1.1 PUBLISHABLE SUMMARY

Context and Objectives

The ultimate goal of the DALi project is to develop a mobility aid (the c-Walker) to support older adults with intact mobility but with declining cognitive abilities to navigate large, open and potentially intimidating environments such as shopping centres, airports or train stations. The c-Walker integrates a complex portfolio of technologies to sense the environment, to decide the safest path and to operate corrections in reaction to potential dangers or stress conditions for the assisted person along the path. The course decided by the c-Walker is represented to the assisted person (AP), by a combination of non-invasive haptic, visual and acoustic interfaces. Important additional goals are the use of low cost technology to enable containment of the final cost of the device, a thorough evaluation of user requirements in the definition of functionalities and interfaces, a preliminary definition of business models that can guide the possible industrial exploitation of the device.

Work during the second year and results

WP1: User-sensitive inclusive design

WP1 addresses four long term overall questions: 1) How do older adults act in congested public environments? 2) How do other agents in the environment react or respond to older adults within shared public environments? 3) What are the needs of older adults for support when interacting with large shared spaces such as shopping malls or airports? 4) How can these be met via the design of an intelligent walker?

During the second year of the project, the consortium has continued to work together on activities converging towards these goals.

We have continued to experiment and input to the work on flow of crowds as input to the social flow model which is part of the cognitive engine.

We carried out a survey of older adults in the U K exploring the relationship between mobility and quality of life measures. We also used this to explore if the stigma of using an assistive device such as a walker, prevented them from using a walker. We believe that the use of a walker promotes a stereotype threat to the older adult of an unhealthy, and immobile older adult. In this study we found a relationship between mobility, perception of stigma and quality of life.

We have further explored this issue experimentally to identify if the design and the marketing of the walker can reduce the stereotype threat. In the first study, we have explored the marketing message around the walker, as being used by healthy and active older adults versus being used by older adults who need mobility assistance. We believe that the framing of the walker via the marketing message will not only affect acceptance of the technology, but also how they use it, i.e. we hypothesis that stereotype framing will have an effect on walking speed. We are currently analysing the results.

In a second experimental study into framing effects, we are investigating the positioning of the walker as a walker or a shopper. We hypothesise that a shopper will be perceived as promoting an healthy stereotype, and the walker as a negative stereotype. We are in the process of collecting data for this study.

During the year WP1 has also contributed to the design and evaluation of the haptic and visual interface. We have carried out a study to understand the distance at which an older adult should be signalled to change direction. The aim of this study was to identify the amount of notice required for a smooth transition and the point at which the older adult would feel to close to an object to change direction. We also explored the difference between providing a haptic signal to one wrist or two wrists. In this study we found that utilising a single wrist for the haptic interface placed extra cognitive load on the older adult, taking longer to make the decision and potentially moving in the wrong direction first, then quickly redirecting themselves. We believe this is a potential fall hazard and therefore recommend that if haptics are used, they should be employed on both wrists.

Lastly WP1 has supported the design of the visual interface, in particular the navigation interface. We carried out work on the type of navigation strategies used by older adults and identified egocentric rather than allocentric navigation as dominant. The cues required for egocentric navigation have been worked into the visual navigation system.

The results achieved during the second reporting period can be summarised as follows:

SOCIAL FLOW MODEL

- The qualitative behavioural patterns identified during the first reporting period, have been further investigated by using different protocols in synthetic experiments;
- Ethnographic studies have been started to verify the applicability of the identified in open environments, with a composite presence of subjects in the scene (diversified in their age and abilities);
- The inadequacy of standard quantitative models (Social Force model) has been exposed in quantitative studies;
- Different models have been defined that subsume the SFM as a special case but contain discrete switches, which can potentially explain the behaviours identified in the qualitative studies.

STIGMA and STEREOTYPE THREAT

- Stigma and stereotype threat have an important role to play in acceptance and use of the c-walker. Marketing and naming of the walker is crucial to reduce these threats.

HAPTIC NAVIGATION

- Two wrist interface is required to reduce cognitive load and fall risk

VISUAL NAVIGATION

- Egocentric navigation strategies must be supported.

WP2: Sensing Technologies

The overall goal of WP2, "Sensing Technologies" is to extract the perceptual information that is required to support all functionalities of the c-Walker platform. During months 12 to 24, the work was focused on extending and implementing map building techniques, on platform localisation, on human detection and tracking and on environment perception via identifying points of interest and hazards using smart OCR and observing the user of the platform by detecting and tracking head pose and orientation. The consortium also started initial integration work of the sensing modules with the planner modules of WP3 and built two prototype cWalkers.

The main results achieved during the second year are the following:

- Localisation of the platform by combining input from dead-reckoning sensors, RFID tags and visual cues.

- Mapping the environment using the onboard cameras of the c-Walker was implemented and tested on various scenarios
- Smart OCR was implemented and tested in real world conditions running on an embedded system
- A novel, real time method for multiple human detection and tracking from a mobile RGB-D camera has been developed and integrated with the short range planner of WP3.
- A novel head pose detection and tracking method was implemented for observing the user

WP3: Cognitive Engine

The overall objective of WP3 is to provide the c-Walker with an efficient path-planning algorithm and with a robust solution for anomaly detection to support the AP in his/her motion across a crowded environment. During the past reporting period, the consortium has achieved the following results:

1. Identified a set of anomalies related to the presence of signs on the ground (e.g., “wet floor”, “out of order”, restricted area”);
2. Associated a semantic with each determining their implications on planning;
3. Defined a graph based set up for the long term planning based on the quad-trees based representation of the map of the environment, which is related Spatial Lite representation adopted consortium-wide to model the environment;
4. Produced a Djikstra solution for the long term planning;
5. Integrated anomalies and heat maps in the Graph modelling;
6. Refined and implemented the short--term planner based on the combination of statistical model checking and predictive models, producing a software component, which has been integrated with the tracker, and with the long--term planner.

In the forthcoming reporting period, the short--term planner and the long term planner will be evolved integrating the more refined model produced in WP1 and optimised to reduce their computation requirements.

WP4: Human/Machine Interface

The purpose of WP4, “Human/Machine Interface” is to design visual/audio and haptic interfaces that can effectively convey the information on the environment and on the planned route to the AP.

The work carried out in the second year focused on the study of Haptic/Audio signals for human guidance and environment representation.

More in detail, the consortium has developed:

- Strategies to gently direct the user toward a pre-computed path allowing him/her to move in a tunnel of configurable width avoiding as much as possible aggressive correction of its trajectory.
- Cutaneous stimuli for the representation of guidance signals and techniques to improve the haptic perception in elderly people.
- Techniques to enhance the capability of the sound algorithm and to discover the amount of information useful for orientation that can be intuitively perceived by the assisted person.

The results achieved can be described as follows:

- Development of a mechanical guidance support to gently direct the user toward a pre-computed path.
- Construction of a prototype of the vibro-tactile bracelet based on the requirements defined in the initial

period.

- Extensive testing and definition of new requirements of the vibro-tactile device in order to improve the haptic perception in elderly people.
- Implementation of a set of audio processing algorithm for the sound spatialisation based on popular techniques using a high-level programming language.
- Testing of the proposed audio processing algorithms. In this regard, a method based on the Head-Related Transfer Functions has been identified and has then been ported into embedded systems to start the analysis of the computational requirements.

WP5: Architectural Design

The goal of WP5 is to design a hardware and software architecture required to execute the different functionalities of the c-Walker. During the reporting period, the consortium has defined a solution for the hardware architecture, which has been instantiated in a first working prototype, has evaluated different alternatives for the software infrastructure (operating system and middleware) and has produced code suitable for the execution on the embedded boards used in the c-Walker.

More in detail, for the hardware architecture the consortium has:

- Evaluated different hardware alternatives by profiling the execution of samples of code which could be representative benchmarks for the different modules; the goal of this activity was to verify the ability of different hardware to run the functionality within the timing constraints identified during the first reporting period;
- Designed a hardware architecture organised in two sub-systems. The first one (mechatronic subsystem) contains all the devices for sensing and actuating, the computing power for low level data processing and high rate feedback control loop and a communication infrastructure based on CAN. The second one (cognitive subsystem) contains the processing power to execute the sensing algorithm and the planning algorithms developed in WP3.
- Constructed a working prototype of the c-Walker.

For the software architecture, the consortium has:

- Evaluated different options for the operating system, with the final decision of using the Embedded Linux OS, equipped with suitable patches to enhance its real—time performance;
- Analysed the requirement for a middleware; a widespread preference in the consortium was found on the convenience of a publish-subscribe mechanism;
- Evaluated the real—time performance of several publish-subscribe middleware solutions;
- Developed a middleware abstraction layer which allows us to use different middleware and/or to easily replace the used middleware if requested by the project;
- Produced re-targetable code for most of DALi’s components

In this reporting period, WP5 aimed at defining the software architecture of the DALi c-Walker. Based on the requirements and constraints defined and highlighted in the first reporting period, the Publish-Subscribe communication paradigm has been selected to glue the various software components. Hence, the resulting architecture will be based on various Linux-based embedded boards (powered by an ARM CPU) connected through Ethernet an some kind of communication middleware providing Publish-Subscribe functionalities will be used for communication. Of course, the definition of the software architecture also required selecting the core software that will run on the various embedded boards.

Different solutions have been tested and evaluated accounting for the designed hardware architecture (also considering some possible alternatives) and for the requirements of the application software developed in the project (considering the applications' requirements and constraints).

WP6: Integration

The integration activities have pursued two different purposes: setting the stage for the user validation to be carried out in the final phase of the project, construction of the integrated prototype.

For the first task, the consortium has:

- Evaluated the adequacy of the space within INDRA premises in Ciudad Real, with a positive conclusion;
- Analysed the possibility to effectively deploy the off-board equipment used to run the demonstrations, with a positive conclusion;
- Designed a scenario that realistically simulates an area of a mall, to be used both for the demonstration in the review meeting and for the final implementation.

For the second task, the consortium has:

- Assembled and tested a prototype implementing the hardware architecture;
- Produced re-targetable code for the different components and interfaced the modules using a middleware
- Tested the integrated and coordinated interaction of different modules, in several scenario, which will be demonstrated during the review meeting.

WP7: Dissemination and exploitation

Scientific dissemination during the second year of the project has been very prolific. High-quality dissemination papers have been produced, not to mention the number of presentations in scientific events that have taken place.

In addition to the publication on relevant scientific conferences and journals, the DALi consortium has taken on a number of initiatives to improve the public awareness of the project:

- Re-design of the website to improve its readability
- Creation of a blog and participation to the social networks
- Post on AAL Forum blog and publication of articles on a technical magazine
- Participation to workshops organized by the AAL forum
- Production of video-clips on the project components and on the consortium activities
- Seminar in University of California at Berkeley.

Additionally, during this second period, industrial partners have been in frequent contact with stakeholders and potential end users of DALi in their market domains. The users' problems have been analysed and considered by the designers and developers of DALI's prototype. The solution analysis has just started by holding solution interviews and showing either sketches of DALi solution or first prototypes. This activity will continue until the end of the project.

These activities are carried out in accordance with the business development methodology proposed in D7.2.2. DALi has adopted the Customers Development Process in conjunction with the lean start-up methodology, whose core component is the build-measure-learn feedback loop.

Up to now, these activities have led to two main results: (1) the establishment of a two-way dialogue between Dali experts and stakeholders and user groups maintaining interactive presentations and explaining preliminary ideas for the technology; (2) a deep understanding of users and stakeholders problems and needs in the different market segments.

Expected results and impact

The first year of activities of the project has set the stage for an effective analysis of the requirements, defining a methodology inspired by the most recent literature in user centred participatory design. It has defined the background for the technical development exploring the state of the art in the different areas of the project and producing new results and ideas. Finally, it has collected a massive amount of information on the business opportunities.

The second year has built on top of this solid foundation producing a first working prototype. The prototype integrates leading edge technologies in different areas. It challenges the natural reluctance of older adults towards ICT technologies and assistive devices in general by a careful recognition of their most urgent demands when they move in crowded areas. The prototype has been designed using low cost components to maximise its potential impact. In the final year of the project, the prototype will be refined and extensively tested with a group of real users. Some of them have been involved in requirement collection along the lines of user—centred design. The objective of producing a full prototype compliant with the initial objective stated in the DoW is now clearly within the reach of the consortium.

There are a few issues that mark a clear distinction between our project and similar ideas produced in the context of ambient assisted living. The most important are its emphasis on cognitive support, its adoption of low cost components and its modular design. An important assumption in the DoW, which has been confirmed to a good extent in our requirement exploration, is that the decline of cognitive abilities is one of the main reasons that discourage older adults from attending large crowded areas, such as shopping malls. This gradual retirement deprives the afflicted of important social opportunities and reduces her/his quality of nutrition. On the other hand, a sustained level of physical activity (such as a brisk walk every day) is believed to significantly reduce the need for health care. Under these premises, we are inclined to think that the c-Walker could indeed have beneficial effects on the quality of life of older adults while reducing the costs incurred by the Health Care system to face an accelerated physical and cognitive decline.

The user acceptance and the possible market penetration of the device are not obvious. Our interaction with users has clearly confirmed their potential reluctance to accept any kind of technology or device that could be perceived as a *stigma* of their conditions. On the contrary the device could be accepted if its look was perceived as young, if it was used by a larger category of users (e.g., under the guise of a shopping trolley) and if it offers opportunities for social interaction. We have continued our activity to make a concrete business case contacting stakeholders in different countries. The main input that we have consistently received was towards cost containment and a modular design, such as can easily target multiple market segments.

Website

Additional information on the entire spectrum of DALi's activities can be found on the website: http://www.ict-dali.eu, which has been totally renewed.