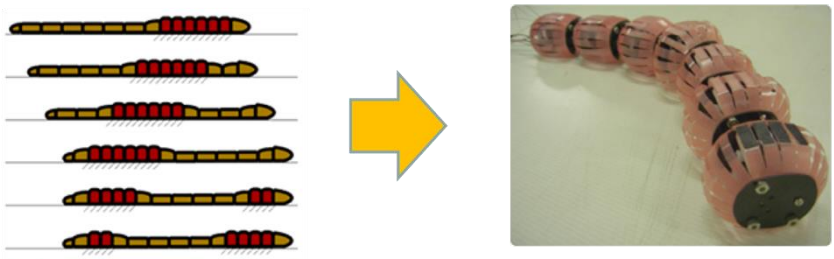
Theme Title	Robot using artificial muscles simulating peristaltic movement of earthworms and its application to pipe inspection, high viscous fluid pumping, and excavation
Name of Organization	Prof. Taro Nakamura, Department of Science and Engineering, Chuo University
Technical Field	Manufacturing, medical-engineering collaboration / life science

Overview

Earthworms move through narrow spaces by peristaltic movements. In Nakamura group, we are developing a robot that simulates the peristaltic movement of an earthworm by using our original artificial muscles as its constituent parts which "contract and expand" by air pressure. This system does not require moving space for its direction change; it can be applied for in-pipe inspection, mixing and separation of solid-liquid mixtures, pumps for solid-liquid mixtures and high viscosity fluids for transportation of sludge, food, cement, etc., and excavation in the ground in combination with an earth auger. We welcome companies that are motivated to commercialize and utilize this technology.

Simplified Image

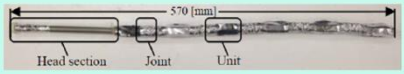
Robot using artificial muscles simulating peristaltic movement of earthworms and its application to pipe inspection, high viscous fluid pumping, and excavation



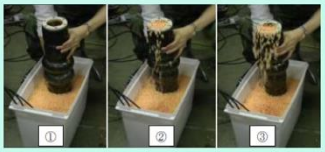
Peristaltic movement of earthworms is simulated by “contracting and expanding” our original artificial muscles by air pressure

[Application Example]

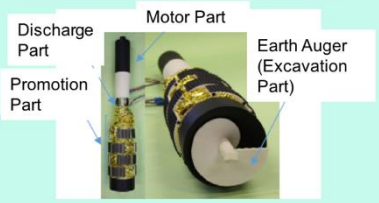
[Pipe Inspection Robots]
- Can move in narrow spaces
- Can turn
- Can incorporate camera etc.



[Pumps for Solid-Liquid Mixtures and High Viscous Fluids]
- High thrust can be generated



[Underground Excavation Robots]
- Combination with earth auger



Background

Earthworms use the expansion and contraction of many joints that make up their bodies to move on and in the ground, and through narrow spaces. This type of movement is called a “peristaltic movement”, which enables locomotion by a very simple movement compared to the leg-based movement found in many animals.

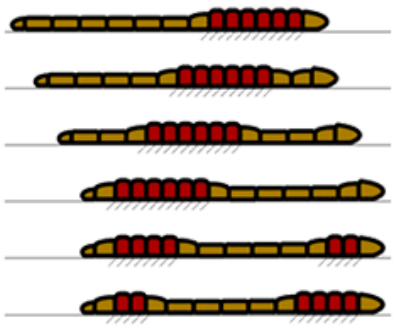
In Nakamura group, we are developing a robot that simulates the peristaltic movement of an earthworm. It can be applied to inspections inside a narrow pipe or pumps that utilize high thrust.

We welcome companies that are motivated to commercialize and utilize this technology.

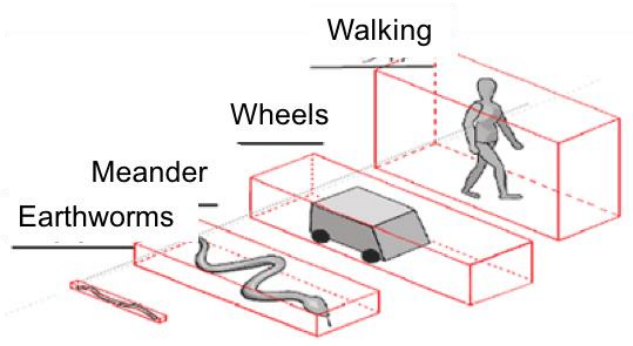
Technology

[Features of Earthworm Peristaltic Movements]

The body of an earthworm consists of about 150 segments, each of which is stretched and contracted to perform peristaltic movements. Peristaltic movement is a movement found in human esophagus and intestines and allows objects to be transferred by moving longitudinal expansion and contraction waves in a certain direction. Although peristaltic movement is slow and appears to be inefficient, it has advantages such as the smallest space required for movement and the ability to secure large area in the surrounding environment. As it moves forward, the earthworm first contracts the body segments of the head and then propagates this contraction to the posterior segments of the body. The contraction of this body segment causes friction with the ground. They then move forward by extending the contracted body segments.



(Peristaltic Movement of Earthworms)

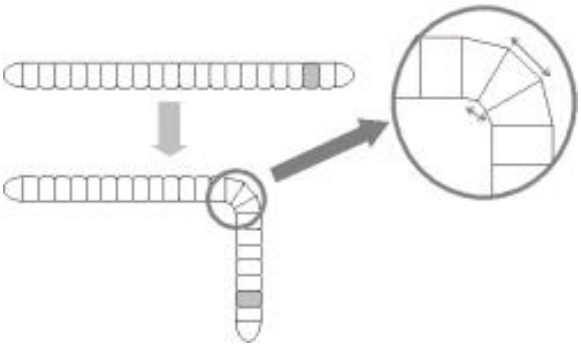


(Space Required for Movement)

[Turning in Peristaltic Movement]

When an earthworm changes direction, it changes the direction of its head by making a difference in expansion and contraction between the left and right sides of several consecutive body segments. Moreover, because earthworms have numerous body segments, they can move by the peristaltic movement using the

remaining body segments.



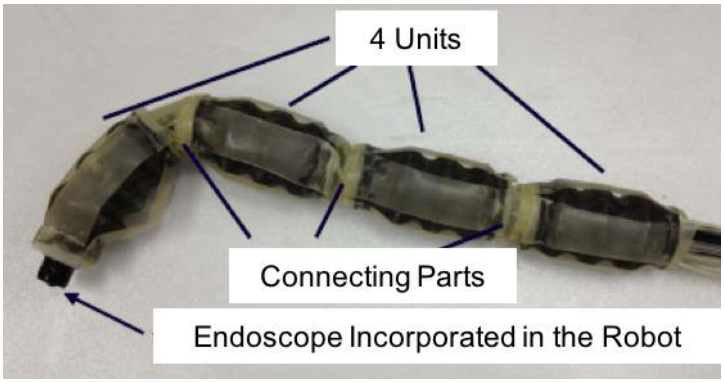
[Earthworm-type Robot]

The prototype that robotize earthworm peristaltic movement is as follows:

We realized flexibility and high elasticity of this robot by using artificial muscles developed in Nakamura group for its constituent parts. When air pressure is applied to an artificial muscle, it "contracts and expands", which can be used as a unit for peristaltic movements.

The interior is hollow and can be customized according to the application and the scene.

For example, an endoscope can be incorporated inside as shown below.



Strengths of the Technology and Know-How (Novelty, Superiority, Utility)

・Can stably and reliably move in narrow spaces.

・Can be attached to existing inspection devices and maintenance equipment because the inside can be made hollow.

・Possible to change its direction of movement by turning.
Therefore, it can move even in places with many curved pipes.

・High thrust can be generated.
Therefore, it can also be used for pumps and underground excavation.

・By using our original artificial muscles, we have achieved flexibility and high elasticity.

Image of Collaborative Companies

For example, we can work with the following companies:

1) Companies that develop and sell inspection equipment in pipes.
2) Companies that develop and sell power pumps.
3) Companies that develop and sell industrial equipment and robots.
4) Other companies that are motivated to commercialize and utilize this technology.
There are various possibilities of application. Please feel free to contact us.

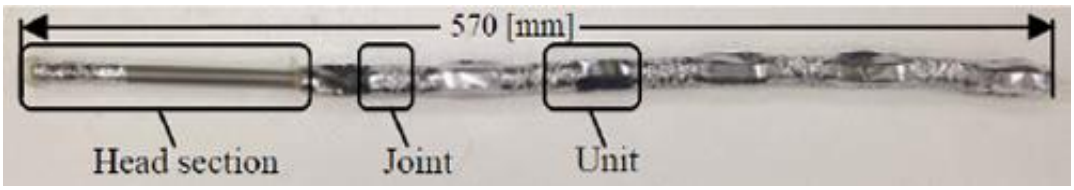
Utilization of Technology and Know-How (Images)

[Inspection in Thin Pipes]

Industrial endoscopes are often used to inspect 25A and 15A pipes, which are often used as thin pipes for water and gas pipes. However, in pipes with many curved pipes or under long distances of 15 m or more, it is difficult to push the endoscope forward due to the effect of friction around the pipe. Therefore, it is difficult to perform the inspection only with endoscopes.

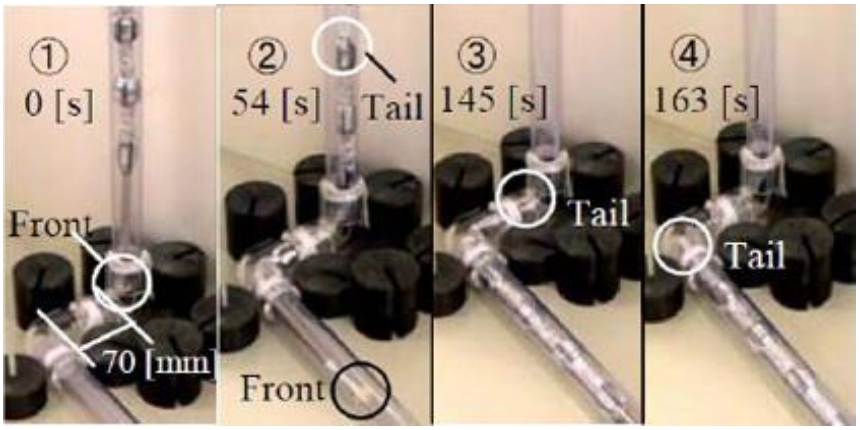
Therefore, there is a need for endoscopes with robotic travel capabilities. However, since the pipes are so small, it is very difficult to run through thin pipes including multiple elbow tubes with cameras and other equipment, and such robot currently does not exist.

The following is an example of an earthworm-type robot applied to the inspection of thin pipes.



The following figure shows the robot passing through the elbow continuously. The

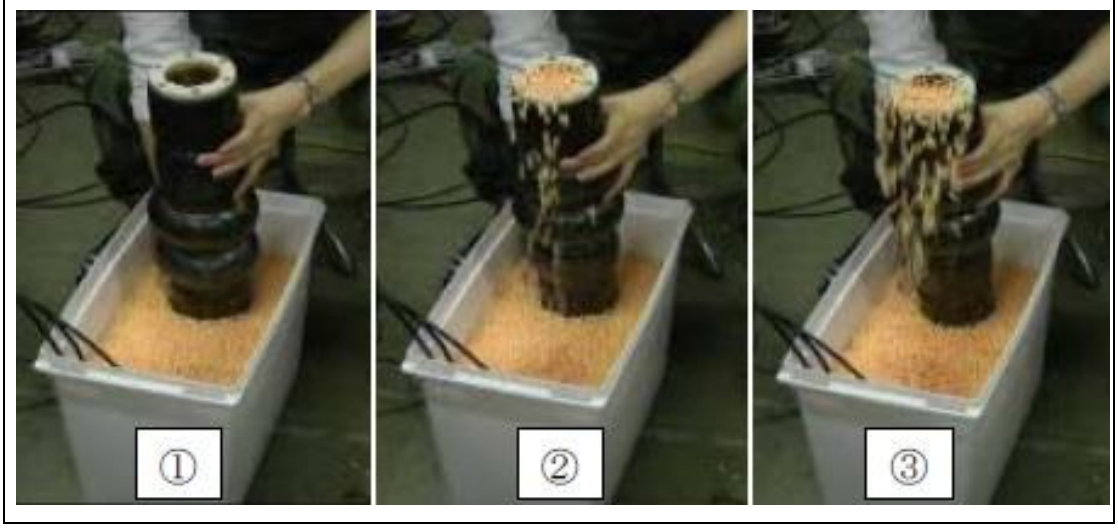
robot is equipped with a camera in its inside and can pass through multiple consecutive elbows in small pipes such as 15A and 25A and inspect long distances of more than 15 m.



[Transport of Solid-Liquid Mixtures and High Viscosity Fluids]

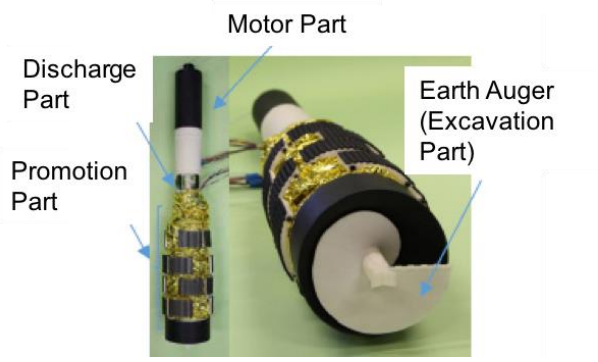
Conveyance systems for solid-liquid mixtures and high viscosity fluids are required in various situations, such as conveying sediment and sand upon natural disasters, sewage treatment, and transporting food and sludge in factories.

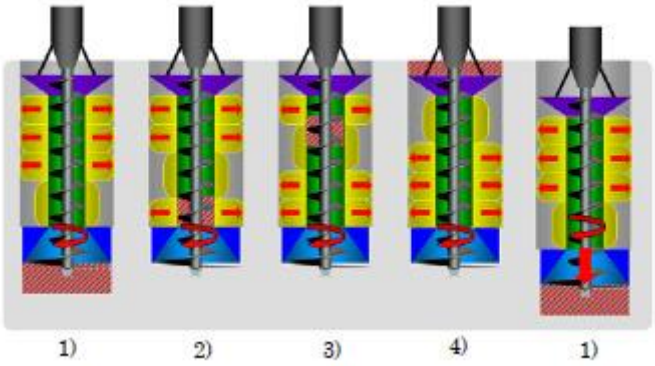
Therefore, we devised the earthworm-type robot to simulate the peristaltic movement of the intestines. The intestine has various functions such as mixing and separating solids and liquids as well as transporting solid-liquid mixtures and high viscosity fluids. By realizing transport by peristaltic movement of the intestines, we achieved in vertical transport of a variety of fluids. The figure below shows the vertical transport of solid-liquid mixture with a solid content of 30%. It is expected to be applied to mixing and separating solid-liquid mixtures and transporting sludge, food, cement, etc.

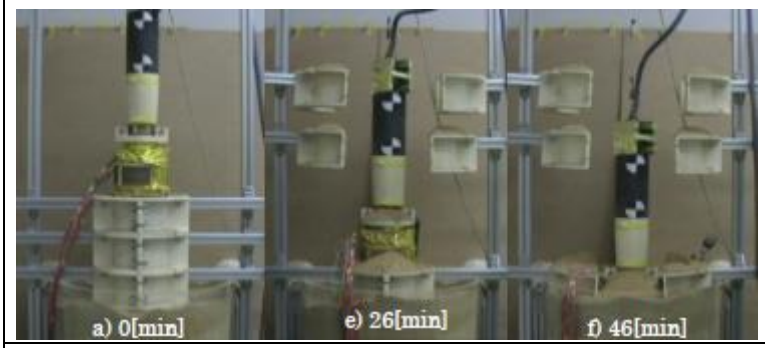


[Excavation Robot]

Our system has the potential to be applied to excavation robots. A peristaltic earthworm robot that can stably move through small holes is used as the propulsion mechanism, and an earth auger that can easily excavate and transport sediment using a single mechanism is used as the excavation mechanism.







Flow of Technology and Know-How Application

If you are interested in utilization of this technology or product development, please feel free to contact us.

We will introduce this system with a demonstration.

Description of the Technical Terms

[Peristaltic Movement]

Peristaltic movement is a wriggling movement that accompanies contraction waves

of muscles, like the movement of digestive tracts of animals, the movement of worms, and so on. In the human gastrointestinal walls and the body walls of earthworms, there are two layers of muscles: outer longitudinal muscle and inner circular muscle, and, outer circular muscles and inner longitudinal muscle, respectively, which alternately perform propagation contractions. These contractions act antagonistically through the hydrostatic pressure of body fluids and gastrointestinal contents, causing some to pinch in and lengthen and others to become thicker and shorter.

[Earth Auger]

Earth auger is a machine for digging holes in the ground by rotating the connected screw through rotation of the power motor. There are various types of machines, from small ones that can be operated by one person to those that are lifted by a large crane and dig down by its own weight.