The CEO Mission IV Rescue Robot for World RoboCup and USAR field

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Abstract: - The paper describes the CEO Mission IV rescue robot design and implementation. Its features are designed especially for World RoboCup Championship Rescue Robot League 2007 and USAR field. It is also designed for real practical usages as the universal robotic platform. CEO Mission IV is one of the CEO Mission rescue robot series from University of the Thai Chamber of Commerce (UTCC), which is engaged in USAR research area since 2004. Not only intended for surveillance in rescue job, but CEO Mission IV is also designed with the modular concept and the concepts for reproduction and ease to maintenance. CEO Mission IV rescue robot is composed of the 6-Joint mechanical arm installed on the robotic platform, which is a track wheel type with double front flippers for climbing up the stairs and rough terrain. Three cameras, laser pointer and sensors like IR temperature sensor, CO\textsubscript{2} sensor, and voice sensor are installed on the tip of the 6-Joint mechanical arm for searching the vital signs of victims in the debris. The forth camera is at the back of the robot for driving control. The robot wheels encoders, yaw/pitch/roll angle sensors, and laser range finder are installed at robot for plotting the 2D obstacle map and robot traveling map. Robot localization and map plotting is implemented by using SLAM and Kalman filter. All sensors and controlling data including audio and video data are communicated with a teleoperator control station via IEEE 802.11a/g WiFi for getting real-time response. The communication frequency can be selected as 2.4 GHz or 5 GHz at the teleoperator suitcase instantly in order to avoid signal disturbance. At teleoperator station, the robot locomotion and the mechanical arm are controlled by joystick via the user-friendly GUI control and monitoring program which is developed based on the clicking and dragging method to easily control the movement of the arm. Moreover, a portable teleoperator suitcase is built for operator convenience and portability. All hardware and software systems are explained. The concept and design of this robot can be adapted to suit many other applications. Testing results are very satisfied. CEO Mission IV is one of the most effective rescue robot systems and won the Third Place from World RoboCup Championship 2007.

Key-Words: - rescue robot, RoboCup, mechanical arm, vital signs, surveillance, SLAM, Kalman Filter, CEO Mission

1 Introduction

The first known actual use of robots for urban search and rescue (USAR) was at the World Trade Center disaster on 9/11/2001. The robots were used for searching for victims, searching for paths through the rubble that would be quicker to excavate, structural inspection, and detection of hazardous materials. After this event, many researchers have become more interested in search and rescue for both in basic research and fieldable systems [1][2]. To specially promote research and technical awareness in these socially significant issues, a lot of USAR robot competitions has been initiated. One of the most popular rescue robot competitions is World RoboCup Championships which started in 2001.

Fig.1 CEO Mission IV rescue robot with 6-Joint mechanical arm in RoboCup 2007 in Atlanta, USA
In RoboCup rescue robot league, it requires robots to demonstrate their capabilities in mobility, sensory perception, planning, mapping, and practical operator interfaces, while searching for simulated victims in unstructured environments. As robot teams begin demonstrating repeated successes against the obstacles posed in the arenas, the level of difficulty will be increased accordingly so that the arenas provide a stepping-stone from the laboratory to the real world. Meanwhile, the yearly USAR competitions will provide direct comparison of robotic approaches, objective performance evaluation, and a public proving ground for fieldable robotic systems that will ultimately be used to save lives [3]. This competition is one of the inspirations for the Thailand Rescue Robot Championship to be held in Thailand for the first time in 2004.

The CEO Mission robot team is interested in the basic research aspects of the USAR field while at the same time trying to develop fieldable solutions. Our CEO Mission robot team has been engaged in this research area since 2004 and participated in many rescue robot competitions. We won many awards from the competitions such as Thailand Rescue Robot Championships [4] and World RoboCup Championships. Starting from CEO Mission I, the track wheel type with double front flippers rescue robot for climbing up the stairs and unstructured terrain and the camera on the top of 125 cm high mast for looking over the 80 cm high partitions and accurately marks the locations of simulated victims in the competition arena, we won the First Runner Up award from Thailand Rescue Robot Championship 2004 [5]. In a year later, CEO Mission II was developed to solve the problem of the two degree of freedom limitation in searching by having a 5-joint mechanical arm with a four bar linkage, which can stretch to 125 cm height and is equipped on its tip with sensors for vital sign searching. This 5 degree of freedom mechanical arm came with the teleoperator user-friendly control and monitoring GUI program [6][7]. In Thailand Rescue Robot Championship 2006, CEO Mission II won the Best Technique award and the First Runner Up award, so we joined the RoboCup Rescue Robot League 2007 in Atlanta, USA as the representative team from Thailand. For overcoming the new criteria of design in this competition, CEO Mission IV has to be developed and improved in many aspects as will be described in this paper. As shown in Fig.1, CEO Mission IV is one of the CEO Mission rescue robot series from University of the Thai Chamber of Commerce (UTCC). This latest development of CEO Mission robots provides a sturdy, reliable, unstructured terrain suitable for real applications robot with 145 cm high 6-Joint mechanical arm, as in Fig.2, while providing the universal robotics platform and sensor interfaces with user-friendly GUI software in the portable teleoperator suitcase that allow basic research on many other robotic applications in the future.

The rest of this paper is organized as follows. Section two gives the criteria of the design. In section three, how the robot hardware is implemented. Section four explains the robot software aspects for both onboard the robot and on the teleoperator station. Testing results and discussions is provided in section five. Section six concludes the paper.

2 Criteria of the Design

In the RoboCup Rescue Robot league, robots explore a specially constructed disaster site about the size of a small house. The disaster site includes mannequins with various signs of life, such as waving hands, shouting noises and heat, hidden amongst a maze of walls, doors, stairs, platforms and building rubble as in Fig.3 and Fig.4. The robots, some under human control, must traverse every corner of the arena, find and approach the victims, identify their signs of life and produce a map of the site showing where the victims are located. The aim is to provide human rescuers with enough information to safely perform a rescue. It requires robots to demonstrate their capabilities in mobility, sensory perception, planning, mapping, and practical operator interfaces, while searching for simulated victims in unstructured environments. Each team is scored based on the quality of its maps, the accuracy of the victim information and the number of victims found. For RoboCup Rescue 2007, the level of difficulty of the arena was increased as shown in Fig.5, which are [8]

- Random mazes with non-flat flooring
- Variety of sensory obstacles for ultrasonic range sensor (absorptive ceiling tiles, and reflective corner angles), laser range sensor (absorptive dark felt, reflective mirrors, and transparent flexiglass), and victim identification sensor (false source of heat, motion and/or sound)
  - Stepfield pallets (half-cubic and full-cubic)
  - Stairs (40°, 20cm riser, 25cm tread depth)
  - Ramp (45° to test torque & center of gravity, CG)
  - Confined spaces (ceiling blocks under elevated floors)
  - Visual acuity (E eye charts, hazmat labels)
  - Directed perception boxes with victims inside
  - Box stacks 2-3 stories height (max. 150 cm)

3 The Robot Hardware

As mentioned above about the criteria, a lot of improved features need to be added to CEO Mission IV to solve the problems in the previous versions of CEO Mission robot series [5][6][7] and other robots such as RobHaz, Casualty, IUB [9][10][11][12] for having the better victim accessibility, reliability and mobility. Our main design purpose is not only for the World RoboCup Rescue Robot League 2007, but also including the modular concept, the concepts for reproduction and ease to maintenance and finally, developing it to be the universal robotic platform for real practical usages. The block diagram of CEO Mission IV can be shown in Fig.6. There are two parts as teleoperator control side and the robot side. All items in the teleoperator side are integrated into a portable teleoperator suitcase in order to be in ready-to-go operations.

Fig.3 Competition arena in RoboCup Rescue 2007

Fig.4 Mannequins with various signs of life as simulated victims, some are entombed.

Fig.5 Stepfields, confined space, stairs and step/pipe combinations to minimize corner traction.

Fig.6 Block diagram of CEO Mission IV

The robot side is composed of the 6-Joint mechanical arm, equipped with sensors, installed on the robotic platform, which is a track wheel type with double front flippers for climbing up the stairs and the stepfields. Due to the size of obstacles and staircase, the robot is designed to be 75 cm long with 30 cm diameter wheels, which is bigger than CEO Mission II as seen in Fig.7. All electronic parts are put together in the E-Box module for ease in maintenance. For better mobility especially climbing up the stairs and the 45° ramp, the mechanical part alignment is designed to obtain the CG in the front of the robot platform. Comparing to 5-Joint mechanical arm of CEO Mission II, one more additional joint (Tilt 1) is added for better victim access angle as shown in Fig.8. Three cameras, laser pointer and sensors like IR temperature sensor, CO₂ sensor, and voice sensor are installed on the tip of the mechanical arm for searching the vital signs of victims in the debris as in Fig.9. In Fig.10, the forth camera is at the back of the robot for driving control.
developed based on the clicking and dragging method to easily control the movement of the arm. Block diagram of hardware on the robot body, which is divided into controlling function and monitoring function can be illustrated as in Fig. 11. The monitoring information is composed of data from all sensors on the robot, audio/video from 4 cameras. The teleoperator can see 4 video with image size of 324x248 at 30 frames/sec in real time. For fast and real time processing, most data are sent from robot to compute on the notebook in the teleoperator side, such as the LRF scanning data, odometer encoder data and yawn/pitch/roll data. Three MCS51 CPUs are used onboard the robot. Controlling commands are used for locomotion control, robot devices on/off, multi-joint mechanical arm control. Multi-channel PWM controller is used for 4 PWM signals, which are left/right flipper control and locomotion speed control. PI Controller is implemented for position control of 6-joint mechanical arm.

Fig.11 Block diagram of hardware on the robot.

4 The Robot Software
Software for CEO Mission IV rescue robot can be divided into two parts as onboard the robot and on the teleoperator station, which are developed in C++ and Visual Basic.

4.1 Software Onboard the Robot
For onboard software, it is developed with C++ to gather all sensor information at the robot and send to the teleoperator computer via WiFi, while as perform the receiving commands for controlling all robot functions. The controlling commands are for locomotion control, robot devices on/off, and multi-joint mechanical arm control. Three MCS51 CPUs work together onboard the robot as in Fig.11.
4.2 Software on Teleoperator Station
Software on teleoperator station needs to be well-implemented in user interface and easy to monitor for all sensor data, the robot locomotion, orientation, and location. It also need to show the 24 V. battery level and easily to control all equipment on the robot side, such as turning on/off light and laser pointer, retrieving/saving camera image. The teleoperator screen is shown in Fig.12. In Fig.13, the multi-joint mechanical arm tips moves to the position where the teleopertor is clicking and dragging on the GUI screen to control the movement of the arm. With Inverse Kinematics analysis method, angles of all joints are calculating and then moving simultaneously to get to the desired tip position [7].

5 Testing Results and Discussion
CEO Mission IV was designed and implemented as a rescue robot with the universal robot platform as mentioned above. Under various testing conditions such as climbing over stepfields, climbing up 20 cm high step stairs, up the 45° ramp, all testing results are very satisfied. The 6-joint mechanical arm with 145 cm height does credit to CEO Mission IV like looking from bird eyes view, searching for victim vital signs from directed perception boxes with victim inside, as shown in Fig.15. The communication range of the robot is about 100 meters line of sight. That is a fair range which will be improved in the next version. The teleoperator can switch between 2.4GHz and 5GHz instantly at the portable suitcase to avoid signal jamming. The full speed of running on flat floor is 55 cm/sec. Without power plug-in, the teleoperator control suitcase can operate for 4 hours if we use one battery and for 7 hours if we use two batteries. The robot platform with the multi-joint mechanical arm
weighs 48 kg. If compared to all previous versions of CEO Mission robots, these are the improvement in this CEO Mission IV. To be a USAR fieldable system, this robot need to be improved for higher speed in mobility, lighter weight, water proof, more accuracy in mapping and better communication range.

Fig.15 CEO Mission IV is climbing up the stairs, The 6-joint mechanical arm does credit to CEO Mission IV like looking from bird eyes view, searching for victim vital signs from directed perception boxes with victim inside.

6 Conclusion
This paper explained CEO Mission IV rescue robot improvement. It was design and built based on the criteria of World RoboCup 2007 competition with modular concept and ease in maintenance, and also to be an effective universal robot platform with a teleoperator portable suitcase, packed with the user friendly control/monitoring GUI program. With two selectable communication frequency system (5GHz and 2.4GHz), this robot works well in various situations. It performance was observed to be excellent in unstructured environment, confined space and up/down stairs. Among those robots from hi-tech countries like Germany, Japan, Sweden, Australia, Iran and USA, CEO Mission IV is one of the most effective rescue robot systems and won the Third Place from World RoboCup Championship 2007. As universal robot platform, it can be adapted to use for other applications, such as for Explosive Ordnance Disposal application, which we already developed this robot platform to be CEO Mission EOD robot and we hope that one day these robots can work in the real situations and save some lives. Thanks the University of the Thai Chamber of Commerce for this project supporting funds.

References: