



UChile HomeBreakers 2011 Team Description Paper

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Publication date:
2011

Document Version
Peer reviewed version

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Citation (APA):

Ruiz-del-Solar, J., Correa, M., Hevia Koch, P. A., & Verschae, R. (2011). *UChile HomeBreakers 2011 Team Description Paper*. Paper presented at RoboCup International Symposium 2011, Istanbul, Turkey.

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UChile HomeBreakers 2011 Team Description Paper

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Abstract. The UChile HomeBreakers team is an effort of the Department of Electrical Engineering of the Universidad de Chile. The team participates in the RoboCup @Home league since 2007, and its social robot Bender obtained in 2007 and 2008 the @Home Innovation Award. Last year we obtained the 5th place in the RoboCup competition. As a team with strong expertise in robot vision, object recognition, and human-robot interaction, we believe that we can provide interesting features to the league, such as: general-purpose object recognition, face analysis tools and human-robot interfaces. This year we have two important improvements in our social robot: the incorporation of a thermal camera and its use in the robust detection and identification of humans, and the use of ROS in our control library. It is also worth to mention that our robot has been used for educational purposes with school children and as referee of robot-soccer games.

1 Introduction

The UChile robotics team is an effort of the Department of Electrical Engineering of the Universidad de Chile in order to foster research in mobile robotics. The team is involved in RoboCup competitions since 2003 in different leagues: Four-legged 2003-2007, @Home in 2007-2010, Humanoid in 2007-2010, and Standard Platform League (SPL) in 2008-2010. UChile's team members have served RoboCup organization in many ways: Javier Ruiz-del-Solar was the organizing chair of the Four-Legged competition in 2007, TC member of the Four-Legged league in 2007, TC member of the @Home league in 2009, Exec Member of the @Home league since 2009, President of the RoboCup Chile committee since 2008, and co-chair of the RoboCup 2010 Symposium. He is also one of the organizers of the *Special Issue on Domestic Service Robots* of the *Journal of Intelligent and Robotics Systems*. The group has also developed several educational activities with children using robots [4][5].

As a RoboCup research group, the team believes that its contribution to the RoboCup community is not restricted to the participation in the RoboCup competitions, but that it should also contribute with new ideas. In this context, the team has published a total of 22 papers in RoboCup Symposia (see table 1), in addition to many other publications about RoboCup related activities in inter-national journals and conferences (some of these works are available in [1]). Among the main scientific achievements of the group are the obtaining of three important RoboCup awards: *RoboCup 2004 Engineering Challenge Award*, *RoboCup 2007 @Home Innovation Award*, and *RoboCup 2008 @Home Innovation Award*.

The team has a strong interest in participating in the RoboCup 2011 @Home League competition. As a team with expertise in robot vision, object recognition and

human-robot interaction (see section 2) we believe that we can provide interesting features to the league, such as: general-purpose object recognition, face analysis tools (face detection, recognition and tracking), hand-gesture detection and recognition, human-robot interfaces, and robust self-localization.

This year we will continue using our social robot, Bender, which obtained the RoboCup @Home Innovation Award in 2007 and 2008. For the 2011 competitions, the main improvements in Bender hardware and software are: the incorporation of a thermal camera and its use in the robust detection and identification of humans, and the use of ROS [15] in our control library. In addition, we have in use the real-time hand gesture and recognition module developed last year [9] (see block diagram in figure 2).

Table 1. UChile articles in RoboCup Symposia.

<i>RoboCup</i>	<i>200</i>	<i>200</i>	<i>200</i>	<i>200</i>	<i>200</i>	<i>200</i>	<i>200</i>	<i>2</i>
<i>Articles</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>010</i>
<i>Oral</i>	<i>1</i>	<i>2</i>	<i>1</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>2</i>	<i>2</i>
<i>Poster</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>-</i>	<i>3</i>	<i>2</i>	<i>-</i>	<i>-</i>

2 Team's Areas of Interest and Expertise

The areas of interest of our team are mainly related to mobile robotics, robot vision and human-robot interaction. Information about our main publications and projects can be found in [1][2][3].



Figure 1. Bender, the official robot of the UChile HomeBreakers.

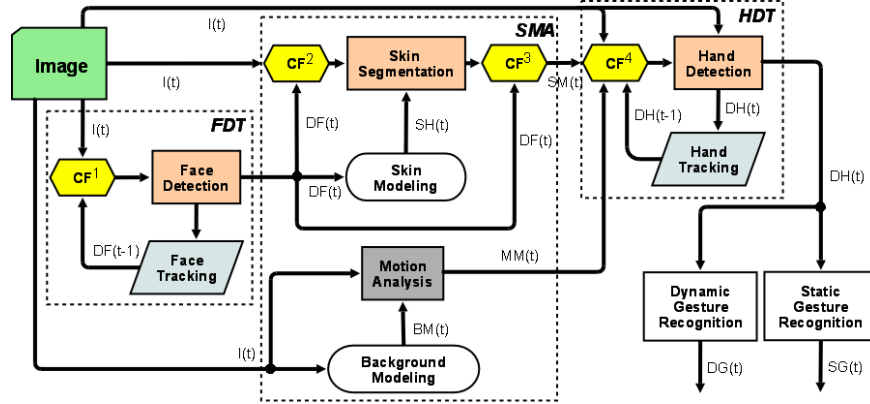


Figure 2. Robust real-time hand gesture detection and recognition module for dynamic environments.

3 Hardware

We have improved our robot *Bender* for participating in the RoboCup @Home 2011 competition. The main idea behind its design was to have an open and flexible platform for testing our new developments. We have kept that idea for our improvement. The main hardware components of the robot are (see Figure 1):

- **Chest.** The robot's chest incorporates a tablet PC as the main processing platform, an HP 2710p, powered with a 1.2 GHz Intel Core 2 Duo with 2 GB DDR II 667 MHz, running Windows XP Tablet PC edition. The tablet includes 802.11bg connectivity. The screen of the tablet PC allows: (i) the visualization of relevant information for the user (a web browser, images, videos, etc.), and (ii) entering data thanks to the touch-screen capability.

- **Head.** The robot's head incorporates two CCD cameras (Philips ToUCam III - SPC900NC), pan-tilt movement of the whole head, and the capability of expressing emotions. This is achieved several servomotors that move the mouth, eyebrows, and the antennas-like ears, and RGB LEDs placed around each eye. In addition, it has RGB LEDs in the forehead to simulate the robot's breathing. The head movements and expressions are controlled using a dedicated hardware (PIC18F4550-based), which communicates with the Tablet PC via USB. The cameras are connected to the Table PC using USB ports. The head's weigh is about 1.6 Kg.

- **Thermal Vision.** The robot is powered with a FLIR TAU 320 thermal camera [17]. The camera has a resolution of 324x256 pixels, and it is sensible in the 7.5-13.5 μ m long-wave infrared range. The camera is placed in the robot head.

- **3D Vision.** The robot is powered with a PMD CamCub2.0 TOF (Time-Of-Flight) camera [16]. The camera, with a resolution of 204x204 pixels, is placed in the robot chest, and used for object detection while grasping.

- **Arms.** The two arms of the robot are designed to allow the robot to manipulate objects. They are strong enough for raising a large glass with water or a coffee cup. Each arm has six degrees of freedom, two in the shoulder, two in the elbow, two for the wrist, and one for the gripper. The actuators are 8 servomotors (6 RX-64 and 2

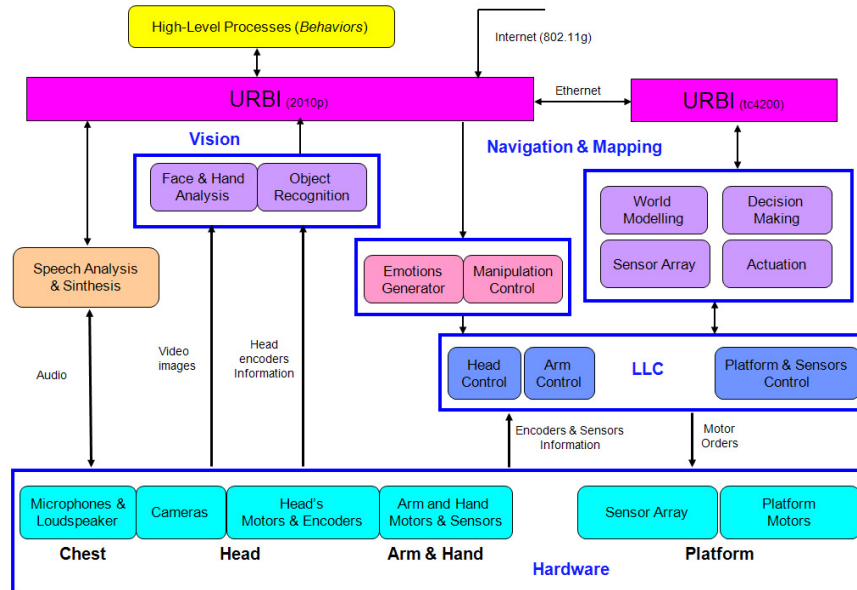
RX-28). The arms are controlled directly from the Tablet PC via USB. The arm's weight is about 1.8 Kg.

- **Mobile Platform.** All described structures are mounted on a mobile platform. The platform is a Pioneer 3-AT, which has 4 wheels, provides skid-steer mobility, and is connected to a Hokuyo URG-04LX laser for sensing. This platform is endowed with a Hitachi H8S microprocessor. A Tablet PC (HP tc4200) is placed on the top of the mobile platform with the task of running the navigation software. This Tablet PC is connected to the chest Tablet PC by means of an Ethernet cable.

4 Software Architecture

The main components of our software architecture are shown in Figure 3. Speech synthesis and analysis, as well as vision tasks (general object recognition, face, hand and gesture recognition), take place in the Tablet PC HP 2710p (running Windows XP Tablet PC edition), while the Navigation and Mapping Modules reside in the Tablet PC HP tc4200 (running Linux), and the low-level control modules run in dedicated hardware (head and arm control). Both Tablet PCs are communicated using URBI (see Figure 3). All the modules running in the HP 2710p are controlled through URBI using UObjects. The Navigation and Mapping Modules are implemented using the CARMEN Navigation Toolkit [14] and ROS [15], which provide localization, simulation, collision avoidance and logging, among other functionalities.

The *Speech Analysis & Synthesis* module provides a speech-based interface to the robot. Speech Recognition is based on the use several grammars suitable for different situations instead of continuous speech recognition. Speech Synthesis uses Festival's Text to Speech tool, dynamically changing certain parameters between words in order to obtain a more human-like speech. This module is implemented using a control interface with a CSLU toolkit [10] custom application. Similarly, the *Vision* module provides a visual-based interface to the robot. This module is implemented using our own algorithms. The latest addition to this Module is the robust real time hand gesture detection and recognition module, which is further described and evaluated in [9]. The other modules have not changed radically since last year, a more detailed description of those modules can be found in our 2009' TDP [11].



LLC - Low-Level Control: Runs in a dedicated hardware (PIC-based)
 All other processes run in a Tablet PC

Figure 3. Modular organization of our software library. The HP tc4200 runs the Navigation and Mapping and the rest of the high level processes run in the HP 2710p.

5 Reusability and applicability in the real-world

Bender can be defined as a personal/social robot, designed to be used for the RoboCup @Home league. However, the main idea behind its design was to have an open and flexible testing platform that can be used in other application domains. Bender has been used as a lecturer for children [5], as a robot referee for humanoid robots [8], and a natural interface for Internet access [12].

Using Bender outside the laboratory environment requires natural and robust human-robot interaction, an aspect on which our team has put great emphasis. Bender's abilities have been tested on a public space setting: we have left the robot alone (under long-distance surveillance) in different places of our university campus and let people freely interact with him and evaluate its ability to express emotions (happy, angry, sad and surprised). The recognition rate of the robot's facial expressions was 70.6% [13]. Public demonstrations of Bender's abilities also include face detection and recognition (using only one face sample from a passer-by), and static gesture recognition applied to playing a game (rock, paper and scissors).

Finally, it is worth to mention that we have carried out comparative studies about face recognition algorithms for HRI application [6]. Last year we have extended our comparative study to consider thermal face recognition [7].

6 New Development: Human Detection and Identification using Thermal and Visual Information in Domestic Environments

The robust detection of humans in real-home environments is a challenging task, mainly because of variable illumination conditions, cluttered backgrounds, and variable poses of a human body with respect to the robot's camera. In fact, a human body is a complex and deformable object with several degrees of freedom, whose appearance can change greatly when mapped into a 2D camera. Thus, the problem of the detection of a human body or a human body-part using standard CCD and CMOS cameras that work in the visible spectrum is far from being solved! Depending on the specific circumstances, humans can be detected by using information about their faces, silhouettes, skin, or movement. None of these methods is all-purpose and any of them can fail depending on the specific circumstances. For instance, face and silhouette detection depends on the specific relative pose of humans (e.g. a face can not be detected when the human is observed from the back), skin detection depends largely on the illumination conditions and on the background (e.g. human skin can easily be confused with other materials such as wood), and human movement detection depends largely on the illumination conditions and the relative movement of humans (e.g. a human in a static position can not be detected). The robust identification of humans using visual information is also dependent on environmental conditions such as illumination, cluttered backgrounds, and relative pose of the person to be identified. When restricted to visual interaction, face recognition is the most frequently used and natural clue for identifying people.

In the case of human observers, key aspects powering the fast and robust detection and identification of other humans in complex environments are: (i) a visual system with a wide field of view, high resolution in the fovea, and active vision mechanisms that allow focusing attention, and (ii) the capability of carrying out a holistic analysis of scenes and using contextual/semantic information to speed up the human/object detection processes. These elements permit implementing fast and robust search mechanisms.

Thus, the human visual system seems to be a perfect source of inspiration for developing systems for robots enabling them to detect and identify humans in domestic environments. However, due to the fact that the sensing capabilities of artificial systems are still far below the performance of human sensing, in terms of achieving high resolution and a wide field of view at the same time, we have proposed a different approach, taking advantage of thermal sensor technology that allows complementing standard CCD and CMOS technology. Hence, robust human detection and identification in domestic environments using visual information is tackled using a combination of thermal and visible-spectrum sensor technology, together with advanced computer vision methods.

Thermal sensors allow the robust detection of human bodies independently of the illumination conditions (no light is required) and of the pose (the thermal radiation of a human body can be detected in any pose), and its detection range is up to several meters, which is enough for domestic environments. In addition, humans can also be identified by analyzing their faces in the thermal spectrum. Taking all of these properties into consideration, it seems natural to include thermal cameras in current and future domestic service robots. The price of thermal cameras is no longer a factor

for not using them in domestic robots, due to the fact that the price has fallen significantly in recent years. In fact the price of a thermal camera of 324x256 pixels, such as the one we used, is now comparable to the price of middle-range laser sensors and time-of-flight cameras, both commonly used in domestic robots.

In this context we have developed a robust system for robot detection and identification of humans in domestic environments. Robust human detection is achieved thanks to the use of thermal and visual information sources that are integrated to detect human-candidate objects, which are further processed in order to verify the presence of humans and their identity using face information in the thermal and visual spectrum. Face detection is used to verify the presence of humans, and face recognition to identify them. Active vision mechanisms are employed in order to improve the relative pose of a candidate object in case direct identification is not possible, e.g. the object is too far away and the robot must approach it, or the view angle is not appropriate for identifying the human and the robot must find a better view angle.

In figure 4 is shown a block diagram of the developed system, and in figure 5 the output of some selected modules.

In conditions of bad or variable illumination, the system relies mainly on the use of thermal information. However, in conditions of good illumination, thermal and visual information complement each other. For instance, visual information allows a better analysis of the textures and a more robust detection of eyes, which is used for face alignment before identification. Thermal information allows an easier segmentation of human bodies and faces in complex backgrounds.

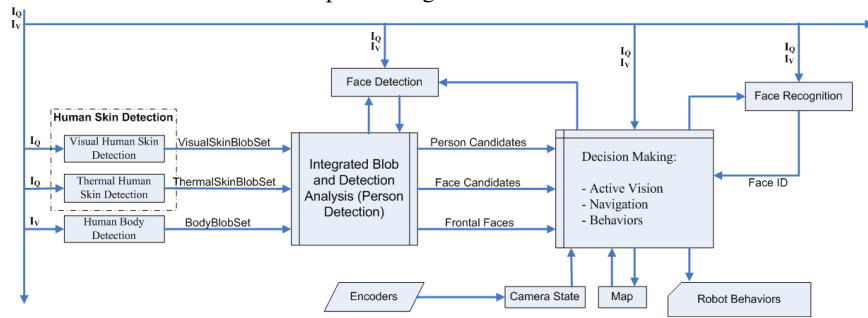


Figure 4. Block diagram of Human detection and Identification system. I_V : visual image, I_Q : thermal image. See text for details.

7 Conclusions

In this TDP we have described the main developments of our team for the 2010 RoboCup competitions. As in the last RoboCup competition, this year we will participate with our Bender personal robot, which as been developed in our laboratory. This year we have two important improvements in Bender: the incorporation of a thermal camera and its use in the robust detection and identification of humans, and the use of ROS in our control library.

It is also worth to mention that our robot has been successfully used in other real-world applications (for educational purposes with school children and as referee of robot soccer games).

Acknowledgements

This research was partially supported by FONDECYT (Chile) under Project Number 1090250.

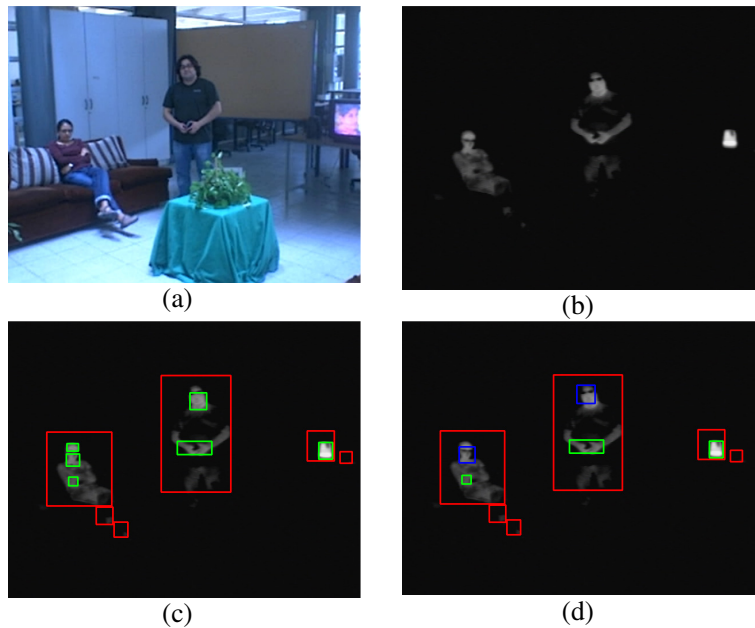


Figure 5. Output of the some selected modules: (a) Visible image. (b) Thermal image. (c) Human Skin detection: human body blob in red and thermal skin blobs in green. (d) Person detector: *Person Candidates* in red, *Face Candidates* in green, and *Frontal Faces* in blue. Some false detections are observed.

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