Design, fabrication and validation of a 3D printed metallic snake-like instrument for Minimally Invasive Surgery

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Introduction

The development of traditional manual MIS is limited by the low manipulation precision, high requirement of surgical skills and visual fatigue of the surgeons. Whereas the robotic MIS has the pain point of expensive manufacturing costs. A balance between the cost and the performance of the robotic surgical instrument should be maintained [1].

Abstract

The project aims to design and fabricate a highly dexterous robotic controlled instrument that can achieve the "Z-shaped" posture during the robotic Minimally Invasive surgery (MIS) by additive manufacturing (AM).

Motivation

The current tendon-driven robotic arms in MIS have a restricted workspace [2].
Difficulty in bending each flexible joint individually without influencing other joints [2].

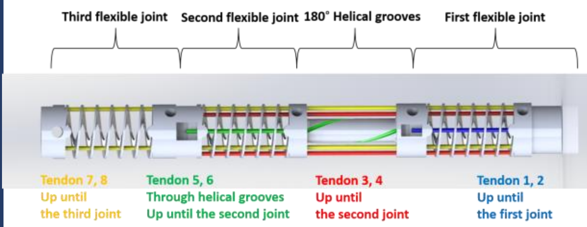

Figure 1 - The tendon arrangement of the metal printed prototype

Methodology

Mechanical Design

SOLIDWORKS
- Tendon-driven instrument
- Responsible for controlling the bending of the robotic instrument according to the commands.

180-degree Helical grooves
- Avoiding influence between the first and the second tendons when bending occurs
- Achieving the "Z-shaped" posture by only pulling one tendon

Fabrication Method

Formlabs (PreForm)
- 3D printing with a complete base
- Material selection: Resin (draft) , 15 - 5ph stainless steel (final) .

Motor Actuation

Serial Communication
- Using the Faulhaber Motion Manager to check the transfer rate and serial port number.
    - Position control
    - Velocity control
- Design a MATLAB programme to send certain commands and transport the signal to the motor.

Preliminary Results

Resin prototype design

A preliminary resin prototype is fabricated to validate the feasibility and test the performance of the model:
- The 3D printing quality is limited
- Compare to the metal printing, the instrument diameter is increased from 9mm to 12mm
- Theoretical maximum bending angle of each flexible joint: 99.3127°

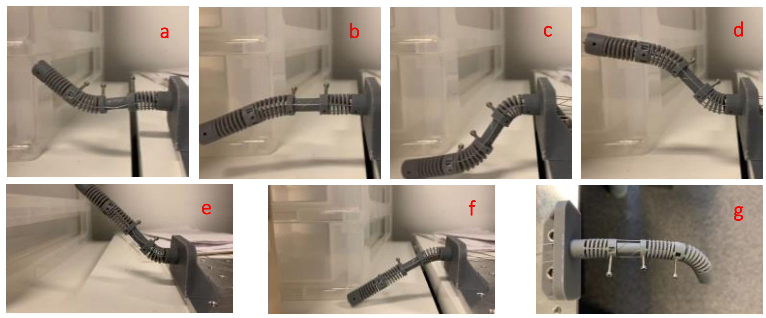

Figure 2 – The Resin prototype (a) The 2nd joint bends upwards; (b) The 2nd joint bends downwards; (c) "Z-shaped", The 2nd joint upwards, The 1st joint downwards; (d) "Z-shaped", The 2nd joint upwards, The 1st joint downwards; (e) The 1st joint bends upwards; (f) The 1st joint bends downwards; (g) The 3rd joint bends rightwards.

MATLAB control system

- Brushless DC-servomotors Series 1226 B
- Motion Controller MCBL 3002 P

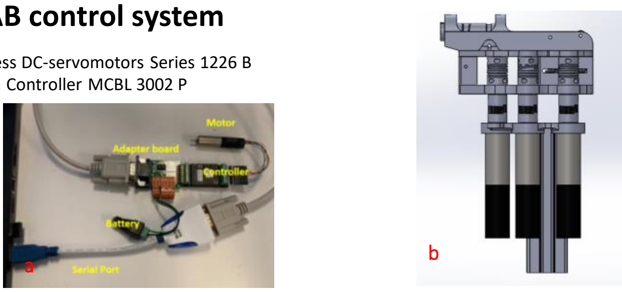

Figure 3 - (a) The overview of the MATLAB control system; (b) The theoretical overview of the motor drive section [3]

Conclusion

The prototype of this tendon-driven robotic instrument can bend without interrupting other joints, and it has a large workspace since the links can be folded into the "Z-shaped" posture.

Current Work

- Adding an end effector on the prototype to accomplish certain tasks
- Preparing for the next metal printing
- Assembling the motor drive module
- Writing a paper

Future Plan

- Calculate the Forward and Inverse kinematics for the prototype.
- Finishing the MATLAB motor control programme to control multiple motors.
- Experimental validations:
    - picking up surgical tools, using the MATLAB programme to control the robotic arm to draw a circle.
- Using the Finite Element Analysis to test its theoretical maximum bending force and maximum bending angle.
- Submit the paper.

References

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