dotMEX 2013 (.MX) Humanoid Kid-Size Team Description Paper

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Abstract. The dotMEX (.MX) consortium constituted to participate at the RoboCup 2012 (kid size category of the soccer league), join together the major Mexican educational institutions, UNAM and Cinvestav, and a SME: Verstand Labs. Now, this consortium includes UPSin another mexicain University. The DotMex Team uses two kinds of robots: the well know DarwinOP manufactured by Robotis and the dotMEX prototype. This paper describes the characteristics and the main scientific aspects of the dotMEX humanoid robot and its subsystems: Electromechanics; Electronics and Computing; Perception; Control; and Programming.

1 Introduction

1.1 RoboCup experience of our Consortium

The dotMEX consortium, constituted by UNAM and Cinvestav, two of the major Mexican educational institutions, with the SME Verstand Labs, was participate at RoboCup 2012 in the Kid Size category of the Soccer League. The dotMEX team inherits the long and wide experience accumulated by its members after five years of works with humanoid robots and their participation in some of the most important Mexican and international tournaments, resumed in next paragraphs.

The pUNAMoids previous experience in RoboCup is as follows: RoboCup Suzhou 2008 - quarter-finals of the tournament and best team in America. RoboCup Graz 2009 – first round. Robocup Mexico Open Tournaments: 2008 - Second place; 2009 - Third place; 2011- Second place, always in the Kid-Size category.

The MexiKatroniX experience can be resumed as: The last two RoboCup participations of MexiKatroniX Team were in the RoboCup championships at Graz 2009 and Singapore 2010. In these tournaments Cinvestav-IPN participated along with La Salle University, together as the Cyberlords team, with good results (second round).

The dotMEX team took part at RoboCup 2012, where one of the dotMEX players was exhibit a good performance in the experimental play (5 vs 5 in a 10 m field) between Mexico against Rest of the World, producing the victory goal.

The dotMEX Team, including UPSin, its new participant, win the First Place at the Hurocup 2012 (United Soccer category), organized by FIRA at Bristol, UK in August 2012, and win the First place in the soccer competition at the 2012 International Robot Contest, organized at Seoul, South Korea, where dotMEX team was, also, third in all around tetrathlon competition.

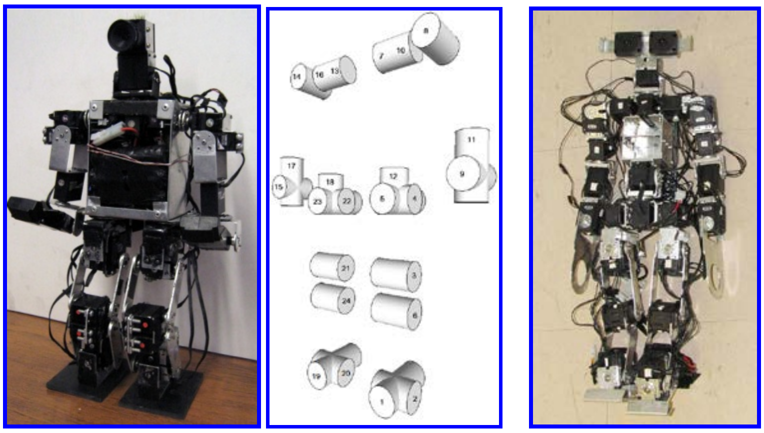

Fig 1. pUNAMoid V3 and AH1N1 prototypes.

1.2 Commitments

We want to express our commitment to participate in the RoboCup 2013 Humanoid League competition, in Kid Size category. Also, we want to propose Alejandro J. Malo, who has sufficient knowledge of the rules, as referee; he will be available during the competition.

1.3 Research Interests

The main research interests of our consortium are: *i*) the development of computational architecture for humanoid robot control based on commercial hardware, with emphasis in software development; *ii*) Perception, with emphasis in feature extraction, images analysis and visual SLAM; *iii*) Humanoid robot control, with emphasis in dynamically stable walk, motion planning, and visual servoing.

1.4 Team description

To participate at RoboCup 2013, the dotMEX Team will use two DarwinOP robot, his own prototype dotMEX (a Darwin like robot), and our ancient prototypes pUNAMoids and AH1N1 in its new version. The dotMex prototype is being developed by pUNAMoids (UNAM) and MexiKatroniX (Cinvestav) teams. This new prototype is based on DARwInOP humanoid soccer robot but it is equipped with one of the actuators used by the AH1N1 prototype (RX28); The dotMEX robots uses the control and vision systems developed for the AH1N1 prototype [1]. The new algorithms for self-localization and behavior control are based on the algorithms developed by both teams in their prototypes used in previous tournaments; in particular, the self-localization is based on 1-Point RANSAC with IDP and EKF [14], [15], [16]. The next sections are devoted to show the main features of the dotMEX humanoid robot and its subsystems.

2 Electromechanical system

The antecedents of our dotMEX prototype are the pUNAMoid and the AH1N1 [1] prototypes. Then, before the DotMEx presentation let us show the mechanical architecture of our previous prototypes: the pUNAMoid (Fig. 1 left) with HiTec® servomotors and the AH1N1 (Fig. 1 right) with 26 Robotis® servomotors (twenty RX28, four RX64, and two RX10).

The mechanical architecture of dotMEX prototype is based on DarwinOP (Fig. 2); then, it has 20 dof (degrees of freedom): 2 dof for the head, 3 dof for each arm (shoulder with 2 dof and elbow with 1 dof) and 6 dof for each leg (hip with 3 dof, knee with 1 dof and ankle with 2 dof). The inverse kinematics problem of robot AH1N1 and DarwinOP are solved through the Paden-Kahan methodology, based on screw theory that splits the whole problem into a series of sub problems whose solution is known [1], [2]. Finally, the dotMEX robot uses 20 RX28 servomotors by Robotis®. The energy system is based on a 3S-YT503560HH LiPo battery of 1000 mAh by Yuntong®, used also by DarwinOP and Bioloid Robotis® commercial humanoid robots.

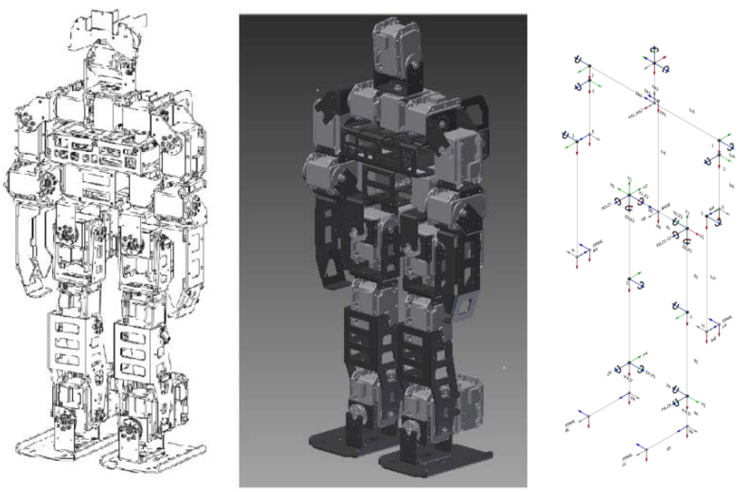

Fig. 2. Kinematic diagram of the dotMEX prototype.

3 Computing System

The previous prototypes of both teams, pUNAMoids and MexiKatroniX, have been equipped with different computational architectures, using always two processors: one to control the servomotors and other devoted to vision, intelligence and communications tasks. In the modified Robonova prototypes we use the MR-C3024 (Atmel ATmega 128 microcontroller 8 bits) and the CMUCam3 (Phillips LPC2106 microcontroller 32 bits ARM7DMI core), but we have other versions with the MR-C3024 and the Roboard 100. The prototypes based on Robotis servomotors use Robotis controllers (CM510, CM700) plus a computing unit for vision and intelligence (Overo, Roboard). Now, in our dotMEX prototype we are using the CM730 plus a fitPC2i. We are trying to use the DarwinOP software, taking advantage of the fact that we use the same kind of hardware, but it is not always possible. Then, we are developing the software described in the next paragraphs.

The OS used by the fitPC2i is Khabelix, a free distribution developed by Verstand Labs especially for the AH1N1 project [3]. This OS permits the development of robotics and artificial vision application by non specialist people in a more easy way than using Armstrong or OpenEmbeded. Khabelix is based on Debian GNU/Linux with Ubuntu libraries and works under ARM architecture and the Intel's architectures used by fitPC2i.

With our OS we don't need to program directly the embedded system, because we can program in any PC using our USB Live emulating Ubuntu Live CD; this USB Live includes all the Khabelix libraries, has persistence, and has Gnome windows administrator. Then, both, Khabelix and its USB Live, have in native form drivers and other resources that permit to develop low level applications. Khabelix has libraries to develop vision applications with IIDC/DCAM cameras, and has drivers for the most used cameras that allow us direct access to firmware resources to increase efficiently in the bayer's camera algorithms for our own computer vision algorithms. Actually, the programs developed on the USB Live Khabelix, are perfectly compatible with the embedded computer.

4 Perception System

One of the most important features of a robot is his autonomy. Autonomy is based on information about the environment and the robot-environment interaction. This information is provided by exteroceptive sensors like vision and touch-force sensors. Laser and IR sensors are forbidden by RoboCup rules. In the other hand, the control system devoted to ensure stable movements in spite of perturbations, needs basically information about the state of the robot variables provided by sensors like joint position and velocity (potentiometers, encoders), and vestibular sensors (IMUs, accelerometers, gyroscopes).

4.1 Vision (Image processing and analysis)

The vision system must provide the controller with information about the actual match situation: ball position, $(x, y)_p$ self position and position of the other two members of our team $(x, y, \theta)_{Ri}$, $i = 1, 2, 3$, and position of the three opponent robots $(x, y)_{Hi}$, $i = 1, 2, 3$,. These seven position vectors are absolute, i.e. they are defined with respect to reference frame associated to field. Note that our robots must be localized with its orientation θ_i.

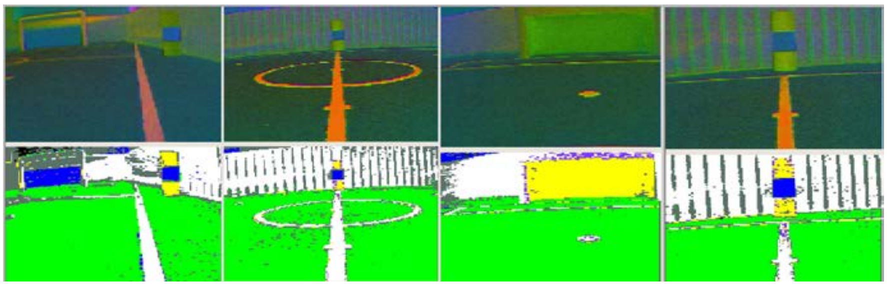

Fig. 3. Four different cases of detection of the opposite goal and beacons.

To do this, the vision system must perform the next tasks over the acquired images: Digital Image Processing (DIP) to enhance the required features, and to implement feature extraction (geometric parameters defining goals, opponents, and ball), Motion detection, and the analysis of all this information to ensure self-localization process, ball detection and tracking, visual control of the robot walk, etc.

First of all, our vision system applies its own Bayer Filter, based on a 5×5 interpolator to avoid artifacts, and performs a space color change over the RGB images to have YUV images. Often, when light conditions are not good enough, we are forced to use some extra DIP methods to enhance features to be detected or extracted, like statistical and/or morphological filters. We are currently using basic YUV color image segmentation to find the ball, opponents and goal areas (Fig. 3). A fast color segmentation algorithm (based on independent YUV thresholds) mostly used in the RoboCup Kid-Size category is being currently used [4]. We have exponentially increased the efficiency in finding objects in the image by a low level algorithm that finds all objects in one memory access of the image [5].

Taking into account that both goals are identical (no colors nor landmarks indentifies the goals), our vision system has a feature extraction algorithm that permits to tag both goals, avoiding ambiguity, using invariable fond textures presents in the field sourroundings. Using these tags, our robots are capable to apply its self-localization algorithms.

4.2 Self-localization

We have proposed some Visual EKF SLAM algorithms useful to locate our robots in the field [7], [16] but they are very expensive in computing time to be implemented over the embedded system of our robots; the obtained results are shown in Fig. 4. These results have gotten with the implementation of a novel combination of RANSAC plus EKF that uses the available priori probabilistic information from the EKF in the RANSAC model hypothesize stage. This allows the minimal sample size to be reduced to one, resulting in large computational savings without the loss of discriminative power. 1-Point RANSAC is shown to outperform both in accuracy and computational cost the Joint Compatibility Branch and Bound (JCBB) algorithm, a gold-standard technique for spurious rejection within the EKF framework [16].

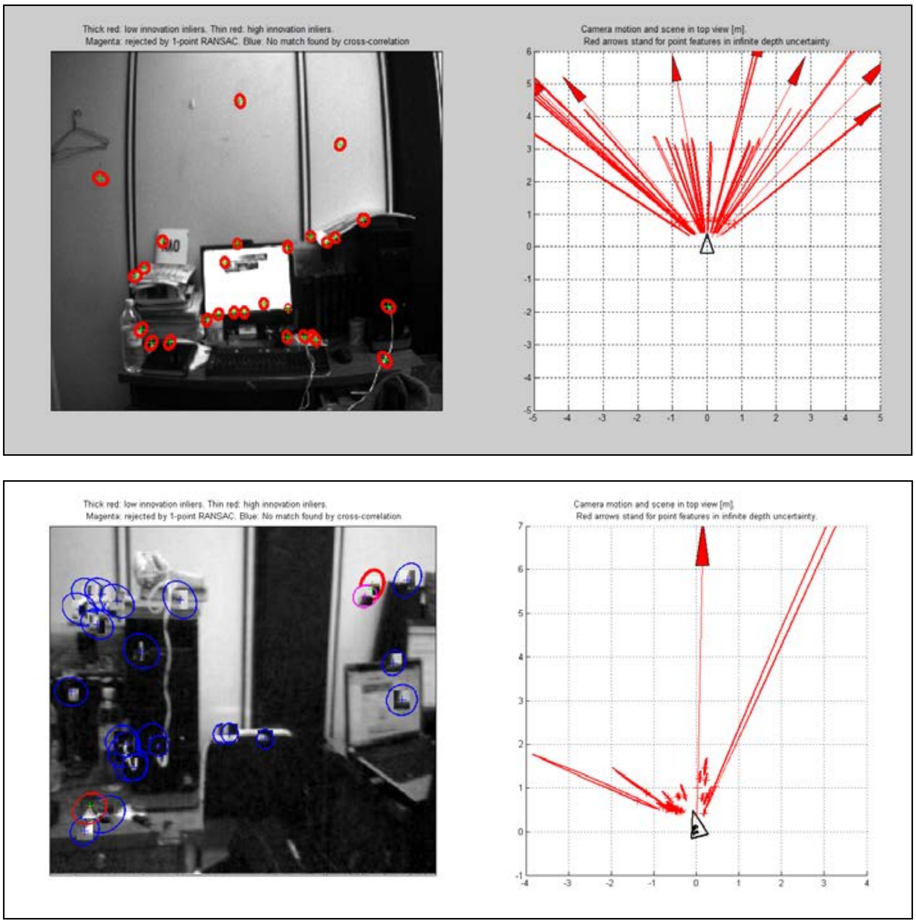

Fig. 4. Some results of our 1-point RANSAC-IDP-EKF Visual SLAM algorithm.

However, we are working to have some less expensive algorithms to implement in our embedded system. Meanwhile, our robots use a very simple self-localization trigonometric method. This self-localization algorithm calculates the (x, y, θ) pose of the robot inside the field by using a very simple triangulation method based in the solution of a quadratic set of two equations: circles centered at a detected feature like beacons or goals. The radii of these circles are obtained directly in only one picture measuring angles of view of the borders of the features detected [8]. Since 2009 we have been developing a vision based localization method. Currently MCL Monte Carlo Particle Filter Localization based on detecting the field lines, goal areas and two landmark poles is being used. By the moment, the localizing algorithm uses the goal areas color and the amount of viewable pixels of such color to determine its distance and current orientation. The motion probability estimation is obtained by previously measuring the movements the robot does after each command and getting its probability density. When turning, for example, each turn has a fixed amount and successive turns are accumulated. The same applies for walking and running. Obviously a good robot calibration becomes fundamental. Currently, we are in the process of incorporating a novel localization method named OVL [9].

4.3 Motion Detection

Our goal keeper has an implementation of an efficient algorithm to calculate the optical flow in real time, with the aim to get the move speed of the ball. This gives the robot the ability to estimate the direction of movement of the ball and its speed. The algorithm implemented is based on the Lucas-Kanade method, as this is easily applied to a subset of image's points, In addition, it is computationally faster compared with other techniques and it can be adapted to a stereoscopic vision system. The experimental results are showed in Fig.5 (estimation of the ball direction and velocity) [10].

Fig. 5. Optical flow: motion direction and velocity components.

5 Control System

Our robot control system, whose scheme is shown in Fig. 6, has three inputs and two outputs; the inputs are signals from the Vision System, the Vestibular System and the Communication System (Game controller and other robots). The outputs are signals send to the Movement System and the Communication System (Other robots and monitor). The Vision System gives the robot information regarding where he is on the playing field (self-localization), and where the ball is. The Vestibular System formed by the accelerometers and gyros allows the robot to determine its attitude and to ensure a stable walk. The Communication System receives and sends messages to the Game Control Program, to other robots in our team and to Monitor. All the information is used by the robot to decide it next move.

The processes are implemented by threads that share information. The shared information is accessed through critical sections, so that the data is not corrupted. The Robot Control System is formed by a Robotis CM-730 and a Compulab fitPC2i, that receives and processes external signals as the video signal and messages from the referee, through the Game Control program. All the data needed for the elementary and reactive movements of the robot (walk, kick, standup) resides in the CM-730 Controller.

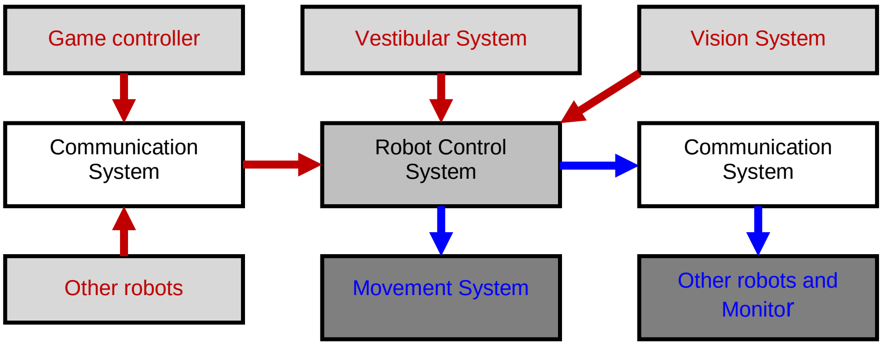

Fig. 6. Robot control system scheme.

Information is shared between robots so that they, as a team, are able to make the best decision. The robot that plays as goalkeeper is in charge of the coordination of its team mates. If this robot must be left the game, the coordination task is taken by a striker robot. The initial state of the robot assumes nothing, as the robot explores itself and its environment it gets a more complete knowledge of its state and the state of the game, allowing him to make a rational decision of its next move.

5.1 Motion Control Subsystem

The joint level control is assured directly by joint actuators (servomotors); while the joint coordination corresponding to a desired gait or other complex movement is calculated off-line with the aid of the ARMS Simulator based on our IK method [2]. Given a desired gait, we define it by using the following parameters: step size, foot's maximum height, body's height, body ripple in both sagital and transversal planes, separation between feet in the frontal plane, the step duration and the double-support phase duration. Then, having defined a desired gait through these 8 parameters, a recently developed version of the ARMS simulator [2], originally developed to participate at RoboCup 2009 [11], produces all the corresponding joint trajectories that realize that desired gait.

Finally, the stability of robot walk is assured by a dynamic control scheme based on a ZMP principle. In case of perturbation (collision with another robot, slippery, etc) the robot can fall. The inertial sensors are supposed to detect that and to inform the ZMP algorithm to compensate this kind of perturbations [12].

5.2 Behavior Control Subsystem

Our previous prototype AH1N1 uses very simple finite states automata to command the behavior of the strikers [13]; while the pUNAMoids prototype uses a Fuzzy Rule Decision System. In both cases, the game strategy is individual, i.e. we have no team strategy. Currently, we are developing a team strategy based on the knowledge of the game situation obtained by the vision system of the three robotic players. The planner resides in the team leader robot (goal keeper) but can be delegated on any robot if the goal keeper must left the game.

Our team strategy can be described as follows: The player nearest to the ball is sent to attack it, while the other striker is positioned in a defensive attitude if the opponent is nearest to the ball than our first striker, or is positioned in attitude to receive a pass if our first striker is not able to kick directly toward the opposite goal. If the ball is positioned behind the strikers, the goal keeper is supposed to kick the ball toward the opposite goal or to pass the ball to better positioned striker. The vision system supplies the game situation needed to plan the strategy described above. The planner calculate the homogeneous transform corresponding to each robot's movement, and the kind of kick needed to solve the actual game situation (direct kick or pass, left or right foot, strong or weak kick, forward or back kick).

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