MS Thesis (Graduation: 2021)

DESIGN AND ANALYSIS OF WIRE-DRIVEN ROBOTIC JOINTS WITH APPLICATION FOR MINIMALLY INVASIVE SURGERIES

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Introduction

Background

Minimally Invasive Surgery (MIS)

- ✓ Operation with as little invasion as possible
  - Less invasion, smaller scar, less painful, less bleeding, short recovery time, better cosmetics
  - Highly advanced and popular robot assisted MIS
- ✓ Benefits of robot assisted MIS
  - Remote control, smoother motion control, better imaging, less fatigue

State of the art

- Long & rigid instruments
- Not flexible
- Manual tool changing
- Hinders natural vision

➢ Onsite (attached to robot joints) motors/sensors

- Long & rigid instruments
- Not flexible
- Manual tool changing
- Hinders natural vision

➢ Damage to electronics due to heat/chemical sterilization

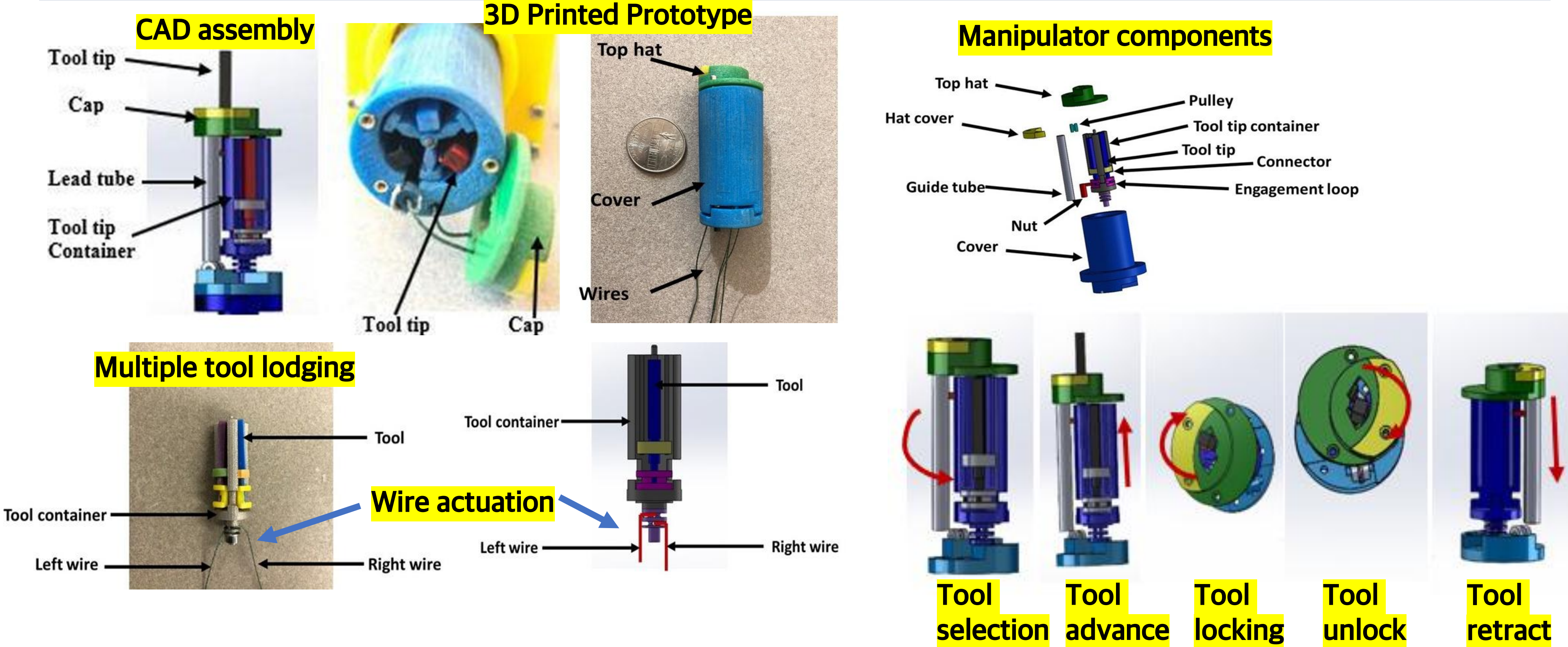
- Long & rigid instruments
- Not flexible
- Manual tool changing
- Tool tip does not have multifunctionality

➢ One tool manipulator can do only one job

Methodology

Experimental Setup

Wire driven multifunctional tool tip manipulator

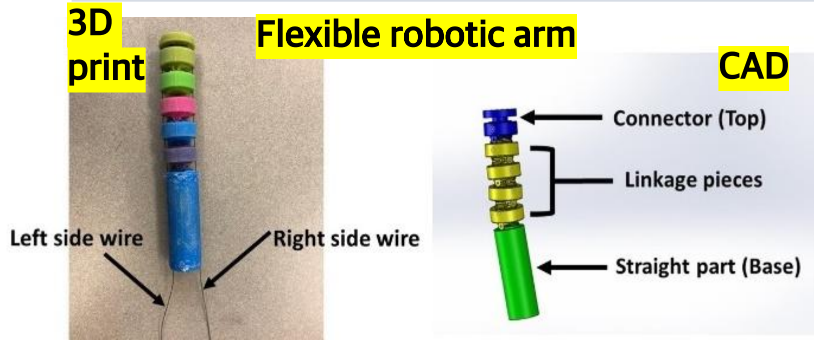


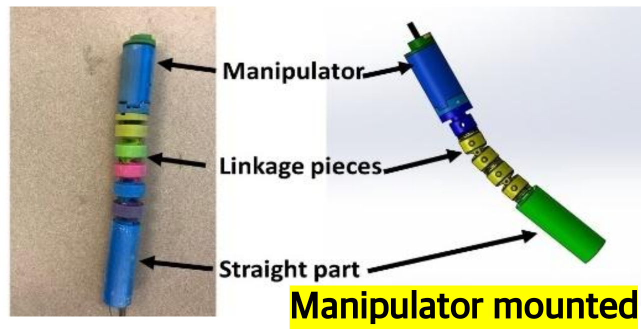
- Remote placement of motors/sensors through wire actuation
- Damage prevention of electronics
- Compact size and lightweight
- Manipulator can hold multiple types of tool
- Multifunctionality with auto onsite tool change without full retraction of the manipulator

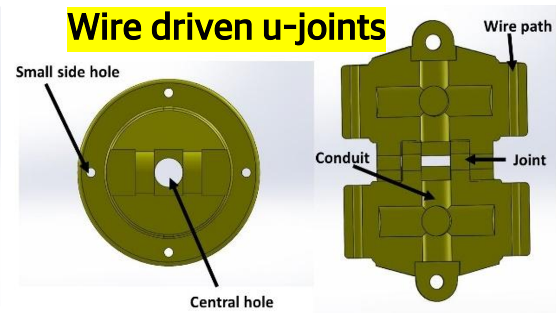
Methodology

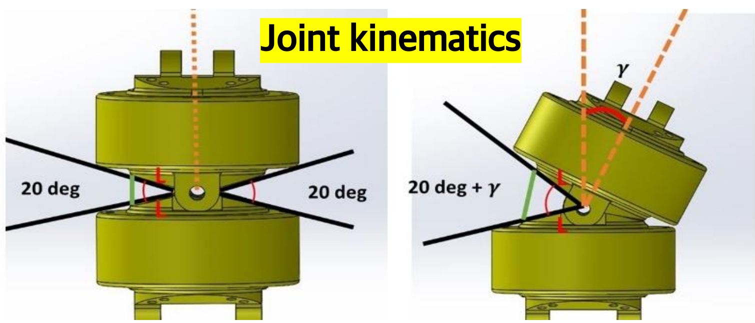
Experimental Setup

Flexible robotic arm





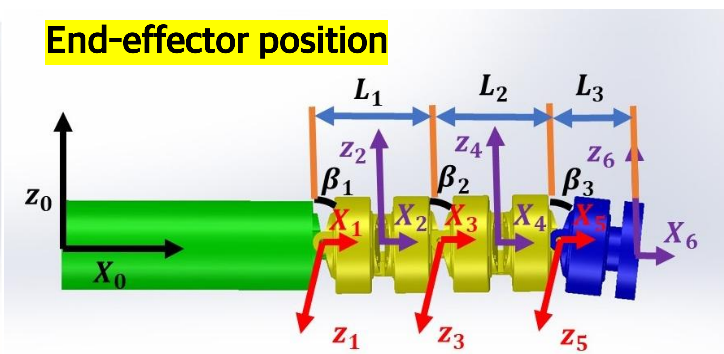




Length of wire when relative rotation is zero, $X = 2L\cos 10$

Length when rotation angle is γ, $X' = 2L\cos\left(10+\frac{\gamma}{2}\right)$

Wire displacement at each joint, $\delta = X' - X = 2L\left\{\cos\left(10+\frac{\gamma}{2}\right) - \cos 10\right\}$



$$X = L_2\cos(\beta_1+\beta_2) + L_1\cos(\beta_1) + L_3\cos(\beta_1+\beta_2+\beta_3)$$

$$Y = L_2\sin(\beta_1+\beta_2) + L_1\sin(\beta_1) + L_3\sin(\beta_1+\beta_2+\beta_3)$$

DH Parameters

i	β	L	α
1	β_1	L_1	0
2	β_2	L_2	0
3	β_3	L_3	0

L_1, L_2 and L_3 represent three consequtive link lenghts
β_1, β_2 and β_3 are the joint rotations

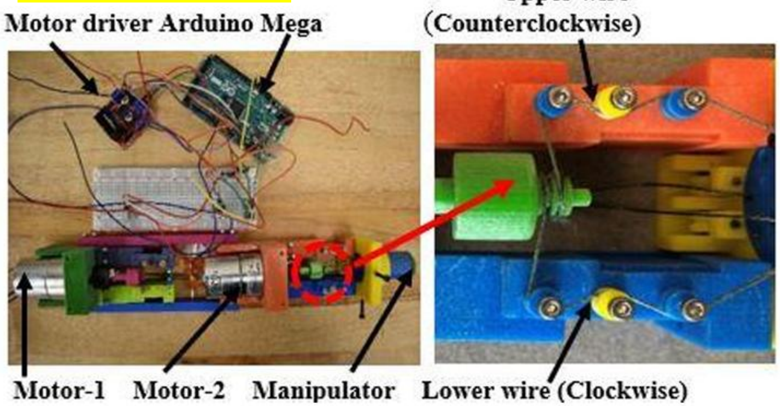
- Flexible robot arm for mounting compact multifunctional manipulator
- Can navigate curved regions
- Can do pitch and yaw motion

Results

Advantages

Solved problems

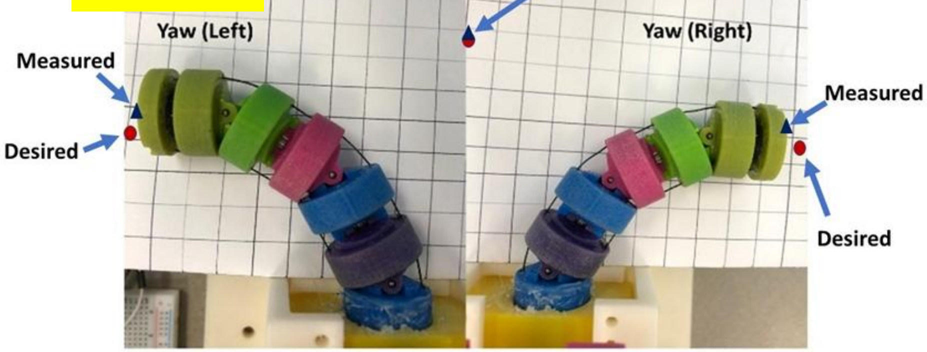
Assembled robot



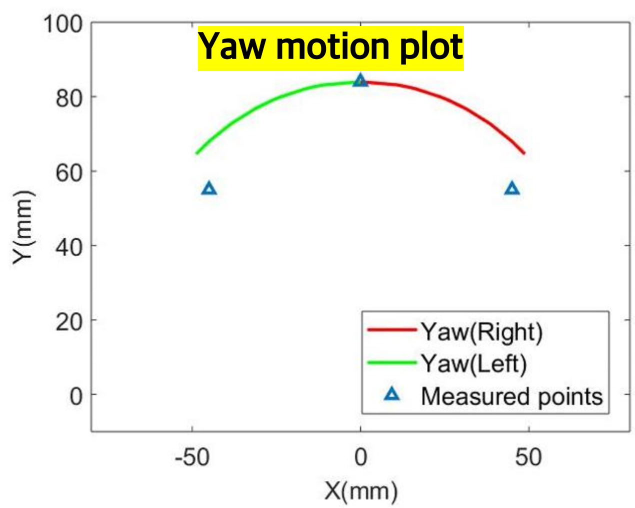
Tool changing

- Reduces tool changing time by 30%

Yaw motion



Yaw motion plot



- Average position error 6.7 mm

➢ Remote motor/sensor placement

➢ Electronics damage prevention

➢ Compact & lightweight

➢ Navigation in complex environments