Electroactive Polymers In Robotics

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Introduction

The aim of this project is to examine the use of Nitinol (Nickel titanium) in robotics and implement a design using an electro-active polymer as an actuator. The prototype will be made up of an input device, a microcontroller and a nitinol controlled hand. A device such as this has potential uses within industry handling hazardous materials or in prosthetics, for use by people with limited use of their hands, such as sufferers from arthritis.

Nitinol

Nitinol, an alloy of Nickel and Titanium was developed by William J. Buehler at the U.S. Naval Ordnance Laboratory (nol) in Maryland. Its name is derived from its chemical makeup and the lab in which it was made. After its discovery in 1959 it took until the late 80's until it began to be implemented into more common uses. Nitinol is know for its shape memory properties which make it incredibly versatile in its applications. This property comes from its crystalline structure which reforms when the material reaches a specific temperature even when it had been deformed.

The applications of Nitinol and shape memory alloys range from medical to industrial. It is commonly used in medical stents as the shape can be set outside the patient and then deformed while it is being put in position.

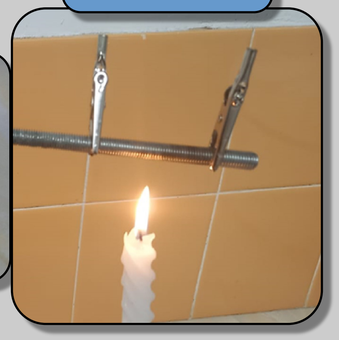
In industry Nitinol has seen use as combination sensor and actuators in fluid systems. If the temperature within a system changes beyond a predetermined value then the Nitinol will react.

Input

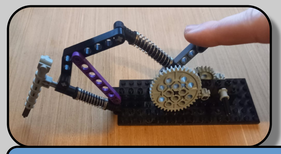
The input mechanism consists of a mechanical component that controls a variable resistor. The resistor provides an analogue input into the Arduino, which can read 1024 step values between 0 and 5 volts. This allows a precise value to be picked. A threshold has been set at 200 which allows a small amount of leeway in the input mechanism. However if this were to be used by someone with limited use of their hands a lower value could be set allowing very small movements to trigger the activation of the nitinol.

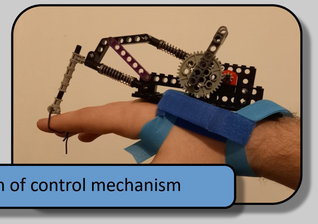
```
int gloveInput = A1; // set pins
int handOutput = 9;
int gloveValue = 0; // varible to store input
int handValue = 0; //varible to store output
int test = 13; //test digital output

void setup() {

 pinMode(gloveInput, INPUT); //pin A1
 pinMode(handOutput, OUTPUT); // pin 9
 pinMode(test, OUTPUT); //pin 13
 Serial.begin(9600);
 while (!Serial)
 {
   ;
 }
}

void loop()
{

 gloveValue = analogRead(gloveInput);

 Serial.print("gloveValue = ");
 Serial.print(gloveValue);
 Serial.print(" -- ");

 if (gloveValue < 200) // determin value from tests - set
 {
   handValue = 0;
   //test = LOW;
   digitalWrite(LED_BUILTIN, LOW);
   digitalWrite(test, LOW);
 }
 else
 {
   handValue = gloveValue; // use to adjust value to appropirate output value
   //test = HIGH;
   digitalWrite(LED_BUILTIN, HIGH);
   digitalWrite(test, HIGH);
 }


 Serial.print("handValue = ");
 Serial.print(handValue);
 Serial.print(" -- ");
 Serial.print("test = ");
 Serial.print(test);
 Serial.print("\n");
 analogWrite(handOutput, handValue);
```

Screenshot of the code in the Arduino software.



Setting nitinol to shape





Prototype and final implementation of control mechanism

Testing

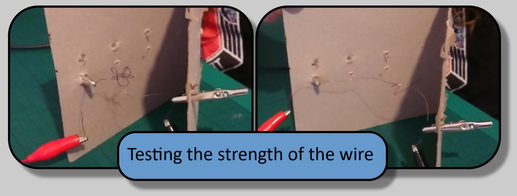
Testing of the nitinol showed that it responded to from around 3.5 volts. The response time improved rapidly as the voltage was increased but plateaued around 6.5 volts. After this the current continues to increase with small improvements on response times. As the voltage/current increased the temperature of the wire increased rapidly. As the tests were conducted at home I didn't have the equipment to record the temperature during the testing but did witness smoke coming from the wire as the coating started to burn off when it was above 10 volts.

Response Time of Nitinol Wire		
Voltage (V)	Current (A)	Average Time (S)
3.0	1.70	x
3.5	1.88	22.85
4.0	2.03	11.78
4.5	2.04	5.63
5.0	2.14	3.75
5.5	2.25	3.52
6.0	2.43	2.34
6.5	2.51	1.92
7.0	2.71	1.25
7.5	2.74	1.18
8.0	2.80	1.24
8.5	2.94	1.14
9.0	3.07	0.88
9.5	3.12	0.74
10.0	3.19	0.70

Hand

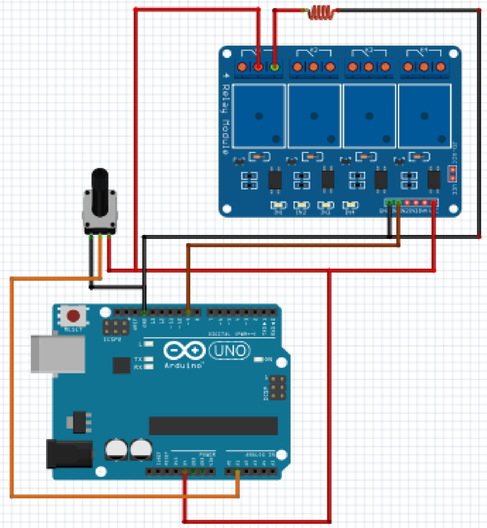
For the hand to actuate as required the pre set shape of the wire needs to be changed. To do this the Nitinol needs to be heated to above 400°C for several minutes and then rapidly cooled. Due to not having access to University equipment this was done at home. Wrapping the nitinol around a threaded bar and placing it over a candle for 5 minutes then submerging it in cold water achieved the desired results.

Timing test setup



Testing the strength of the wire

Final Circuit



Conclusion

Nitinol works well as an actuator and has many applications in robotics. However the heat generated when it is in use is an issue. With sufficient cooling processes and short activations or if it was in use in cold environments it would work well.