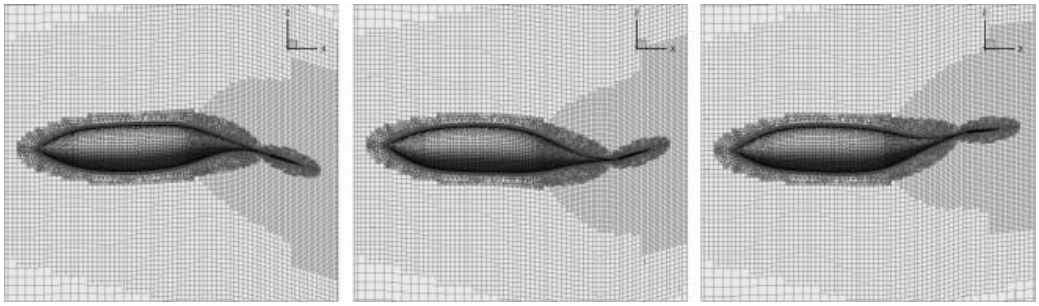
生物策略表

類別	發明 (Innovation)
生物策略 STRATEGY	使特定難以達到及被限制的水下區域易於偵測 (Making certain underwater areas are constricted and hard-to-reach to inspection easier.)
生物系統 LIVING SYSTEM	鮪魚 (Tuna)
功能類別 FUNCTIONS	#在水體/水表移動 # Move in/on Liquids
作用機制標題	尾巴和尾部的鰭通常很大且呈新月型，以增加每個擺力的力量 (The tail or caudal fin is usually large and crescent shaped to increase the power of each sweeping motion.)
生物系統/作用機制示意圖 (確認版權、註明出處；畫質)	 (Elsevier Computers & Fluids Volume 68, 15 September 2012, Pages 54-70)
作用機制摘要說明 (SUMMARY OF FUNCTIONING MECHANISMS)	

挑戰

特定難以達到及被限制的水下區域，使偵測困難。此外，環境可能油膩和危險，使人們難以進行。傳統無人水下交通工具遇到推進力和機動性的困難，使他們不適合在這些區域進行。

創新細節

靈感來自於鮪魚的 BIOSwimmer™ 被設計在嚴厲環境有高機動性。可以偵測像被淹沒的底艙和水槽的內部區域和像統艙、推進力和海底門的外部區域。他可以偵測和保護港口和突堤，執行區域調查和字執行其他安全任務。它是被波士頓工程設計國土安全部使用。

生物模式

鮪魚是快速且有效率的泳者。他們使用鮪形式游泳，大部分發生在尾巴和鄰近的區域用少量的彎曲身體的側向移動。尾巴和尾部的鰭通常很大且呈新月型，可增加每個擺力的力量。這種游泳形式適合鮪魚，因為他們必須游得很快、游過長距離，同時保持著能量。

The Challenge

Certain underwater areas are constricted and hard-to-reach, making inspection difficult. In addition, the environments can be oily or dangerous, making it hard for humans to work. Traditional unmanned underwater vehicles (UUVs) struggle with propulsion and maneuverability, making them less than ideal for working in these areas.

Innovation Details

The BIOSwimmer™ was inspired by the tuna and is designed for high maneuverability in harsh environments. It has a flexible body with fins for maneuverability. It can inspect interior areas of ships such as flooded bilges and tanks, and external areas such as steerage, propulsion and sea chests. It can also inspect and protect harbors and piers, perform area searches and carry out other security missions. It was designed by Boston Engineering for use by the Department of Homeland Security.

Biological Model

Tuna are very fast and efficient swimmers. They utilize thunniform swimming, where most of the lateral movement occurs in the tail and adjacent area of the body with very little bending of the fish's body. The tail or caudal fin is usually large and crescent shaped to increase the power of each sweeping motion. This form of swimming is ideal for tuna, as they must swim fast over long distances while still conserving energy.

文獻引用 (REFERENCES)

「作為 BCF (Body and Caudal Fin) 模式中最快速、最有效的模式，鮪形模式被一些大型魚類如鯊魚和鮪魚採用。在鮪形模式下，身體的擺動相對較小，但尾鰭左右（或鯨魚的上下）擺動以產生足夠的游泳動力。因此，尾鰭的面積和構型對於它們的游泳能力一定是非常重要的。

當整個身體相對於周圍的水波動時，可實現最高的機動性，就像在鰻魚形運動中一樣。另一方面，當身體運動被限制在像鮪魚和鯖魚這樣的鮪形游泳者的剛性尾鰭時，推進效率最大。在這裡，鰭執行稱為拍打 (flapping) 的旋轉-平移運動，當魚向前移動時追隨起伏的路徑，以調整其攻角 (angle of attack)，從而防止通常與效率損失相關的流動分離。」

「As the most swift and efficient mode of BCF(Body and Caudal Fin) mode, the thunniform mode is adopted by some large-scale fishes, such as shark and tunny. Within the

thunniform mode, the swing of body is relatively small, but the caudal fin stroking left and right (or up and down for whales) to generate sufficient power for swimming. Therefore, the area and configuration of the caudal fin must be very important for their swimming ability.」

「The highest maneuverability is achieved when the whole body undulates with respect to the surrounding water, like in anguilliform locomotion. On the other hand, propulsive efficiency is maximal when the body motion is confined to the rigid caudal fin of thunniform swimmers, like tunas and scombrids. Here, the fin performs a roto-translation motion called flapping, tracing an undulating path as the fish moves forward, in order to adjust its angle of attack and thus prevent the flow separations which are commonly associated to efficiency loss.」

參考文獻清單與連結 (REFERENCE LIST) **Harvard 或 APA 格式**

Xinghua Chang, Laiping Zhang, XinHeb(2012). Numerical study of the thunniform mode of fish swimming with different Reynolds number and caudal fin shape. Computers & Fluids, 68, 54-70 (https://www.sciencedirect.com/science/article/pii/S0045793012003027)

Daniele Costa, Giacomo Palmieri, Matteo Palpacelli, David Scaradozzi(2020). Design of a Thunniform Swimming Robot in a Multiphysics Environment. Mechanisms and Machine Science, 84 (https://link.springer.com/chapter/10.1007/978-3-030-48989-2_28)

延伸閱讀: Harvard 或 APA 格式（取自 AskNature 原文；若為翻譯者補充，請註明）

生物系統延伸資訊連結 (LEARN MORE ABOUT THE LIVING SYSTEM/S)

撰寫/翻譯/編修者與日期

宋芊慧翻譯 (2022/03/28)；許秋容編修 (2022/06/08)

AskNature 原文連結

https://asknature.org/innovation/unmanned-underwater-vehicle-uuv-inspired-by-the-tuna/#biological-model

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