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, 2010 to September 30th, 2011

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

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 three 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. Extensions to the physical architecture have been prototyped, including the capability of effecting control over the coefficient of dynamic friction, and further experiments have considered the role of orientation of the vibrational stimulus. Exploiting the capabilities of the McGill tiles, a new study is now being conducted on the effects of the visual, auditory, and haptic modalities on gait, in particular for the presentation of what are ordinary perceived as hazardous surfaces, e.g., ice. To date these tiles represent a reference in the state of the art of foot-based interaction. Such recognition has been made possible thanks to Canadian resources drawn by McGill University through affiliation with the NIW project. McGill has also been pursuing a number of avenues, to date tentative, for follow-up funding to extend the current NIW research in new directions.

Work done at UMPC has been oriented toward engineering, and subjecting to validation new types 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. A miniature actuator design has been completed and implemented along with a scaling theory. A fluid-based actuator has also been prototyped. UPMC has furthermore delivered equipment to AAU and UNIVR, that was used to support a number of studies.

AAU and UNIVR have imported vibrotactile actuators from UPMC and active tiles from McGill University, and designed hardware/software prototypes as well as evaluation experiments thanks also to joint work. An instrumented shoe prototype has been completed, capable of sensing the user's force during walking and instantaneously responding with auditory and tactile cues of natural grounds. In this prototype, both participants included physically-inspired synthesis algorithms for the simulation of everyday materials. Problems of interface wearability, accuracy of the force sensing, wireless communication between the located and mobile components, system latencies and fidelity of the feedback have been solved at prototype level, under the planned design and cost constraints and in the limits of current (especially vibrotactile) technology. Shoe prototypes have been integrated in multimodal environments including also visual feedback provided by an head-mounted display. The numerous experiments and demos conducted with the instrumented shoes testify the overall versatility and effective behaviour of this prototype.

Work done at INRIA has continued to deal with the visual modality and the design of novel visual rendering and interaction techniques for navigating virtual worlds, also this year with a strong flow of applied concepts. A new input device called the "JoyMan" was designed to enable navigation in virtual worlds using equilibrioception and a human-scale joystick. Novel "King-Kong effects" based on visual and tactile vibrations were designed to be applied at each virtual step and enhance walking sensations in VR.

UNIUD, in force to NIW starting on July 1, 2010, has supported the work done at UNIVR on the instrumented shoes by consolidating the mobile version as well as collaborating on their evaluation. Furthermore, this participant is leading the delivery of the book on natural interactive walking.

All participants have contributed to the project's experimental campaign in their own domains. INRIA has played a notable role in the experiments, by both leading psychological tests in which the visual component was prominent, and performing multi-sensory experiments jointly with other participants. Thanks to a number of short term missions performed by (especially young) researchers, bringing precious interaction design and validation knowledge around the respective institutions, the experimental campaign has produced a number of significant results across the three years, furthermore bringing a substantial acceleration in the design-validation cycle of the interface concepts and prototypes issued by the consortium.

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 three 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 officially supported events also in synergy with other EU funded actions.

1.3 Main results achieved since the beginning of the project

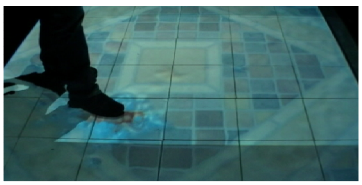
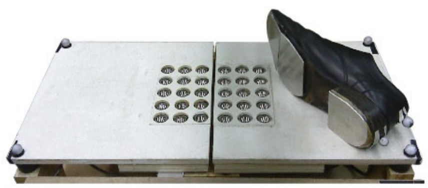
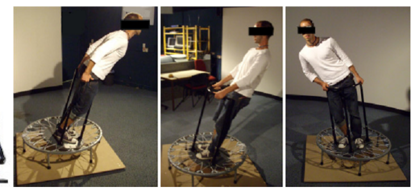
This paragraph puts emphasis on the main results achieved during the third period, while devoting some final lines to the results gained along the three years. A comprehensive description of the results achieved since the beginning of the project can be found in the final report, by Deliverable 7.3, or indirectly from the booklet of publications that comes out in parallel to this report.

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.

Two innovative miniature actuator technologies suitable for shoe-based virtual reality and many other applications have been prototyped at UPMC.

AAU and UNIVR, also with the help of UNIUD, 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 synthesis algorithms, and shoe-based interfaces providing continuous audio-tactile feedback via wireless communication with a host. Validation of these components included: electro-mechanical characterization of the acquisition system; latency of the wireless transmission; performance and accuracy of the synthesis algorithms; realism of the multimodal feedback. Experiments have also been performed assessing the role of multimodal feedback during different tasks, such as balancing on a virtual rope or recognizing simulated bumps and holes using a wobble board especially designed for the task.

Work done at INRIA has developed "JoyMan": a human-scale joystick for virtual navigations based on equilibrium, and "King-Kong effects" which are vibrations applied on user at each step to improve sensation of walking.

As a final note on the overall set of results finalized during the three years, the consortium has achieved a number of concepts, models, designs and prototypes that would be reductive to condense in this paragraph, and go well beyond the initial expectations of the participants. Concerning the actual consistency of such results, the goals which were listed in the Description of work have been covered to a very good extent. The few deviations from these goals, listed in this and previous reports, do not seem to have diminished the impact of the project in nurturing future technologies.

1.4 Expected final results and their potential impact and use

The methods that have been 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 (refer also to the project's Final Report).

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.

Apart from few, specific issues which are listed in the following of this report, the project's expected results have all been achieved. A complete integration of the many project components into a coherent, unitary interface as prescribed by the final milestone was long discussed within the consortium, but finally not attempted. These components in fact were definitely too many to be put together into one common scenario of application. On the other hand NIW has made possible to validate a number of applications, obtained by concretely assembling diverse hardware/software components available within the consortium. Most such applications aimed at creating kinaesthetic illusions in augmented walking scenarios: a topic that alone would be worth making further research, and that in a sense gathered these applications into a constellation responding to the prescriptions of milestone M3.

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

Together, the above objectives have led to the milestone no. 3, scheduled for the end of this period: "Integration and usability testing of floor interaction technologies in immersive scenarios".

2.1 Summary of the recommendations from the previous reviews, and how they have been dealt with

In occasion of the first project review, the board of reviewers had expressed an overall feeling about the need for more intensive cooperation between subprojects with focus on specific goals. In synergy with this recommendation, reviewers had suggested to concentrate resources on the most promising hardware and software prototypes.

The consortium responded to such recommendations during the second project year, by trying to wrap up a common research core as well as by making the largest use of inter-project research missions. In the coordinator's opinion, the latter tool helped conceptualize and finally achieve such specific goals: at the end of the project, it is quite evident that substantial consensus has coalesced the consortium during the second and third period around the theme of kinaesthetic and proprioceptive illusions in augmented and virtual walking.

The effort done was already recognized at the second project review. In spite of this recognition the reviewers again expressed some concern, that is perfectly summarized by the following excerpt from the second review report: *The plans [for the third year] presented at the review were not convincing. An effort needs to be made now to federate available resources either around a demonstration or a series of scientific challenges to be dealt with in year 3.*

After a number of brainstorming sessions taking place at every project meeting also in obligation to the aforementioned recommendation, in which people speculated on ways to put together the numerous interface components developed so far, the consortium finally continued to deal with specific challenges mainly around the theme of *multisensory illusions during walking*. Indeed, this choice was not detrimental to the integration of such components toward more inclusive demonstrators, that hence must be seen as by-products of those challenges rather than results of a deliberate choice to "put things together": although not converging to one single interface gathering together the best project results, nevertheless the consortium constructed some demonstrators for genuine scientific purposes, by assembling components belonging to different participants. These demonstrators, including (but not limited to) the "Shoes your style" interface jointly made at INRIA, UNIVR, AAU and UPMC as well as the AAU-UPMC wobble board are listed in Section 3.

In synergy to this activities, thanks to overseas funds fertilized by NIW McGill University finally came up with a full-modal interactive floor, on which several European researchers could develop their own applications once visiting the Canadian participant during inter-project missions.

Concerning the implementation, the consortium continued to maximize the exchange of ideas, prototypes and researchers among participants. In particular such exchanges have involved McGill

University also during the third year, confirming the commitment of this project in maintaining a broadest scope on the topic of interactive walking across its entire life cycle.

3. Work progress and achievements during the period

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

a) Completed the development of actuated floor and instrumented shoes;
b) completely characterized the tile- and shoe-based analysis techniques and components − apart from the acoustic pavement-based sensing of walking activities, an issue that is extensively discussed in Section 3;
c) proposed further virtual reality concepts and control tools;
d) closed the experimental campaign with some more experiments;
e) concluded the dissemination activity, including contributions of NIW at several conferences and on different media.

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, in charge of developing new haptic actuators as well as of providing working versions of the same actuators to the other participants.

Taking advantage of know-how developed in the initial periods of the project, work has been performed toward the miniaturization of the vibrotactile actuators developed, also attracting interest from two large companies. As a result, a patent is being submitted to protect this advance and temporarily delaying publication of the results. Another type of shoe-compatible actuator based on the controlled circulation of fluids has been prototyped and a patent has also been submitted. A theoretical study regarding the scaling properties of alternating field, tubular electromagnetic actuators has been completed.

It is noted that in the field of vibrotactile transducers, there is a pressing need to minimize the size of actuators while maximizing the highest acceleration that they can produce, particularly in the low frequency range of the spectrum corresponding to the tactile domain, that is, 20−1000 Hz. Previous research has shown that owing to thermal effects, to iron saturation, and to progress in the permanent magnet technology, the miniaturization of permanent magnet machines benefits from “iron-less” designs, where the magnetic circuit includes significant regions that are not filled with iron.

Tubular geometries are appealing because they lend themselves to efficient designs where current and magnetic circuits can be made optimally short. For instance, the optimal electromagnet geometry is the torus, which is well known in demanding applications such as plasma confinement. This is due to the natural symmetries that are introduced to allow field and current lines to close onto themselves along the shortest paths possible.

The main advantage of ironless designs is to achieve electromagnetic actuators that are made of only three components: a set of permanent magnets, coils, and structural elements to maintain a geometrical relationship between the components, without the use of iron to guide the magnetic field lines.

The transducer, like the voice-coil motor, uses the Laplace force. In order to gain favourable thermal properties, the windings are configured outside the magnetic circuit, so that heat can be evacuated. To compensate for the absence of an iron armature to concentrate the field lines, we employed an arrangement that focuses field lines within a small surface by stacking cylindrical magnets so that their poles oppose each other and by optimizing the iron-filled gap there-in-between.

With very small (~4 mm) magnets, it is possible to create concentrated fields of nearly 0.8 Tesla in air. To achieve linear operation, two options available to the designer. Either the high-field region is smaller than the coils so that the output is decoupled from the relative displacement of the moving parts, or the coil must be much smaller that the uniform field region. This design is very efficient since there are hardly any stray lines.

The next innovation introduced by UPMC was to eliminate the mandrel on which coils are ordinarily wound. At the millimetre design scale, this gain is highly significant since these devices must maintain exact tolerances. This innovation allows to reduce the air gap below a fraction of a millimetre, something that would be impossible to achieve with the conventional approach where a ~1 mm thick mandrel would have been necessary. But of course the coils must be located with high geometrical accuracy.

UPMC also devised a manufacturing process based on gravity molding. In the first step, epoxy is poured to secure the three coils held in place with one single plug with high geometrical accuracy, sparing the hollow cavity. In a second step, the moving assembly will be inserted. Because of the freedom of shape creation afforded by molding, the device can also be provided with mounting holes for fasteners and routings for the coil leads, while protecting sensitive areas.

Since these actuators are meant to be scaled down, in order to conserve the output level and simultaneously extend the response in the low end, it is necessary to provide increasingly large moving part excursions from the rest position. In previous, larger designs, the suspensions were made of laser-cut rubber disks that were simple to manufacture and were not strongly limiting factors because of their diameters. With an 8 mm design, however, simple disk-suspension would have greatly limited the performance and introduced distortion at high amplitudes. UPMC therefore designed new membrane geometries that could provide adequate radial stiffness, high axial compliance, and above all distortion-free large excursions. The result of the optimization consists of half-tori membranes that were moldered out of natural rubber, a material that is very durable. This design achieves a 6 mm stroke before bottoming and leaves room for improvement.

A scaling law theory has been developed for these actuators. It was found that the motor constant, the ratio of the force by the square root of the power was proportional to their volume, that the electrical time constant proportional to the diameter, and the thermal time constant to their diameter. The largest stroke, which determines the lowest producible frequency was proportional to the cube of the diameter times the length divided by the equivalent Young modulus of the membrane's material, justifying the design of super deformable suspensions.

The purpose of the fluid based actuator is to modify the mechanical properties of the shoe as a function of the pressing force created by the wearer during stepping. The device can be included in many object of common use where it supports a dynamic load. It can be used for instance to simulate the response of certain materials in a virtual reality setting to simulate the contact with various surfaces. Alternatively, it can be used in many types of rehabilitation devices in contact with the anatomy such as prosthetic limbs.

Finally, UPMC has proposed an enclosure comprising two elastically deformable pockets with a common border and arranged in series in relation to the force applied to the enclosure, the two sections with pockets of different sizes, the two pockets being in communication and filled with the same fluid. There is a valve regulating the flow of fluid from the pocket of a smaller section at the largest section of pocket. The enclosure is extremely compact because both pockets are arranged in series to the force applied to the enclosure. Thanks to a pressure differential created between the two pockets when the is a force applied because of the difference in their section, the fluid flows from one pocket to another creating the sought after tactile sensation. The system developed is about 2 cm thick and can fit in an ordinary shoe sole.

Concerning the activity of other participants in this work package, McGill University has developed a number of prototypes for rendering reduced foot-ground friction, such as would be required to simulate slippery surfaces and separately, carried out preliminary testing of tangentially actuated vibrations applied to the floor tiles. Additionally, in collaboration with INRIA and UMPC, a simulation has been developed that provides the multimodal perception of stepping into a volume of water, taking advantage of actuators (*haptuators*) embedded in a pair of sports sandals, which are used to reproduce the bubble-based vibrations associated with solid-fluid impact.

About the conclusion of related work package tasks:

- Task 2.3 has been carried on with energy also during the third period, resulting in the aforementioned haptic models, manufacturing directions, and prototyped devices.
- Task 2.4 has been completed by validation experiments of the actuators designed by UPMC, made by AAU using instrumented 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, concerning the goals of R2.2 [M3].

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 third period.

WP3 – Multimodal sensing, analysis, and integration

Research at McGill has focused on enhancement of the software architecture underlying the floor tile structure and applications of the floor's sensing capabilities to foot-based user interfaces, initially involving a geospatial navigation activity. With regard to the former, this has primarily involved integration of both FSR and motion capture data into a single module, providing a common access method for all applications to sensor data, significantly improving maintainability and extensibility of our software. The investigation of foot-based user interfaces involved an experiment comparing three interaction methods for navigating (panning and zooming) within a large workspace, in this case, a Google maps display, with accompanying street view data displayed around the user to add a compelling immersive element to the experience.

In addition to work made at McGill University, during the third period UNIVR and UNIUD have carried out research on an interactive floor, that would track the position of a walking person without relying on visual capture. Inspiration for this system, and the models and technologies used were based on results coming from the former EU-funded project TAI-CHI (Tangible Acoustic Interfaces for Computer-Human Interaction): the basic idea behind the sensing floor is that the position of acoustic sources moving over a surface can be detected by analyzing the acoustic waves propagating through such surface.

The acoustic sensing floor relies on one or more arrays of contact microphones that are attached to the floor surface (see also the image below). Two different kinds of devices were tested for this application: the AKG C411PP condenser microphones and the Knowles BU-21771 piezo-ceramic accelerometers, the former being designed mainly for musical applications (e.g. for recording instruments), whereas the latter being primarily used as contact microphones in noisy environments as well as accelerometers for lightweight structure vibration measurements.

Several recording sessions were taken using both types of microphones, during which a person was asked to walk around the sensing floor area. The data were first analyzed to compare the performance of the microphones. Moreover, the band of interest – that is the spectral region where the audio signal generated by the walking person was more informative – was tested with different types of floors. It was discovered that most components outside the range 100-1000 Hz contained uninformative environmental noise, along with sounds caused by spurious movements of the walking person.

In the end, the Knowles microphones were chosen as they ensured a better response in the band of interest. Because of their power requirements, it was necessary to build a custom power supply. In practice, eight such microphones were connected to a pre-amplified A/D converter (Behringer

ADA8000) that was set to sample the inputs at 48 kHz and 24 bit of resolution, and to forward an eight-channel ADAT signal to a RME Fireface 800 audio interface connected to a laptop.

The experiment considered a sensing floor area of about 4 m². N evenly distributed nodes (again see the figure) were marked on this area, corresponding to vertices of an approximately square tessellation of the sensing floor. Then, N template recordings consisting of one single step were taken in correspondence of each marker. Every template is an M-channel audio signal, in which M is the number of microphones used ($M \leq 8$).

An algorithm for tracking the position of a walking person was implemented first in MATLAB. The algorithm aims at finding the squared location delimited by markers, or *tile*, where the step has occurred. The algorithmic procedure can be summarized as follows:

1. Automatic segmentation of single steps.
2. For each step:
   a. for each audio channel, the cross-correlation between all channel templates and the step is calculated. The resulting correlation values are stored into a matrix sized N x M;
   b. for each template (i.e. for each matrix row), the median of cross-correlations (i.e. of the columns) is computed and put into an array. The length of the array equals the number of templates;
   c. for each *tile*, the sum of the medians associated to the (four, i.e. one for every *tile* vertex) templates is calculated and put into a new array;
   d. the index of the most likely tile corresponds to the position of the highest value in the array assembled at point c.

The simplicity of this algorithm was motivated by issues of real time implementation, necessary not only to validate the procedure itself through experiments made with users, but also to test and demonstrate the sensing floor in practical settings before the end of the project.

The hardware setup was tested using four different versions of the above procedure, in some cases allowing to change the position of the microphones. To asses their performance, in particular concerning accuracy and latency, each version of the algorithm was implemented as a Pure Data real-time object.

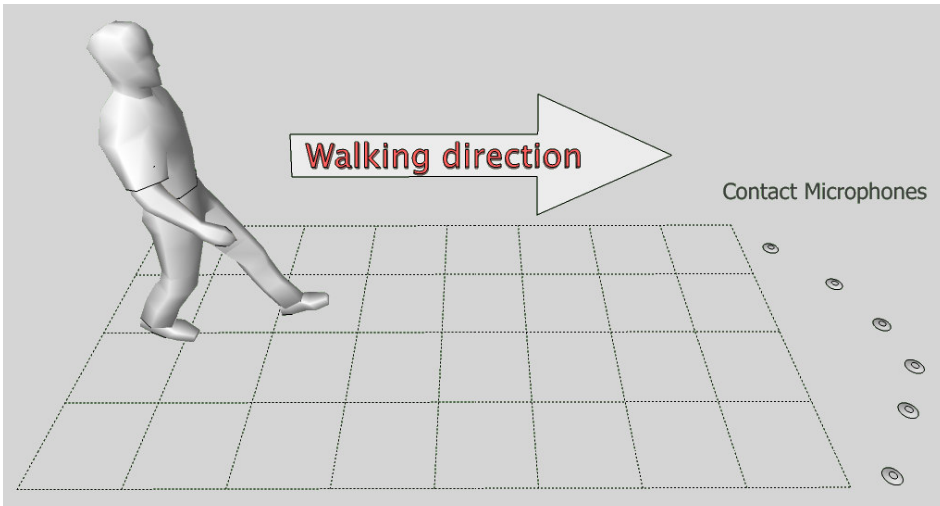
The following versions were tested:

1. Version 1 allowed to modify the tessellation by varying the position of the nodes, in this way providing the necessary flexibility during early user localization tests. The related procedure is composed of two main blocks:
   a. offline templates acquisition and multi-channel pre-processing (noise filtering, gain and automatic segmentation);
   b. real-time user data acquisition and multi-channel processing (segmentation in single steps, time-domain cross-correlation with all the templates, and stochastic decision).

Although performing close to real time, the results of this procedure were however not satisfactory in terms of accuracy: this is mainly due to the poor signal-to-noise ratio provided by the hardware components. The cross-correlated data were heavily affected by noise, that propagated to the subsequent statistical processing. Changing the microphone positions did not help. Moreover, the algorithm failed to stay within the real time during continuous walking tests lasting more than few seconds.

2. The second version aimed at detecting the foot position perpendicularly to a (1-D) microphone array line (see next figure). The hypothesis behind was that farther distances correspond to greater

attenuations. In this case the algorithm does not make use of templates: once a step is detected (i.e., identified as a signal peak on at least one channel, with adjustable peak thresholds), an envelope follower collects amplitude values over a temporal window with adjustable size. The sum of the collected values should give a measure of proximity to the microphone array.



Since this version involves less post-processing on the input signals, one major advantage over the first implementation is the lower computational load. On the other hand, provided that the acoustic energy generated by foot-floor impacts remains constant during the walk, accuracy is improved, too. In practice, heavy footsteps far from the microphones determine similar peaks as lighter footsteps do at closer distances.

Another flaw of this approach depends on constraints on temporal windowing: tests show that in order to have a significant measure of the envelope, a slightly large window is required (at least 50 ms). This implies the introduction of an inherent delay in the computations, in spite of the low computational load. On the other hand, with shorter windows, the risk of false detections is very high.

3. The third approach is similar to the second, since no templates are required. The main difference concerns the detection module: this version used an instance of the Pure Data [bonk~] object. Unfortunately, while improving the performance in terms of latency, the use of [bonk~] did not affect the robustness: in particular, the ambiguity between heavy-far and soft-near steps persisted.

4. The last version basically simplifies upon version 1. Once again, a set of templates was collected and pre-processed offline as previously described: the same process was applied in real-time to the incoming signals. Moreover, time domain cross-correlations between the incoming isolated step and all the templates were computed. The main difference from the first version concerned the statistical computations: in this case the index of the grid node which is closest to the incoming step was simply computed by taking the highest cross-correlation value for each channel, and then by calculating the mean of the obtained values. The purpose of the simplification with respect to the first approach was to minimize the aforementioned error amplification.

The time-domain cross-correlation introduces the same latency experienced in version 1, furthermore there are no significant improvements in terms of accuracy of the results.

From the results described here it is clear that, as to now, a sensing floor based on a reduced number of affordable consumer hardware components and furthermore providing real time localization of users cannot provide reliable tracking of the position of a person walking over it. Even more, the acoustic sensing seems to actually have few or no chance to compete with solutions based on visual capture. Several reasons can be found that partially motivate this inadequacy:

- since the aim of the sensing floor is to provide position tracking in everyday contexts, environmental noise is one major issue. Of course, the contact microphones used in the prototype record such noise, therefore affecting the reliability of the position tracking algorithm;
- the signals coming from the microphones had to be strongly pre-amplified (by about 60 dB) before being converted to digital. Because of their average quality, the pre-amplifiers added further noise to the (already very noisy) data;
- although four versions have been attempted, the localization algorithm that had proved to be effective in the TAI-CHI project conversely showed a number of unexpected flaws when used for the purposes of NIW. First of all, the stochastic procedure that had worked well in the case of relatively thin, homogeneous, spatially bounded, and relatively low-noise domains such as those dealt with by TAI-CHI conversely was not capable to govern the unbounded, highly anisotropic and non homogeneous, noisy and multi-user case tackled by NIW. More in general, the TAI-CHI technology seems to be too dependent on the homogeneity/continuity of the floor material and invariance of the shoe-floor interaction, both giving rise to a very broad range of different sound possibilities when varying instead.

Unfortunately, the project's Description of work had not taken this specific contingency into account. In practice NIW did not foresee, in the case the TAI-CHI models proved ineffective, dedicated resources for figuring out a specific floor surface model on top of which to build a correspondingly novel machine learning algorithm.

In spite of this negative result, it is clear that many improvements can be envisioned for future implementations. Higher quality microphones could be used, and the isolation from environmental noise could be improved. A custom pre-amplification stage could be built which maximizes the signal-to-noise ratio in the frequency band of interest, without adding excessive noise. Finally, the latency between a step and the response from the algorithm could be reduced by calculating the cross-correlation in the frequency domain once the localization procedure would prove effective.

Concerning the soft computation, an alternative algorithm could be implemented based on the calculation of inter-arrival times of the wave fronts, instead of the attempted "signal matching" approach. By attaching the contact microphones so as to cover the perimeter of the area being tracked, one could measure the inter-arrival times of the wave fronts at each microphone. Then by applying some geometric calculations, the current position within that area could be obtained. One major issue in this case would be that mechanical waves propagate very fast within solids, therefore a very high sampling rate (e.g. ≥ 192 kHz) is required to appreciate the delays between wave fronts, provided that the resulting mass of data can be later dealt with without sacrificing the real time.

Concerning the conclusion of related work package tasks:

- Task 3.1 has been entirely completed. Contact-based sensing via a distributed network of force sensing tiles was investigated (Visell et al., Proc. IEEE 3DUI, 2010), and were used for interaction with virtual ground materials (Visell et al., Proc. IEEE VR, 2010) and for pedestrian tracking in computationally augmented environments (Rajalingham et al., Proc. CRV, 2010). The acoustic techniques explored for sensing floors were discovered to be not convenient to implement for purposes of interaction with walking persons.

- Task 3.2 was essentially completed. Measurement- and model-based simulations of real time interactions with several types of ground materials have been investigated. Perceptual evaluations of several examples were performed under WP5. The techniques used are described in a variety of publications of the project (see also Chapters 7 and 8 of the NIW book).
- Task 3.3 has been accomplished. First, both the shoes and the active tiles were 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 a modular system design that was presented in Deliverable 3.2 (see also Chapter 3 of the NIW book). In line with the comments above, acoustic sensing techniques were not pursued further.
- Task 3.4 was addressed in the context of 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. Machine learning techniques were also applied to enable us to track the foot locations of pedestrians moving across a force-instrumented floor surface, as related in (Rajalingham et al., Proc. CRV, 2010) and (NIW Book, Chapter 3).

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 R3.3 [M3]. The analysis of foot gestures through contact-microphones arrays onboard the acoustic sensing floor unfortunately led to a negative result.

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 third period.

WP4 – Auditory, haptic and visual feedback modeling

The third period has concluded the integration of the auditory and haptic modality in the shoe interface. The work done in this period on the auditory and haptic models has been relatively small, mainly limited to understanding questions of fine tuning and dependence on the user's characteristics. Indeed, such questions are by no means minor once envisioning a progressive evolution of the shoe prototype into pre-production samples. As usual during this project, McGill University's active tiles have maintained a fast development pace during the third period, and demonstrated a number of scenarios enabling visual, haptic, and auditory feedback.

The physics-based software models which had been either designed or adapted during the first period, and systematically tested during the second year to simulate floor-based feedback, have definitely confirmed their versatility in synthesizing ground information suitable to both the auditory and tactile sense. The third period, in fact, has been mainly devoted to select those models, whose realism has been positively received by users in occasion of several scientific events – see the paragraph reporting about WP7 on dissemination. The most credible simulated materials to date include snow, creaking wood, metal grate, and mud. Qualified by a now long-tested stability and robustness, this selection forms a stable subset of software modules for the Puredata environment, enabling walking sounds in real time.

Once it became clear that the instrumented shoes could not be further developed with the resources left to the project toward the conclusion of the third period, a couple of visionary experiences have been attempted by making use of rhythmic and musical feedback. Also taking inspiration from the especially positive feedback that the instrumented shoes had received at FET2011 when displaying highly resonant and rhythmic sounds (i.e., of bouncing metal grate), UNIVR together with UNIUD designed and implemented the instantaneous generation of drum-like stimuli underfoot in consequence of users' foot tapping gestures. UNIVR and UNIUD also worked on the design of vibrotactile feedback for the hands, for sound quality augmentation in the context of a musical perception and action tasks.

McGill has hosted research missions by personnel from INRIA devoted to an effective multimodal simulation of solid-fluid interaction, e.g., stepping into a puddle or pool of water, and the preparation of associated perceptual experiments, described under WP5.

Concerning visual feedback, INRIA has extensively designed a novel approach for simulation of complex virtual grounds made of different states of matter (i.e., populated with fluid, solid and deformable bodies). These techniques have been tested with force-feedback devices (for manual interactions) and vibrotactile feedback with UPMC shoes and McGill University tiles for walking sensations. Our evaluations showed that participants could successfully discriminate interacting with liquid, rigid or deformable surfaces.

INRIA has also worked together with UNIVR and AAU on sonic shoes. Together they have proposed the concept of "Shoes your style" which enable to change the sounds emitted by shoes for various novel walking experience in reality.

Concerning the conclusion of related work package tasks:

- Task 4.1, which was already at an advanced point at the end of the second period, received supplementary information about the model fine-tuning through the experiments and demos performed during the third period.
- Task 4.2 was at a mature point as well. The calibration parameters acting over the mechanical resistance maps, capable of adapting the local sensitivity of the force input sensors to the user's characteristics (weight and foot/sensor coupling), have provided a satisfactory fitting of the shoe interface to most users.
- Task 4.3, already relying on a very efficient interface/host communication in terms of accuracy and latency, has been further developed thanks to the custom-made wireless transmission layer design ensuring sufficient mobility and freedom of movement to users.

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 R4.3 [M3].

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 third period.

WP 5 – Pseudo-Haptics and Perceptual Evaluations

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

INRIA has notably designed a novel pseudo-haptic technique for the simulation of ground properties based on visual feedback: a "king-kong" effect based on applying visual and/or tactile vibrations at each virtual footstep. This effect is inspired by visual effects applied on camera in movies such as King-Kong. We have conducted a series of experiment to tune and evaluate the King-Kong effects which suggest that such effects could be applied in immersive virtual environments to increase the sensation of walking on virtual grounds.

INRIA has also continued to work and study its novel Walking-In-Place technique for desktop virtual reality based on head movements called the "Shake-Your-Head" technique. This technique enables to walk by moving head, in front of a webcam, i.e., with very low-cost VR equipments. A novel analysis of the experimental data enabled to exhibit very different patterns of walking/navigation compared to standard desktop inputs (joystick and gamepad).

UNIVR and UNIUD have tested, on a perhaps more loosely related research however linked to the main project theme of cross-modal illusions, the sensation of improved musical sound quality by vibrotactile feedback augmentation: since it was unclear how to make this test involving the feet with the needed realism, the experimental task was successfully performed on a musical setup involving the hands. This experiment was intended to be symmetrical to that on haptic illusions driven by footstep sounds, conducted during the second period. Although in very preliminary stage, these experiences disclose promising scenarios for future research on the use of the instrumented shoes to entrain users on a prescribed walking cycle, for rehabilitation, sport training, musical practice or entertainment purposes, furthermore they highlight the complex cross-modal interplay existing between auditory and vibrotactile feedback in the context of perception and action tasks.

Furthermore, UNIVR and UNIUD have preliminary analyzed the effects on human gait of underfoot ecological auditory and vibrotactile feedback. Subjects were asked to walk along a predefined path wearing the instrumented shoes. Three experimental conditions were implemented, corresponding to different types of feedback provided through the footwear: two conditions which simulated different ground materials (mud, snow and ice) and a neutral (control) condition with no feedback augmentation. Preliminary results indicate that the use of non-visual interactive feedback can influence the gait patterns of the subjects, although not significantly.

AAU has performed experiments aiming at evaluating the ability of subjects to perceive sense of presence in virtual environments. Specifically, subjects were exposed to a multimodal simulation of a canyon, including auditory, haptic and visual cues.

In collaboration with INRIA, McGill has prepared an experiment to investigate the perceptual realism of foot contact with a volume of water, taking advantage of sandals with embedded haptuators to render the haptic response. This overcomes the limitations of previous efforts, in which the haptic stimulus was provided only upon contact with the floor tiles, thus creating a perceptual conflict between the expected compliance of a fluid and the actual stiffness of the tiles, resulting in users reporting a sensation of stepping on a waterbed or other surface on top of water, rather than into the body of water. In collaboration with McGill's Department of Kinesiology and Physical Education, a second experiment has been prepared to investigate the effects on gait and muscle activity resulting from uni- and multimodal presentation of a hazardous surface, i.e., ice. These experiments are now being started, with results expected to be reported by the end of the year.

At UPMC, and experiment about self-motion perception was carried out. Self motion is related to the sensation of displacement relatively to the environment. It is a multimodal perception based on different sensory channels like the vestibular system, the tactile system, proprioception and vision. Among illusions of self-motion, vection is the illusory experience of self-motion given by visual stimulation in the absence of the other sources of motion information. In the present study, we wondered whether vibrotactile stimulation in the feet of a standing person combined with vection would enhance the experience of self-motion compared to vection alone. Two different stimuli wre given in a trial, each representing a given condition. The task was to: "Jugde which one of the two stimuli give a more intense sensation of self-motion." The results showed that vection can be strongly enhanced when the vibration applied to the feet when standing are frequency modulated and when the modulation is correlated with the rate of the frontal visual flow.

Concerning the conclusion of related work package tasks during the third period:

- Task 5.1 was substantially over already at the end of the second period. Though, the experiments that took place during the third period implied further experimental designs.
- Task 5.2 was complemented by evaluations on tactile and visual feedback designed for the King-Kong effects, as well as evaluations of auditory feedback developed at AAU.
- Task 5.3 was substantially over already at the end of the second period. Though, the new King-Kong effects could be considered as falling into the pseudo-haptic category and represent a novel pseudo-haptic feedback.
- Task 5.4 was also substantially over at the end of the second period, and it is followed by the evaluations conducetd in WP 6.

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 R5.2 [M3].

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 third period.

WP6 – Iterative Integration and Presence Studies

McGill University and INRIA have continued the development of a system for the multimodal rendering of fluids. The simulations were performed using a physics based synthesis engine, and delivered using the actuated floor present at McGill University.

Another instance where a full multimodal environment was developed is in a collaboration between AAU and UPMC. Specifically, shoes instrumented through actuators and pressure sensors were provided with markers for tracking by a motion capture system. Wearing these shoes, users were exposed also to visual feedback provided by a head mounted display. The overall simulation was evaluated to assess its realism and conveyed sense of presence.

One further result obtained by means of joint work by AAU and UPMC consisted of an experiment in which subjects balance on an instrumented wobble board, controlled using a 2D accelerometer and containing "haptuators" that provide audio-tactile sensations of a rolling ball traversing bumps and holes. The haptic modality, as opposed to other modality combinations, significantly affects the perception of different heights of the bumps and holes

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 R6.2 [M3].

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.

WP7 – Dissemination, Collaboration and Exploitation

On top of the number of dissemination activities which occurred during the first and second period, the third year has confirmed an intensive and cost-effective approach to this work package. Notable events for this period include: a press release of NIW at FET2011 in Budapest; the organization of a thematic hands-on teaching course at the SMC2011 international Ph.D. school, with related project advertising; the invitation to demonstrate at the IC-0601 SID COST action final event. Since being satellite of scientific conferences, all such activities were at no cost for the project except for the usual registration at the conference. A detailed list of WP7 activities follows here below.

WP7.1 Dissemination

NIW personnel has participated, or will present project results, to the following events:

- FET2011 in Budapest (Hungary, May 2011)
- GI2011 in St. John's (NL, May 2011)
- CMBEC2011 in Ottawa (ON, June 2011)
- NIME2011 in Oslo (Norway, June2011)
- Forum acusticum in Aalborg (Denmark, June 2011)
- World Haptics in Istanbul (Turkey, June 2011)
- SMC2011 in Padua (Italy, July 2011)
- ACM SIGGRAPH 2011 in Vancouver (Canada, August 2011)
- HAID2011 in Kyoto (Japan, August 2011)
- DAFX 2011 in Paris (France, September 2011)
- CHIItaly 2011 in Alghero (Italy, September 2011)
- ACM SIGGRAPH ASIA 2011 in Honk-Kong (December 2011).

In particular, INRIA has participated and demonstrated research results obtained in NIW in two major and very popular events: ACM SIGGRAPH 2011 in Vancouver with one booth on "the virtual crepe factory" in the "Emerging Technologies" exhibition (demonstrating haptic interaction with liquids), and ACM SIGGRAPH ASIA 2011 in Hong-Kong with one booth on "the JoyMan" in the "Emerging Technologies" exhibition.

In parallel, UPMC has featured NIW at WorldHaptics in Istanbul along two workshops: "Haptics in Surgical Robotics", organized by Evren Samur, Laura Santos-Carreras, Ali Sengül, Hannes Bleuler, speakers Monika Hagen, Stéphane Dominguez, Andreas Tobergte, Patrick Helmer, Katherine J. Kuchenbecker, Vincent Hayward; and "Vibrotactile Haptics for Touch Screens", organized by Cagatay Basdogan, speakers Ivan Poupyrev, Vincent Hayward, Manuel Cruz, Seungmoon Cho.

Press coverage of NIW-related research outcomes during this year:

- KTIRIO Architectural Magazine (Greece), Sept. 2010 Issue (not included in previous periodic report).
- Dan Simmons' "Click" science TV programme, broadcasted by the BBC, May 21st, 2011.
- Olivier Dessibourg on Le Temps (Switzerland), May 10th, 2011, in the Sciences&Environnement pages.
- Fabrice Delaye on Bilan (Switzerland), July 6th, 2011.

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 other funded projects and initiatives.

- Federico Fontana was invited to the Final Event of the COST action IC0601 SID at NIME2011 in Oslo, for a demonstration of the project achievements having links in the area of Sonic Interaction Design, in May 2011.
- Stefania Serafin was invited speaker to the session “Sound in multimodal environments” at the Forum Acusticum conference in Aalborg, June 2011.
- Stefania Serafin was invited speaker at the workshop “Music is motion” which took place in Stockholm in June 2011.
- Federico Fontana was invited to talk about NIW activities under the umbrella of *Enactive sound design: Movement, touch, audition* at the workshop entitled Multimodality and Cross-modality in Art and Science, organized at the International Superior School of Advanced Studies (SISSA) in Trieste in June 2011.
- Stefano Papetti and Marco Civolani collaborated with Maurizio Goina of EGGS, a national project coordinated by the Conservatorio di Musica (Italian school of music) “G. Tartini” in Trieste, while teaching at the SMC2011 international Ph.D. school in July 2011.
- Federico Fontana, in his role of EU project coordinator, was invited to give a short talk at the national *Researchers' night* in Udine (Italy) on September 23rd, 2011, entitled “The researchers' night: instructions for a dawn in Europe”.

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 R7.1 [M3].

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, which is published at the end of the every period, has been updated with web statistics accounting for the third period (see also the related section below).

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**
6.1	Presence studies in multimodal augmented floors	6	AAU	R+P	PU	36	Yes		
7.1	NIW web infrastructure	7	UNIVR	O	PU	12, 24, 36	Yes	13, 24, 36	
7.2	Panel on foot-based interfaces and interactions	7	AAU	R+O	PU	36	Yes		
7.3	Book on ecological foot based interfaces and interactions	7	UNIUD	O	PU	36	Yes		Copy of the final edition of the book will be delivered to the reviewers and Project Officer

a.1 Brief report on delivered prototypes

- Prototype 1 (lead AAU): the prototype includes a pair of shoes enhanced with pressure sensors, and a motion capture system. Markers are placed on top of the shoes as well as on the head of the subjects, to track the position of the subject in the laboratory together with the orientation of the head and the feet.

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

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
3	Integration and usability testing of floor interaction technologies in immersive scenarios	WP2, WP3, WP4, WP5, WP6, WP7	AAU	36	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 second period to the other beneficiaries have been done without unjustified delay.

The coordinator has kept the records and financial accounts for the third 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 third period.

Besides ensuring the technical and administrative management of the project, during the third period the Coordinator has intensively worked to keep the spirit of co-operation consolidated among participants during the previous periods. 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 communicated by email. The coordinator recognizes the reactivity of the Project officers.

The coordinator required one amendment 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 third period.

Amendments to Grant agreement: no. 3

[PENDING INFORMATION FROM UNIUD ADMINISTRATION]

Project meetings

The reporting documentation for the third period has been prepared. It includes four deliverables (D6.1, D7.1 update, D7.2, D7.3, all to be delivered at month 36), this periodic report (final delivery date Nov 30, 2011), the final report (final delivery date Nov 30, 2011), the booklet of project publications as recommended by the second review report, and three minutes from the project meetings that are listed below:

- INRIA - Campus Beaulieu, Rennes (FR), Oct. 11-13, 2010.
- UNIUD - Dipartimento di Matematica e Informatica, Udine (IT), Feb. 23-24, 2011.
- UPMC - ISIR, Paris 6, Jul. 12-13, 2011.

Personnel exchanges

The third period has seen a number of exchanges, especially of young personnel. Periods, objectives, and names of the persons as well as hosting and hosted participating institutions are listed here below.

Gabriel Cirio, Ph.D. student at INRIA, visited McGill University for the week of August 15, 2011, assisting in the integration of software components for the water simulation.

Yon Visell, key person in the project, moved from McGill University to UPMC where he got local NIW funds starting July 1, 2011.

Changes in legal status

No legal changes were notified to the Coordinator during the third project period.

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 provided 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.

The web statistics that have been measured during the third 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.

The web site will be moved to a free hosting service or dismantled after the end of the project, due to lack of financial support for its active maintenance.

Use of foreground and dissemination activities

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

There are two pending patents, concerning technological exploitation at UPMC.

A French patent has been released by INRIA to claim a priority on the JoyMan: « Dispositif de génération d'ordres de commande de l'attitude d'un élément télé opérable par un utilisateur et système de jeu comportant un tel dispositif », M. Marchal, J. Pettré, S. Pineau, A. Lécuyer, Patent FR10/595551, 2011.

McGill University has been in discussion with Google Montreal with respect to the possibility of deploying a version of the tiles in their foyer and with Cirque du Soleil regarding their interest in the technology.

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

[FIGURES OF PERSON-MONTH CURRENTLY UNAVAILABLE]

Costs for personnel are limited to RTD and management activities. Involvement of personnel during the third 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.

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

Major direct cost items

[FIGURES OF COST CURRENTLY UNAVAILABLE]

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