Development of Crawler type Rescue Robot with Slide Mechanism

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Abstract: In this paper, we develop a rescue robot that searches for the victim in the disaster scene. To go in to a narrow space in such a scene, size of the robot should be small. But the ability to pass over the trench and the rubble is important. We propose the crawler type robot which has the expandable side crawler. This mechanism can enlarge mobility of the robot by expanding the side crawler when it is necessary. And this r escue robot pass the rubble by using the side crawler as the arm. So that the swing mechanism for the side crawler is also installed. Details of the developed robot and several experiments are denoted in this paper.

Keywords: Rescue Robot, Expandable Side Crawler, Narrow Environment

I. INTRODUCTION

When the disaster such as earthquakes occurs, there might be the survivors left in collapsed buildings. The life rescue in the disaster scene has hope for 72 hours, then the survival rate after that decreases remarkably. Therefore, quick and safe rescue operation for the survivors are important. But the rescue team can not go into the rubble immediately, because there is danger of the second disaster. Moreover, it takes much time for the rescue in a narrow space where is difficult for human to enter. In such a situation, it is important to know whether the survivor is trapped in the rubble.

To search for the survivors in a narrow space in the rubble, snake-like or multi-connected robots are developed by many researchers. Mori et al developed the snake-like robot "ACM-R3 [1]. They proposed three-dimensional serpentine motion to realize omni-directional locomotion. The multi-vehicle connected crawler type rescue robot are developed [2],[3],[4]. These robots connect several units in serial so that total length of the robot is long. A turning motion in the narrow environment might become difficult for the robot with long length. The size of the robot should be small to go into a narrow space in such a scene. But the ability to pass over the trench and the rubble is important.

In this paper, we develop the rescue robot with compact body to search for the survivors trapped in a narrow space. This robot is composing four crawlers and transformed corresponding to the environment in the rubble. We propose a novel slide mechanism. This mechanism can enlarge mobility of the robot by expanding some crawlers when it is necessary. And the swing mechanism is also installed. The robot can pass the rubble by using expandable crawlers as the arm. This paper organized into four sections. In section 2, we describe concept of the rescue robot and details of proposed mechanisms for the side crawler. The experimental results are shown in section 3. Finally, the conclusion is given in section 4.

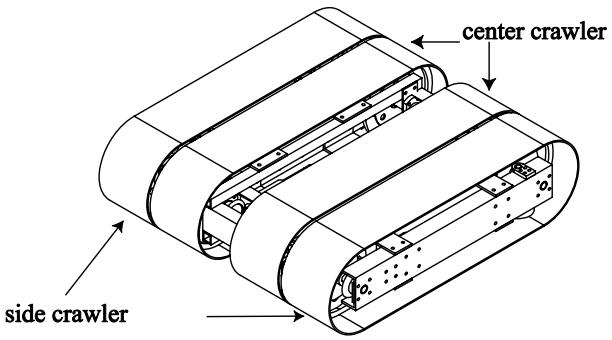

Fig.1. Rescue robot with Expandable Side Crawler

II. CONCEPT OF PROPOSED ROBOT

We consider the searching task in the narrow space of the rubble. We propose the crawler type rescue robot which has the expandable side crawlers shown in Fig.1.

Four crawlers are arranged in parallel, two crawlers fixed to the main body are called the center crawler. Other two crawlers installed in both sides are named the side crawler. Each crawler can be controlled independently. The robot moves by these driving forces in searching filed. Position of the side crawler is Fig.2 (a) usually. Under such a condition, the robot goes into the inside of the rubble and can change the direction of move on. When the robot can not move because of stack or the existence of high obstacle, the side crawler is expanded as shown in Fig.2 (b). Then the side crawler can rotates as shown in Fig.3. As a result, the side crawler can be used like the arm to improve the performance of the robot temporarily. The side crawler of the robots developed by other researchers doesn't have the slide mechanism and only have rotate one. Therefore, the space in the direction of height to rotate is necessary. Our robot expands the side crawler in parallel to the robot body direction even in a low ceiling. The total length can be freely adjusted without changing the total height of the robot.

It is possible to transform the configurations of the robot even in the narrow and tight space. The degree of freedom of the robot is eight, four degree of freedom for each crawler drive, two degree of freedom for slide mechanism and two degree of freedom for swing mechanism. The DC motors that installed in the robot drive these mechanisms. However, it is necessary to think about the center of gravity of the robot when expanding the side crawler. So as not to influence even if the position of the crawlers are change, the positions of the DC motors are arranged in symmetry as shown in Fig.4. As a result, it doesn't depend on the position of the side crawler, and the center of gravity of the robot can be located at the center of the total length at any time. We explain the mechanism, the design, and the hardware organization of the proposed rescue robot as follows.

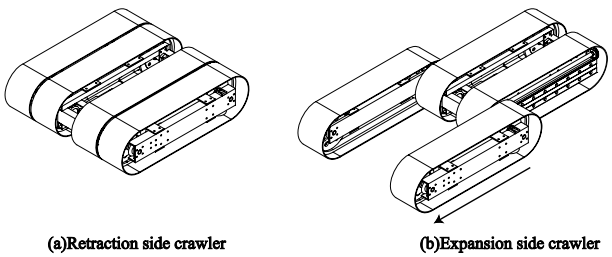

Fig.2. Slide motion of side crawler

1. Swing mechanism

The side crawler and the main body are united only with the rotation shaft. This shaft is also united with the slide mechanism. Then, the side crawler will rotate around this shaft. In this robot, two DC motors are used for crawler drive and for swing motion. And each driven mechanism is built into the inside of the side crawler. As a result, the side crawler becomes heavy. Because the robot passes over the obstacles and the rubbles, the side crawler must be maintained in arbitrary posture. Sometimes a big impact and the reaction force act on the side crawler while moving. It is necessary to consider the breakage prevention of the motor and the gear. Then, a warm gear is adopted in the swing mechanism so as not to rotate reversibly mechanically by a high reduction ratio.

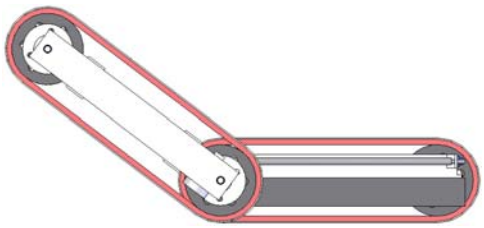

Fig.3. Swing motion of side crawler

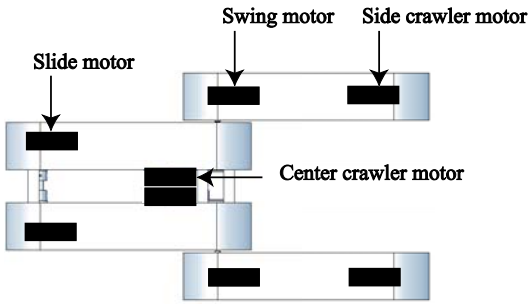

Fig.4. Installed location of DC motors

2. Slide mechanism

The side crawler moves in parallel along the center crawler. The range of movement is from the position in Fig.2 (a) to the position in Fig.2 (b). In a word, it is possible to slide only in the wheelbase length of this robot. The slide mechanism and its actuators are installed in the main body of the robot. The rotation shaft of the swing mechanism is connected with the slide mechanism. Therefore, the impact forces are applied to the slide mechanism when the robot is moving on the rubble. A linear guide is used as a slide

mechanism in consideration of these forces and moments. Weight of the side crawler, resultant force and moment that act on the rotation shaft are estimated. The trapezoid screw is used for the drive of the slide mechanism, and installed it inside of the center crawler as shown in Fig.5.

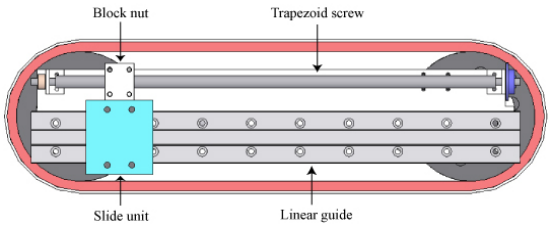

Fig.5. Arrangement of slide mechanism

3. Crawler mechanism

The crawler driven mechanism is composed of the sprocket with the chain. Two sprockets are used for each crawler, and the DC motor is installed and driven it. The aluminum boards are installed in the chain with the attachment that transmits the driven power to the ground. In addition, rubber is disregarded on the aluminum board to improve the frictional force with the field.

4. Developed Rescue Robot

The rescue robot that we developed here is shown in Fig.8 and Fig.9. Figure 8 shows the normal configuration of the robot, and Fig.9 denotes the configuration of expanded in the maximum position. This robot has eight degree of freedom and use eight DC motors. Details of the DC motor and the reduction ratio, etc. used are shown in Table 1. All the same motors are used for four crawlers. The rotary encoder is equipped in all DC motors, so that rotational speed can be measured. The turning angle speed of each crawler, the amount of the slide length and the swing angle of the side crawler can be calculated. The space is open between center crawlers of the main body, the battery, the power supply circuit, sensors and CCD camera, etc. can be built in.

Table 1. Specifications of selected DC motors

	DC motor	Gear head	encoder
swing	Amax26,12V	GP32A,66:1	MR-500
slide	RE13,12V	GP13A,17:1	MR-256
crawler	Amax26,12V	GP32A,86:1	MR-500

Fig.6. Overview of rescue robot in initial position

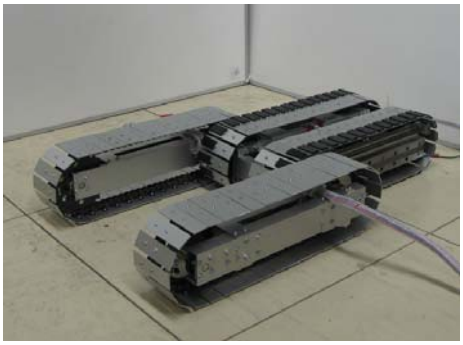

Fig.7. Overview of expanding side crawler

Table 2. Specifications of rescue robot

Length[mm]	444
Max. length[mm]	763
Width[mm]	408
Height[mm]	125
Weight[kg]	16

III. EXPERIMENTS

We show some experiments to confirm the mobility of the proposed rescue robot. The specifications of the developed robot are shown in Table 2.

1. Basic motions

At first, we demonstrate straight and turning motion of the robot. The straightforward motion is able to drive with stability regardless of the expansion of the side crawler. The maximum speed of the robot is 581[mm/sec], the time that finishes sliding is 24[sec] and the time to swing the side crawler up to 90[degree] is 24[sec]. However, the turning motion is unstable operation according to the condition. It is thought that friction to the road of four crawlers is large. But the

robot turns as the crawler slipping. This friction forces change depending on the contact state of the crawler and ground. The center of rotation is depending on the amount of the slide of the side crawler and the speed of each crawler. Therefore it is necessary to derive those relational expressions of the motion to do the turn operation with stability.

2. Step climbing

Next, we try to confirm the ability of the step climbing of the robot. The procedure is shown below. Here, the step height is 170[mm], and the side crawlers are shrinks at initial position.

Step1. Move just before the step (Fig.8 (a)).
Step2. Expand the side crawlers to the maximum position (Fig.8 (b)).
Step3. Rotate the side crawlers until it exceeds the step, then move forward the robot and contact the side crawlers with the edge of the step (Fig.8(c)).
Step4. Rotate the side crawlers in the opposite direction to Step2 to lifts the main body and center crawlers (Fig.8 (d)).
Step5. Move ahead until the whole of the side crawlers get on the top of the step (Fig.8 (e)).
Step6. Rotate the center crawler body by swing mechanism until the main body and the side crawlers become straight. Then shrink the center crawlers by expand mechanism (Fig.8 (f)).

This robot can also climb the continuous stairs as same procedure.

IV. CONCLUSION

In this paper, we develop crawler type rescue robot that has the expandable side crawlers. The main aim of this robot is to search survivors trapped in the rubble made by an earthquake or a disaster. Proposed rescue robot is designed to go into a narrow space in such a scene. Then, the side crawlers are expanded when it is necessary to enhance the mobility of the robot. Some experiments are performed, and effectiveness and the problem of this mechanism are shown. As future works, we will improve the stability at the turn running, derive the control method based on kinematics, and construct the remote control systems.

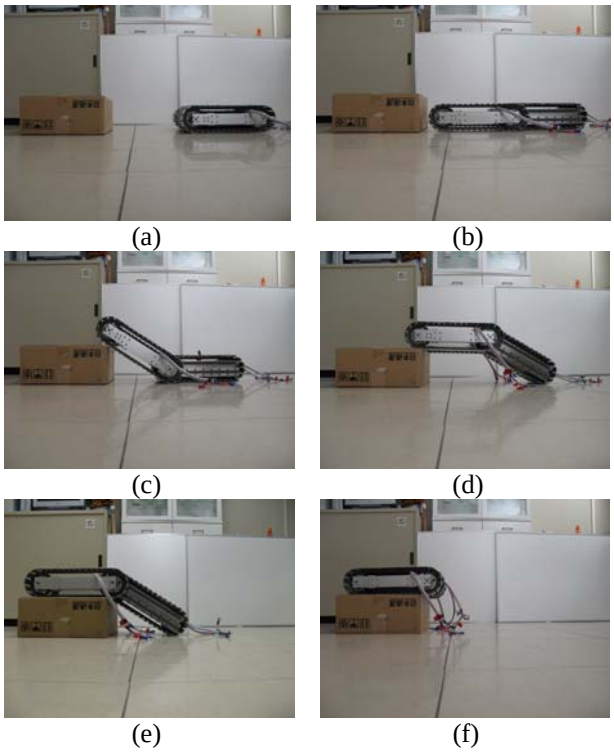

Fig.8. Experiment of step climbing motion

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