James Dyson Outreach - Visual Artificial Intelligence in Soft Robot Control

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What are soft robots?

Soft robotics is the modern fashion in the world of robotics. These robots, built from materials that can squish, stretch, and bend, mimic the things we see in nature. Picture a robot moving like a snake, squeezing itself into tight spaces, or delicately picking up an egg. That is soft robotics! Their shape-shifting abilities make them tough, adaptable, and super useful for things like space exploration or handling delicate items. They can even mimic the movements and functions of living organisms.

However, teaching our squishy robots to perform is not a straightforward task. The challenges begin with 'high-dimensionality', a term describing how the nearly infinite number of possible shapes the robot can move into.

Moreover, our ability to give instructions is limited - our inputs are 'low-dimensional'. So, we must figure out how to guide our robot through a complex dance routine with just a few simple commands. The relationship between these instructions and the robot's moves is 'non-linear', meaning small changes in instruction might trigger drastic changes in its movement, introducing 'chaos' into the equation. This complexity makes controlling soft robots an exciting challenge being widely researched by modern engineers.

Artificial Intelligence and Learning from Videos

Just as you improve at a video game the more you play, learning the patterns, and anticipating what comes next, our robot learns in a similar fashion. We use an artificial

(a) (b)

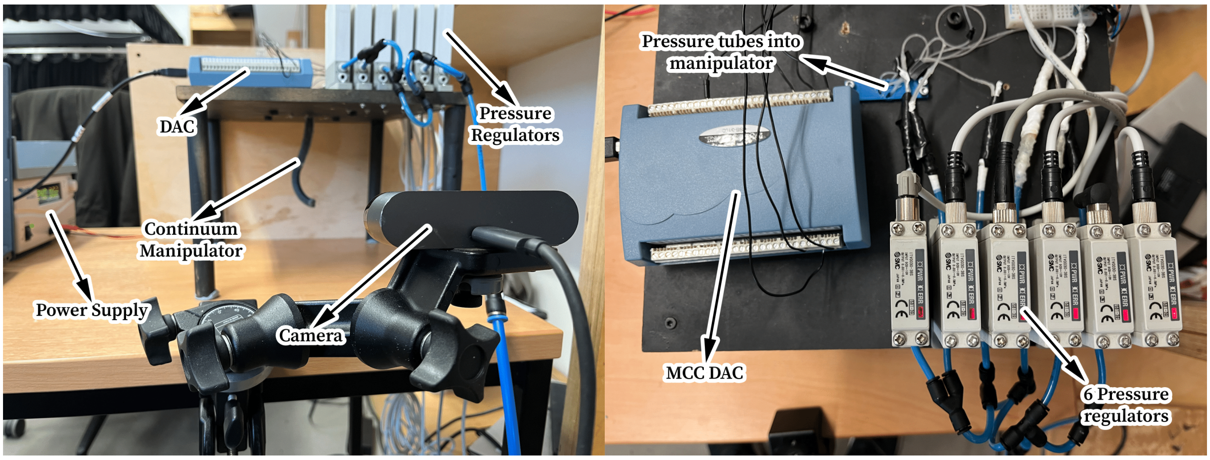
Figure 1: (a) STIFF-FLOP soft robot (b) Biological inspiration from elephant's trunk

intelligence (AI) system and tons of video data showing the robot's movements. Over time, by watching these videos repeatedly, AI becomes proficient in predicting the robot's next move.

The objective of this research project is to train the AI to make the robot execute our desired actions perfectly. With each training iteration, the AI gets better at controlling the robot's movements. Our end goal is to transform our robot into a master dancer, performing intricate routines thanks to its trained AI brain.

The Robot Setup

We use a robot named STIFF-FLOP in this project. Its movements, similar to an elephant's trunk or an octopus's arm, are powered by inflating silicone 'muscles' with pressurised air controlled by a computer. The robot hangs upside down from a platform, and its movements are managed by computer code that sends signals to a series of regulators and a power supply. A high-definition webcam films the robot's every move.



(a) (b)

Figure 2: (a) A fixed camera records the robot's movement (b) Voltage signals sent through a circuit control the pressure to 6 tubes built into the robot

To teach an AI how to predict and control the robot's movements, we use a 'motor babbling algorithm'. It generates random pressure inputs which when repeatedly executed enable the webcam to capture the robot's various movements. This data gives the AI plenty of idea of how the robot moves according to the pressure values.

The captured footage is processed for AI training. We simplify it by reducing the image size and converting them to black and white to focus on the robot's movements. This processed data feeds into the AI, which learns from it, enabling the AI to predict and control the robot's actions over time.

Control Tests

The effectiveness of the control method is tested by examining whether the robot performs the desired actions. First, we assign a target image to the robot to achieve within a certain time frame. The AI then provides a sequence of air pressure values to accomplish that target. These values are tested on the actual robot to determine if it moves as expected. The target could be any image, such as a picture of the robot or even a hand drawing. We can even incorporate obstacles that the robot needs to avoid.

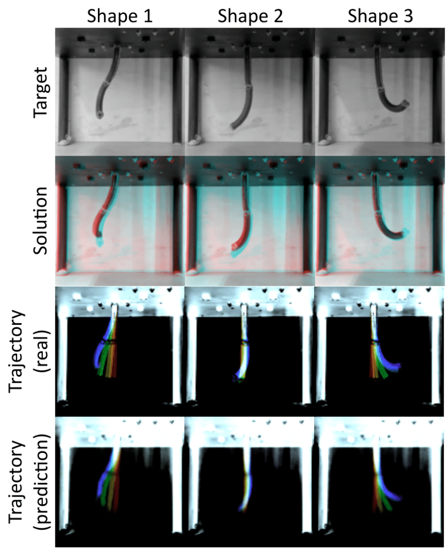


Figure 3: Three different targets that the robot must achieve in 3 seconds. The solutions (red) are shown mixed with the target (cyan) for comparison. The trajectories follow the movement from red to violet

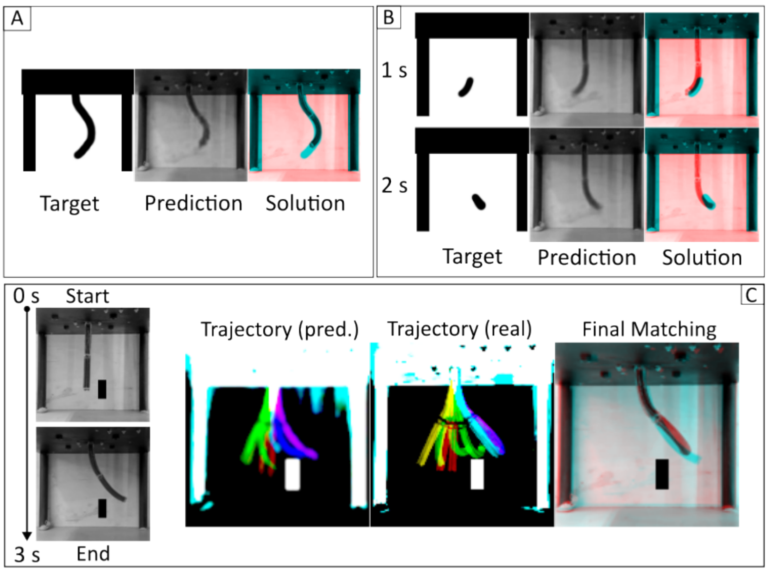


Figure 4: (A) Robot control with a hand-drawn shape target (B) Robot control with only the tip drawn as a target (C) Obstacle avoidance: attempting to achieve a robot shape without colliding with the box