A hyper-redundant manipulator has unconventional features such as the ability to enter a narrow space while avoiding obstacles. Thus, it is suitable for applications:

(a) Maintenance of the nuclear reactor  
(b) Maintenance of the highway  
(c) Care of patients  
(d) Collection of manganese lumps
Application of Hyper-Redundant Manipulators
Development of Hyper-redundant Manipulators

Problems for Realizing Hyper-Redundant Manipulators

- A hyper-DOF-driving mechanism mounted on the arm makes the manipulator quite heavy
- Control of the large DOFs is complicated

Mechanism & Control of Hyper-redundant Manipulators

- Special light-weight and powerful rotating joints
- Coupled tendon-driven mechanism
- Slider-installed robot arm
- Redundancy and Hyper-redundancy resolution
- Control of Coupled tendon-driven mechanism
- Control of Slider-installed robot arm
Weight Problem of Traditional Mechanisms

(a) Directly-driven Joint Mechanism

(b) Conduit-wire Joint Mechanism
Offset Linear-driven Root Arm

(a) OL Joint Mechanism  
(b) OL Arm
Coupled Tendon-driven Robot Arm

(a) Finger Mechanism
(b) Coupled Tendon-driven Mechanism
(c) Coupled Tendon-driven Robot Arm

Vincula Brevia
M. flexor Digitorum Superficialis
M. flexor Digitorum Profundus
Vincula Longa
Principle of Coupled Mechanism

(a) Decoupled Mechanism

(b) Coupled Mechanism

(c) Connected Differential Mechanism
Coupled Tendon-driven Mechanism

(a) Mechanism of Type 1

(b) Mechanism of Type 2
Moray Arm: Slider-installed Robot Arm

Moray arm is a slider-integrating multijoint manipulator, where a powerful slider is installed at the base of the arm

(a) Moray Arm  (b) Controller of Moray Arm
Properties of Moray Arm

i) The slider that is mounted on the ground is free from the restriction of the weight. It is thus possible to utilize a powerful actuator to drive the slider. **Powerful motions of the Moray arm could be generated by subrogating most of the driving power to powerful slider actuator.**

ii) Moray arm can be controlled to trace the planned trajectory with only a small flourishing arm motion.

iii) Since the small flourishing arm motion, **the resistance caused by the arm motion while the Moray arm is operated in the fluid environment, is minimized.**

iv) The slider can simultaneously act as a housing for the arm.
Control Methods for Moray Arm

Problems of Traditional Jacobian-based Approaches

It is not possible to make full use of the slider and difficult to the real-time control

Moray Drive and 2-DOF Moray Drive

- Moray drive control generates rotating motion of the joints in synchronization with linear motion of the slider while restricting the arm on the trajectory.
- 2-DOF Moray drive control derogates the control problem of the hyper-redundant degrees of freedom (DOFs) to the simple one of 2 DOFs: one of the control variables signifies the linear combination of the objective initial and final postures of the arm, while another one expresses the amount of the pull-out-displacement when pulling the arm out of the housing slider.
Control of Hyper-Redundant Manipulators (1)

Local control technique for a redundant manipulator

i) Redundancy Decomposition Control (RDC) in acceleration-based formulation and in torque-based formulation; (Parallel-processing is possible but Multi-processor necessary)

ii) Improving local torque minimization techniques by balancing joint torques against joint accelerations (No warranty of ZERO end-motion joint velocities) and by balancing joint torques against joint velocities (ZERO end-motion joint velocities)

iii) Minimizing kinematic criterion as the norm of joint velocities to guarantee ZERO end-motion joint velocities

Control schemes for Coupled tendon-driven mechanism

i) Decoupling algorithm for unifying tendon traction force to all actuators

ii) Optimal arm posture control and Dynamic decoupling control algorithm

iii) Minimum-time control technique with constraints of the limits of tendon forces
Control of Hyper-Redundant Manipulators (2)

**Moray Drive control (Specifically for Moray arm)**

i) Optimal trajectories in the Basic Moray Drive control (*Clothoid Curve*)

ii) Inertia Moray drive and/or 2-DOF Moray Drive Control by the continuous curve theory

iii) An obstacle avoidance control scheme on basis of posture space analysis

iv) Time-optimal control with consideration of actuator’s actuation characteristics

**Real-time control of Hyper-redundant manipulators**

i) Real-time Posture control through a Continuous curve

ii) Obstacle avoidance control scheme by an analysis in the posture space

iii) Real-time Dynamic control of Hyper-redundant manipulators