Artificial Motion Guidance: an Intuitive Device based on Pneumatic Gel Muscle (PGM)

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ABSTRACT

We present a wearable soft exoskeleton sleeve based on PGM. The sleeve consists of 4 PGMs controlled by a computing system and can actuate 4 different movements (wrist extension, flexion, pronation and supination). Depending on how strong the actuation is, the user feels a slight force (haptic feedback) or the hand moves (if the users relaxes the muscles). The paper gives details about the system implementation, the interaction space and some ideas about application scenarios.

Author Keywords

Haptics and Haptic Interfaces,Wearable Devices, Pneumatic Artificial Muscles (PAMs)

INTRODUCTION

There is an increased interest in the HCI research community towards haptic/muscle interactions and interfaces, as they can provide "eyes-free" means of receiving information. There are several related works with regards to tactile feedback techniques. Kon *et al*. showed walking navigation that does not require explicit interpretation by mean of Hanger Reflex [4]. Chen *et al*. showed motion guidance by means of external artificial muscle that mainly consists of stepper motors and elastic band [1]. Electrical Muscle Stimulation (EMS) has been also applied to create simple display that provide information by feeling the pose of user's muscle. Lopes *et al*. developed an interactive system based on EMS that allows object to communicate their use by means of actuating user's muscle (*e.g*., a spray can, by itself, show the user that shaking is mandatory before spraying) [5]. However, EMS is often difficult to handle as it requires to find the right muscles, one has to overcome the impedance of the skin and for some body locations it's not save to apply an electrical current. In contrast we are using Pneumatic Gel Muscle (PGM). These are pneumatic "tubes" that can be activated by fairly low air pressure compared to the conventional Pneumatic Artificial Muscle (PAM) [6]. PAM are often used in rehabilitation and assistive applications and PGM is also already proposed for these purposes. Yet, we focus on potential interaction caused by actuating human muscle by means of PGM.

Figure 1: The Artificial Muscle sleeve is a soft exoskeleton that enables the user to obtain information or skill through their body. In assisting navigation scenarios, users can feel a slight drag towards the direction he/she is suppose to take.

We actuate arm movement and provide tactile feedback using our PGM sleeve system. We also introduce several use cases for enhancing human motion in sport and assisting navigation.

In this work, we introduce an Artificial Muscle sleeve, a device consisting of four PGM. We designed the Artificial Muscle sleeve fitting a wearable form factor. The Artificial Muscle sleeve can actuate the human hand easily (4 movements) and there is no risk of injury as PGM is very flexible (also compared to rigid exoskeletons).

INTERACTIVE SYSTEMS BASED ON PGM

PAM is a conventional type of actuator that operates by compressed air, for example the systems used by McKibben ac-

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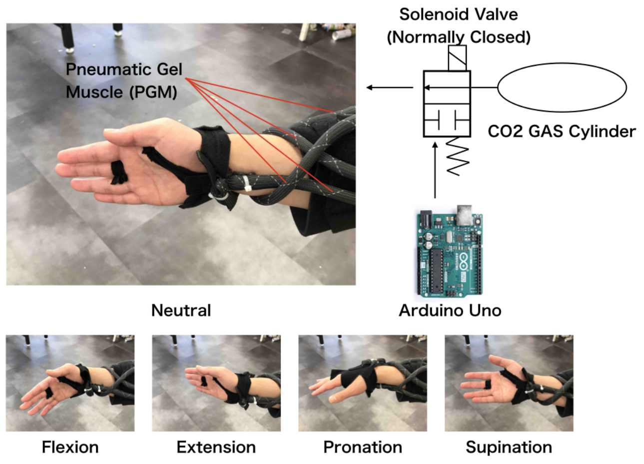

Figure 2: The device based on PGM attached around user's forehand and it can actuate human arm for extension, flexion, pronation, supination. If the solenoid valve for each artificial muscle open, the device show the specific movement for the user.

tuator require high pressure to actuate while also requiring a power source, *i.e.*, an air compressors which are costly and not practical for users to wear [2]. PGM overcomes this limitation as it can be actuated at a lower pressure of approximately 20KPa compared to conventional artificial muscle. Compared to rigid exoskeletons, our artificial muscle is found to be easier to wear and integrate into a wearable form factor. Researchers use PGM to build assistive suits to support the elderly or enhance human motion in sport. For example, Ogawa *et al*. developed an assistive suit to enhance the walking gait experience [6]. Das *et al*. provide force-feedback by means of PGM [3]. Force Hand Grove is enabled with pneumatic actuators and stretch sensors which support the user in performing wrist flexion, extension, pronation, and supination. The work focuses on assistive applications our system is an improvement of the work from Das *et al.* , making the system wearable and supporting all hand movements at the same time.

We demonstrate two application scenarios for our interactive system based on PGM: enhancing human motion in sport and assisting navigation. These prototypes focus on two particular benefits of PGM: (1) strong driving force without high electricity consumption, which enables easy actuation of the user's muscle in mobile scenario; and, (2) lightweight and flexibility to ensure zero restriction of the user's motion, yet does not sacrifice a wearable form-factor.

SYSTEM & IMPLEMENTATION

A system schematic is shown in Figure 2. The sleeve consists of 4 artificial muscles (from Daiya Industry Co. Ltd., Japan). Two 20cm artificial muscles are used for wrist extension and flexion, whereas two 30cm artificial muscles are used for wrist pronation and supination. Artificial muscle for extension and flexion were attached along the user's arm and artificial muscle for pronation and supination wrapped around the forearm in each direction of actuating.

Each Artificial muscle is actuated by CO2 gas from a gas cylinder and the amount of gas is adjusted by a pressure regulator. The PGM is either actuated or deflated through a solenoid valve, which normally closed configuration. An Arduino Uno sends the signal to actuate the solenoid valves. The system is stand-alone and can be controlled just by the Arduino.

For the demo interactions, we prepare a sleeve and the user can wear it and experience the different actuation types. We can extend, flex, pronate and supinate the users wrist if the muscles are activated strongly. However, we can also give just a slight "dragging"/"pulling" feeling (haptic feedback) if the muscles are only activated softly (with less air pressure).

APPLICATION SCENARIOS

In the following we describe a couple of application scenario ideas.

Enhancing Human Motion in sport. We already mentioned that PGM is useful for sport application. Sakoda *et al*. already work on improving the baseball swing [8]. In this paper, the swing timing is detects automatically and supports the swing posture by shrinking the PGM. Although this system only focus on supporting sport by fixing human posture, PGM could be useful to teach specific motion, for example, how to smash a ball in tennis because PGM could be helpful to calibrate human posture directly.

Assisting Navigation. There is a several idea for assisting navigation. Although navigation information is often provided on a visual display or descriptive audio, the assisting navigation based on tactile feedback is also proposed [9, 7, 4]. The artificial muscle could be helpful on assisting navigation scenarios and it indicates which direction you should go by actuating your arm. The user can feel a slight drag to the left in their arm if they are supposed to take a left turn.

CONCLUSION

We present an initial implementation of an artificial muscle sleeve based on PGM. In demonstration, we will show the Artificial Muscle sleeve, which can actuate the user's forearm like extension, flexion, pronation, supination. The system can either actuate the 4 different wrist movement or give haptic feedback in the 4 directions. Users can experience these in the demonstration. We present two application scenarios here, enhancing motion in sport and assisting navigation, yet we are interested in what kind of application scenarios demo users will come up with. In this paper, we mentioned only two application scenarios, however there are potential interaction because of the feature of PGM that enable to actuate human muscle directly. We plan to further improve the development of the suit as a wearable device and combine it with tracking techniques for more practical application, so that we can more get seamlessly information through our body.

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REFERENCES

1. Chia-Yu Chen, Yen-Yu Chen, Yi-Ju Chung, and Neng-Hao Yu. 2016. Motion guidance sleeve: Guiding the forearm rotation through external artificial muscles. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 3272–3276.
2. Frank Daerden and Dirk Lefeber. 2002. Pneumatic artificial muscles: actuators for robotics and automation. *European journal of mechanical and environmental engineering* 47, 1 (2002), 11–21.
3. Swagata Das, Yusuke Kishishita, Toshio Tsuji, Cassie Lowell, Kazunori Ogawa, and Yuichi Kurita. 2018. ForceHand glove: a wearable force-feedback glove with pneumatic artificial muscles (PAMs). *IEEE Robotics and Automation Letters* 3, 3 (2018), 2416–2423.
4. Yuki Kon, Takuto Nakamura, Michi Sato, and Hiroyuki Kajimoto. 2016. Effect of hanger reflex on walking. In *Haptics Symposium (HAPTICS), 2016 IEEE*. IEEE, 313–318.
5. Pedro Lopes, Patrik Jonell, and Patrick Baudisch. 2015. Affordance++: allowing objects to communicate dynamic use. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, 2515–2524.
6. Kazunori Ogawa, Chetan Thakur, Tomohiro Ikeda, Toshio Tsuji, and Yuichi Kurita. 2017. Development of a pneumatic artificial muscle driven by low pressure and its application to the unplugged powered suit. *Advanced Robotics* 31, 21 (2017), 1135–1143.
7. Sonja Rümelin, Enrico Rukzio, and Robert Hardy. 2011. NaviRadar: a novel tactile information display for pedestrian navigation. In *Proceedings of the 24th annual ACM symposium on User interface software and technology*. ACM, 293–302.
8. Watura Sakoda, Antonio Vega Ramirez, Kazunori Ogawa, Toshio Tsuji, and Yuichi Kurita. 2018. Reinforced Suit Using Low Pressure Driven Artificial Muscles For Baseball Bat Swing. In *Proceedings of the 9th Augmented Human International Conference*. ACM, 30.
9. Emi Tamaki, Takashi Miyaki, and Jun Rekimoto. 2010. PossessedHand: a hand gesture manipulation system using electrical stimuli. In *Proceedings of the 1st Augmented Human International Conference*. ACM, 2.