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GROW-HOSE-I: A HOSE TYPE RESCUE ROBOT PASSING SMOOTHLY THROUGH NARROW RUBBLE SPACES

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ABSTRACT

This paper presents a hose type rescue robot with new movement abilities, for passing through narrow spaces and searching for victims under debris. At the disaster site, the fiber scope and the pole equipped with a camera on its head were previously used to search for victims. However, there are problems with going into complex curved and rugged spaces due to the friction between the robot body and surface of debris. So in this study, the hose type robot named Grow-hose-I, growing with a rapid motion type hose, is proposed which can move smoothly with no friction between the hose and the ground surface. The hose is composed of flat tubes driven by pneumatics, and it can be actively curved to enable steering.

KEY WORDS

Rescue Systems, Pneumatic Systems, Rubble Space, Grinding Friction, Curving Control

NOMENCLATURE

d : Span between the Tubes
F : Driving Force on the Hose.
p : Air Pressure of the Tube
l_1 : Width of the Flat Tube
l_2 : Thickness of the Flat Tube
R : Driving Resistance on the Bent Part of the Tube.
ρ : Radius of the Bent Part of the Tube

INTRODUCTION

At the disaster site, the fiber scope and the pole equipped with a camera on its head have been previously used to search victims under debris. These tools are available when a straight route can be secured, on the other hand they can't really be used when debris formation is complicated. However, even in such a situation rescue tools are required to be able to be inserted. In addition, the tools are required to have the ability of supplying water, air, and medicine for prolonging the life of survivors.

We have previously developed several types of hose robots which can supply water and medicine from outside the debris [1]. Through these past examples, we can see that technology that moves the hose with decreasing sliding friction as much as possible between

the surface of the hose and the rubble is an indispensable factor. Accordingly, there has been suggested some new types of robots which can move without grinding friction but only have straight motion [2], or can control motion while decreasing the grinding friction by vibrating the thin hair attached to its surface [3]. However it's necessary for the hose to pass through the debris in narrow spaces like Figure 1 while controlling the direction actively.
In this study, we propose an inner body drawn-out type hose "Grow-hose-I" (Figure 2) which can move without grinding friction between the hose surface and the debris. In addition, it can also control the direction on its head part actively by adjusting the air pressure valves.

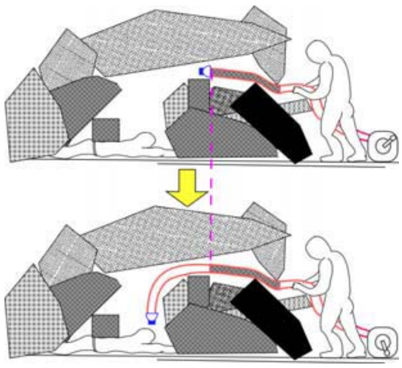


Figure 1 Feature of Complex Debris

Figure 2 Feature of "Grow-hose-I"

DEVICE CONCEPT

It is preferable that the device is a hose type robot that can secure the route between the victims and rescue team members to supply water and medicine for prolonging life.
Some research has previously done on hose robots, and these can be classified into the following types for the most part.

1) Grinding friction decreased type
2) Body crawling type
3) Inner body drawing-out type

1) Grinding friction decreased type
This kind of robot can move smoothly while decreasing the sliding friction between the robot body and debris environment. During movement, Active Scope Camera [3] decreases sliding friction by vibrating the thin hair around the robot using the vibrating motor.

2) Body crawling type
This kind of robot can move by using the actuator equipped on the body. Active Curve Hose [1] can crawl into the debris and can control the direction at the head part while using the search camera. Moreover, it can also supply water through the robot body to survivors.

3) Inner body drawn-out type
This kind of robot moves forward like the growth of a plant stem by drawing out the body at the head part. Pneumatically Controlled Expandable Arm [2] can haul the inner body by using pneumatic power (Figure 3). As a result, the robot can move regardless of the sliding friction between the robot body and the debris.

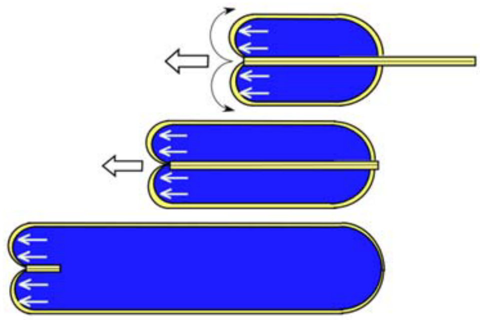


Figure 3 Concept of Grow-hose-at disaster site

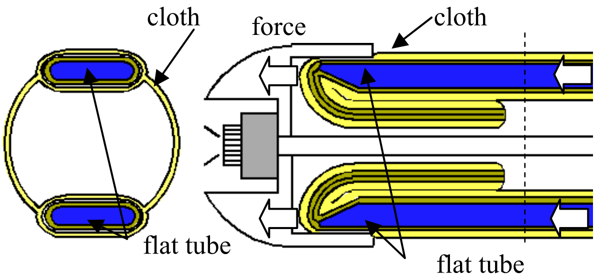
SUGGESTED METHOD

We will use type 3. This is because a robot which can move without grinding friction in a complex pebbles environment might be very useful.

Method of Driving
We use the urethane tube flattened by heat-treatment (flat tube, (Figure 4)) to construct the hose. The flat tube has a property that the force is generated on the bent point of the tube when it is bent to 180° and the air pressure is input from one side (Figure 5). We construct the hose with 2 flat tubes and flexible cloth (Figure 6). Then, the hose can drive like the growth of a plant stem as the inner body is being drawn out by inputting the air pressure from the outside tube edge (Figure 7). Therefore it's possible for the hose to go deep into the debris smoothly because the hose surface and the debris don't grind against each other greatly. Moreover, the tubes and the cloth are NOT bonded so that they can slide mutually to achieve a large curving motion .

Figure 4 Flat Tube

Figure 5 Bent Flat Tube



(a)Cross View (b)Side View

Figure 6 Figure of Hose with Air Pressure Applied

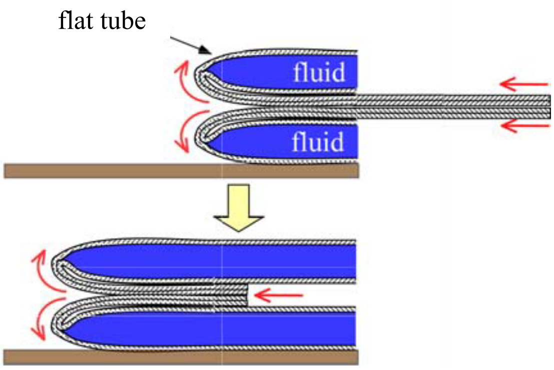


Figure 7 Motion of Hose like Growth of Plant Stem

Curving Motion

The hose curves by adjusting the air pressures of two flat tubes. Moreover, a bigger curving motion can be achieved by pulling the wire installed at the edge of the tube (Figure 8).

Mechanism of Fixed Curving Shape

To keep a hose shape after a curving motion in the assumed environment, a rigid outside body and a flexible inside body might be needed. Therefore, metallic grippers are set over the tube of the hose at constant intervals (Figure 9).

Only the outside tubes of the hose get swollen because the flat tubes seal the air flow at the head point of the hose. Therefore, the grippers are fixed on the tube outside of the hose and are NOT on the inside. As a result, the spans among the grippers are fixed at the moment of curving motion and the hose can keep its curving shape (Figure 10).

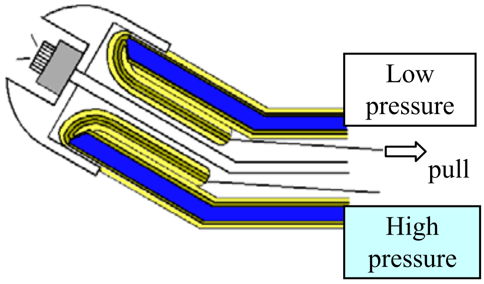


Figure 8 Curving Motion of Hose

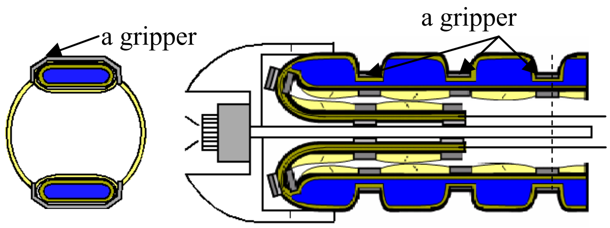


Figure 9 Figure of Hose with Grippers

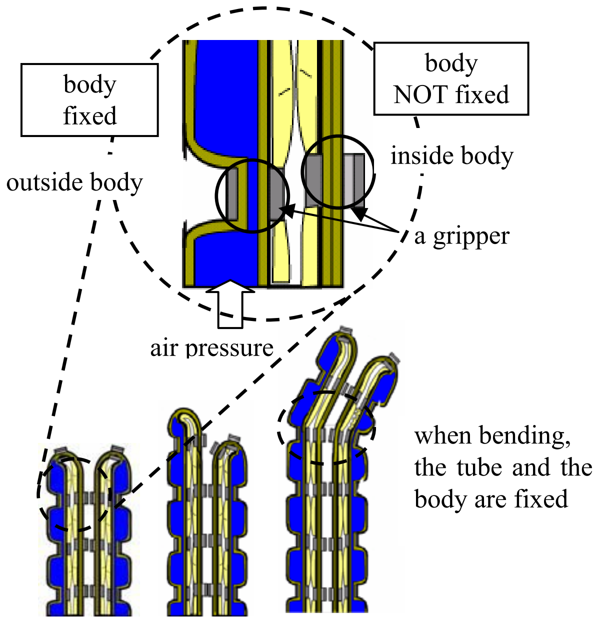
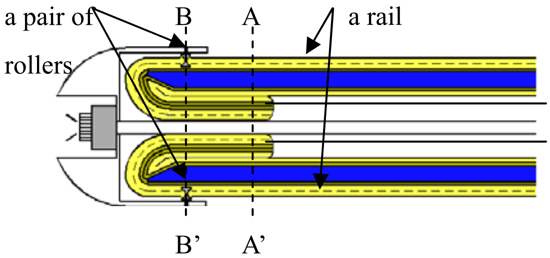


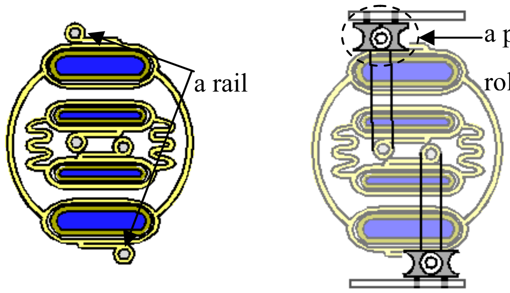
Figure 10 Figure of Fixed Curve Shape

CAMERA MODULE

It is preferable that the search camera is set at the head part of the hose for looking through the debris. However, the camera module cannot be fixed on the head part of the hose directly because of the structure of hauling body inside the hose. Therefore, flexible rails are set up on the hose and couples of rollers are set up on the camera module at first, so that the camera module can be fixed on the head part of the hose with the rollers pinching the rails. As a result, the camera module can run while sliding on the rails just like rollers rotating (Figure 12).



(a) side view



A-A' section B-B' section

(b) cross section

Figure 11 Camera Module on top of the Hose

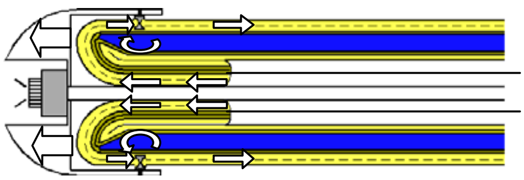


Figure 12 Motion of the Camera Module

PROTOTYPE (GROW-HOSE-I)

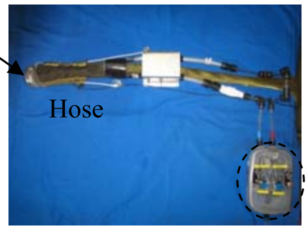
The developed hose "Grow-hose-I" and camera module are shown below.

Table 1 Specification of Grow-hose-I

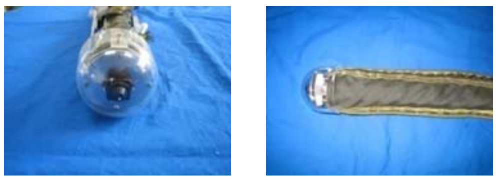
Length of Robot	3.0m
Tube	Flat Tube made of Urethane (width :20mm) ×2 (inside :φ10 outside :φ12)
Gripper Span	25mm-35mm
Hose Body	Spark Satin (Polyester :62%,Nylon :38%)
Tube Span	45mm
Rail	φ2.0

Table 2 Specification of Camera Module

Whole Size	φ62mm×62.5mm
Camera Size	21mm×21mm×16mm
Roller	Stainless steal
Cover	Acrylic fiber



(a) whole view



(b) front view (c) side view

Figure 13 Figure of Grow-Hose-I

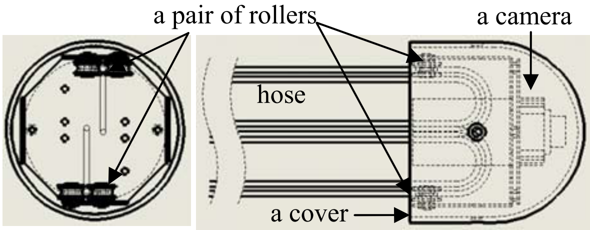


Figure 14 Camera Module

DRIVING FORCE OF HOSE

We measured the driving force of the hose while changing the air pressure p and the tube span d (Table 3)

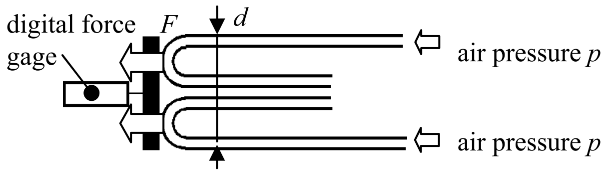


Figure 15 Feature of Driving Force Experiment

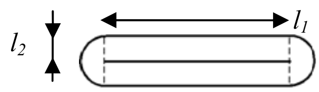


Figure 16 Cross-Section of Tube

Table 3 Experiment conditions

d	40,50,60[mm]
p	0.10, 0.20, 0.30, 0.40, 0.50[MPa]
l_1	16.8[mm]
l_2	1.0[mm]

Result of the Experiment

The result of the experiment is shown in Figure 19. The theoretical value of the driving force used in the figures is that of the ideal condition; where the cross-section of the tube is a perfect circle.

Summary and Discussion

The measured value of the driving force was 80-110% of the theoretical value. In addition, the driving force varied due to the tube span d. Furthermore, the force tended to decrease in the high air pressure range. The reasons are as follows.

(a) There exists a resistance R at the bent part of the flat tube (Figure 17).

(b) The smaller the radius ρ of the bent part, the greater the resistance R becomes.

(c) The R varies due to the air pressure p, because the radius ρ becomes smaller when the air pressure is input and the tubes expand (Figure 18).

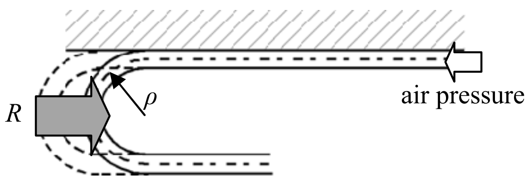
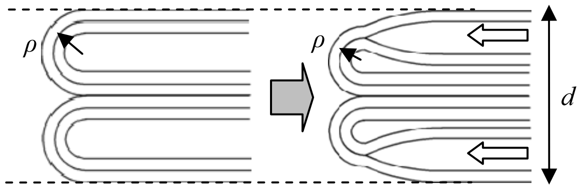
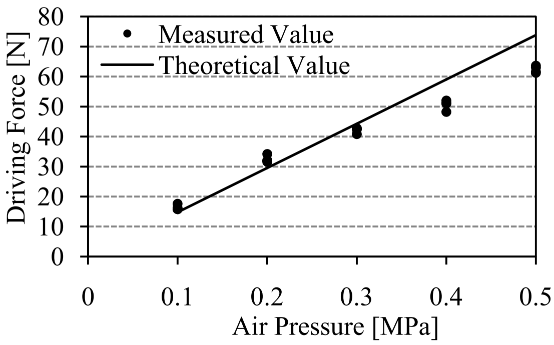


Figure 17 Resistance of Bent Tube

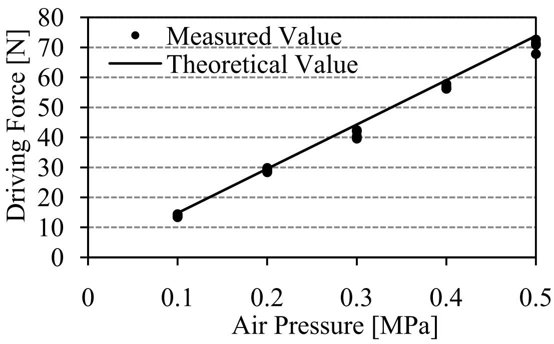


(a) Without Air Pressure (b) With Air Pressure

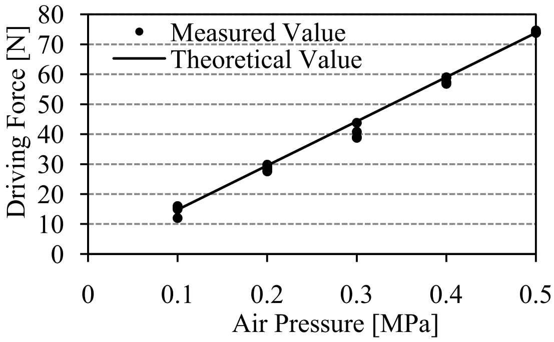
Figure 18 Change of the ρ by the Tubes Expansion



(a) d=40mm



(b) d=50mm

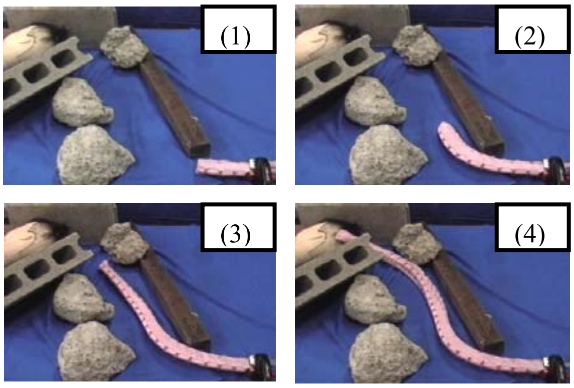


(c) d=60mm

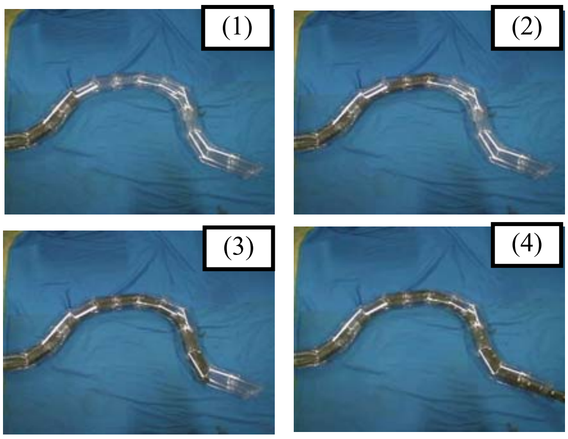
Figure 19 Driving Force of the Hose

EXPERIMENT OF GROW-HOSE-I

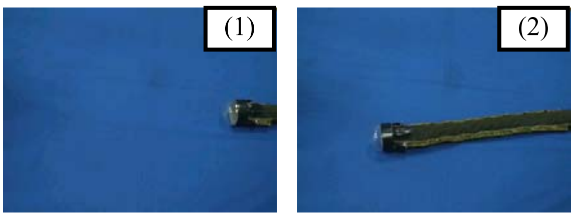
The appearance of the hose during the driving experiment are shown below while the hose performs (a) a crank drive, (b) a drive inside a pipe and (c) a drive with the camera module (Figure 20). On crank driving, the hose is controlled by inputting the air pressure 0.5 [MPa] to the tube outside of the curve and 0.3 [MPa] to the one inside. Bigger curve curvature can be generated by pulling the wire (inside of curve).



(a) Crank Drive



(b) Drive inside Pipe



(c) Drive with Camera Module

Figure 20 Experiment of Grow-hose-I

As a result of the experiment, we can see that on a crank drive the direction of the hose can be controlled toward the destination and the curving shape can be kept by the effect of the grippers. In addition, when the camera module was set on the head of the hose, the module was able to move while synchronizing with drawing-out operation of the hose. Moreover, drawing-out motion can be done smoothly in a narrow conduit. Therefore it is thought that this kind of the hose can be applied not only for rescue operation but also for the inspection of piping, etc.

CONCLUSION

In this study, we suggested 'Grow-hose-I' which can pass through the complex debris without grinding friction between the surface of the hose and the debris. The suggested hose can perform a growing motion like a plant stem by drawing-out the inner body. The summary of the results obtained in this study is shown in the following.

1. The hose direction could be controlled by adjusting the air pressure of the flat tubes on the hose.
2. The hose could keep the curving-shape by the effect of the grippers on a crank motion.
3. The camera module equipped on the hose was able to move while synchronizing the drawing-out operation of the hose.

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