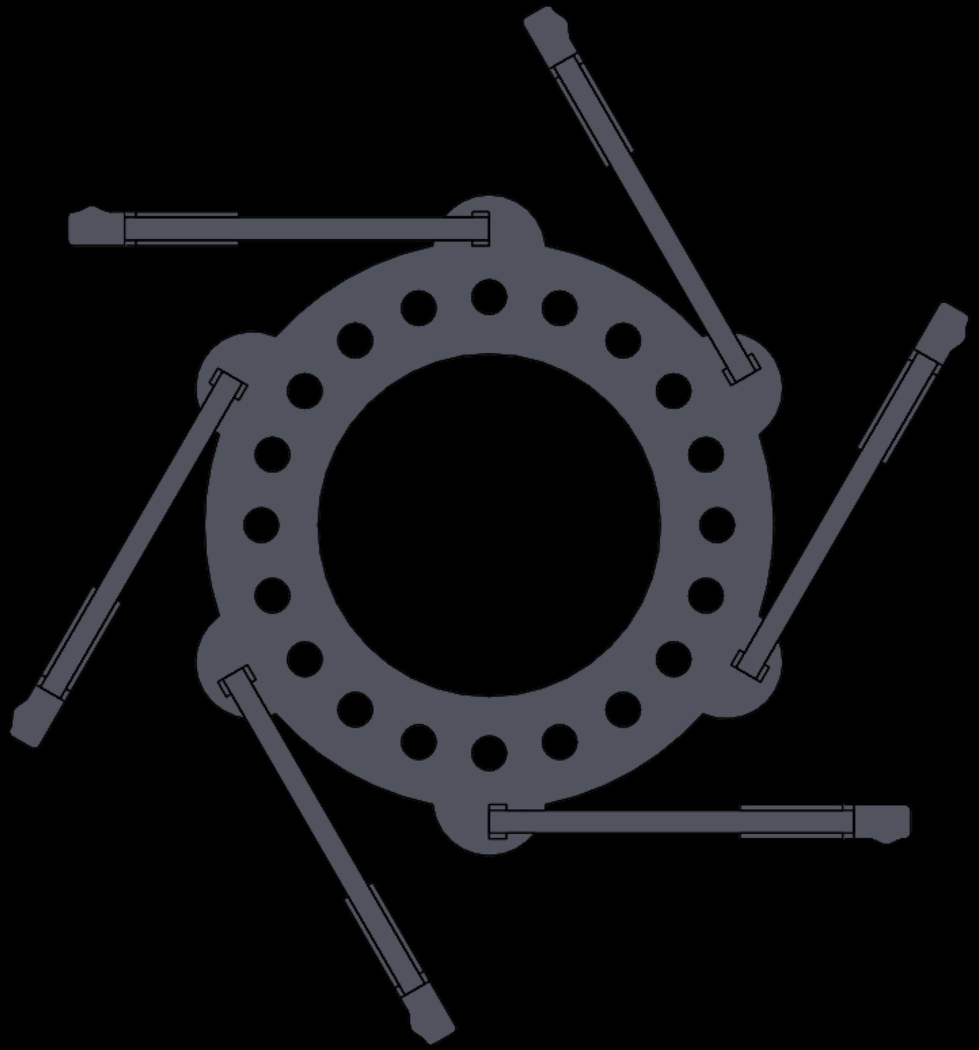
Seoul National University
Mechanical & Aerospace Eng.
BioRobotics Laboratory



소형 등반 플랫폼 제작

2019-14570 백채원

20210701~20210914

담당조교: 이종은, 채수환

연구 주제 선정

현재 드론은 체공시간이 짧다.

DJI의 고급라인인 인스파이어 2의 경우 체공시간이 25분, 부속을 달 경우 더 감소.

또한 전동기의 효율 및 배터리의 효율 또한 종래의 방법으로는 올리는 데에 한계 존재

Drone Perching & Climbing Mechanism 제작

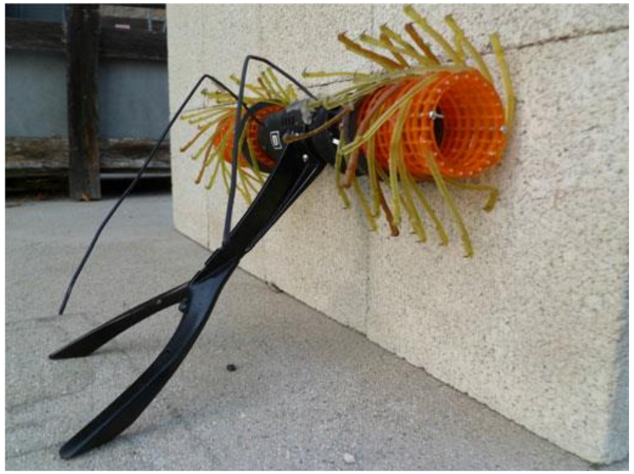
목표

Microspine을 이용하여 벽을 등반하는 다양한 메커니즘이 현재 개발/상용화중임

그 중 본 연구에서는 Rotary Microspine이라는 형태에 주목:

복잡도가 낮고 제어가 쉬워 드론에 접목하기 쉬울것으로 전망

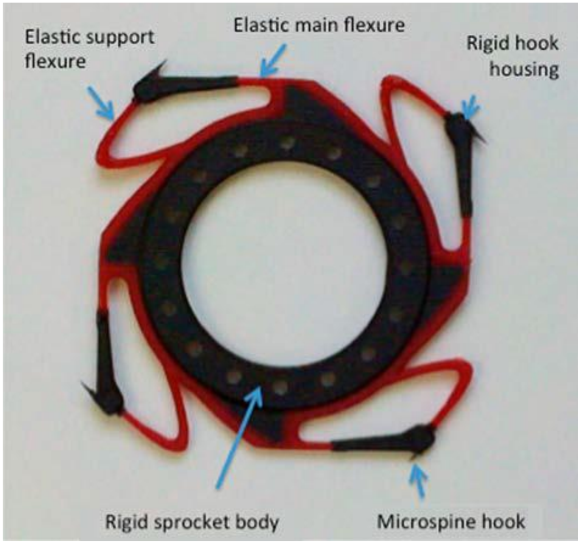
Rotary Microspine 구조를 이용한 소형 등반 플랫폼을 제작, 개량해본다.

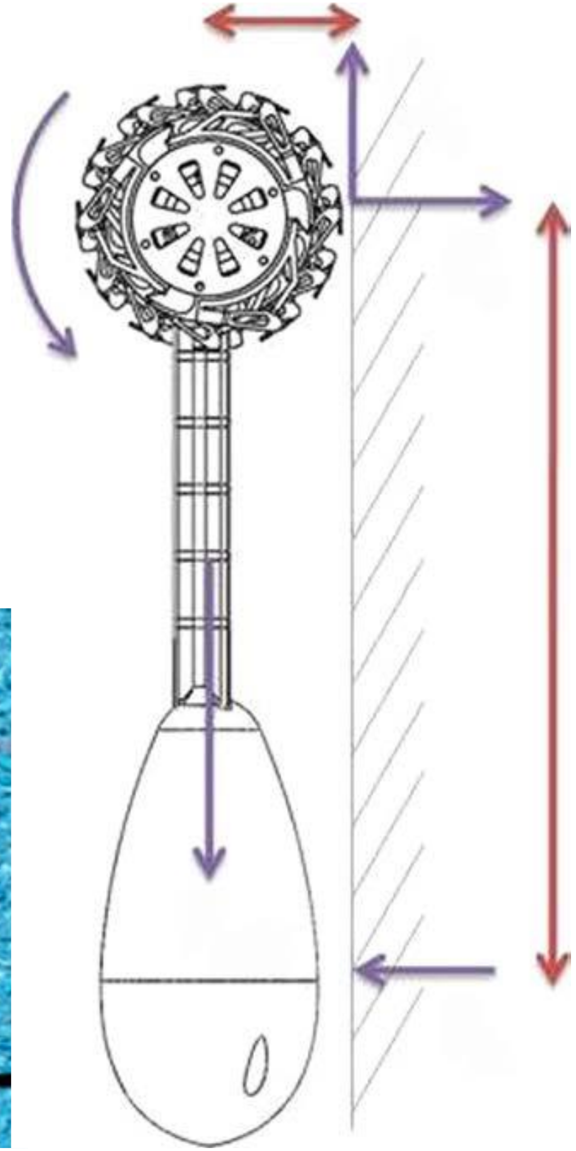


1. Precedent Research

DROP: the Durable Reconnaissance and Observation Platform (Aaron Parness, Clifford McKenzie)

- 1. Microspine 구조의 rotary implementation 개념 제시
- 2. 40개 정도의 microspine 사용
- 3. Attack angle 45~60도
- 4. Divider disk를 사용해 microspine끼리 얽힘을 방지
- 5. 로봇의 몸체 부분을 flexible하게 설계해 낙하 시 충격을 흡수하도록 제작

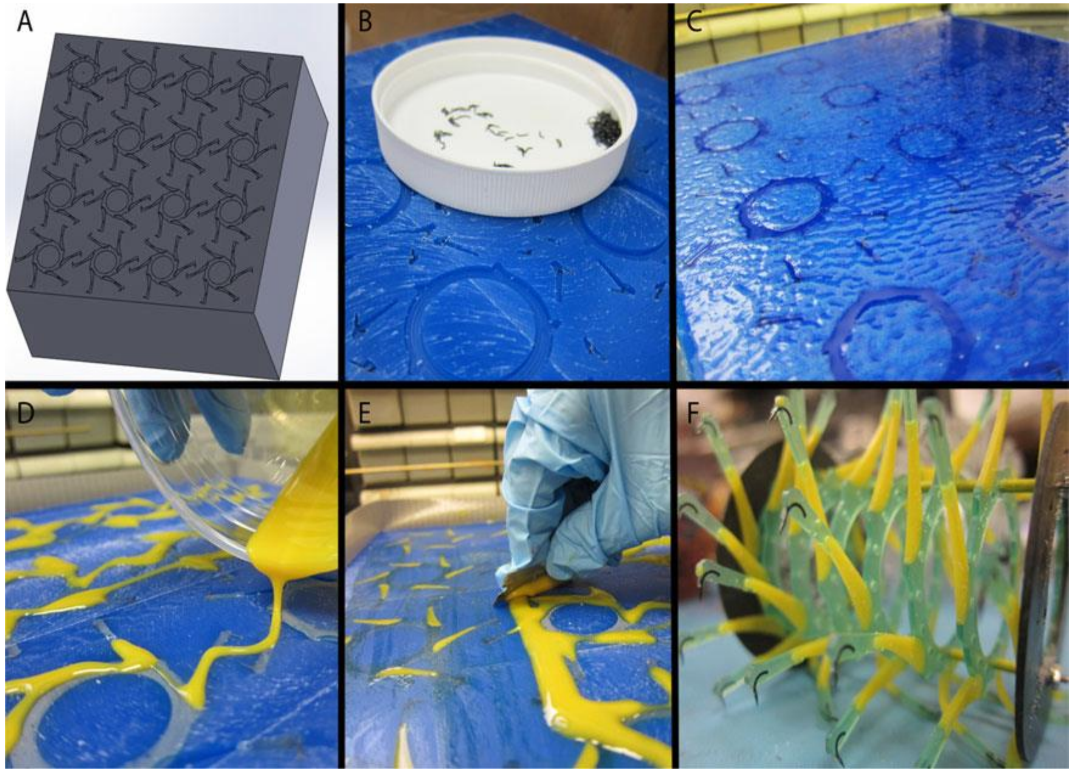




Rotary Microspine Rough Surface Mobility
(Kalind Carpenter, Nick Wiltsie, Aaron Parness)

Rotary microspine 구조의 제작과정 제시

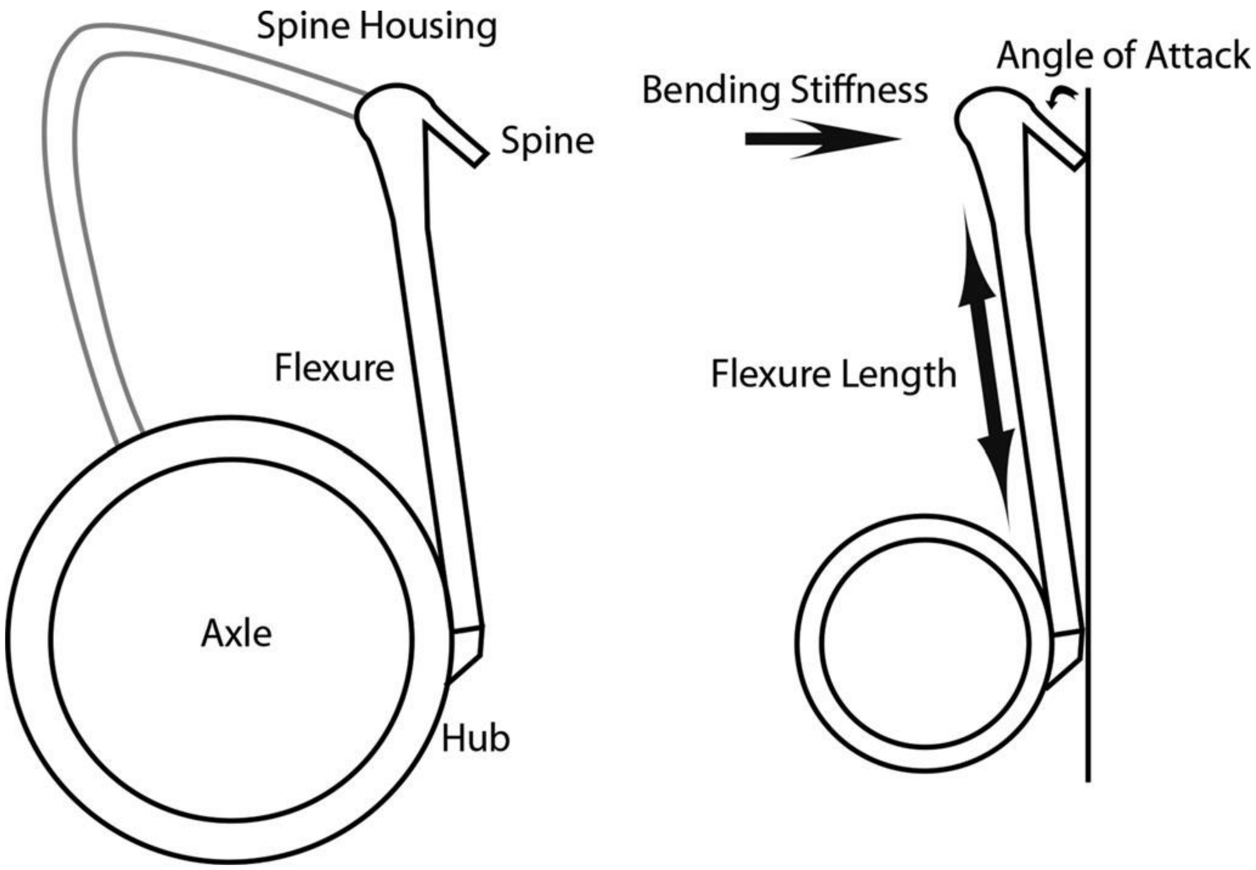
- 1. Mold for axle, spine housing, hooks are cut using CNC
- 2. Hooks placed into position by hand, and rigid urethane is cast in the mold(Spine Housing)
- 3. Mold for flexures are cut(secondary cavity for flexure), wax and rigid urethane is removed as necessary
- 4. Flexures are cast using Flexible Urethanes
- 5. Mounting holes are cut in the axle, and rotary microspines are removed from the wax block
- 6. Assembly using Threaded rod, spacers



Rotary Microspine Rough Surface Mobility (Kalind Carpenter, Nick Wiltsie, Aaron Parness)

Rotary microspine 구조의 소재 제시

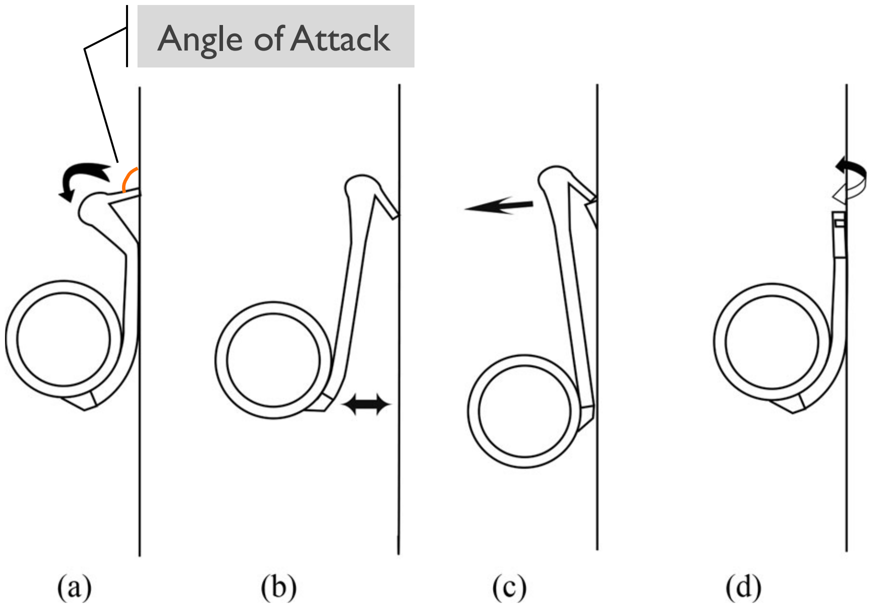
- 1. Material must be elastic, does not ware quickly, strain harden, rip, change properties after a few uses, not too much viscoelasticity
- 2. Urethane rubber materials with Shore A hardness of 80~95A provided appropriate bending stiffness, improved torsional stiffness, did not rip during use, no back flexure needed.
- 3. Spring metal is also a good candidate as the flexure material

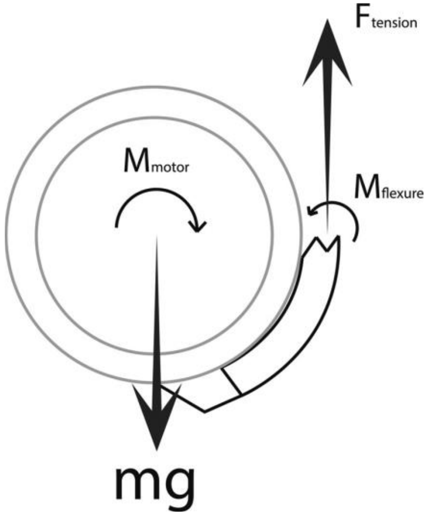


Rotary Microspine Rough Surface Mobility (Kalind Carpenter, Nick Wiltsie, Aaron Parness)

Rotary Microspine 구조의 이론적/실험적 분석

- 1. Best angle of attack: 70도
- 2. using longer flexure with stiffer materials increase climbing performance(by reducing transitions between one spine and the next), but spine density is lessoned and chance for entanglement is increased
- 3. Bending Stiffness: Empirically, climbing platform with best performance had 20 flexures on each wheel on 200g platform(5g of restoring force per flexure when fully wrapped)

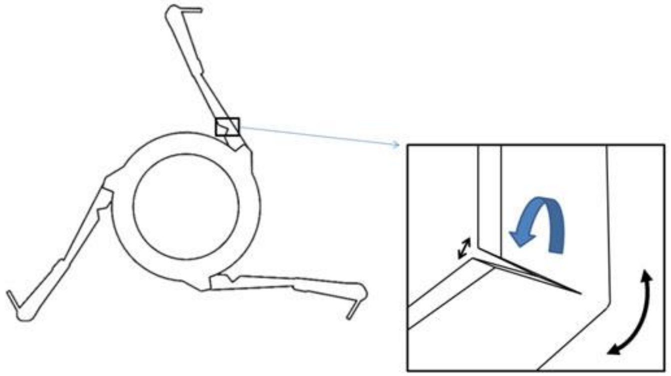


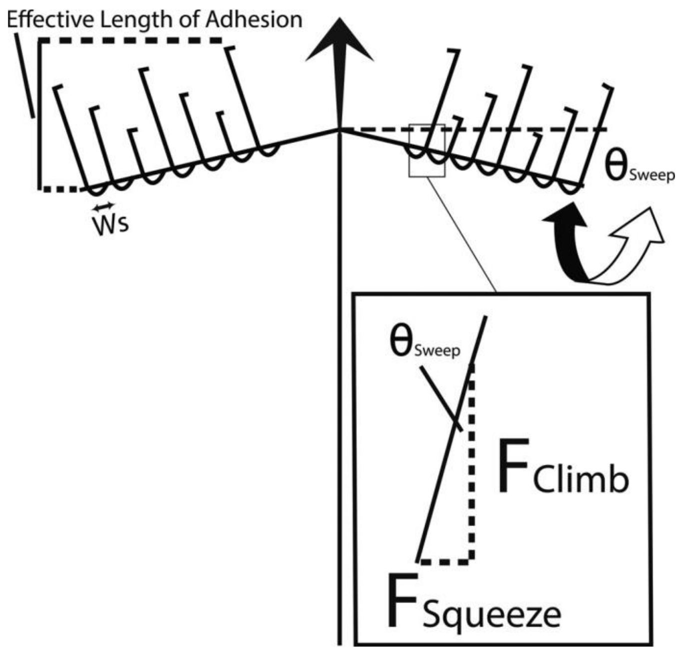


Rotary Microspine Rough Surface Mobility (Kalind Carpenter, Nick Wiltsie, Aaron Parness)

Rotary Microspine 구조의 이론적/실험적 분석

- 4. Torsional Stiffness: flexure must be resistant to twisting out of the plane
- 5. Increasing Spine density improves the likelihood that a spine will be in position to engage, but has tradeoffs that flexures must be shorter, weight is added, and entanglement is possible. Empirically, more spines improved performance on smoother surfaces, and shortening of flexure length limits performance on rougher walls.
- 6. Sweep angle: -10 degree is best for vertical movement, but for transition from horizontal to vertical surfaces, -5 degree is best(here, - notates that the robot is arrow shaped: + is chevron shaped)





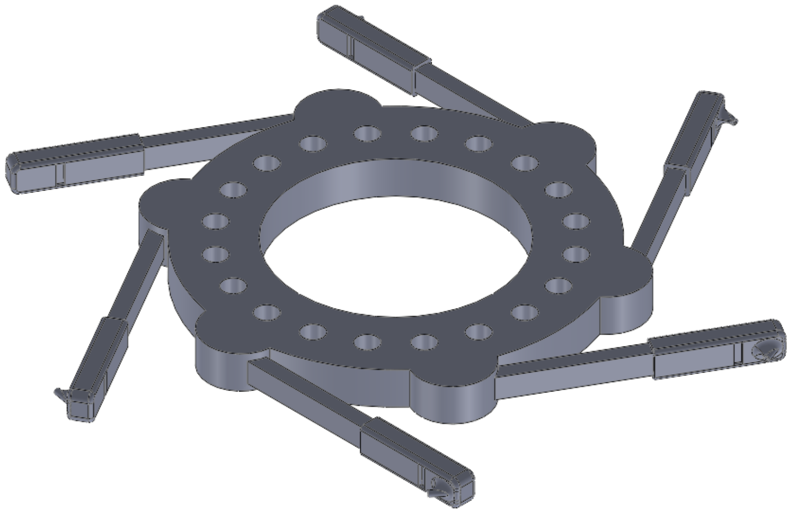
2. Mechanism Modeling

Microspine Wheel 제작(7/6~9/9)

목표: Rotary Microspine Unit의 양산

3D 프린팅을 사용하여 Mold 및 Hub 설계, 수지침을 절단하여 Spine으로 사용

Flexure 소재 PMC780 폴리우레탄 사용(Shore A Hardness 80)



Rotary Microspine Unit

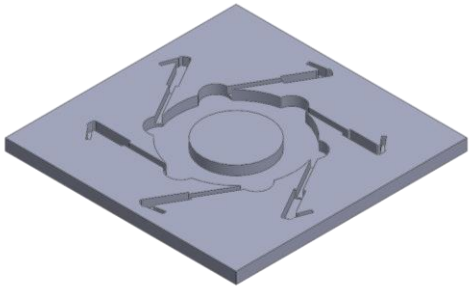
Microspine Wheel 제작(7/6~9/9)

제작 과정

Spine Housing에 수지침 결합

Mold에 이형제 도포 후 Hub, Spine Housing을 조립

PMC780 폴리우레탄을 금형에 부은 후 75도 오븐에서 1일정도 굳혀 분리



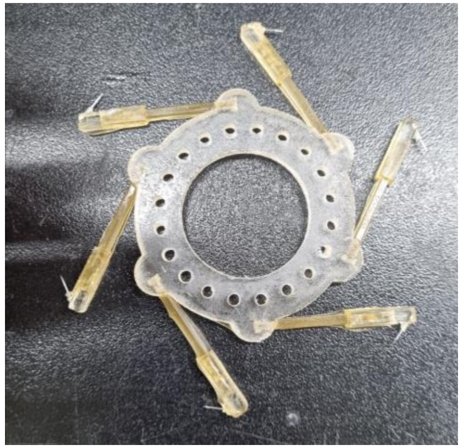
Mold

Hub

Spine Housing

Pour PMC780 into cavity

Curing time ≈24hr

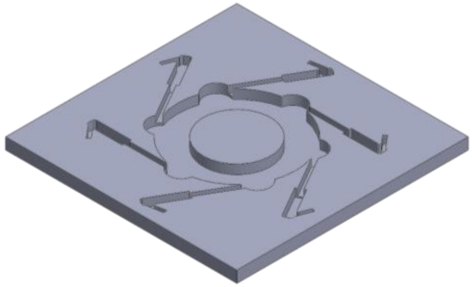


Rotary Microspine Unit

Microspine Wheel 제작(7/6~9/9)

Mold의 변천과정

Injection이 가능하도록 Mold 재설계



Mold

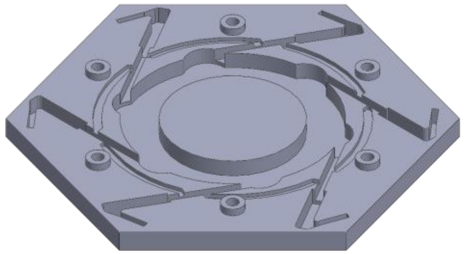


그림2: Modified Cast

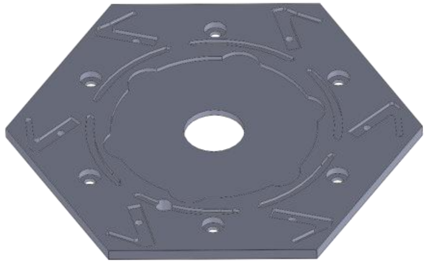


그림3: Cast Cover

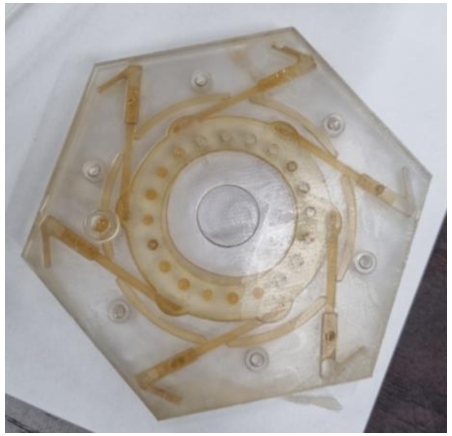


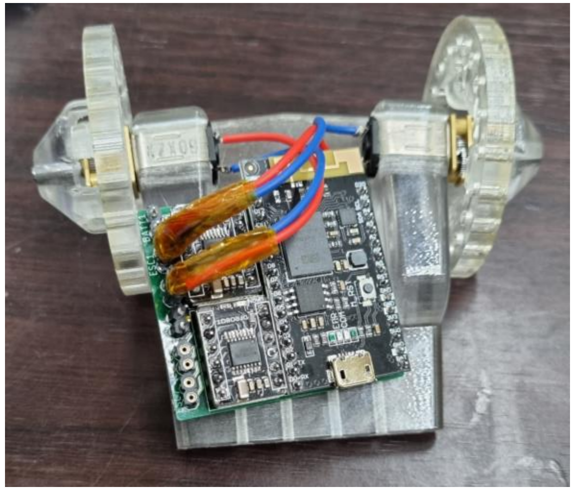
그림4: Disk-Cast Assembly

제어 프로그래밍(7/20~7/29)

기어비 200:1 정도인 모터를 사용

DFRobot CurieNano 보드 및 Arduino, Blynk App을 통해 폰으로 로봇 제어

아래는 Bluetooth로 Arduino 101 보드와 통신하여 모터를 구동하는 Test code의 일부이다.



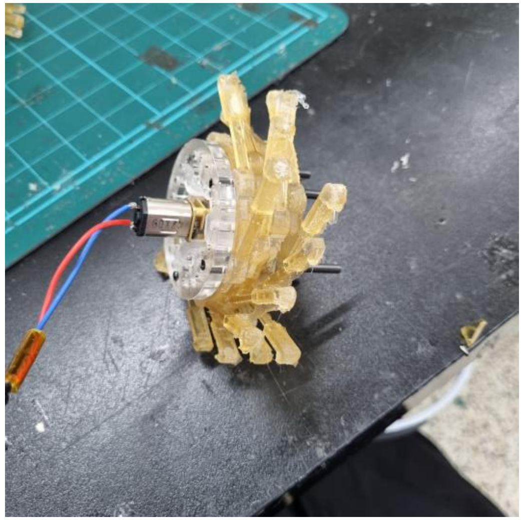
Robot Assembly

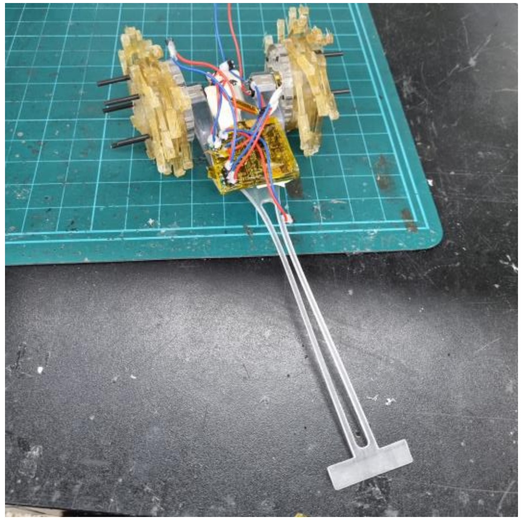
```
void setup() {
  Serial.begin(9600);
  delay(1000);
  blePeripheral.setLocalName("C-4Chan");
  blePeripheral.setDeviceName("C-4Chan");
  blePeripheral.setAppearance(384);
  Blynk.begin(blePeripheral, auth);
  blePeripheral.begin();
  pinMode(6, OUTPUT);
  pinMode(7, OUTPUT);
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);
  analogWrite(6, PWMValue);
  analogWrite(7, PWMValue);
  analogWrite(8, PWMValue);
  analogWrite(9, PWMValue);
  digitalWrite(13, HIGH);//chip check
  delay(500);
  digitalWrite(13, LOW);
  Serial.println("Waiting for connections...");
}

void loop() {

  blePeripheral.poll();
  Blynk.run();
}
```

```
BLYNK_WRITE(V0) {
  Serial.println("Mode setting:\n");
  switch (param.asInt()){
    case 1: //Left Motor Check
      Blynk.virtualWrite(V1, "Left Motor\n");
      MB1_Forward(0);
      MA1_Forward(200);
      delay(1);
    break;

    case 2: //Right Motor Check
      Blynk.virtualWrite(V1, "Right Motor\n");
      MA1_Forward(0);
      MB1_Forward(200);
      delay(1);
    break;

    case 3: //Full Stop
      Blynk.virtualWrite(V1, "Full Stop\n");
      MA1_Forward(0);
      MB1_Forward(0);
      delay(1);
    break;
  }
}
```

```
void MA1_Forward(int Speed1)  //fast decay;
Speed = High duty-cycle
{
    analogWrite(6,Speed1);
    digitalWrite(8,LOW);
    //delay(100); //
  }

void MA2_Backward(int Speed1)  //slow decay;
Speed = Low duty-cycle
{
   int Speed2=255-Speed1;
   analogWrite(6,Speed2);
   digitalWrite(8,HIGH);
  }

void MB1_Forward(int Speed1)
{
    analogWrite(8,Speed1);
    digitalWrite(6,LOW);
    //delay(100); //
  }

void MB2_Backward(int Speed1)
{
   int Speed2=255-Speed1;
   analogWrite(8,Speed2);
   digitalWrite(6,HIGH);
  }
}
```

Microspine 로봇 어셈블리(8/31~9/7)



DFRobot CurieNano Board

1:298 Pololu Motor

Rotary Microspine Unit 4개

Wheel-Motor Hub

Carbon Rod

꼬리 조립

흡착로봇 설계(8/10~8/30)

미스미 흡착패드 사용

흡착패드가 지면에 부착되고 분리될 때의 각도변화를 수용할 수 있도록 Compliant하게 설계

그림1: Suction Pad Unit

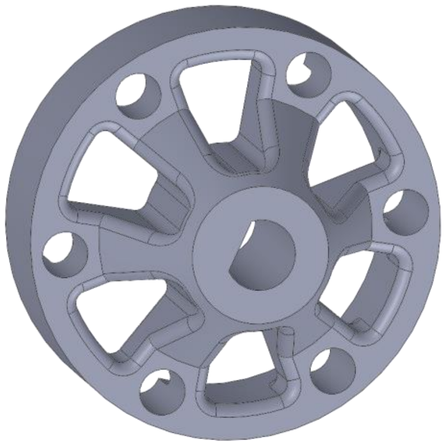


그림2:Wheel-Motor Hub

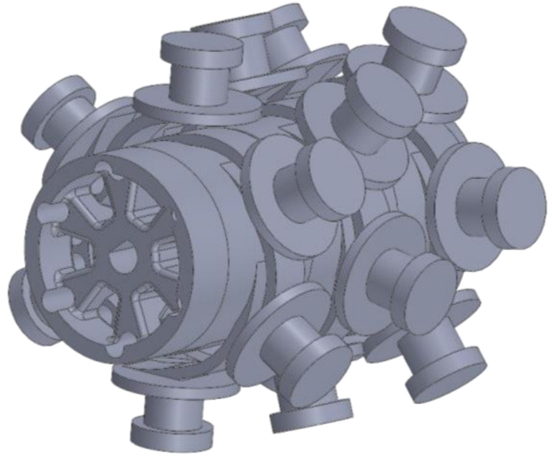
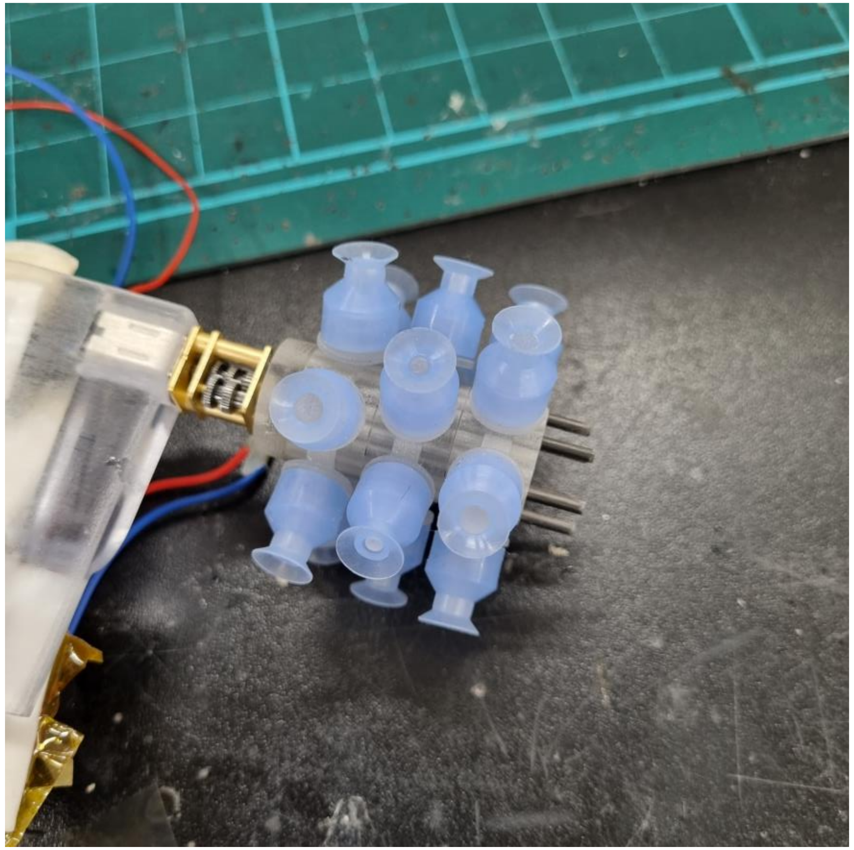
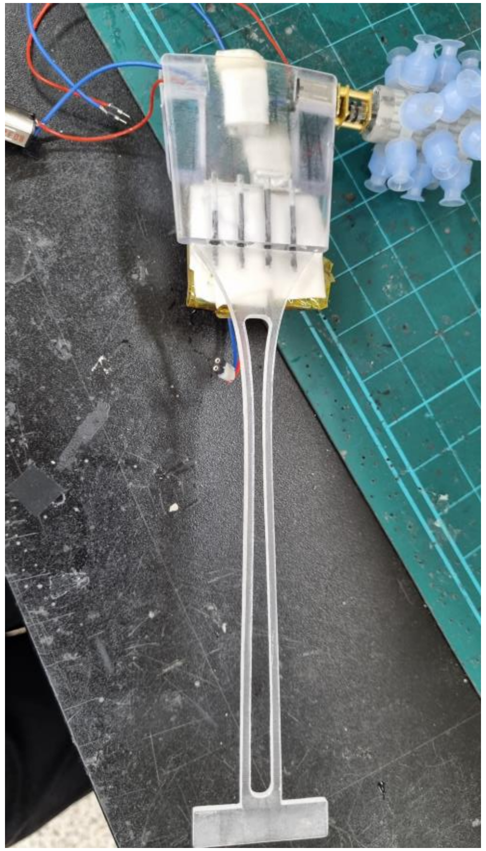
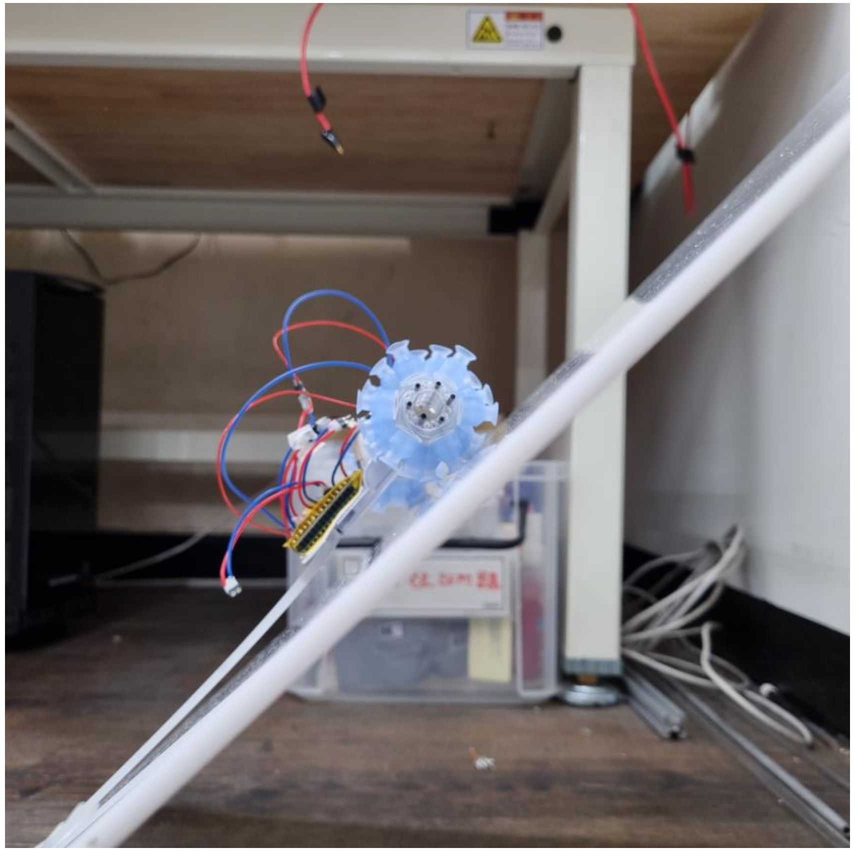


그림3:Wheel(Hub-Unit Assembly)

흡착로봇 어셈블리(8/31~9/13)



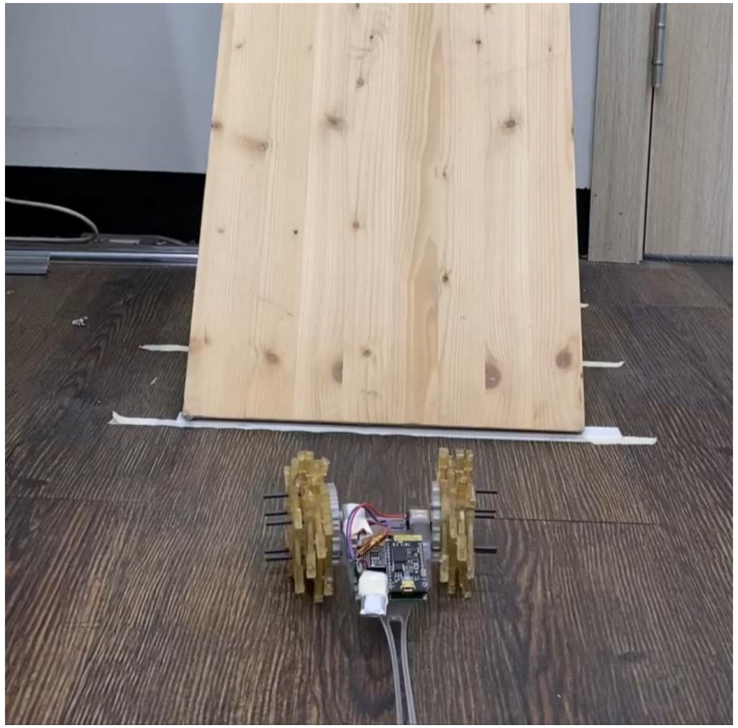




3. Discussion

Microspine 로봇 실제 구동 영상

영상1: 45° 경사



영상2: 60° 경사

흡착로봇 실제 구동 영상

영상1: 45° 경사

영상2: 60° 경사

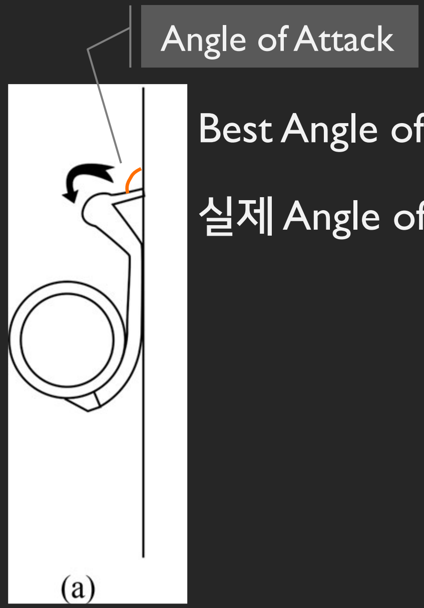
실패 원인 분석: Microspine 로봇

Torsional Stiffness 부족:

Flexure이 지면에 고정되지 않고 돌아가버림

Flexure의 구조적 문제:

Flexure이 원주방향으로만 구부러지지 않고 바퀴의 축방향으로도 구부러짐



Best Angle of Attack: 70°

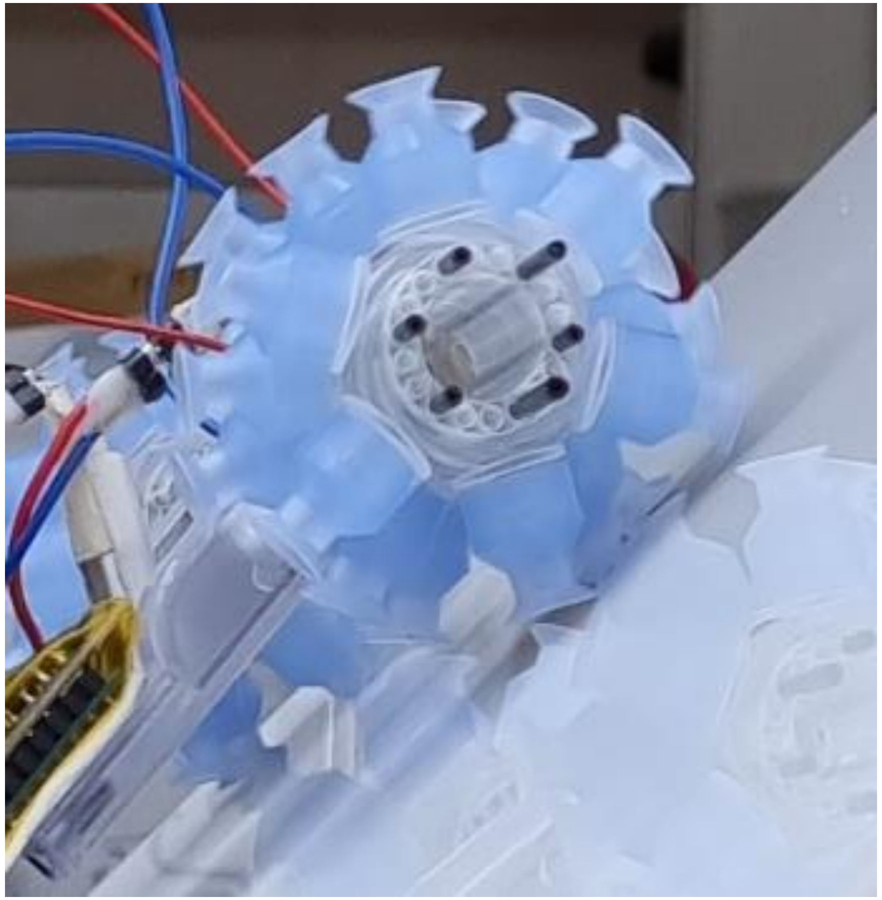
실제 Angle of Attack: 45°~50°

Spine의 길이 조절문제:

Spine Housing이 지면과 접촉하는 모습이 예상과 달라 Angle of Attack에 차이가 생김, Spine 길이조절 필요

실패 원인 분석: 흡착로봇

1. 패드 자체의 흡착력이 너무 약함
2. 패드가 제대로 흡착되지 않고 접히는 현상이 생김
3. 패드가 지면과 평행한 상태에서 부착되지 않음



추후 설계 방향

-Microspine 로봇

1. Flexure에 다양한 물질을 사용하여 실험

2. CNC 사용 제작

3. Spine의 길이 조정

-흡착 로봇

1. 흡착패드 재구매

2. 흡착패드가 지면과 평행한 상태에서 부착될 수 있도록 메커니즘 설계

-두 로봇 모두

경량화 설계

참고문헌

[1] Aaron Parness and Clifford McKenzie. “DROP: the Durable Reconnaissance and Observation Platform”, Industrial Robot Vol.40, N0.3, pp. 218-223.

[2] Kalind Carpenter, Nick Wiltsie and Aaron Parness. “Rotary Microspine Rough Surface Mobility”, Transactions on Mechatronics Vol.21, No.5.

[3] Ge D, Tang Y, Ma S, Matsuno T, Ren C. “A Pressing Attachment Approach for a Wall-Climbing Robot Utilizing Passive Suction Cups”, Robotics Vol. 9, Issue 2, 2020.