MRL @Home 2010 Team Description Paper

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Abstract. Robotics is one of main research area in our university. There are several active teams with successful experiences in the Mechatronics Research Laboratory (MRL). Our team consists of a mixture of Bachelor and Master Students who are advised by professors from Qazvin Islamic Azad University. Our group is interested in robot autonomy and human-robot interaction. We have designed and implemented a central software plan which is working as a debugger, commander and coordinator so our robot would be very robust and flexible. Vision related software is more reliable than last year, and we use new additional algorithms in order to detect and recognize faces, objects, facial emotion and gesture so fast and more reliable. Using laser scanner, sonar sensors and fusing with vision software, make our novel map generator, very strong and suitable for semi dynamic environment. Our hardware is also improved by developing electrical & mechanic platform. In addition, we are going to use two robots in the competitions.

Keywords: Robotics, @Home Robot

1. Introduction

In order to emphasize on robotics researches, MRL laboratory was constituted in 2002. It has organized with several teams that research on different branches of robotics. Through the participation in the Robocup match the teams have experienced and shared their knowledge with other research groups, and they have improved the quality of the developed technology. MRL teams are arranged to initiate several research programs on autonomous mobile robot such as: simultaneous localization and mapping, navigation strategies, exploration and motion planning, sensor fusions, scene understanding, visual odometry and search algorithms. With support of existence knowledge in the Mechatronics Research Laboratory (MRL), we have developed and improved an autonomous mobile for doing standard tests in @home Robocup contests. Our robot is powered by Laptop and embedded controlling boards that are connected together through network. The main improvements in MRL @home robot's hardware and software are:

Hardware:

- We have 3 robots (the old robot "Robina", a new PIONEER 3-AT robot and a NAO robot) and decided to have two of them in Singapore.
- Two new Laptop (IBM T61 and T500) for better performance in image, speech and navigation processing.
- Improved electronic board and mechanical components of our robot.
- Tow arm for tow platform. A new 5 degree and old 3 degree of freedom arm.
- A new face that able to have emotions.
- A new conical microphone to prevent noise effect.

Software:

- New central program as server debugger and manager that covers modularity.
- Using new face detection and recognition algorithm.
- Using corners features and depth information for better track.
- Using new gesture recognition and facial emotion algorithm.
- Using a text recognition algorithm.
- Using a new sensor for human detection.
- Using a new approach in localization "Gateway" that gives us a safest path.
- Using stereo vision to detecting objects depth detection.

This paper is organized as follow. We describe our mechanic platform in section 2, hardware description in section 3, software description including its architecture, localization and mapping software, and vision and speech software in section 4. Finally we describe applicability in the real-word in section 5 and introduce team members and their contributions in section 6.

2. Mechanical tips

Mechanic section of the team acts about design, improvement and optimizing mechanical features and structures; consist of the robot's platform and its upward structure, navigation, manipulator and Appearance. In this year we have 3 robots. Beside of "Robina" (our old robot) a new platform equipped with new arm (in preparation) and a NAO robot with some compatibility such as tracking, grabbing recognizing object/speech and etc. We decided to have two of them in Singapore. New platform model is PIONEER 3-AT. It is a highly versatile all-terrain robotic platform, software compatible with all ActiveMedia robots, chosen by many DARPA grantees and others requiring a high-performance robot with plenty of real estate for customization. P3-AT's powerful motors and four monster wheels can reach speeds of 0.8 meters per second and carry a payload of up to 20 kg. (See Fig.1.c)

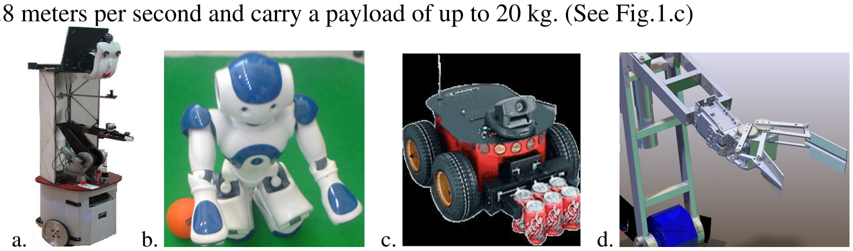

Fig 1. a) "Robina" old robot. b) NAO robot. c)New Platform (PIONEER 3-AT) d) New 5 degree arm

An appealing appearance that comes with a user friendly face, that can show emotions like happiness, sadness etchant moves its details when speaking, undeniably can make the user have more reliable and satisfactory feeling about the robot functions.

The robotic arm of the robot that has just been finished to build has five degrees of freedom: base rotation, shoulder, elbow, wrist and the gripper. Two main materials for constructing are steel profiles for links and aluminum for components (Fig.1.d). There are three compact dc motors that drive worm gear boxes together with two digital high torque servo motors, all are assembled to the manipulator and can provide its powerful and accuracy movements. The gripper is made of two titanium jaws and can be assembled in two different moods, one for parallel jaws and one for angular, derived by a Dynamixel servo motor that can provide 64 kilograms/cm of stall torque. There are many advantages rather than the former arm like less weight, more payloads, more speed, and more degree of freedoms, more range of movement and an optimized gripper. (See table 1)

Controlling and getting feedback data is possible with many encoders and sensors like IR sensor, sonar, laser scanners, load cell and even vision abilities of the robot if it is necessary. With IR sensors on the gripper, robot can see if the object is ready to grip, and with angular wrist can grip vertically or meet the objects in an awkward place in a cupboard. Robina's platform carries out navigating, transferring electronic boards, computers, power suppliers and any other essential equipment at the same time. It is four wheeled, two of them are derived in differential mode and other two wheels are of Omni kind and are about to save the robot's stability. One problem for wheeled platforms is how to overcome the ramps or stairs and so this is just one of the big challenges for a day's robot to contest human.

Table 1. Properties of new arm

Weight	Height	Navigating	Maximum speed	Materials to build	Weight	Max payload
~30 kg	~ 180 cm	four wheeled, differential movement	1.5 m/s	Aluminum, steel and composite materials.	7 kilo grams	4 kilo grams

Projects in progress:

At the present we are researching to construct a new robotic face with special abilities. Defined points are to show emotions like sadness, happiness and excitants and also ability to mechanically lip movements when speaking. Along this project we've designed and finalized a mid-human like structure with two simple arms attached to the robot to do simple tasks like shaking or waving hands.

In the near future we are going to have 2 robots, each for specific tasks. We are going to provide a multipurpose traditional platform with extra features that can help us progress faster as soon as we receive. The research and development never ends in a research laboratory, thus we are effort to have a more stable robot with improved navigating.

3. Hardware

We have developed our network based hardware and improved some part for this year competition. We have designed low-coast, Modular, flexible and industrial robot hardware and our suggestion for this design was the Human body structure. The robot hardware equipped with two laptop, one Logitech webcam, one stereo camera , one DirectPerspective pan tilt, two Hokoyo laser scanner , Devantech Ultrasonic sensors (SRF08), two Maxon DC motor(with Encoder) for main structure and also 3 Maxon motor for arm movement and 3 angular sensor for arm feedback.

We have used several low-coasts and small controlling board which every board independently control one device and connect to other controller and spinal cord through the standard RS-485 bus. Due to this modular and Network structure you can easily add/remove or change every part of the robot in future and it makes our robot hardware very flexible and compatible with industrial standards. Spinal cord coordinating all of controllers and also connect to computers through Ethernet bus to send and receive data/command and acts like human body spinal cord. The controller algorithms must ensure that the set speeds correspond to an admissible configuration. If that does not happen, there will be some unpredictable slippage on one or both wheels.

The control system consist 5 main parts:

1- Fast reflection system which analyzing sensors data and prevent robot from Crashing to objects (In emergency cases this board shut down motors and send error to Computer).

2- PID controller that receives the moving commands from computer and sensors then sends suitable data to motor driver boards.

3- Sensor fusion system that calculates position of the robot based on the data of Sensors.

4- Smart motor drivers.

5- Data acquiring system that acquiring data from all sensors.

6- Ethernet modem that connects spinal cord and laptop together.

Currently we are developing new hardware architecture based on ARM processors, and instead of laptops we want to use Sony's CELL processors in future design (This system is currently under development in our university for about 1 year). We except using this processor make our software run faster because it is multi-core and it has wonderful ability to parallel processing. We decide to use PS3's board and as we use LAN port for communication we think that we won't have any problem with our hardware. At this time we have tested some algorithms with PS3 and we expect to get some good result to port all software's to Cell's Linux.

4. Software

We developed our software to execute on Windows7. It uses LAN port to communicate with Spinal cord. The robot sends the generated path, Log file and sensors data to the laptop computer through LAN port. Our software and hardware do several tasks to control robot. These tasks can be broken down into a number of important sub tasks which are: 1) Acquiring sensors data 2) Sensor fusion[1] and data filtering 3) Low Level controlling such as PID controller 4) Self localization and obstacle detection 5) A communication interface to high level process 6) Fast reflection system. Sensors data will be collected by associated data acquisition module and passed to sensor fusion module (in spinal cord) to be fused and acquire a better perception of environment. This data will be analyzed by Self Localization and Obstacle Detection (SL/OD) to obtain the robot and obstacles pose (in the software). Sensors data will be sent to sensor fusion module for error correction and sensor fusion algorithm. Output data such as robot rotation movement and obstacles distance will be sent to SL/OD and PID Controller module (in spinal cord) to further process.

As we have several problems in previous years about robot configuration during competition setup time, we designed a central software as a manager of all scenarios. It means that we run just one program that contains modules. In other words, all scenarios are implemented in central program. We have some important module in our software such as SLAM, navigation, speech, face analyzer, object analyzer and etc. We have a central server program that uses these modules to do robot tasks (Fig 2).

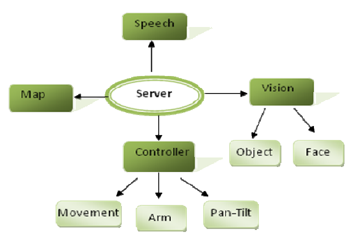

Fig 2. Schema of central software

4.1. Localization and mapping

As we has experienced in Robocop competitions we believe that navigation and localization is one of most important parts of @home robots and developing robot software. We use semi dynamic path planning which is able to generate map and find true path almost dynamically and perfectly. Our localization algorithm is based on scan matching. We use PSM [2] algorithm for scan matching by Laser Range Finder UTM-30LX. As the robot proceeds to search and identify the field, the map of the environment will be developed which might be printed at the end of the robot mission. In our program, two maps will be generated. In this method, environmental conditions will be recorded by laser scanner and a set of 12 SRF08 sonar sensors. It should be mentioned that each of these two types of sensors are necessary to fulfill the deficiency of the others. Then, it is possible to merge the scanned data using different methods such as SLAM [3], Bayesian and extended Kalman filter [4] to have 2D map. We use simple feature base scanning for matching continual scene of laser scanner.

Path planning [5, 6, 7] is a part of our program that the original map is included in it, and indicates goal or sub goals and it generate shortest and safest path between current position and that goals. Safest path reach by using 2D Voronoi diagram and shortest path will find by Dijkstra algorithm (Fig 3). Also this path is simplified by other complex techniques. After comparing two maps, the real position is calculated. But this year we use a different way for mapping and navigation that doesn't work with Voronoi diagram. This approach works with static paths in all of the map. We call it Gateways. These paths in gateways are static and optimized and continuous for each map and also all paths are safe.

We use Gateways in simple tests that robot must navigates static paths; for example Fetch & Carry. We speed up doing tests with reducing time to analysis for finding safest path. But in other tests we use the first approach (Voronoi diagram).

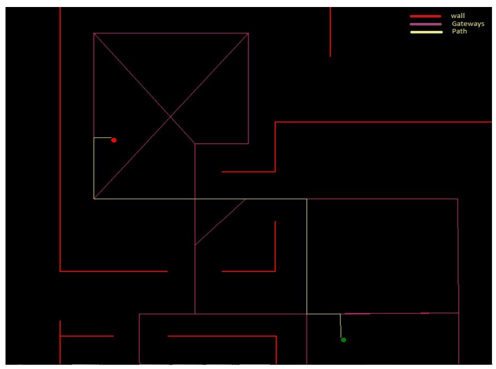

Fig 3. Output of new Gateway algorithm

4.2. Vision system

We employed some different vision techniques, such as object detection/recognition (Fig 4.a), face detection/recognition, object tracking, emotion detection [8] and recognition, Gesture Recognition (Fig 4.b) [9], depth perception, finally scene understanding techniques in our robots. The Object detection/recognition algorithms are based on SIFT/SURF features and some other low level features like color and texture [10]. We use face detector algorithm based on Haar-like features and we use a face reorganization algorithm based on Eigen Vectors algorithms that create face spaces and evaluate the differences of face details and some new methods like body pattern based on the object colors diagram (Fig 3) [11]. This task is accomplished by extracting certain image features, such as edges, patterns, color regions, textures, contours, etc. and then using some heuristics to find configurations and/or combinations of those features specific to a certain object. We used this algorithm in Who Is Who and Lost & Found tests. We used same techniques for Fast Follow test; moreover we used Camshift [12] and corner detection (Harris Feature) algorithm this test too.

Our robot is equipped with a CCD camera and also a stereo vision (Bumblebee) camera for scene understanding. We fused their data with laser scanner data to measure mobile objects depth and position in a real time process which as applied in the follow test to keep distance with the walker person.

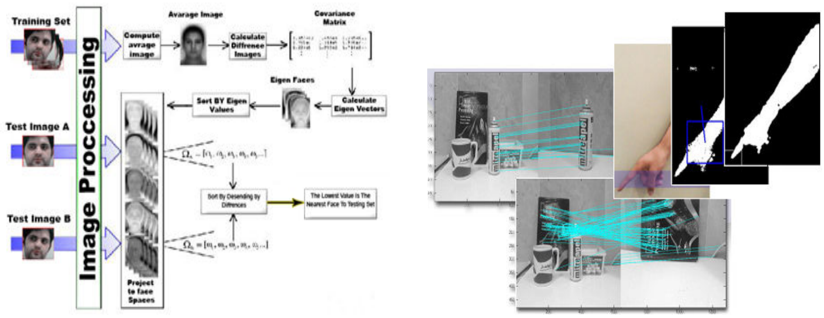

Fig 4. a) Face detection chart. b) The Sample of Object and gesture recognition.

OpenCV is a set of open source computer vision libraries originally developed by Intel3. The libraries are cross-platform and mainly aimed at real-time image processing.

They showed great results in a very huge amount of application areas, ranging from the Human-Computer Interface field to the robotics one, passing through the areas of the biometrics and of the information security. For all of these reasons we decided to use the set of OpenCV libraries in our application.

4.3. Speech system

For better human communication we used Microsoft speech engine as our speech recognition tools. It is so fast and has a high accuracy for speech recognition. The speech recognition system is one way for human computer interaction. As all tests are speaker independent, so we preferred vista engine speech to Sphinx SDK which we used last years, however for speech synthesis we use Windows TTS for Robot speaking. It is primary communication gate for our robot that takes commands from human. In noisy environment, noises disturb us, especially when unknown people would say commands. So we are interested to use microphones which able to decrease noises.

Currently we use conical microphone that gets signals at one way and it is suitable, but tools and algorithm that can improve signal to noise ratio are also interested and it still is under construction.

5- Applicability in the real-world

Our robot has a human like structure, and as it has arm and also strong motors so we don't worry about working in real world. Our robot is able to go through uneven path, so we except that our robot can go outside and help his owner for shopping. Robot can follow its owner whereas it carries a basket. Our robot can be used as a housecleaner too. It can learn objects and search them on the floor; if it finds any of them it will fetch them by its arm and carry it to defined place. As it can learn objects, you can order it to fetch something, then the robot will go to the place that except to find your requested object, so it will recognize and fetch that object with its gripper and bring it near the commander.

Newspaper reading (with OCR and TTS) and predicting weather are other the robot's ability in real world.

6 Team Members and Their Contribution

• Fariborz Mahmoudi	Team Leader
• Reza Javanmard Alitappeh	Supervisor and Vision
• Mohsen AkbariTabar	Localization
• Amir Ali Pasdar	Electronic
• Saeid Zamani	Mapping
• Farhad Maroufkhani	Mechanic
• Mohammad Reza Koshyar	Mechanic
• Emad Majidi	Speech
• Azad University of Qazvin	Sponsor

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