Luminescent Tentacles: A Scalable SMA Motion Display

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ABSTRACT
The Luminescent Tentacles system is a scalable kinetic surface system for kinetic art, ambient display, and animatronics. The 256 shape-memory alloy actuators react to hand movement by fluid dynamics and Kinect. These actuators behave like waving tentacles of sea anemones under the sea, and the top of the actuator softly glows like a bioluminescent organism. To precisely control a large number of actuators simultaneously, the system utilizes one microcontroller per actuator for distributed processing. In addition, it provides a scalable platform, which can be easily built into various forms.

Author Keywords
Kinetic surface; actuated surface; shape-memory alloy; soft actuator; smart material interface

ACM Classification Keywords
H.5.2. Information interfaces and presentation: User interfaces

INTRODUCTION
Inspired by waving tentacles of sea anemones or grasses being blown by wind, we proposed a shape-memory alloy (SMA) motion display [6]. Our previous works [7, 8] introduced a control method for various motions of an SMA actuator that can bend in multiple directions. Whereas several research works similar to our idea have been conducted, most of these systems provide awkward motion of actuators or have a small number of actuators. The goal of the present research is to realize a fantastic scene similar to the waving tentacles of sea anemones under the sea. Its applications include kinetic art, ambient display, and animatronics. To engage users in a high level of expression, we explored a control method for smooth motion of an SMA actuator and for aesthetic kinetic representation. In the present paper, we describe a new firmware of microcontroller for distributed processing to provide a scalable platform with a large number of actuators and an application example to react like a water ripple.

UIST'16 Adjunct, October 16-19, 2016, Tokyo, Japan
ACM 978-1-4503-4531-6/16/10.
http://dx.doi.org/10.1145/2984751.2985695

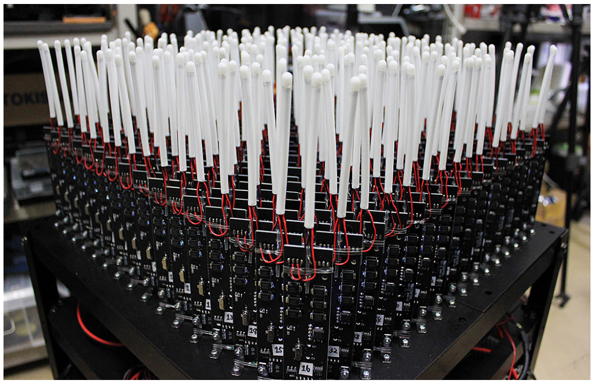

Figure 1. Luminescent Tentacles system.

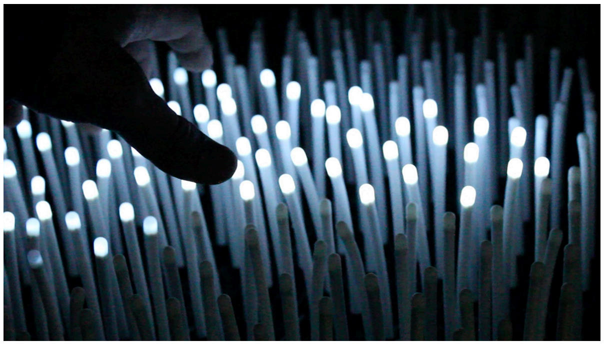

Figure 2. SMA actuators reacting to a hand movement in the dark.

RELATED WORK
Public Anemone in the interactive robot theatre [1] is a robotic creature with a sea anemone motif, but it has only four tentacles. The Luminescent Tentacles system (Fig. 1) mimics a long-tentacle anemone with a large number of tentacles. Some haptic interfaces [2, 3, 11] have kinetic components. However, the actuator of these systems is unlike the tentacle of a sea anemone that can softly bend in multiple directions. Soft-robotic researchers create various types of bioinspired actuators [4, 5]. These actuators include the abilities to deform their shapes to accomplish some types of complex motion. However, these studies do not focus on a kinetic representation using a collection of actuators but focus on a single actuator only. Hairlytop [9, 10] is a scalable haptic interface consisting of SMA actuator units. It closely resembles our research and the design of our actuator, but the actuator motion is awkward. In contrast, our system can precisely perform control using distributed processing; therefore, it is appropriate for a kinetic representation using a large number of actuators.

IMPLEMENTATION

Hardware and Firmware

The Luminescent Tentacles system is composed of tentacle units (Fig. 3). The current setup has an array of 256 tentacle units built into a square aluminum frame (45 cm^2). The tentacle units are composed of an SMA actuator and a control circuit that we developed, and they are spaced 26 mm apart from each other. The SMA actuator has a simple structure: a silicon tube (5 mm in diameter and 80-mm long), three BioMetal Fibers (BMF150, developed by TOKI Corporation), a white LED chip, and a diffuser cap. Each SMA actuator is actuated by a BioMetal Fiber, a thin SMA wire, which contracts when heated and expands to its original length by cooling. The heat of each BioMetal Fiber is controlled through pulse-width modulation (PWM) control currents. The actuator can bend in six directions by the combination of three PWM control currents [8]. The top of the actuator softly glows like a bioluminescent organism. The PWM control currents are produced by a control circuit composed of a peripheral interface controller (PIC), a field-effect transistor, and some electrical parts. In addition, to communicate with the PC application, our system adopts the DMX512, a serial communication protocol developed to control stage lighting, which supports a daisy chain. In our previous works [6–8], all the current changes at a certain time were calculated by the PC application, and the control circuit only worked as the interface for the DMX512 to control the current. A smooth controller system needs to precisely control a large number of current channels at the same time. Our present system needs to simultaneously control 1024 channels (three SMA channels and one LED channel per actuator). However, our previous method creates a high CPU load or high traffic and often loses data. Therefore, we improved our previous PIC firmware. The current changes are processed on the PIC, and the PC application only transmits the trigger data. Therefore, our system with a certain number of PICs can reduce the load during processing. Furthermore, the distributed processing system with the DMX512 creates a scalable platform, which can be easily built into various forms.

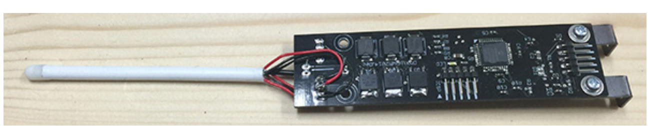

Figure 3. Tentacle unit composed of an SMA actuator and a control circuit.

Application: Interaction by Fluid Dynamics

The control circuit that we developed interacts with applications that support the DMX512, and we selected openFrameworks, which is an open-source development environment with many powerful libraries, including ofxDmx and ofxKinect. The sample application that interacts with fluid dynamics utilizes Kinect to detect hand movement and ofxFlowTools, a third-party library of openFrameworks, for fluid simulation. The trigger data that are calculated by the sample angle and strength data from the result of the fluid simulation are transmitted to the PIC. By waving a hand above the tentacle units, each actuator moves in the direction of the wave propagation similar to sea anemones under the sea (Fig. 2). The sound reaction to the hand movement creates music via a software synthesizer.

CONCLUSION AND FUTURE WORK

The Luminescent Tentacles system is still at an early stage of development, and many challenges need to be addressed. We plan to build a colored wave using RGB LEDs, a sound visualizer to follow the tentacle dance, and a haptic interface with a touch sensor. In addition, we envision an animatronics work with a three-dimensional form.

ACKNOWLEDGMENTS

This work was supported by JSPS KAKENHI 26330418.

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