Towards Pervasive Robotics

Artur M. Arsenio
Artificial Intelligence Lab - Massachusetts Institute of Technology
545 Technology Square, Room NE43-936, MA 02139
arsenio@ai.mit.edu

Abstract

Pervasive robotics will require, in a near future, small, light and cheap robots that exhibit complex behaviors. These demands led to the development of the M2-M4 Macaco project - a robotic active vision head. Macaco is a portable system, capable of emulating the head of different creatures both aesthetically and functionally. It integrates mechanisms for social interactions, autonomous navigation and object analysis.

1 Motivation

One approach of AI is the development of robots whose embodiment and situatedness in the world evoke behaviors that obviate constant human supervision [Brooks, 1999]. With this in mind, we developed the M2-M4 Macaco project, which is described in this paper. M2-M4 Macaco is a robotic active, modular and compact system. This creature was designed to fit different mobile robot platforms or act as a stand-alone system. Another design goal was the portability of both the mechanical and electronic devices and its brain. Macaco characteristics make it a portable, fully operational robotic head whenever not assembled to a mobile platform, able to act as a social agent. A simple communications interface enables operation onboard mobile platforms, turning the robot into an autonomous, sociable machine.

Research robots are enclosed most of the time at lab facilities in which they are developed, most often operating just for demonstration goals. We expect in a near future to have both the robotic head and its brain physically present at exhibitions/seminars, interacting socially. This new approach with complex, portable research robots will lead to commercial applications and increasing synergy among roboticists. Eventually, pervasive robotics - robots present everywhere to perform a variety of tasks - will be possible as smaller, lighter and cheaper robots become available.

1.1 The Robotic creature

This robotic mechanism was designed to resemble a biological creature, exploiting several features of an evolutionary design, but adding others (such as a thermal camera for human detection and night vision) for improved performance.

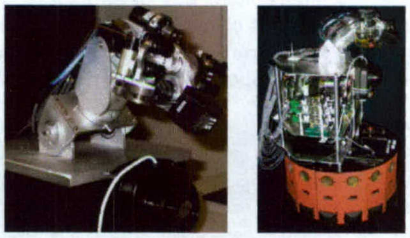

Figure 1: (Left) The M4 Macaco robot, designed to resemble a dog's head. (Right) The M4-Macaco robotic head and processing hardware assembled to a *Magellan* mobile platform.

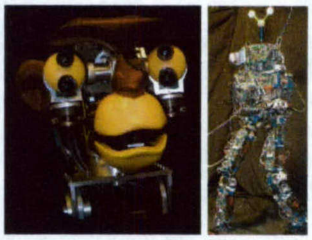

Figure 2: (Left) M2-Macaco, a biological inspired robotic head, designed to resemble a chimpanzee head. (Right) M2 robotic body built by the MIT LegLab.

The replacement of a few M2-M4 Macaco's aesthetic components allows for the metamorphosis of a dog-like (M4 - see Figure 1) into a chimpanzee-like (M2 - see Figure 2) robot. The weight of the head, including motors, gears and gyro, is $\sim 1.6Kg$. The hardware consists of nine small CPU boards with Pentium III at 800MHz, all modules connected by an Ethernet network. Four cameras and a total of nine framegrabbers are used for video acquisition.

2 Implementation

Security is one possible operational scenario for this active head. For this class of applications, Macaco robot was equipped with a behavioral system capable of searching for people or faces, and to further recognize them. In addition, human gaze direction might reveal security threats, and thus a head gaze detection algorithm was developed. Probable targets for such gazings are other people and mostly important, explosives and/or guns. Therefore, salient objects situated in the world are processed for 3D information extraction and texture/color analysis. Current work is also underway for object and scene recognition from contextual cues.

Another scenario includes search and rescue missions by a mobile robot, which requires additional navigation capabilities in rough terrain. Finally, real world applications are often characterized by strong light variations or the absence of light. This is taken into account through thermal image processing for people detection and for night navigation.

2.1 Visual Pre-Attentive System

Although the real world does not avail precise or singularly adequate perceptual information, unique interpretations of the world can be constructed using an attentional mechanism. A logpolar attentional system was developed to select relevant information from the cameras output, and to combine it in a saliency map (see Figure 3). This map is segmented into three regions of stimuli saliency - the attentional focus.

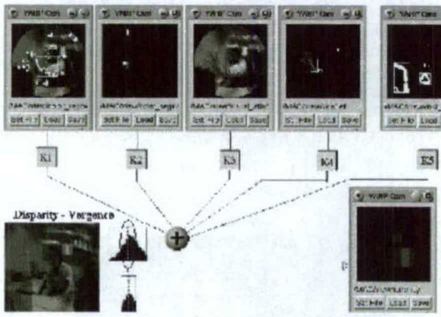

Figure 3: The basic feature maps (Color Processing, Skin Detection, Optical Flow and Edge Detection) are weighted and summed, yielding the saliency map. The focus of attention is obtained from segmenting this map.

Macaco's robotic eyes are equipped with a set of basic movements made by frontal eyed, foveal animals: Ballistic movements are executed without visual feedback; Vergence to a target is maintained by a disparity signal from stereo images; and Vestibulo-ocular-reflex (VOR) stabilizes the cameras using data from the inertial sensor.

2.2 Post-Attentional Vision

The brain for the M2-M4 Macaco robotic head consists of a flexible, modular and highly interconnected architecture that integrates social interaction, object analysis and functional navigation modules, as shown in Figure 4 - the post-attentional modules are described in detail in [Arsenio, 2003],

- Object Analysis: Texture and Color Segmentation algorithms run in parallel, and are integrated with 3D object reconstruction to obtain a rendered object model.
- Social Mechanisms: For the robot to achieve a convincing social role, the vision system is equipped with face detection and recognition modules, together with an algorithm for the detection of human gaze direction.
- Navigation: Although 3D information is lost with low visibility, the platform is still able to operate thanks to a thermal camera. A navigation algorithm based on monocular cues runs at frame-rate, for night navigation.

Figure 4: (Left) Object Analysis. (Center) Social and (Right) Navigation Mechanisms.

2.3 Architecture

The software architecture includes, besides the Visual Attention system, releasers from body sensors and motivational drives that modulate attentional gains. Action is determined by competing behaviors, which also share resources to achieve multi-behavior tasking.

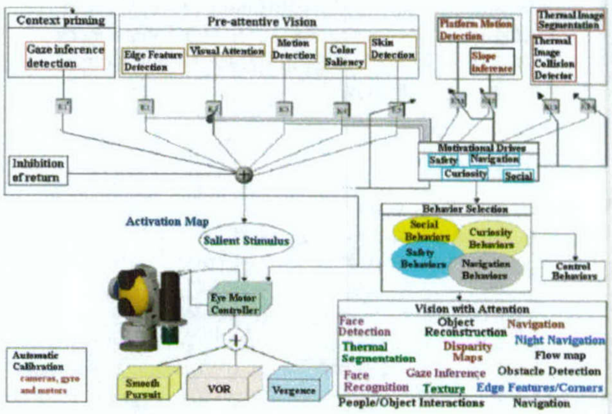

Figure 5: M2-M4 Macaco software architecture.

3 Conclusions

We presented the project of a portable robotic head, modular at the mechanical, hardware and software levels. Although equipped with a complex cognitive system, its small weight and compact size allows it to be incorporated into multiple mobile platforms, and also to be used as a portable autonomous sociable robotic creature.

Acknowledgments

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References

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