AmbienNet: An Intelligent Environment to Support People with Disabilities and Elderly People

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ABSTRACT
AmbienNet is an ongoing project aiming to demonstrate the viability of accessible intelligent environments to support people with disabilities and elderly people living autonomously. Based on the Ambient Intelligence paradigm, it tries to study in depth its advantages and disadvantages for people with sensory, physical or cognitive restrictions. To this end diverse supporting technologies and applications have been designed, in order to test their accessibility, usability and validity. After introducing the objectives and findings of the project, in this paper a number of preliminary results are presented and discussed.

Categories and Subject Descriptors
I.2.11 [Artificial Intelligence] Distributed Artificial Intelligence – *Coherence and coordination*. I.2.9 [Artificial Intelligence] Robotics – *Autonomous vehicles.*

General Terms
Design, Experimentation, Human Factors, Verification.

Keywords
Ambient Intelligence, Ambient Supported Living, Smart Homes.

1. INTRODUCTION
AmbienNet project aims to demonstrate the viability of intelligent applications (such as assisted navigation systems) to assist users with disabilities supported by intelligent environments. In order to do that, diverse heterogeneous technologies at different levels (network and hardware, middleware) have been developed making them interact to each other. Specifically, AmbienNet is composed of an indoors people localization system, a network of sensors and intelligent wheelchairs (acting like autonomous mobile platforms). The resources management depends on a middleware layer that recognizes high level dynamic contexts (network scope independent) and provides services continuity and high availability. On these elements, a new "context and location services level" has been developed that, processing the data provided by the sensors and the localization system, provides abstract information to the services offered by the intelligent environments. Two applications are being set up as a demonstration of the proposed approach suitability: a navigation application to support intelligent wheelchairs for users with disabilities and a handheld guide application for users with cognitive disabilities.

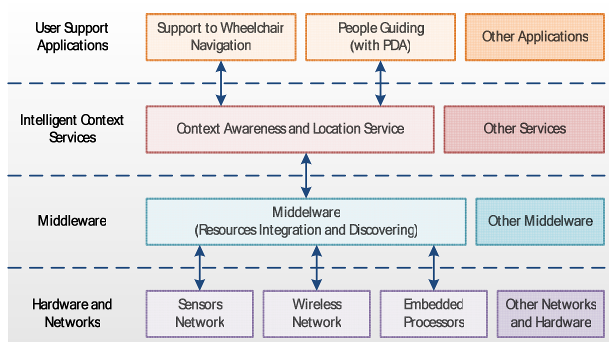

Figure 1. AmbienNet infrastructure model.

2. THE AMBIENNET PROJECT
AmbienNet implemented functional prototypes of the diverse technologies involved. Firstly a set of low level modules necessary to build up a context aware intelligent environment to support context aware applications, such as indoor navigation systems, has been developed. These modules are briefly described below.

2.1 Localization System and Sensor Network
The purpose of the localization system is to precisely locate a device, covering a large enough area, and with an adequate refresh rate in order to support indoor guidance and navigation aid tasks. Other desirable features are scalability, low cost, and easiness of installation and maintenance. Our prototype is based on ultrasounds and ZigBee. Ultrasounds allow accurate localization at low cost, although speed propagation limits refresh rate.

The area of interest is divided into cells, according to the coverage of the fixed devices that emit ultrasound, named beacons. The system operates in two granularity modes. In the *proximity mode*, a rough location —typically the stance related to the cell— of the target is computed. This operating mode requires just one or two beacons in every stance from which we want to provide location information, and for the guiding application, the achieved accuracy is enough. Second one is *multilateration mode*, where location of the target is computed accurately by measuring the ultrasound times of flight. This mode requires some additional beacons to enable multilateration and deal with non-light-of-sight (NLOS) errors —typically five, up to eight elements on biggest stances—. The multilateration algorithm, based on the Least Median of Squares, can handle up to near a half of the measurements affected by NLOS errors, achieving centimetric accuracy. More details can be obtained in [1].

2.2 Middleware

A level of context awareness and location service has been developed that processes the information collected by sensors. Since it is not convenient that applications manipulate data from sensors directly, the context service level takes charge of processing and interpreting that information, in such way that applications can have higher level information of position and localization. It is necessary to design the format in which the context information will be specified, and also the processing mode of the large amount of special data provided by sensors. The techniques used in sensor fusion can be a good starting point for interpreting and classifying this type of information. The result of data fusion and spatial data interpretation is available to context aware user support applications in an adequate format. This level will allow studying the feasibility of developing a context modelling system to identify patterns relative to persons and/or objects.

2.3 Navigation assistance

The navigation aid applications try to show how context and localization information (processed and provided by the context level) allow designing several applications to support users. One of these applications, no disabled user's guidance, enables to provide dynamic and context dependent using a mobile device (e.g. a PDA) for guiding a user through a building. The second application uses the same localization information to interact with a smart wheelchair guidance system, to help navigation.

The AmI system includes a Wireless Sensor Network (WSN) that is the base to support indoor navigation of a wheelchair. Zigbee is again the wireless technology chosen to support our system. Our aim is to use sensors that are part of the environment (that is, external to the wheelchair). This WSN performs detection and tracking of a mobile object (wheelchair), taking into account possible obstacles. Wheelchair position detection is obtained from the positioning system (section 2.1) and from the analysis of video images from cameras situated in the ceiling. The use of information from other environmental sensors is currently under study. The wheelchair position and approximate speed are obtained from the ceiling cameras in order to perform a "local" navigation aid (avoiding obstacles and allowing reaching specific goals) as opposed to a "global" navigation. The speed is computed by the micro-controller based camera, a CMUcam3 board with a CMOS camera based on an ARM processor (Philips LPC2106). The cameras are also used to detect (static) obstacles, distinguishing them from the floor, shadows, etc., using simple, well known image processing algorithms. Although this will be a matter of further research, as a first prototype we simply define a grid map with cells having two possible values: "free" or "occupied". The occupied cells correspond to obstacles as detected by the image processing algorithms, as well as to the architectural limits defined in a map of the building stored in the wheelchair controller. The free cells represent the space where the wheelchair can move.

These obstacles become repulsive (virtual) potentials while targets (doors, desks) become attractive potentials. Virtual Potential Field (VPF) control techniques give us a simple and intuitive way to implement the shared control needed for semiautomatic navigation [2]. It is based on the idea that any obstacle generates a virtual potential field that repels the wheelchair (RVPF-repulsive VPF). To reach the desired goal (e.g. a door or a desk) an AVPF (attractive VPF) is used. VPFs generate virtual forces affecting to the wheelchair and guiding its motion. User intentions, taken from the steering device (e.g. joystick), are treated as an additional force by the navigation system for a semiautomatic navigation. "User virtual force" is added to virtual forces generated by VPFs associated to obstacles (occupied cells) and desired goals. The resulting force contains both user and automatic navigation intentions.

Several questions arise from the use of external sensors in the wheelchair navigation, that have to do with the transmission through wireless links (connecting the external sensors with the wheelchair) of information with real-time constraints like actual and desired position, obstacles, local map, etc. In order to guarantee a safe navigation even in difficult situations like crowded areas, the wheelchair is equipped with ranging sensors and well-known robotics algorithms to autonomously navigate during two consecutive information updates. These include Wavefront path planning algorithm to set checkpoints between its initial pose and the desired one provided by the environment, Adaptive Montecarlo Localization (AMCL) algorithm to overcome odometric errors and enhanced Vector Field Histogram (VFH+) algorithm for obstacle avoidance.

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