Nautilus Robot Rescue League Team
Tecnológico de Monterrey
Campus Estado de México

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Abstract. This paper describes the Nautilus Rescue Robot Team Development at Tecnológico de Monterrey, Campus Estado de México. Based on the development of rescue robots which can handle all terrain, the team is working in an own onboard computer vision, sensing, communication and locomotion robotics system focused on participating in the fourth Latin American Robotics Contest for the first time.

1 Introduction

In this paper we describe the work done by Nautilus Robot Rescue Team which has been working on mobile robotics since 2000 and currently focused in search and rescue applications. This is the first time that our team participates in an international contest in rescue league. Our robot design called ***"Nautilus"*** reflects our vision that a robot needs to be autonomous and focused in very crucial tasks like rescuing people in a zone of disaster.

The locomotion system allows the robot to be an indoor and outdoor robot in a very irregular terrain i.e. (collapsed areas after an earthquake), the ability to climb stairs without using extra motors or an external source of energy only using the physical capability (weight and shape), computer vision system that identify an object of interest or person using pattern recognition algorithms[1][2] and onboard artificial intelligence for the Simultaneous Localization and Mapping (SLAM)[3][4][5][6] that create a full autonomous robot which can also be teleoperated in order to participate in two challenges during the competition.

2 Mechanical Design

The CAD software CATIA (V5R17)[15], helped us creating the model in which our different designs have been based on.

The first design of Nautilus Fig.1was based on the idea of having a suspended two-caterpillar system that may work independently. This idea came after watching the specifications of some Robocup rescue robots and taking into account the fact that the robot must climb stairs and go over unstable terrain.

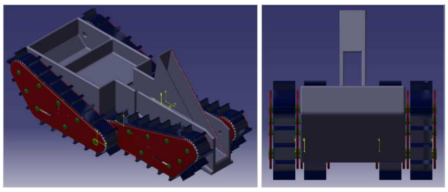

Fig. 1. Isometric and front view of the first Nautilus design.

On the initial stage, we considered that the robot should have a single square body where all the electronical and mechanical devices would be placed. We also included two bands one for each side for locomotion. This design is showned in 2

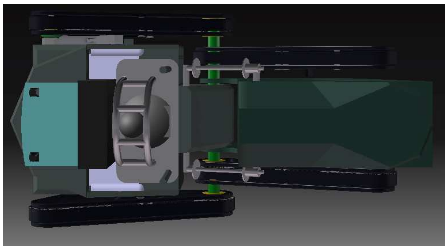

Fig. 2. Top view of Nautilus.

As illustrated in the pictures below, one of the most evident changes in the Nautilus design was the decision to separate the body in two main parts. This idea meant to have a more flexible system to provide a more efficient interaction with different kinds of terrains and surfaces. (For stability reasons a suspension system was added between both boxes).

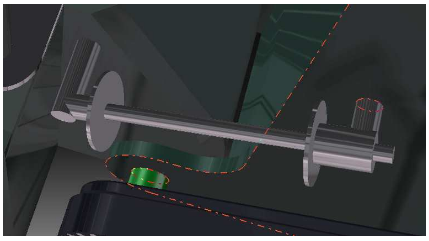

Fig. 3. Detail of the box-box suspension system.

Another important modification, was based on the decision of using profiled conveyor chains instead of a synchronous belt. We added new mechanisms like an elevator system for one of the cameras, the preliminary design of the suspension system, the space for the SICK Laser and the ultrasonic sensors.

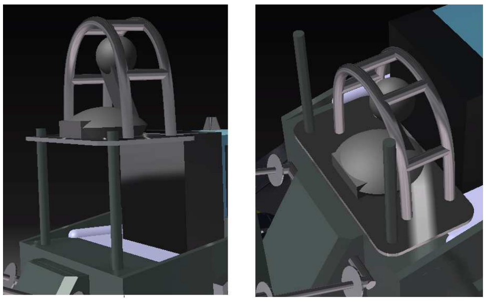

Fig. 4. Camera's elevator.

In Table1 we present the Nautilus'general dimensions.

Maximum height	415mm
Maximum width	466mm
Maximum length	780mm

Table 1. Nautilus dimensions.

3 Mechanical Locomotion

3.1 Electrical Motors

The impelling source consists in two DC motors with the following characteristics:

Electric Power	Torque (full load)	Angular velocity (no load)
120 W	3.29 N	25.52 rad/s

Table 2. Nautilus DC Motors Team Description

The Nautilus speed is controlled by PWM (Pulse Width Modulation Digital Technique). Since each motor controls an independent caterpillar we can modify the robot direction electronically.

3.2 Power Transmission System

The speed and torque transmission are mechanically related in a set of spur and bevel gears within the transmission system.

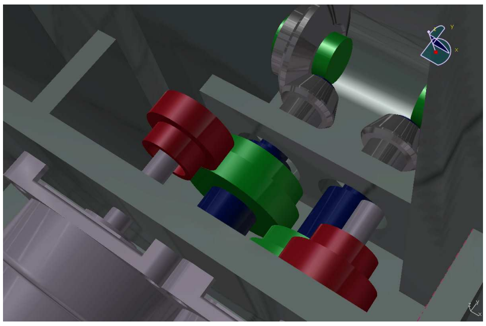

Fig. 5. Transmission model.

Gears.- The spur gears were machined in Nylamid and designed for a 1:1.5 torque relation. The steel-tempered bevel gears were calculated for a 1:2 torque relation. In [8], the analysis of stresses and resistances (bending and superficial) determined the final dimensions of the gears, with a factor of safety around 2.

Shafts.- The aluminum shafts were designed based on the distortion energy theory[8] and the fatigue failure criteria[7] with a factor of safety around 2.

Fig. 6. One-side transmission system.

Roller bearings.- The roller bearings based on SKF catalogues[16], were designed for the specified charge capacity, dimensions and for a life-time of 5000 h.[7].

Sprockets and chain.- Calculated based on dimensions and load resistances.[17]

3.3 Track System

A Chain is a reliable machine component, which transmits power by means of tensile forces, and is used primarily for power transmission and conveyance systems. In the case of Nautilus, the caterpillar system works as a conveyance chain application, the conveyed object is the weight of the robot. Neoprene profiles are attached to the double chain for two main purposes: handle the climbing of stairs, and provide adherence in difficult surfaces.

4 Onboard Sensor Systems

4.1 Navigation and Localization Sensors

SRF05 Ultrasonic Range Sensor. This sensor provides up to 4 meters with its 150mW output power. The measurement feedback is used to assist navigation by detecting difficult vision spots.

ADIS16201 Dual-Axis Inclinometer. This sensor gives the inclination on x and y axis in $\pm 90°$ as well as the acceleration, so Nautilus can stabilize and provide a feedback to the motion control block.

CMPS03 Compass Module. With this module Nautilus is able to identify its position according to North, to contribute to map generation, and also useful in define and corroborate landmarks.

GP2Y0D340K IR Distance Measuring Sensor. These sensors operate just in case undetectable objects are closer than thirty centimeters to Nautilus. They also provide support for the collision avoidance matter.

LMS200 Laser Measurement System. The Laser is used with the stereo camera to provide an excellent measurement system. It is used in the autonomous map generation engine, victim identification, landmark setting and recall.

PT7137 IP Camera with 350° Pan, 125° tilt. This lightweight IP camera has VGA resolution with a frame rate up to 30fps. It also provides low use of bandwidth due to the implementation of MPEG4 as a streaming protocol. The information is used to assist the navigation system to see around the robot, it is also used in map generation providing high-resolution images of specific points, and in victim identification by using the integrated motion detection.

4.2 Victim ID Sensors

TPA81 Infrared thermal array sensor. This high resolution thermal array sensors detect infra-red signals in the range of 2μm 22μm used to identify victims by their radiating heat. Depending on the pointed direction, Nautilus can plan the movements to reach that spot as fast as possible.

STH-NDCS2 Stereo Camera. This camera is an essential device for map generation and victim identification. To perform map generation the camera is used in conjunction with the laser so Nautilus is able to acquire accurate landmarks. Motion identification and pattern recognition algorithms are used for victim localization. The algorithms also compare the acquired landmarks to the actual view to take decisions.

5 Communications

Nautilus uses the new standard 802.11n for wireless communication between the robot and the base station. Because of the robot autonomy, all data is stored inside Nautilus and transmitted to the base station using TCP sockets for control messages as well as UDP for streaming audio, video and information. If robot looses connectivity with the station, all information stored on this stage is retransmitted when radio coverage is reestablished.

For internal communications all sensors, and motor control are connected via microcontrollers using serial interfaces to the PC on board, the Laser is connected via bluetooth to avoid cabling. The channels used for communication between the robot and the base station are elected depending on the amount of interference detected on the environment. The 802.11n standard, allows the channel extension from 20MHz to 40MHz to achieve higher data rates when needed. This standard takes advantage of signal reflections by using Multiple Input Multiple Output (MIMO) technology, so the use of this technology favorable in zones of disaster where there's a lot of signal reflection due the collapsed materials.

6 Cost

The cost for each bare robot with control and locomotion system plus an onboard PC is in the order of 11,700 US Dollars. The most expensive sensor is the SICK LMS200 Laser Measurement System with 5,771.43 US Dollars.

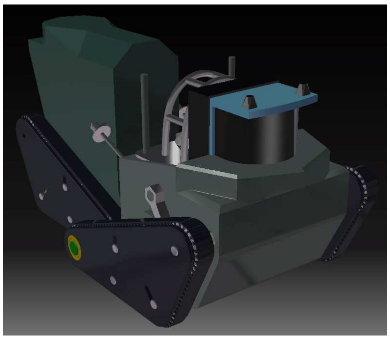

Fig. 7. Nautilus

7 Conclusions and Future Work

The work done during the designing, building and testing stages of our robot "Nautilus" has allowed us to have a better Mobile Robotics research in outdoor and indoor environments. Finally, our research will allow us to partipate in the 6th IEEE Latin American Robotics Contest (LARC 2007).
Further work is to continue developing faster and robust autonomous segmentation for our vision systems, implement sensing and information spaces navigation algorithms, restart of research in mobile robots SLAM and create a better communication module in order to allow multi-robots strategies based on multi-agent systems.

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