

# Multilink IPMC manipulator

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**Abstract**—Multilink IPMC (Ionic Polymer Metal Composite) manipulator is a manipulator arm consisting of rigid links and revolute joints with axes coincident with links. The revolute joints are made of pieces of IPMC material. The aim of this paper is to investigate the potential of the IPMC material for the design of the described linked manipulator as well as its controllability.

**Index Terms**—electroactive polymer actuators, robot manipulator control

## I. INTRODUCTION

Polymers that change their shape or size when electrically stimulated are known as Electroactive Polymers (EAPs). They can be used as actuators or sensors. Ionomeric polymer-metal composites (IPMC) are the EAPs which bend when electric current is applied due to mechanisms of ion migration and liquid swelling [1,2]. Large controlled displacements and good damage tolerance are achievable, similar to those of biological muscles, therefore such materials are also known as artificial muscles and they have possible applications in the field of robotics. [3] The typical behavior of IPMC in electric field is shown in Figure 1.

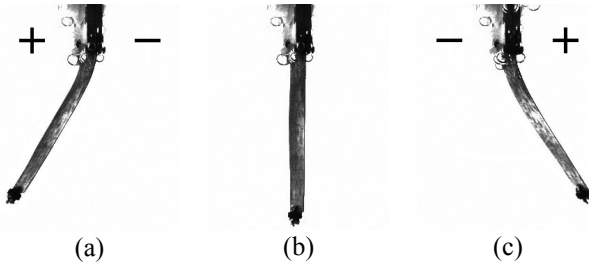


Figure 1 IPMC with (a and c) and without (b) electrical stimulation.

We research the multilink IPMC actuators. Several pieces of IPMC are used as revolute joints with axes coincident with rigid links. These experimental situations are far from linearity of electromechanical characteristics and thus each of the IPMC pieces are separately calibrated before experiments. The objective of the current paper is to investigate the precision of the described actuator by first creating a calibration-measurement set and then trying to reach random points with the manipulator.

## II. MANIPULATOR DESIGN AND EXPERIMENTAL SETUP

We used IPMC strips cut from a 0.2mm-0.5mm thick Musclesheet™ provided by BioMimetics Inc. The experimental setup is shown in Figure 2 and 3. The manipulator was in a horizontal position in a container filled with de-ionized water. The controlling voltage pulses were generated by NI PCI-6703 DAQ board, amplified with NS LM675 power op-amp and applied to the IPMC joints by contacts U1, U2 and ground. Along the manipulator three surface-mount LEDs D1, D2, D3 were attached for facilitating visual detection of the link position with an off-board camera.

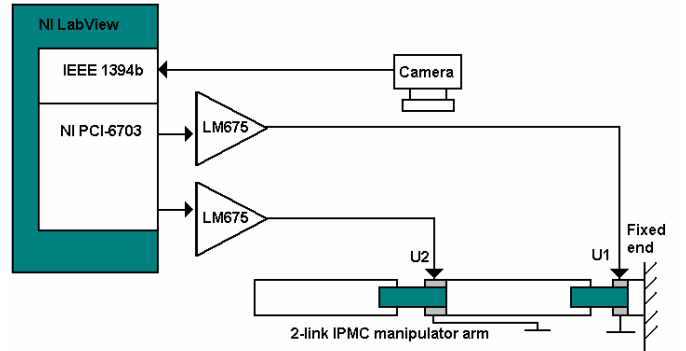


Figure 2 Experimental setup.

The links of the manipulator were made of plastic with the density close to the density of water. The wires between the manipulator and the amplifiers were chosen as lightweight as possible in order to reduce their mechanical disturbance. The wires connecting LEDs were thin (0.05 mm) to prevent them from disturbing the manipulator movements. The photo of the manipulator arm is shown in Figure 4. Manipulator as seen by the camera is depicted in Figure 5.

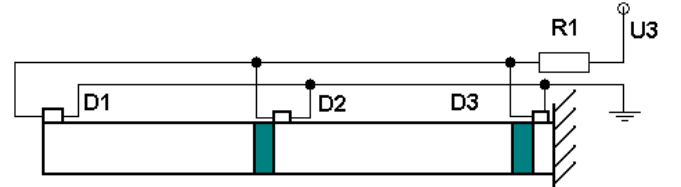


Figure 3 2-link arm of the manipulator.

The experiments were conducted in the following order: first - the joint muscles were calibrated; then series of attempts to reach random positions of the tip of the manipulator arm were performed

The calibration of the Manipulator joint was conducted in the following order:

1. An image was acquired

2. LED positions were identified
3. Initial joint angles were calculated
4. Voltage was applied to one of the muscles
5. After 0.5 seconds zero voltage was applied and an image was acquired
6. LED positions were identified
7. Angle differences were calculated
8. The same was applied to the second muscle

The calibration was performed with driving voltages between -4V and 4V for both joints. Before each measurement series a calibration file was created. The signal applied to the muscles was a rectangular pulse of variable amplitude with duration of 0.5 seconds.

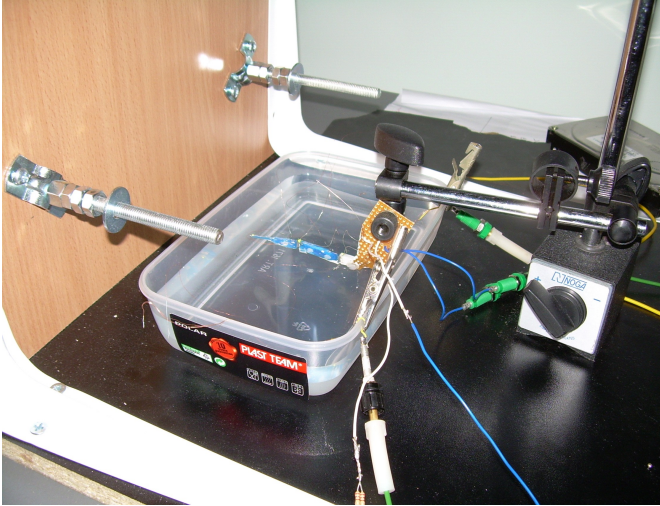


Figure 4 Manipulator arm in a water tank.

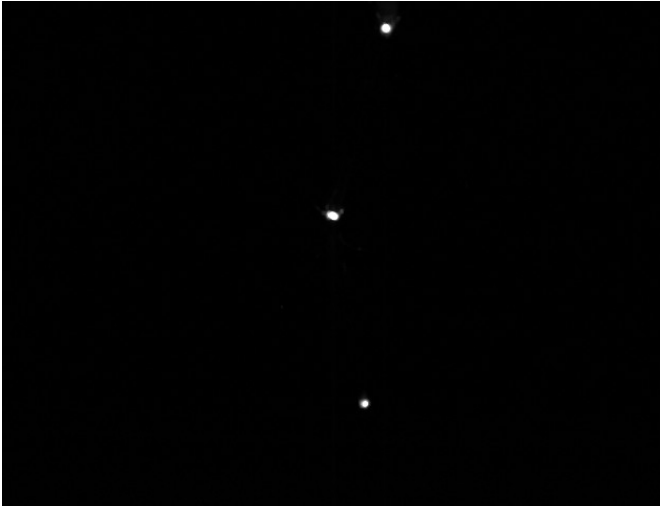


Figure 5 The 3 LED-s of the manipulator as seen with the camera

Measurement program followed next steps:

1. Acquire an image
2. Identify LED positions
3. Calculate initial angles
4. Generate random points until one falls into the working area of the manipulator
5. Using inverse kinematics to calculate necessary joint angles
6. From calibration file find the according voltages

7. Apply voltages for 0.5s and acquire an image
8. Process results
9. Write results to results file

In order to describe the motion of the IPMC manipulator we developed a computer vision system. It consists of a fast CCD camera and PC with an image processing software. The National Instruments Vision was used for both – frame grabbing and image acquisition. The position images of the manipulator were created with a camera. The high-speed firewire camera *Dragonfly Express* from *Point Grey Research Inc.* was used. The direction of camera was set transverse to the actuator and the LEDs were used to get manipulator position. In perfect conditions the image of the manipulator consists of three contrast white objects. It is easy to use image processing software to process the contrast points on the manipulator in each particular frame. The initial tip coordinates were written into the measurement file together with the desired and achieved coordinates. Through these figures the precision of the manipulator could be evaluated.

### III. CONCLUSION

After processing the experimental results we can declare that the precision of the manipulator does not depend on the distance of the reachable point. It rather depends on the number of previous movements after last calibration. The precision decreases remarkably after 150<sup>th</sup> reached points. An example of calibration results is shown in figure 6 as voltage-angle chart. Figure 7 represents the distribution of the errors. On the horizontal axis there is error percent and on the vertical axis the percent of measurement results remaining below according percent on the horizontal axis.

As a conclusion of the experiments it can be said that IPMC material is quite well controllable when using described algorithm and can be after some more research work used successfully as manipulator revolute joint with axes coincident with links. By improving some steps of the setup it is possible to get the manipulator working much more

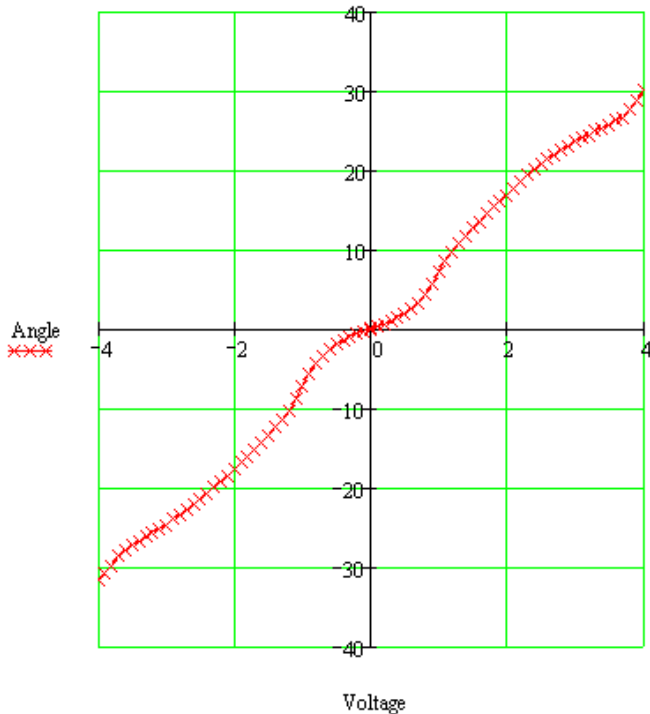


Figure 6 The typical results of the calibration of the manipulator.

precisely. Due to the relative unstability of IPMC the actuators need recalibration after some hundred moves.

Our future is to investigate IPMC materials with different coating from Pt, such as Cu or Au.

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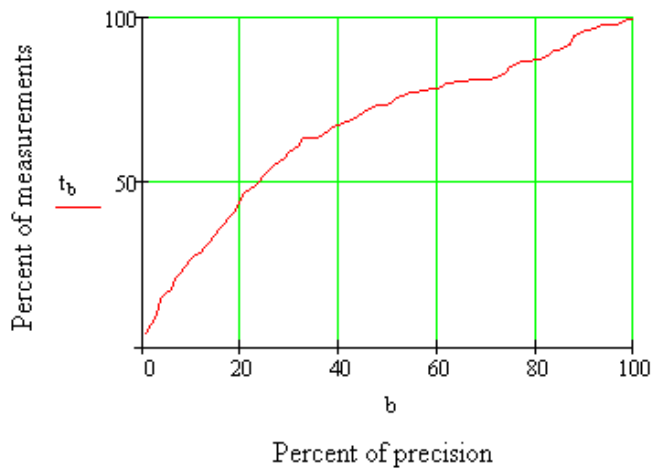


Figure 7 Distribution of the errors.

Also we plan to change the manipulator setup, calibration algorithm and experimenting program to reduce mechanical disturbance and achieve the best results with IPMC material.

#### ACKNOWLEDGMENT

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