial report

All Form C's and related Summary financial report come along with paper copies of this Periodic report, furthermore in the form of supplementary material that can be found on the web site along with the 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	UNIVR	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