J-RAPID: Search in Disaster Rubble Piles by Collaboration of CRAWLER and Active Scope Camera

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RAPID: CRAWLER Robot with Dual-Use Limbed Locomotion and Manipulation for Void Inspection

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Proposed Work - CRAWLER & Active Scope Camera

- CRAWLER aka TerminatorBot
  - Limbed Crawler for Rubble Penetration
  - Two limbs for locomotion and manipulation
  - Drags body like a cold-blooded animal
- Physical Enhancements
  - More robust limb design
  - Water proof skin
  - Cellphone chip camera
- Active Scope Camera (ASC)
  - Mobile video scope with Actuated Cable Skin
  - Robust intrusion into narrow gap of rubble piles
  - Need of Explosion Proof
- Application to CRAWLER
  - Actuated Control Tether for deep penetration

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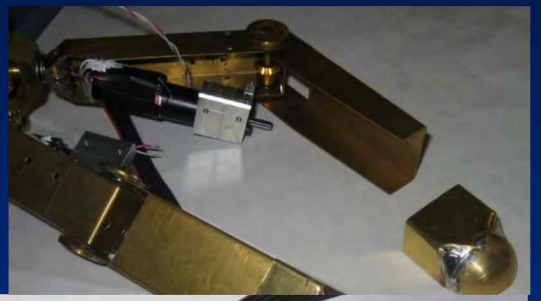
Proposed Work - CRAWLER: Results

- More Robust Elbow Design
  - Eliminates Precision Gears (subject to dirt and damage)
  - Tougher Cable Drive
- Cellular Phone Chip Camera
  - < 1 cm in Size, Digital
  - Easy to include multiple cameras
  - FPGA-based frame grabber
- First Visit to Sendai Region in Nov. 2011
  - Tohoku University for lab tests



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Active Scope Camera for Search in Confined Space

Video Scope with Active Surface

(Oct.3, 2006 @ Intl. Disaster Relief Team Exercise)

(Tadokoro, Tohoku U)

Search in 3 cm gap

(Intl. Rescue System Inst. Kobe Lab., Collapsed House Simulation Facility)

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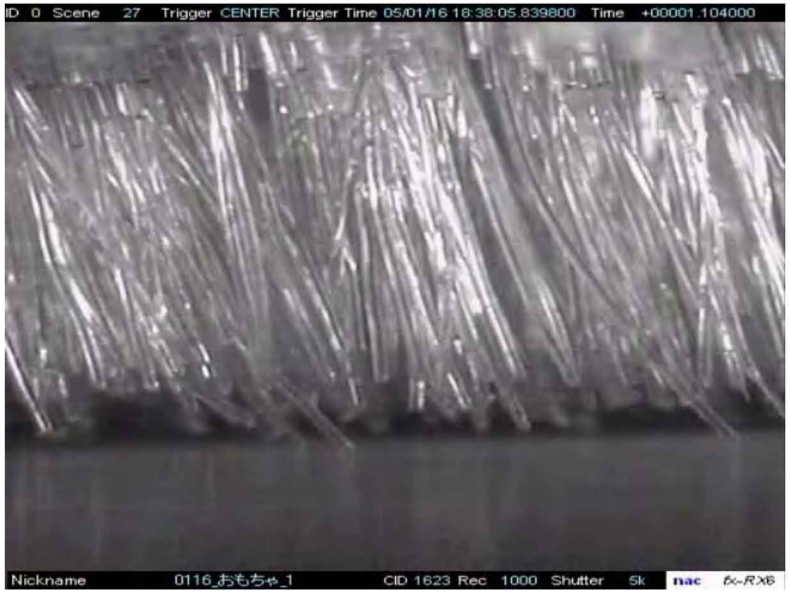
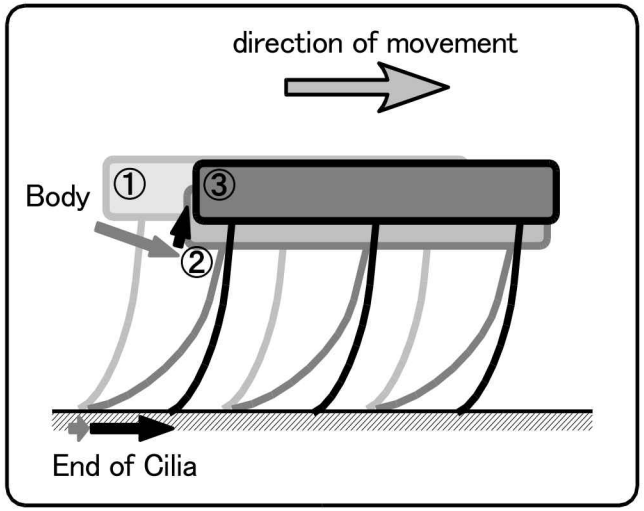
Ciliary Vibration Drive Mechanism

- **Principle of Motion**

[Actuator2006, IROS2006]

  - Drive by reaction force produced by pressing inclined cilia using vibration
  - Tips of cilia repetitively stick and slip





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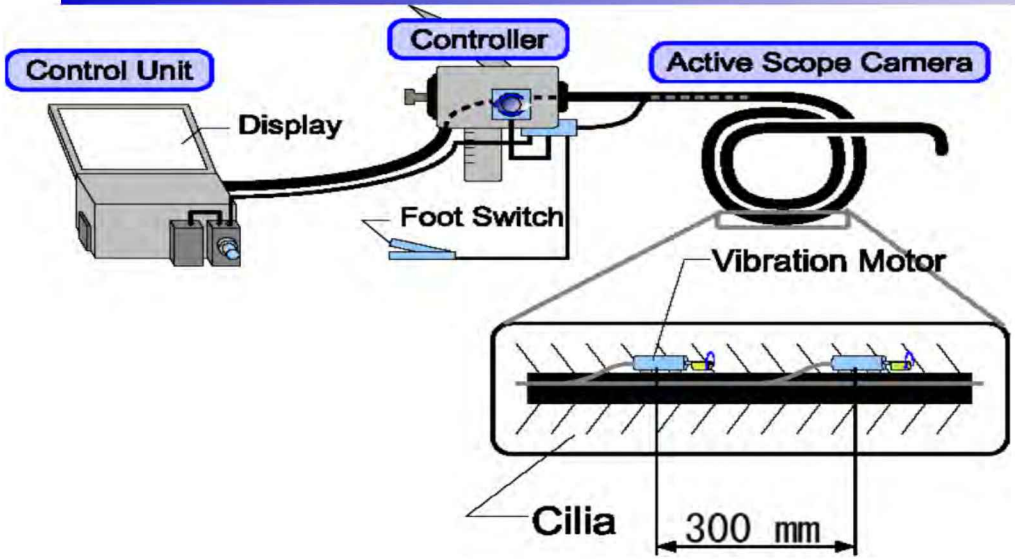
Active Scope Camera



Actuation by the whole surface

Change the direction of motion

ACTUATOR

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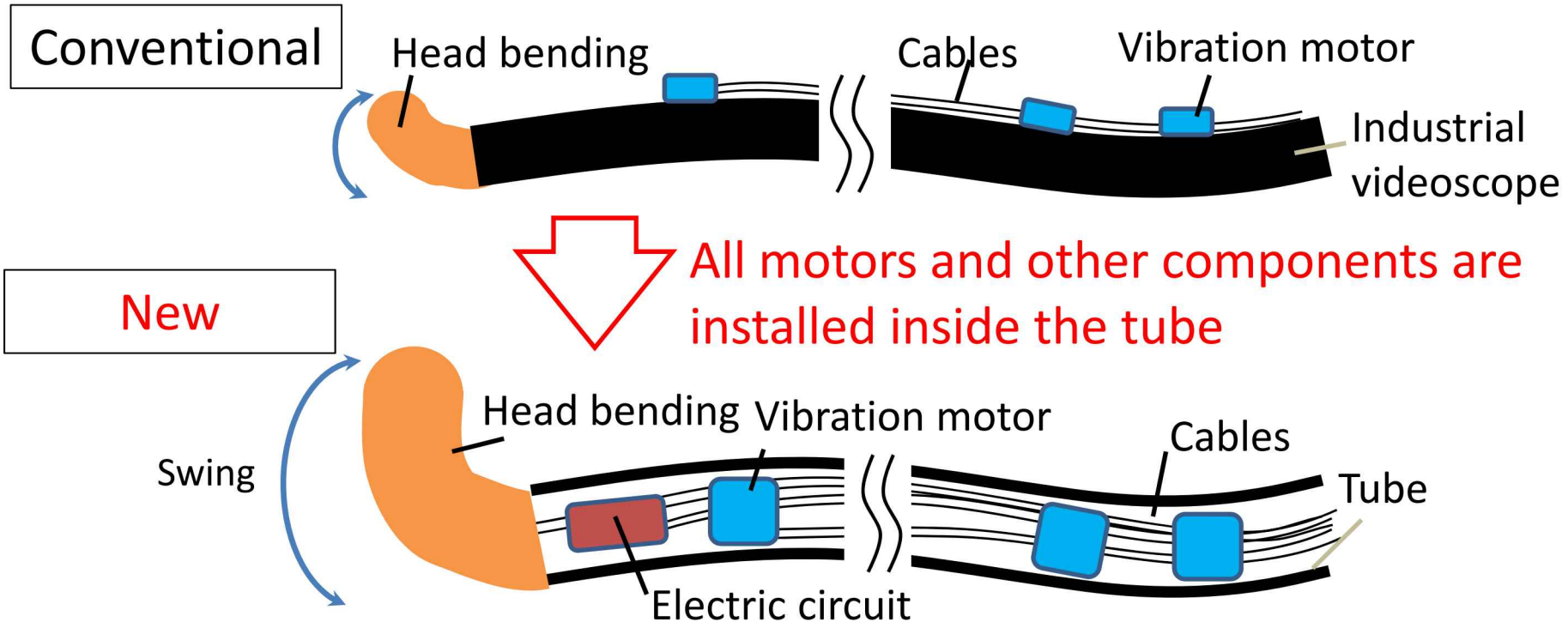
J-RAPID Objectives

- Enhance collaboration of DU and Tohoku U
- More performance of ASC
  - Long design for deep search - scalability of fabrication
  - Higher mobility
- Anti-explosion of ASC
  - Application of fluid water-hammer actuator
- Active tether for mobile robot CRAWLER of DU
  - For more deep penetration
- Collaborative experiments

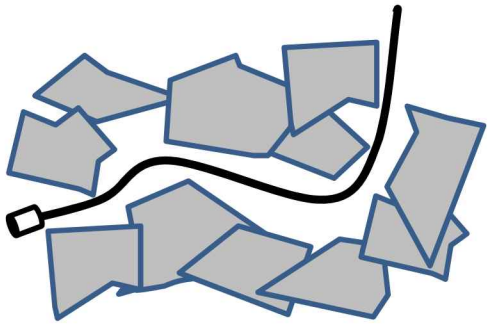
Proposal: Tube-type ASC

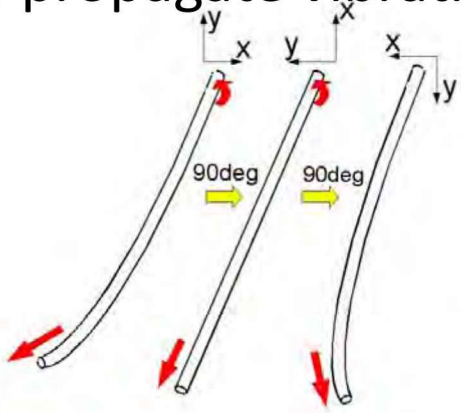


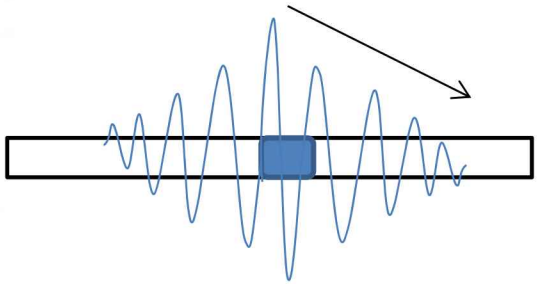
- Advantages
  - No projection out side of the tube
  - Enough space to mount

(1) Suitable tube design

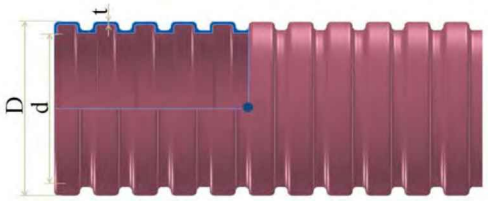
- Criteria
  - Flexibility in order to insert into narrow space
  - High torsion rigidity for twisting operation
  - Low damping to propagate vibrations ⇒Experiments







We selected a corrugated tube



-Flexibility by the corrugated structure
-High torsion rigidity by being made from a hard material

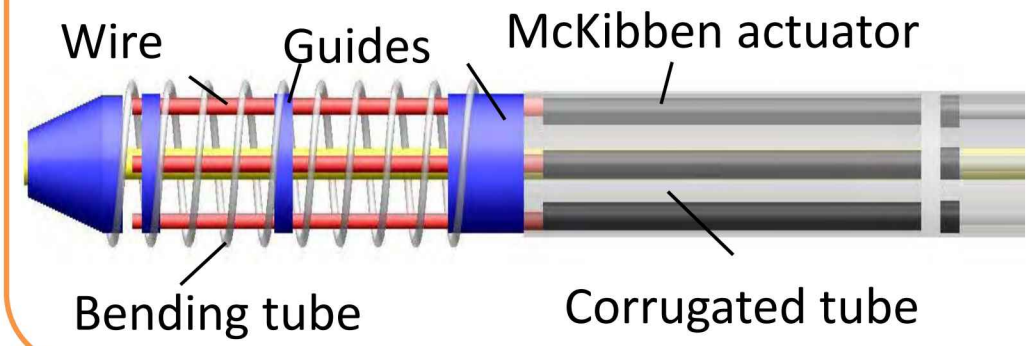
(2) Smart head bending mechanism

Designed to satisfy three points

1. Expand the length of the motion range
2. Maintain the bending angle at 90 degrees
3. Increase the occurring impelling force

Adopted a wire pulling drive with McKibben actuators

Composition of the head bending

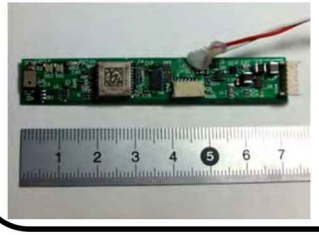


-Four McKibben actuators
-Bend in 2 degrees of freedom
-Controlled ON or OFF
-Actuator length: 240 mm
-Moving part length: 120 mm

(3)Auditory communication and gravity indicator

- Development of electric circuit put in the tube
  - Miniaturization

Electric circuit



- Small microphone, speaker
- 3-axis accelerometer
- Microcontroller

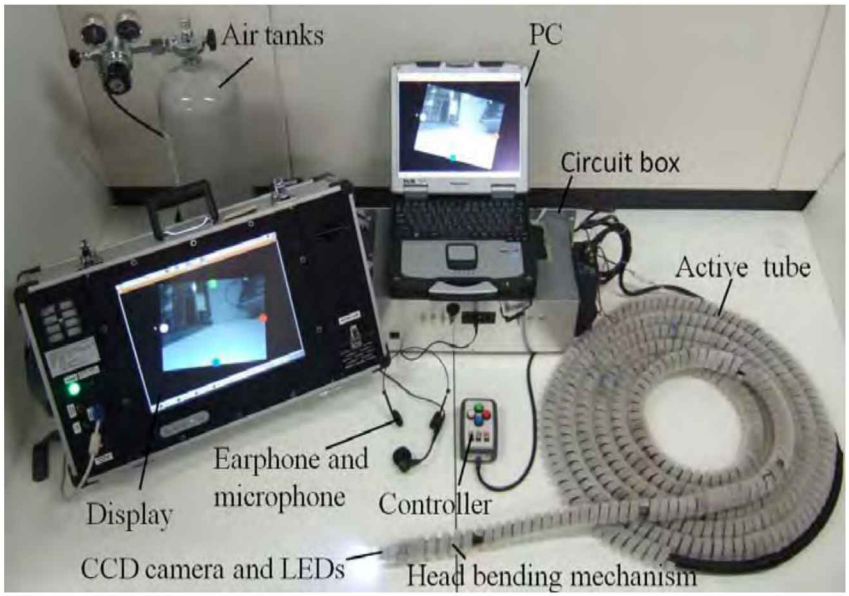
- Operation with gravity indicator

➢Selects a suitable bending direction

➢Understands map information

- Image indicates the color corresponding to buttons
- Image rotates for adjusting the gravity direction

ASC system for rescue operations



Overall the length: 8.1 m
Outside diameter: 37 mm
Vibration motors: 27 motors total
(300 mm Intervals)

Functions

- CCD camera
- The head bending mechanism
- A auditory communication system (A microphone and 9 speakers)
- A gravity indicator
- Gas-drawing pipe

ASC for Vertical Insertion

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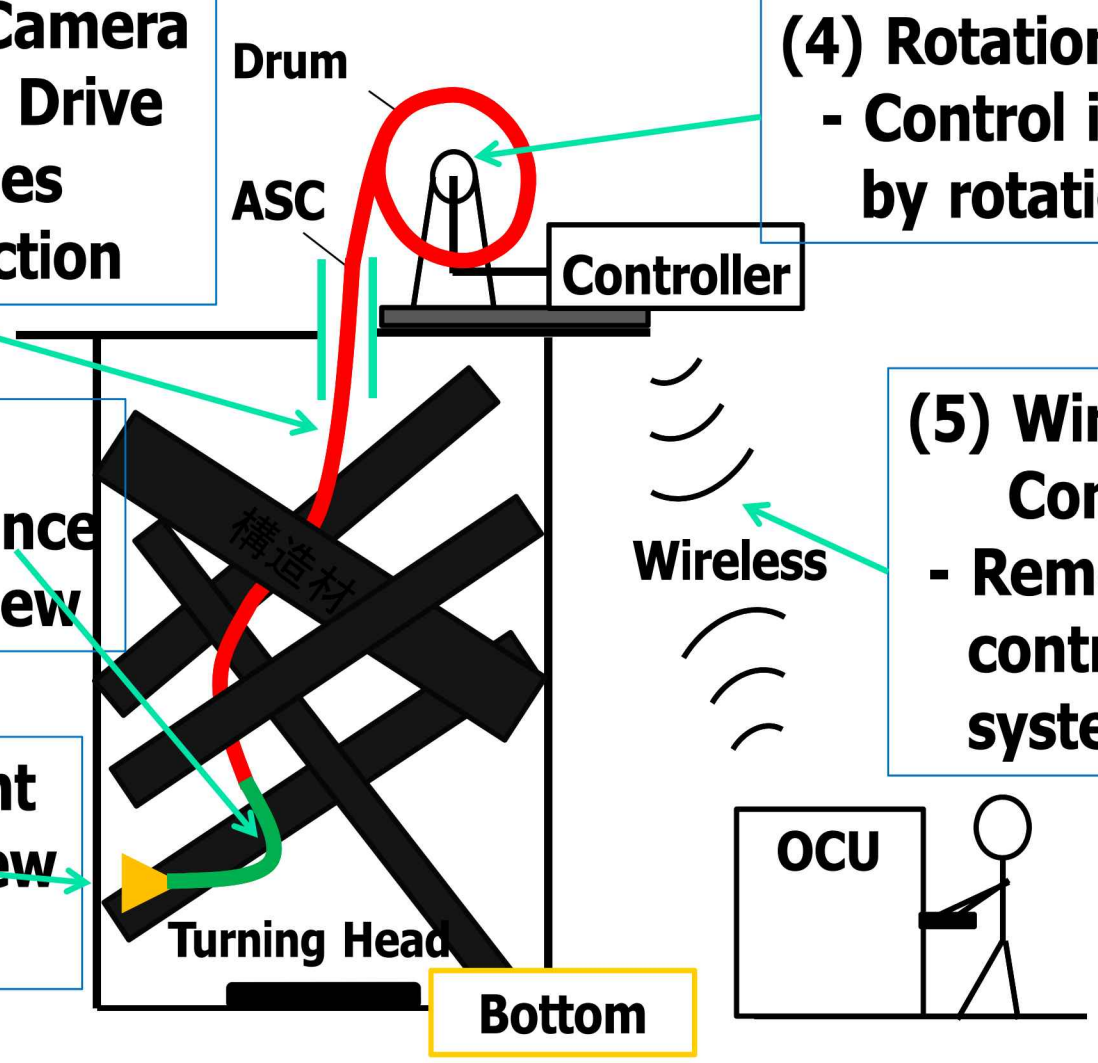
(1) Active Scope Camera
- Ciliary Vibration Drive
- Motion on rubbles
- Reduction of friction

(2) Turning Head
- Obstacle avoidance
- Wider field of view

(3) Camera + Light
- Wide field of view
- LED



(4) Rotational Drum
- Control insertion by rotation

(5) Wireless Comm.
- Remote control of system

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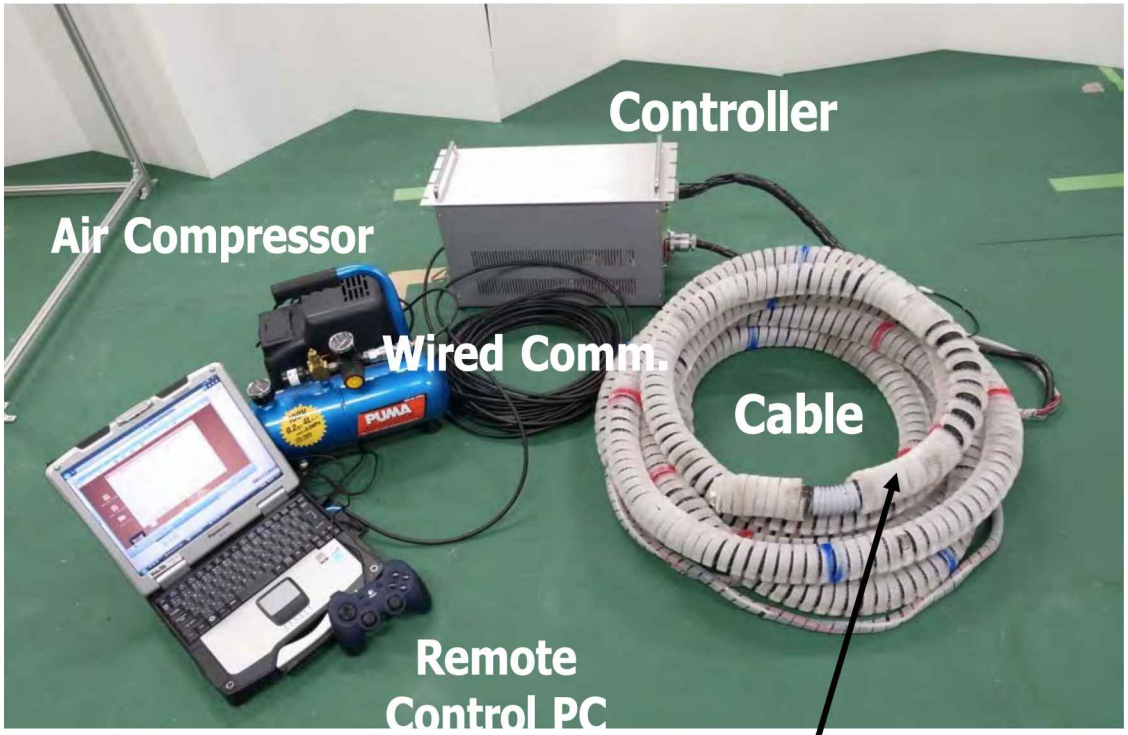
SHIMZ

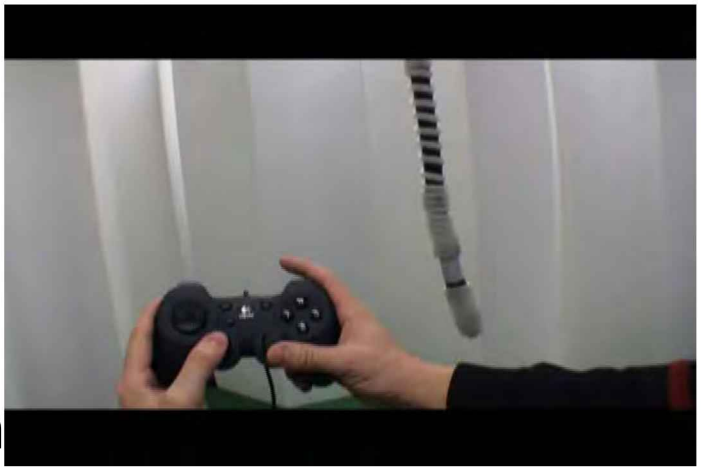
New ASC System



Horizontal Motion

Camera + LED

2-DOF Bending Mechanism



Bending Head

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Experimental Result

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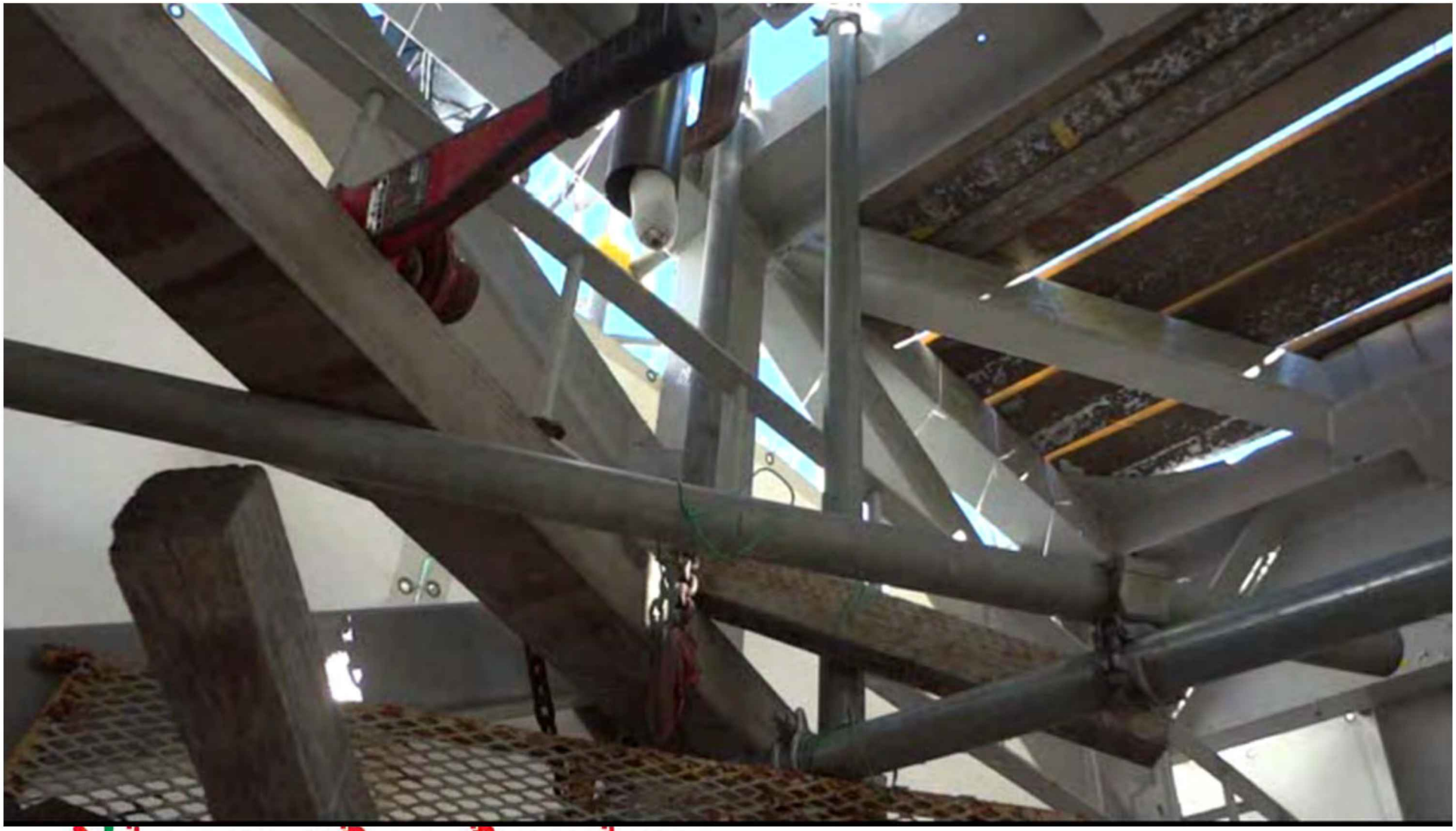

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Conclusions

- **Purpose: Collaborative improvement research of rescue robots, CRAWLER and Active Scope Camera (ASC)**
- **Major Achievements:**
  - **Finding effectiveness of ASC technology for CRAWLER's tether and WH actuator for ASC**
  - **Physical enhancement of CRAWLER (robust limb design, water proof skin, cellular phone chip camera)**
  - **New-type high-power water hammer actuators with compact design for potential use in ASC**
  - **New design of tube-type ASC which can use the water hammer actuator**
  - **High performance of tube-type ASC in narrow passage (motion through 25 mm-diameter pipe-elbow systems)**
  - **New-type flexible pneumatic actuator designs with explosion proof**
  - **High-speed motion of the flexible pneumatic actuator up to 7 m/s**
  - **Application of the flexible pneumatic actuator for new-type ASC for uneven terrain**
  - **Improvement of mobility of ASC on rubble piles**
  - **Voice communication capability with victims under rubbles**
  - **Image processing functions for measuring and showing the gravity direction**
  - **Practical verification of new ASC at firefighters' training center**