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WHAT RANGE OF VISIBLE AREA IS ENOUGH FOR TELEOPERATION OF FLEXIBLE MONO-TREAD MOBILE TRACK?

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Abstract – The paper provides a shelled track using bent track shoes and a dual-camera system for flexible mono-tread mobile track (FMT). Some previous prototypes of FMT could traverse on various rough terrains. However, an edge of the track shoe deflected when they touched to a prominence of obstacles and interfered to the body. The side surface of the FMT was not covered with the track shoe; thus, the weak parts made of ABS plastic were broken. Moreover, there is no practical camera system for teleoperation of FMT. Generally, a bird's-eye view is practical for teleoperation of a small ground vehicle. However, a camera (sometime with a long arm) and a laser sensor for the bird's-eye view implemented on the robot's deck is not suitable to take advantage of FMT, i.e., almost all the surface is covered by the track belt. Therefore, we introduce a prototype, RT05-COBRA with shelled track shoes, propose a dual-camera system covered a wide-range in a horizontal plane for FMT, and evaluate its mobility under teleoperation.

Keywords: shelled track, tracked vehicle, camera system

1. INTRODUCTION

We have proposed flexible mono-tread mobile track (FMT), which can travel over rough terrain. Some prototypes, RT02-WORMY [1], RT03-LIPAN, and RT04-NAGA [2], were developed and its mobility was validated through some experiment. However, NAGA, which had best performance against various obstacles, had some problems such as interference of track shoes as the track shoe took a large load from the ground. Both side surfaces did not cover the track belt; thus, some projections on obstacles penetrated the FMT and broke some parts. Moreover, there is no practical camera system for teleoperation of FMT. Generally, a bird's-eye view is practical for teleoperation of a small ground vehicle [3 - 6]. However, a camera (sometime with a long arm) and a laser sensor for the bird's-eye view implemented on the robot's deck is not suitable to take advantage of FMT, i.e., almost all the surface is covered by the track belt.

In the study, we introduce a shelled track belt using a rigid and bent track shoe to cover a body, propose a dual-camera system that covered wide-range view in a horizontal plane, and validate its effectiveness using a new FMT prototype, RT05-COBRA.

2 . RT05-COBRA [7]

Firstly, we introduce a FMT prototype, RT05-COBRA [7] (Fig.1). COBRA, which inherits the same basic structure of NAGA [2], consists of 10 passive rotational joints (6 of them rotate about the yaw axis and 4 rotate about the pitch axis). Each joint can rotate ±15º, and then COBRA can flex ±90º to the lateral direction (Fig.1 left) and ±60º to the up-and-down direction (Fig.1 right). The both flexion are realized by a tendon mechanism using a worm gear system, which achieves little energy consumption to maintain a static flexed shape. The worm gear system is driven by a electric motor of 60W (RE30, Maxon motor). The track belt is driven by a dual-motor system of 300 W (RE40, Maxon motor). The total length, width, height, and weight are 1100 mm, 220 mm, 160 mm, and 21 kg, respectively.

Fig. 1. Flexed posture of RT05-COBRA.

2.1. Shelled Track

The shelled track consists of a slatted bendable belt made of plastic (Fig.2 left, gray parts, TPU826-T, Tsubakimoto Chain Co.) and bent track shoes made of duralumin A2017 (Fig.2 left, silver parts). The past track shoes were made of fiber reinforced plastic (hand made). Young's modulus of A2017 and the hand made FRP were 69 and at most 10 GPa, respectively; thus, the new track shoes are approximately 7 times stiffer than the old shoes. A thin rubber sponge (thickness of 5 mm, Fig.2 right) is pasted on each track shoe. The rigid track shoes cover the body of COBRA even though it is a part of the side surface. The strain of the track shoe becomes a little and the open space of the side surface is reduced, simultaneously. The track shoe and obstacles are difficult to interfere with and penetrate a part of body. As a result, the problems of the previous prototypes are overcome using the shelled track.

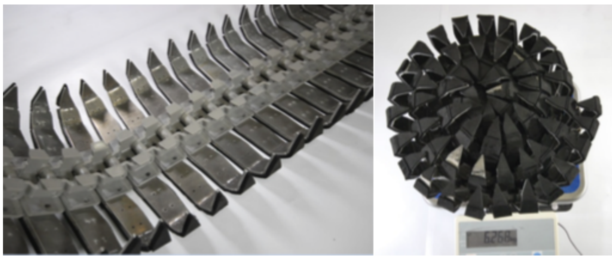

Fig. 2. Bent track shoes and track belt of COBRA.

2.2. Dual-Camera System

COBRA is covered by the shelled track, which provides high mobility. Therefore, we should implement sensors inside the shelled track not to interfere its mobility. A dual-camera system is implemented. A small camera unit attached a wide-angle lens is located at both side of body as shown in Fig.3 (top). The front edge of the lens is fitted on the inside of the shelled track. TPIP3 can also send the camera image.

An image of the both camera units is shown in the middle of Fig.3. The middle figure also indicates the telemetry of COBRA. The visible angular fields of the camera system in 3-D and 2-D on the horizontal surface are shown in the bottom left and right of Fig. 3, respectively.

Fig. 3. Angular field of camera system and control panel.

In the middle of Fig. 3, some track shoes were appeared at the center of the camera image. The block arranged like a 'T' shape in front of COBRA (bottom left) could not be found in the image, but the both edge of the arrangement could be seen at the center of the image. The block towers located along the sidewall were visible. The white walls (height of 90 cm) were completely visible at the center, but the top part of the both side (latter part of the sidewall) could not be found. Therefore, the visible angular field covers approximately ±90º in a horizontal plane and from 0º to 30º in a vertical plane excepting a small front area. COBRA also has dual rear camera system located at the middle part of the body, which can provide similar visible fields to that of the front cameras. For teleoperation, it seems important to achieve a wide range in the horizontal plane as mentioned in Section 3.

2.3. Attitude Display [8]

The camera image is not enough for teleoperation, because the attitude display of the vehicle assists to decide the moving direction, especially for the FMT. COBRA has an inertial measurement unit (IMU, UM7-LT Orientation Sensor, CHRobotics), which measures its attitude of COBRA. The IMU has a magnetometer, a rate gyro, and an accelerometer. The measured data are combined using an extended Kalman filter. The angle of each joints can measures potentiometer. The sensors are connected to a teleoperation device implemented, TPIP3 (Sanritz Automation Co. Ltd.), which sends the data to the operating computer through the wireless network system. Using the information, the attitude display proposed and developed by Kurisu [8] is implemented to the operation system for COBRA. The attitude display indicating the posture and attitude of COBRA is shown in Fig. 4.

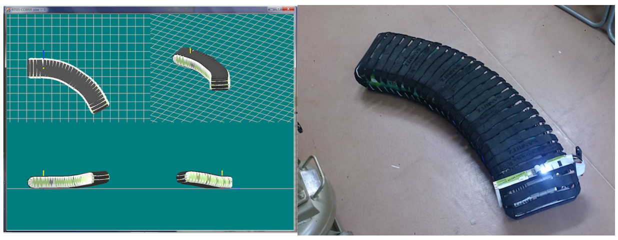

Fig. 4. Attitude display.

3. EXPERIMENT

3.1. International Standard Test Methods for Response Robots [7]

We conducted a standard test based on those of the National Institute of Standards and Technology (NIST) developed at the International Rescue System Institute (IRS) in Kobe, Japan. The standard test fields are shown in Fig. 5. COBRA was remotely operated; however, we visually observed all of the trials for the standard test.

First, we conducted the test against the crossing pitch shown in Fig. 5 (left). The flooring terrain consists of crossing a 15° full ramp and half ramp terrain element setup. Two pylons define the prescribed figure-8 path. COBRA could traverse the ramp including the intersecting sections of consecutive two ramps, where the previous prototype NAGA could not traverse (Fig. 6).

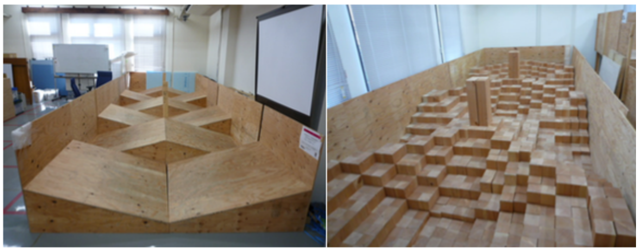

Fig. 5. Test fields called "Crossing Pitch" and "Symmetric Stepfields" for the International Standard Test Methods for Response Robots.

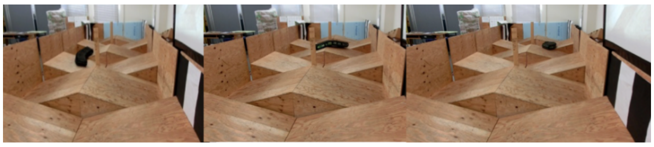

Fig. 6. Snap shots of mobility performance on the crossing pitch.

Second, we conducted the test against the symmetric stepfield (Fig. 5, right). The flooring terrain consists of symmetric stepfield terrain element fabricated using 10-cm square wood posts cut to prescribed lengths (10, 20, 30, and 50 cm) and set up in groups of four posts per step height. Two pylons also define the prescribed figure-8 path. Figure 7 shows the trial. COBRA could traverse the symmetric stepfield, where NAGA could not travese.

Fig. 7. Snap shots of mobility performance test on the symmetric stepfiel.

3.2. Teleoperation Using Dual Front Camera System

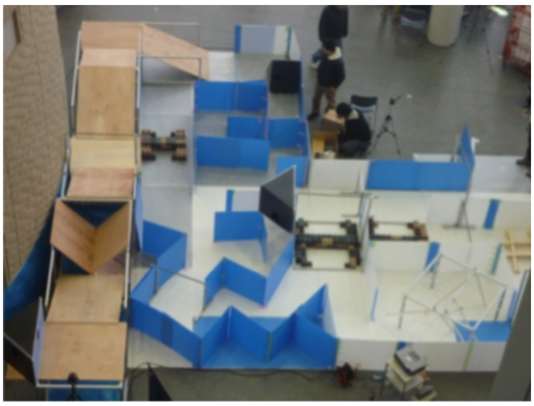

Fig. 8 Test field

We tested mobile performance of COBRA under teleoperation on a test field of Robocup Rescue Camp of Japan League. The field (Fig. 8) consists of 90 cm wide passage surrounded by a thin plastic board (90 cm high, blue board), slopes (shown in the top and middle figures), and 'V' shaped valley (shown in the bottom figures), and various obstacles (small blocks, pipes, etc.) are arranged on the way. An operator must operate a robot only using image given by cameras and other sensors mounted on the robot. In our case, the front dual camera system was only used for the teleoperation. The attitude display system and the rear dual camera system were not completed for this trial. Before the trial, the operator who took part in the test trained on a flat surface several ten minutes only. Figure 9 shows snap shots of the performance test. COBRA could move on the field excluding a narrow passage (45 cm wide) under teleoperation. The flexed radius of COBRA was 50 cm; thus, COBRA could not move on the narrow passage. Generally, a bird's-eye view, which can obtain an image of wide area with a robot itself, is effective for teleoperation, because an operator can recognize the relative position between the robot and the field. The wide-range image in a horizontal plane was also effective, even though the operator could not see the robot. In the test, the camera could not be tilted nor mount a rear camera unit; thus, the operator could not see lower front and rear resulting risk of fall down and damage for the field, which indicates the necessity of tilting. Moreover, it was difficult to teleoperate COBRA without damage for the field as he went backward because there was no camera nor attitude display. COBRA touched the wall in the field and often broke them. Therefore, we expect that the wide-range view is enough for teleoperation of FMT.

Fig. 9. Snap shots of mobility performance test and test field

3.3. Attitude Display

Next, we tested the effectiveness of the attitude display. We prepared a loose ground using plastic blocks as shown in Fig. 10. The blocks were heaped up loosely, which could easily collapse as COBRA traversed. The operator should choose the pass carefully. Using the attitude display, the operator could see the posture and attitude of COBRA as shown in the top left of Fig. 10, even if he could not see the obstacles below the vehicle through the front dual camera system. The operator achieved that COBRA could traverse the obstacle. The attitude display helped the teleoperation.

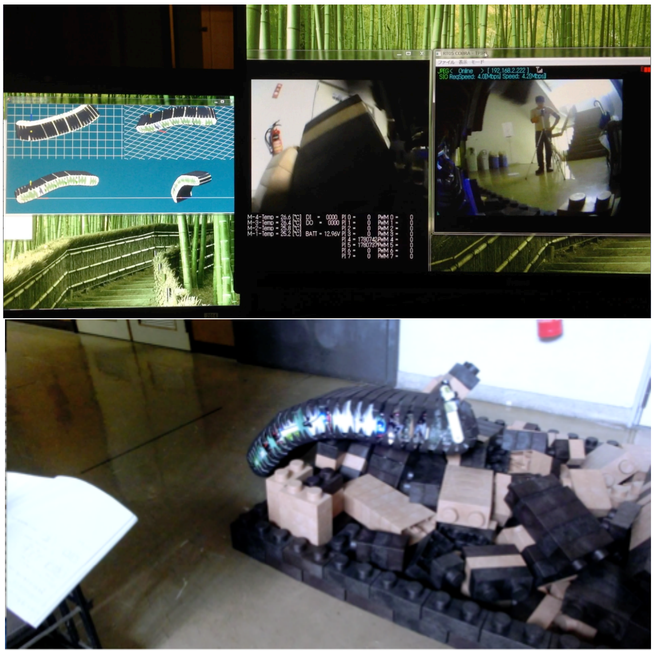

Fig. 10. Mobility performance test with the attitude display

4. CONCLUSIONS

In this study, we developed a new FMT prototype, COBRA, introduced shelled track and a dual-camera system. The shelled track made COBRA traverse uneven terrains. The dual-camera system covered wide-range and the attitude display enabled practical teleoperation of FMT without a bird's-eye view. Quantitative evaluation and field tests for the teleoperation system will be performed in the future.

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