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Modeling and priority-based control of a bio-inspired hybrid actuation underwater robot with soft universal joint framework

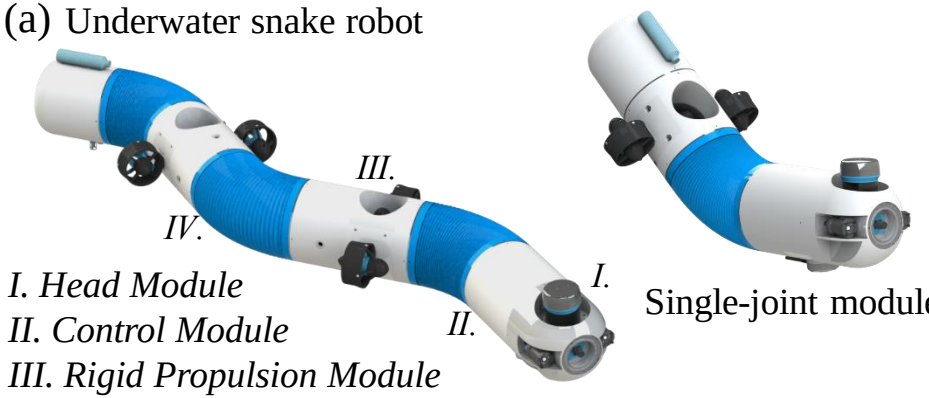
Junhao ZHANG, Jiancheng YU

Keywords:
Underwater robots; Underwater Manipulator; Priority-based Control; Swimming robot; Hybrid actuation

中国科学院沈阳自动化研究所
SHENYANG INSTITUTE OF AUTOMATION, CHINESE ACADEMY OF SCIENCES

Underwater snake robot: featuring a modular slender structure, rigid-flexible coupled actuation, and flexible joints. It can swim flexibly in a 5-meter water tank and perform actions such as traversing narrow spaces and making sharp-angle turns.

(a) Underwater snake robot

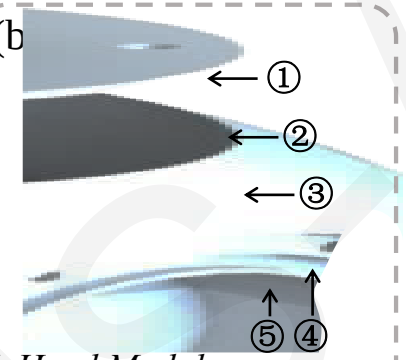


I. Head Module
II. Control Module
III. Rigid Propulsion Module
IV. Soft Joint Module

Single-joint module

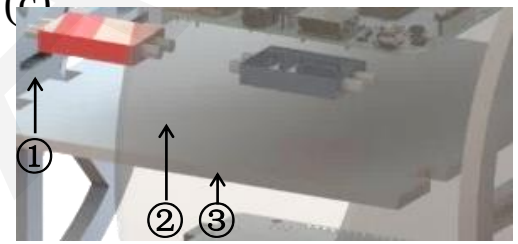
Multi-joint modular robot

(b



I. Head Module
① Sonar ② Connecting Plate③ Head Body ④ Lighting Lamp ⑤ Camera

(c)



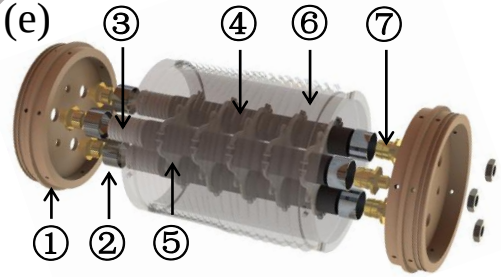
II. Control Module
① Waterproof connector
② Raspberry Pi ③ STM32

(d)



III. Rigid Propulsion
① Vertical thruster
② Tangential thruster

(e)



IV. Soft Joint Module
① End Cap ② Sealing Ring
③ Soft Actuator ④ Fabric Layer
⑤ Cage ⑥ Bellows
⑦ Pressure Connector



modular system



slender structure



pass ability



intervention

(f) Prototype of underwater snake robot

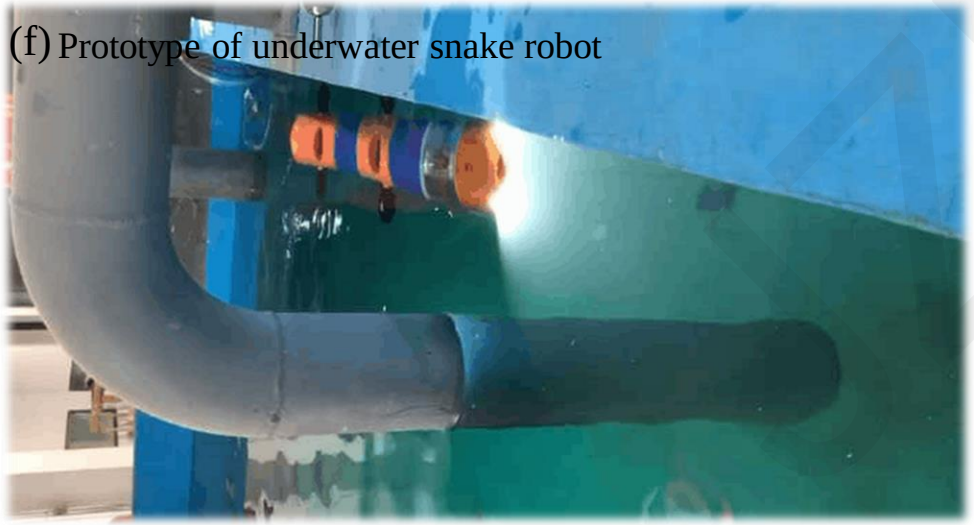


Fig. 1 The 1nd Generation Prototype of Underwater Snake Robot and Pool Test

Based on Generation I, it is equipped with propeller arrangement, vector propulsion, built-in power supply, joint pump-valve drive and other functions. It weighs 90 kg, can swim normally in a 10-meter water pool, and has completed trajectory tracking tests.

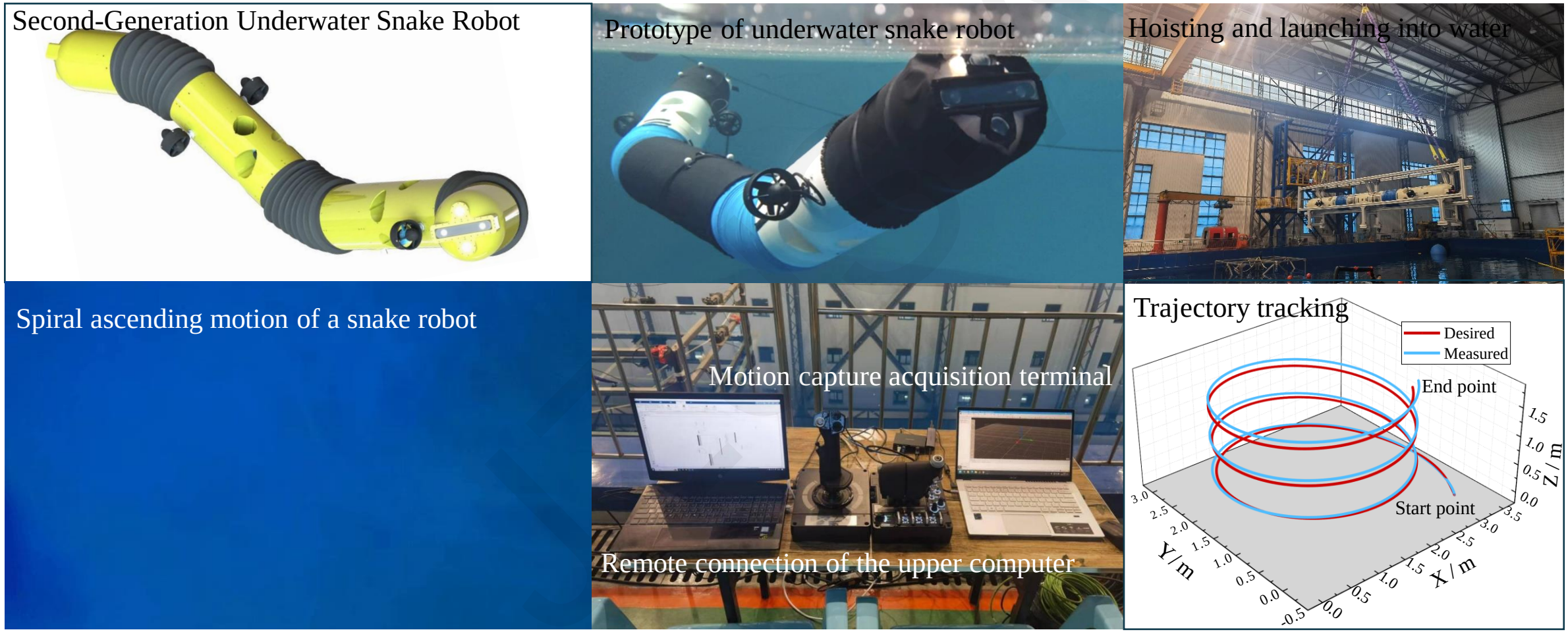


Fig. 2 The 2nd Generation Prototype of Underwater Snake Robot and Pool Test

The robot features an inherently modular architecture, enabling flexible expansion into a scalable, multi-module structure. To describe this reconfigurability, we formulate a generalized kinematic model that applies across arbitrary configurations.

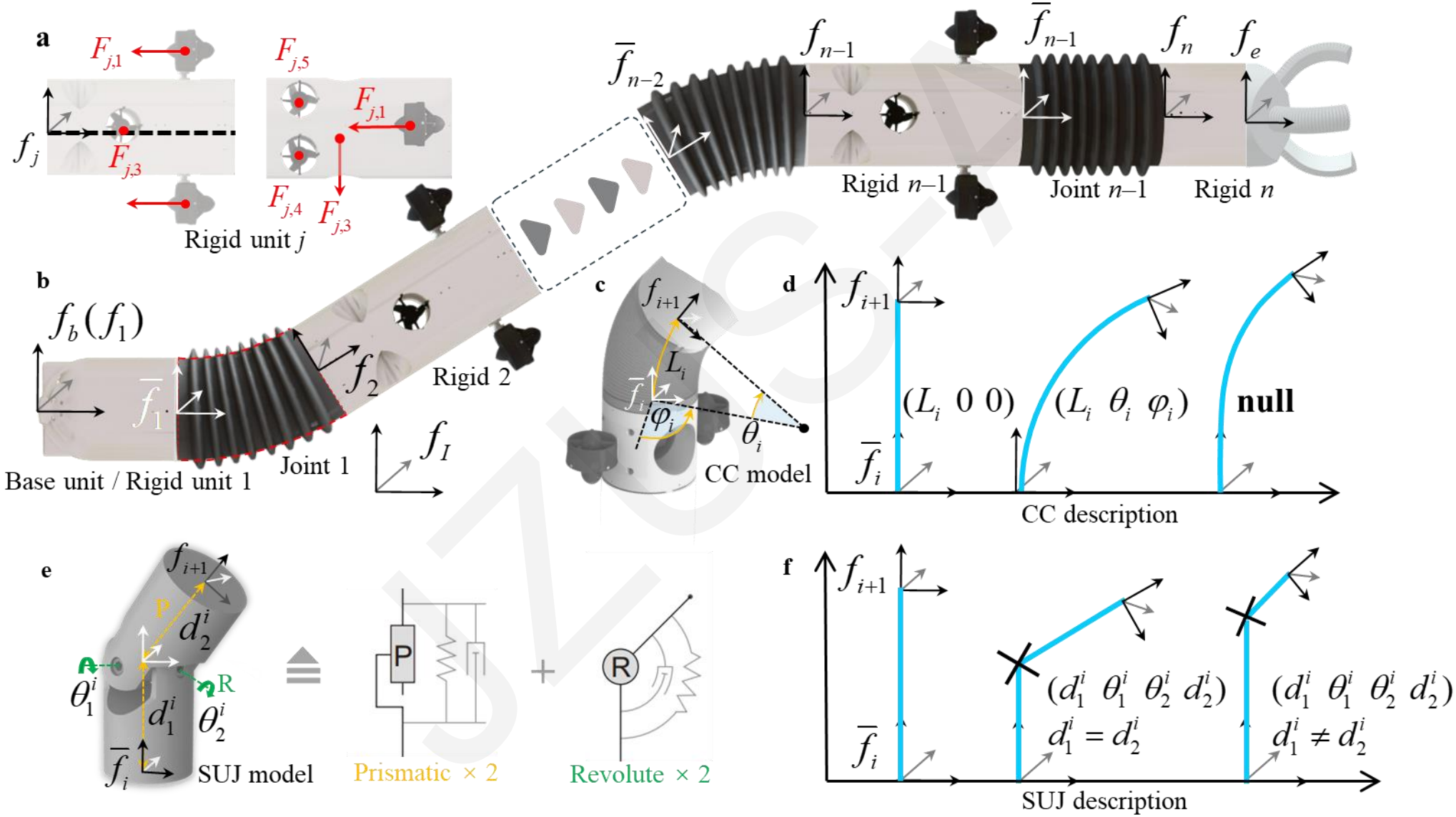


Fig. 3 Schematic illustration of the mathematical modeling of the robot

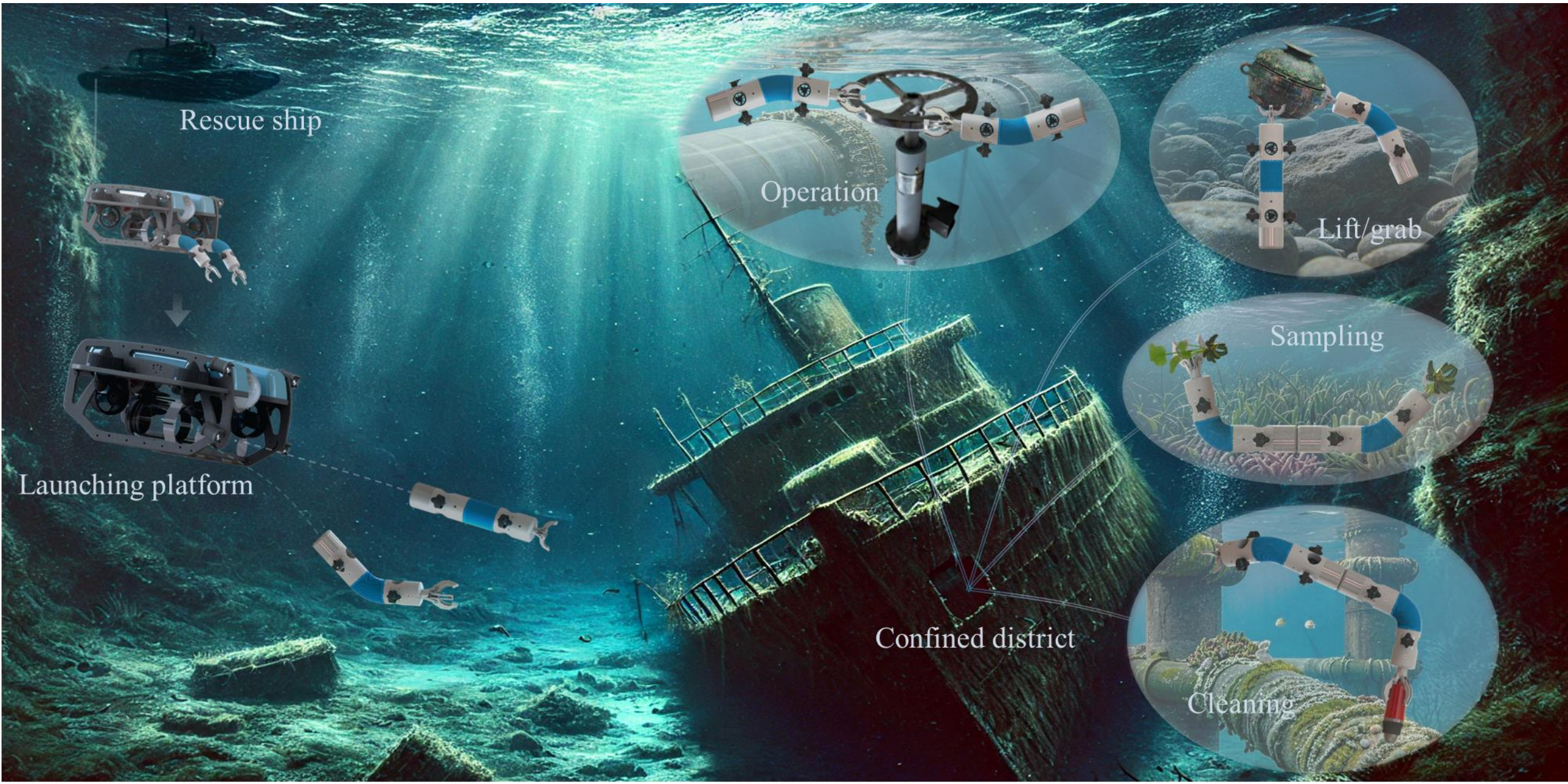


Fig. 4 Conceptual illustration of the HRFUM and its operational modes.