# Experiences with A Museum Robot

J. Cabrera*, D. Hernández, A.C. Domínguez, M. Castrillón, J. Lorenzo
J. Isern, C. Guerra, I. Pérez, A. Falcón, M. Hernández, J. Méndez.

Centro de Tecnología de los Sistemas y de la Inteligencia Artificial (CeTSIA)
Universidad de Las Palmas de Gran Canaria - SPAIN

**Abstract**

In this paper we will present Eldi, a mobile robot that has been in daily operation at the Elder Museum of Science and Technology at Las Palmas de Gran Canaria since last December. This is an ongoing project that was organized in three different stages of which only the first one has been accomplished. The initial phase, termed "The Player", the second stage, actually under development, has been called "The Cicerone" and in a final phase, termed "The Vagabond", Eldi will be allowed to move erratically across the Museum. This paper will focus on the accomplished first stage to succinctly describe the physical robot and the environment and demos developed. Finally we will summarize some important lessons learnt.

## 1 Introduction

Last years have revealed Education and Entertainment as promising, though demanding, new application scenarios for robotics with a great scientific, economic and social potential [1]. The interest raised by products like Sony's Aibo or the attention deserved by the media to projects as Sage [2], Rhino [3], Kismet [4] and, more recently, Minerva [5] demonstrate the fascination of the general public for these new fashion robotics "pets".

In this paper we will present Eldi, a mobile robot that has been in daily operation at the Elder Museum of Science and Technology at Las Palmas de Gran Canaria since last December. This is an ongoing project that was organized in three different stages of which only the first one has been accomplished. The initial phase, termed "The Player", was devoted to design and build the physical robot, obtain a scalable and extensible software control architecture and put all this into operation in a number of shows and demos that should be offered to visitors. The second stage, actually under development, has been called "The Cicerone" and aimed at adding better navigational capabilities in the robot such that it can give tours through some of the Museum's halls. In a final phase, termed "The Vagabond", Eldi will be allowed to move erratically across the Museum during its "spare" time (i.e. while not required to give a tour, attend a show or recharge batteries) and it will be possible for a visitor to demand its attention and services through a multimodal interface (gesture, voice and a touchscreen). This paper will focus on the accomplished first stage to succinctly describe the physical robot and the environment and demos developed. Finally we will summarize some important lessons learnt.

## 2 ELDI system anatomy

### 2.1 Hardware description

As stated above, the first phase of the project, carried out during 11 months, was devoted to build the robot and accomplish a first level of capabilities. The main goal is to attract visitors' interest towards Science and Technology. Physically, the robot's body has two main components (see figure 1). The lower part integrates a commercial Nomadic's XR4000 mobile platform that gives the robot its basic mobility and sensor capabilities. On top of this platform, it integrates a "torso" that hosts a second processor, several radio communication systems that offer a 802.11 network interface with off-board systems and

*Contact address: Dpto. Informatica y Sistemas, Campus Univ. de Tafira, 35017 Las Palmas, SPAIN. E-mail: jcabrera@dis.ulpgc.es. Fax: +34 928 45 87 11

Figure 1: Front and side views of Eldi

transmission of color video and sound from the robot, a touchscreen, loudspeakers and two degree of freedom head. The robot is equipped with an active vision system that comprises a pair of Sony EviG21 motorized color cameras housed in the head, a Directed Perception pan-tilt that articulates the neck, and a PCI frame grabber. Basically, the processor installed in the mobile platform controls the motion, localization, obstacle avoidance, selects the video input for transmission and power resources of the whole system using a digital Port Control Board. It runs under the Linux O.S. The second “upper” system, that runs under Windows NT 4.0, controls the whole robot and develops all the interaction with user through a number of devices that include the vision system. Communications with off board systems are routed through the Linux system. The robot is also capable of recognizing voice commands from a number of people.

## 2.2 Control Systems

Three main subsystems control the robot (Eldi). In the upper body a 350 MHz Pentium II running NT takes care of vision, communication, interaction and high-level robot control. In the base, a micro-controller network manages the power and sensor systems (ultrasonars, infrared, bumpers) at low level, and a 233 MMX Pentium under Linux is in charge of platform sensor control, obstacle avoidance, localization, and low level motion control.

Several external machines complete the system (PC’s connected using a local net with two segments being Eldi the net gateway): GameController dual Pentium 350Mhz under NT, BoardController Pentium 300 under W98 and ConacPC Pentium 100 under W95.

Global control is achieved by means of CAV software architecture that provides a sustract for combining different machines in an asynchronous manner, which can exchange signals with parameters. It models the distributed systems as a DES system, facilitating control.

## 2.3 Sensors

In its upper body, the robot incorporates an active color vision system (SONY EVI-G21 and Imaging PCI frame grabber) mounted on a pantilt by Directed Perception for color detection and tracking (faces, robot games pieces), and a 14” SVGA color touchscreen by ELO Touchsystems for direct interaction with visitors (information, screen games). A laser beacon is also included as part of the location system (CONAC).

In its lower body (XR4000 Nomadic Technologies), there are microswitches for door opening detection and temperature probes for motor overheating control. The robot base has two rings with 24 sensor modules with ultrasonic sensors for long range obstacle detection, infrared sensors for short range obstacle detection and bumpers for contact detection (there are additional contact sensors on doors).

External sensors include a pair of color vision cameras mounted on the ceiling of the robot area to help players and robot location using a PCI Imaging frame grabber, a wireless microphone (TOA) for voice recognition, and laser detectors for location system.

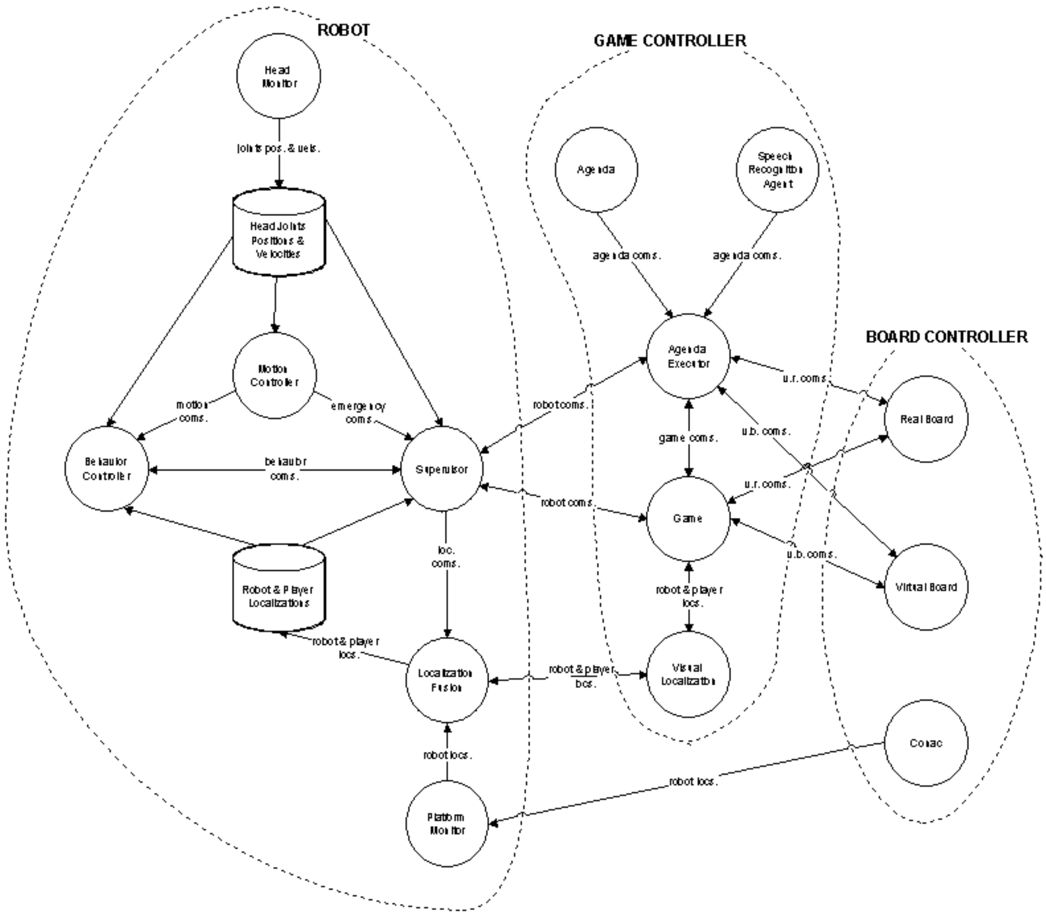


Figure 2: Software architecture under CAV

## 2.4 Degrees of freedom

The robot head is mounted on a neck (PTU-Directed Perception) with 2 degrees of freedom (pan, tilt). The robot eyes are constituted by two motorized cameras that contribute with 2 mechanical degrees of freedom (pan, tilt) and 2 optical degrees of freedom (zoom, focus).

An holonomic system allows for the movement of the base with 4 wheels driven by 2 motors each (wheel rotation and translation).

## 2.5 Power Systems

A microcontroller based system is in charge of power distribution. The robot has a main battery set with four 33 Amp·h batteries and an auxiliary battery set with four 18 Amp·h batteries, both sets located in the base. Two DC-DC conversors and a devices power control board supply upper body systems from battery sets.

## 2.6 Communication Systems

All the machines compose a two segments local network connected by means of Wireless network interface (Lucent Technologies Wireless IEEE 802.11 interface in 2.4 GHz using DS) that uses the lower body as gateway. Internal robot communication systems include a 100 MB/s Fast Ethernet linking the robot's main processors (upper and lower body) and an Arcnet network for information transmission between microcontrollers and the platform main processor. External systems are connected using a classic ethernet.

Audiovisual data are transmitted from the robot using the video-audio transmitter (Eagle 2.4 GHz PAL video and audio transmission).

## 3 Functional description: CAV in Eldi

A major breakthrough accomplished during this first phase has been the software architecture and associated methodology used to control the robot and off-board systems. The system that controls Eldi and the rest of the installation has been conceived as a set of agents that interact by means of discrete events. Eldi has been built using an extended version of CAV [6], a tool that enormously eases the definition and implementation of distributed systems modeled as discrete event system. It had been used previously in the design and implementation of active vision systems to facilitate the development and reduce the integration effort of such systems [7]. CAV allows modeling a robotic system as a set of distributed asynchronous weakly coupled active entities or agents [8] making tasks in parallel or concurrently, and interacting among them by means of events or signals, in this way the system is viewed from an agent perspective, where all agents share the same control and communication schemes. In Eldi, all agents, both on-board and off-board, share the same control and communication architecture. This fact proved to be crucial during the integration of the whole system and sets the basis for the extension or modification of the system across other phases of the project.

Along Eldi development CAV proved to be crucial during the integration of the whole system and set the basis for extension or modification of the system across future phases of the project. In figure 2 are depicted the main CAV agents involved in the current phase of project Eldi, there are other secondary agents that are their subsidiaries which are not shown. In the diagram circles are agents, the cylinders are memory storages, arrows are data flows among agents, bi-directional arrows implies a protocol of command request and response. Functionally, as it is displayed on the diagram, the dashed contours, three different computer systems are distinguished:

**The ROBOT:** That physically includes the mobile platform and TopRobot. The mobile platform which is a Nomadic XR4000, contains also some extra power supply units for some devices (a speaker, TopRobot, the CONAC emitter and a video transmitter). It is in charge of controlling low level platform movements, video transmission to external machines, the platform sensors (ultrasonars, infrared, bumpers, motor temperature sensors and odometry) and the extra power supply units. TopRobot is the upper part of the robot, that is, the torso and the head.

**The GAME CONTROLLER:** It is responsible of:

**1.-** Attending user commands through speech recognition (using IBM ViaVoice).

**2.-** Executing agenda commands.

**3.-** Controlling the evolution of board games.

**4.-** Robot and player visual localization through the external ceiling cameras.

**The BOARD CONTROLLER:** In charge of controlling the game board (the Real Board), the video board (the Virtual Board), and also hosts an agent collecting information about robot localization from the CONAC system.

## 4 Daily activity

Actually, the daily activity of the robot cycles between a show that is carried out over a backlighted 8x8 glass board where it develops several shows and plays different games as “Treasure search” against a human player detected using vision or interacts with a visitor to solve an instance of an 8-puzzle using vision, or synchronise a choreography combined with video and game board, and a “rest” period during which it recharges batteries and offers the public the opportunity to play different games as mastermind, chess or four-in-a-line, or learn more about robotics using a multimedia information system. Some of the available games has been programmed to offer the opponent explanations of the actions taken by the robot during the course of the game or to even comments that reflect the judgement of the robot for the player’s actions. These comments are constructed using a set of phrase patterns that are randomly selected and offered via the voice synthesizer available on board. These comments are accompanied by movements of the head and eyes that track the face of the player. Eldi also attends monitor commands by voice and interacts with users using its Voice-based interface, i. e., a voice synthesizer (Outloud and sound card), gameboard lighting, video projector and the touch screen. Eldi can also perform a weak obstacle detection, semi-automatic system checking, produces a multimedia show.

## 5 Conclusions

The first and perhaps most important lesson learnt from the Eldi project is that a museum robot must be conceived as a living being. Shortly after the initial goals had been accomplished, the museum staff will probably require the development team to add new capabilities to the robot to allow for new or better shows or activities. Indeed, this situation must be considered in the light that these “pieces” normally capture a great deal of attention from the visitors and it is not unusual that they end up being considered as the “flagship” of the exhibition. A logical consequence is the staff demand to constantly update the shows or add new capabilities to the robot to renew the interest of the public and attract new visits. Surprisingly, we have observed, as other authors [9], that it is the emotional and expressive abilities of the robot what captures much of the people’s attention and not its navigational or obstacle avoidance capabilities. Most people do not realize (and do not mind) if the robot is avoiding obstacles or not. People enjoy frequently catching robot attention (cameras) and seeing themselves on videoboard or on eldi’s screen. In our opinion, a clear indication, of the type of expectations these type of robots poses on the general public.

Another aspect that is intertwined with the aforementioned extensibility is reliability. After the installation and initial verification of the system by the developers, it will be maintained or at least, operated on a daily basis by personnel not specialized in these systems. If the system is hard to maintain or does not assist the maintainer in discovering the cause of a failure, the system may not survive the first problems. Reliability need to be addressed not only during a startup checkouts but specially during operation. This demands a software control architecture that must guarantee the correct operation of the different parts of the system both hardware and software. These goals have been partially addressed within this project associating watchdog timers with communication links and light weight verification daemons with device controllers.

In our opinion, these facts emphasize the importance of a suitable control architecture and associated design implementation that must hold the extensibility and easy integration demands of these systems in particular and of mobile robotics in general.

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