News Release and Fact Sheets **Immediate release**

Octopus-inspired robot – the fastest underwater robot based on the given power – developed in Singapore

Ability to morph (change shape), propel itself and turn quickly in water (i.e. super-manoeuvrability) efficiently and silently, lending itself to future possibilities in surveillance and inspection

Fig.1: (L -R): Polycarbonate skeleton of robot, testing apparatus, fully blown membrane (last two pix)

Singapore, 30 Mar 2015 – Scientists in Singapore have developed a new octopus-inspired robot which can zip through water 10 times its body length within one second, in an ultra-efficient manner. This first-ever ultra-fast propulsion and super-manoeuvrability demonstrated in underwater vehicles is unprecedented; and is the work of researchers and an engineer from the Singapore-MIT Alliance for Research and Technology (SMART) [新加坡-麻省理工学院科研中心]. The first author, originally from SMART, is now with the University of Southampton.

This ground-breaking research was published in Bioinspiration & Biomemetics and Nature.com in Feb 2015, and validates the physics of shape change (that forms the basis of jet propulsion of cephalopods) to give additional thrust to underwater vehicles.

Inspired by the speed at which cephalopods like the octopus, flee from danger by inflating its mantle cavity with water to a bluff-body shape and then quickly expelling it to dart away, the researchers started building an octopus-inspired robot in November 2013.

The end result is a polycarbonate 3D printed streamlined skeleton which had no moving parts (Fig.1) and no energy storage device other than a thin elastic outer membrane. It works like blowing up a balloon and then releasing it to fly around the room. The 27-cm long robot is inflated with water and once released, rapidly deflates by shooting the water out through an aperture at its base to power its propulsion. As the rocket contracts, it can achieve more than 2.6 times the thrust of a rigid rocket doing the same manoeuvre, while creating minimum turbulence – an important feature in underwater research / survey vehicles. The skeleton within the robot keeps the final shape streamlined, while fins at the tail, help in stabilization.

Prof Michael Triantafyllou (迈克尔 崔昂塔夫罗), SMART Principal Investigator (PI) for Centre of Environmental Sensing and Modeling (CENSAM) (环境监测及模拟中心)], said: "When a fish escapes by swimming fast, it bends its body and zooms through the water, losing some energy to the surrounding water and recovering about 30% of the energy. An octopus, on the other hand, uses more effectively, energy recovery mechanism to power its ultra-fast escape, and is able to recover more than 50% of the energy available at the beginning. Hence, rendering this octopus robot highly energy efficient."

Professor Michael Triantafyllou who is also the William I. Koch Professor of Marine Technology, Professor of Mechanical and Ocean Engineering and Director of the Center for Ocean Engineering at MIT, explained: "With this fundamental understanding in fluid mechanics, our research will pave the way for future robots that require fast maneuvers to help us get close to something that moves fast or quickly evade hazardous situations such as a sharp temperature rise in mid-ocean ridges. For instance, these octopus robots could follow dolphins for quick observation, or inspect thermal vents safely in the mid-ocean ridges."

Mr Vignesh Subramaniam, research engineer with CENSAM, added: "Currently, no autonomous underwater vehicle (AUV) can achieve this ultra-fast performance except torpedoes which require a lot of fuel. With further R&D, future AUVs and other marine vehicles can adopt this mechanism to help it evade threats or track something fast stealthily underwater without the need for much energy."

Moving forward, SMART will continue in its research on understanding the physics of jet propulsion underwater and implementing the technology on marine vehicles.

The research was funded by the Singapore National Research Foundation (NRF) through SMART at the Campus for Research Excellence And Technological Enterprise (CREATE).

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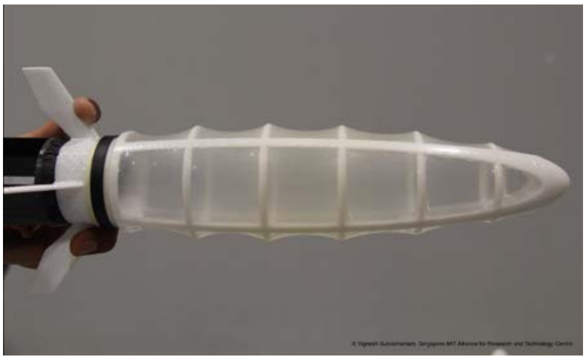
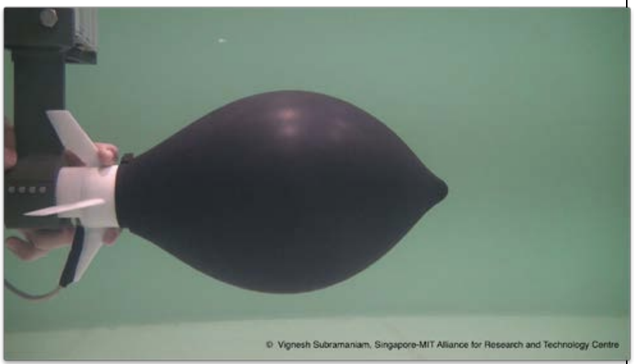
SMART
Singapore-MIT Alliance for Research and Technology

Fact sheet

Octopus-inspired Robot





No	Innovation	Key Features
1.	Physical dimensions	The length of the robot is 27cm (1 Body length). The frame is a rigid 3D printed polycarbonate 5:1 ellipsoid. An elastic membrane surrounds the hull and can be inflated to about 50% of the length laterally.
2.	Capabilities	• Ultra-fast escape manoeuver • Biomimetic jet propulsion mechanism • Maximum speeds of up to 10 Body lengths per second and acceleration of 14 Body lengths per square second with current membranes used; potential for better performance in the future.
3.	Purpose (present & future)	To understand the physics of shape-change underwater and mimic the jet propulsion mechanism of cephalopods and to develop underwater vehicles with shape-change capabilities unlike traditional underwater vehicles.
4.	Mechanics of working	Water is pumped into the membrane and the robot is released to jet forward. Energy is recovered from the fluid surrounding the body to provide additional thrust.
5.	Other unique/key features	Shape-change, ultra-fast escape, quiet propulsion that does not disturb ocean environment
6.	Background	Research began in November 2013 in SMART; and is funded by the Singapore National Research Foundation (NRF) through SMART at the Campus for Research Excellence And Technological Enterprise (CREATE).

Info updated by Vignesh Subramaniam (vignesh@smart.mit.edu) as of March 2015

Fact sheet

Unmanned Aerial Vehicle



1.	Physical dimensions	Varies depending on quad or hexacopter
2.	Capabilities	• High maneuvering capabilities • 6 Degrees of freedom • Carry light-weight payloads like camera
3.	Purpose (present & future)	• Aerial video/photography • Helps identify peculiar patterns and features in the sea
4.	Mechanics of working	• DC brushless motor with electronic speed control • Flight controller, GPS/compass, IMU onboard for navigation
5.	Other unique/key features	• Measures environmental disturbances in the near field • Autonomous mission capable • Thermal plume imaging
6.	Background	Research began in 2011 in SMART; and is funded by the Singapore National Research Foundation (NRF) through SMART at the Campus for Research Excellence And Technological Enterprise (CREATE).

Fact sheet

Autonomous Kayaks

1.	Physical dimensions	• 3 m long regular ocean kayak
2.	Capabilities	• Speed: 2 m/s • Duration: continuous 4 hrs on battery • Carry payload sensors (salinity, dissolved oxygen, turbidity, temperature, chlorophyll) for real-time data sampling
3.	Purpose (present & future)	Autonomous platform for surveying/monitoring Singapore coastal waters
4.	Mechanics of working	• Propelled by trolling motor • GPS, Compass and IMU used for navigation • Can be remote-controlled
5.	Other unique/key features	• Autonomous navigation • Real-time sensor data collection • Scenario based decision-making capability
6.	Background	Research began in 2009 in SMART; and is funded by the Singapore National Research Foundation (NRF) through SMART at the Campus for Research Excellence And Technological Enterprise (CREATE).

Singapore-MIT Alliance for Research and Technology

Fact sheet

Autonomous Underwater Vehicle (AUV)

1.	Physical dimensions	• Length: 180 cm • Diameter: 15cm
2.	Capabilities	• Speed 2.5 m/s • Autonomous underwater exploration rated to 100m • Carry various payload sensors (DVL, acoustic modem, water quality measurement probes)
3.	Purpose (present & future)	Autonomous platform for surveying/monitoring Singapore coastal waters
4.	Mechanics of working	• Propelled by DC brushless motors • Directional fin enables diving of the vehicle underwater
5.	Other unique/key features	• Autonomous waypoint mission capable • Iridium satellite communication
6.	Background	Research began 2009 in SMART; and is funded by the Singapore National Research Foundation (NRF) through SMART at the Campus for Research Excellence And Technological Enterprise (CREATE).

About SMART

The SMART Centre is a major research enterprise established by the Massachusetts Institute of Technology (MIT) in partnership with the National Research Foundation of Singapore (NRF) since 2007. It is the first entity in the Campus for Research Excellence and Technological Enterprise (CREATE) developed by NRF.

The SMART Centre serves as an intellectual hub for research interactions between MIT and Singapore. Cutting-edge research projects in areas of interest to both Singapore and MIT are undertaken at the SMART Centre. SMART comprises an Innovation Centre and five Interdisciplinary Research Groups (IRGs): BioSystems and Micromechanics (BioSyM), Center for Environmental Sensing and Modeling (CENSAM), Infectious Diseases (ID), Future Urban Mobility (FM) and Low Energy Electronic Systems (LEES).

About CENSAM

Using measurements from a variety of sensors and sensor networks, the Center for Environmental Sensing and Modeling (CENSAM) IRG aims to develop an accurate and predictive model of the natural and built environment of Singapore that seamlessly transitions between different scales, from the level of a single building or facility to the level of the state, including the surrounding seas.

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