Himawari: Shape Memory Alloy Motion Display for Robotic Representation

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CHI 2010, April 10–15, 2010, Atlanta, Georgia, USA.
ACM 978-1-60558-930-5/10/04.

Abstract
We propose the concept of shape memory alloy motion display (SMD), a new type of physical display, and introduce a plant-shaped robot "Himawari" based on this technology. SMD is a display apparatus taking advantage of existence of an actual object, and gives visual expressions by movement and change in shape of actuators, which are components of this device. Visual expressions resembling tentacles of sea anemone and foliage of grasses and trees are possible by designing the actuators, making way for new expressions by physical display. We built the plant-shaped robot Himawari as a piece of art applying SMD technology. We discuss the possibilities of SMD through fabrication of the completed piece of art, Himawari.

Keywords
physical display, robots, shape memory alloy

ACM Classification Keywords
B.4.2 Input/Output Devices, **I.2.9** Robotics, **H.5.2** User Interfaces

General Terms
Design

figure 1. Himawari

Introduction

In this paper, we propose shape memory alloy motion display (SMD), a completely new type of display equipment taking advantage of existence of an actual object. In developing SMD, first we developed actuators using shape memory alloys (SMA). We can place actuators with less spacing and at high density using SMAs, therefore reducing the weight of the equipment. Then, we built a plant-shaped robot Himawari (Fig. 1) by combining SMD technology with robotics technology. In this work, we do not report on fundamental experiments of actuators as in conventional research, but discuss possibilities of SMD by building and presenting the completed piece of art, Himawari.

What's Shape Memory Alloy Motion Display (SMD)?

SMD does not display images with a combination of changes in light as in visual displays, but the elements corresponding to light dots in visual displays are replaced by objects (actuators). We do not aim to display high density information as in images, but realize abstract expressions with physical movements and changes in shape. Mechanical Mirrors [2] is a piece of art expressing visually by changing shapes and moving objects, therefore is a physical display. SMD further improves the capability of expression by focusing on the "movement" of actuators, a component of physical display. We are working on devices that give visual expressions and feeling of creature-like existence by soft, creature-like movements. Applications include interactive walls as Digital Public Art [4], digital signage using visual expressions, Ambient Displays [12] using organic life-like movements, and the moving dolls in theme parks combining three-dimensional structure impossible with images and robotics technology. Fig. 2 is a conceptual image of an application of SMD "Interactive wall of foliage". Leaves are attached on tips of actuators, and give a visual image using the whole equipment through the boundary of sections where leaves move and rustle, and sections where leaves do not move.

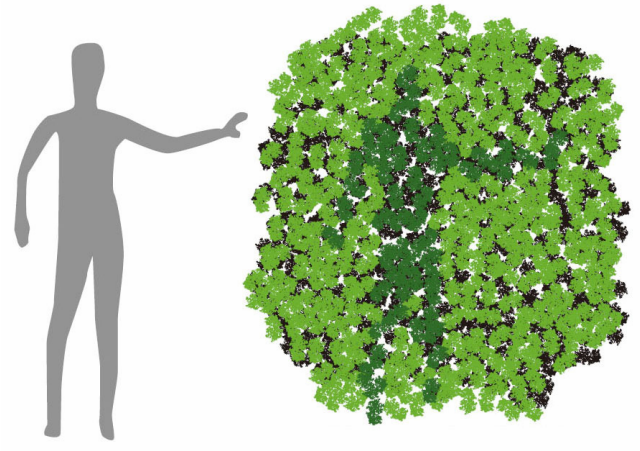

figure 2. Interactive wall of foliage

Idea and Inspiration

The movements of SMDs, and tentacles and petals of the head in Himawari are inspired by tentacles of sea anemone or grasses and trees swaying in the wind. We wanted to develop a device that gives new types of expression by precisely controlling the creature-like, organic expression of movement.

Related Work

We introduce related work on plant-shaped robots and on SMDs. First, on plant-shaped robots: when we think of robots we tend to think of humanoid or animal-

shaped robots, but there are few robots shaped like organic creatures or plant-shaped. However, in the field of art there are some plant-shaped art as kinetic art. Una Lumino [1] is mechanical creatures made by designing plants composed of mechanical parts and combining with robotics technology. Hylozoic Soil [7] and MSOrgm [9] use SMA to realize organic movements. FLOWER ROCK 2.0 [11] and Pekoppa [10] are examples of plant-shaped moving toys. These facts suggest research was conducted primarily to develop practical products in the engineering field, but in the fields of art and toys development was conducted exploring expressions freely. However, as recent robotics research are expanding to topics such as communicating with humans and relaxation, there is a possibility that robots inspired by plants may be actively researched. From this aspect, Himawari proposes a new type of robot, the plant-shaped robot.

On the other hand, regarding related work on SMD we can draw upon expressions in Super Cilia Skin [8] and Sprout I/O [5]. Super Cilia Skin is inspired by grasses and trees swaying in the wind. Sprout I/O is inspired by footprints on a carpet. These work focus on interaction with soft movement of plants or fur by tactual perception on a tangible interface, and focus more on tactical movement rather than the "movement" itself. Therefore, there is not much focus on the "movement". However, SMD and the actuators in Himawari are focused on plant-like, creature-like "movement", and the principal goal is to realize advanced interaction between humans and changes in movement or shape.

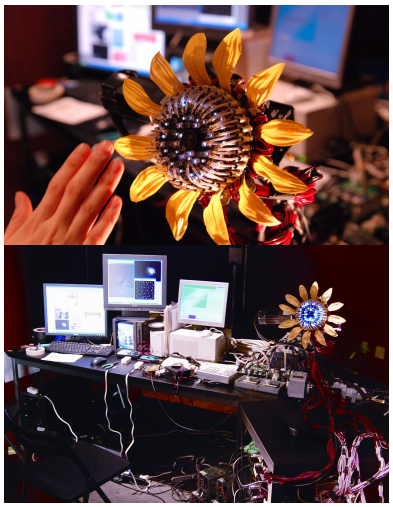

figure 3. Snapshots of Himawari

Himawari

Himawari (Fig. 3) is inspired by the sunflower plant (Himawari in Japanese), and is a plant-shaped robot made of mechanical and electronic parts. We describe the motivation behind building Himawari, and the concept and design as a piece of art.

Background of Himawari

Himawari is a piece of art made for the art event "MACHIJYU ART in Kitakyushu 2008" [3]. MACHIJYU ART in Kitakyushu 2008 is an event focused on art and technology, where artists collaborate with local companies and make pieces of art utilizing technical expertise of the companies and using materials made by the companies. This event aims to raise awareness of local manufacturers through art. Himawari used servo motor control technology of a company developing control units for medical applications (Yoshikawa Kogyo Co., Ltd.), and built a robot based on the sunflower, the municipal flower of Kitakyushu City. The sunflower, the symbol of Kitakyushu City, was made using technology of local companies. Furthermore, we realized movement of tentacles and petals using proprietary developed SMA actuators, the core technology in SMD in the head of Himawari. Himawari adds biological movement such as wiggling and murmuring to a structure made only with mechanical and electronic parts to give creature-like existence in interacting with humans.

Concept of Artworks

Biologically speaking, plants differ from animals because there is no central nervous system. Plants do not think, and live while staying still. However, the more we observe the behavior of plants (conduct photosynthesis, bloom flowers, pollinate using insects), the more we feel plants have some will. Sunflowers bloom toward the sun. Sunflowers tilting their heads

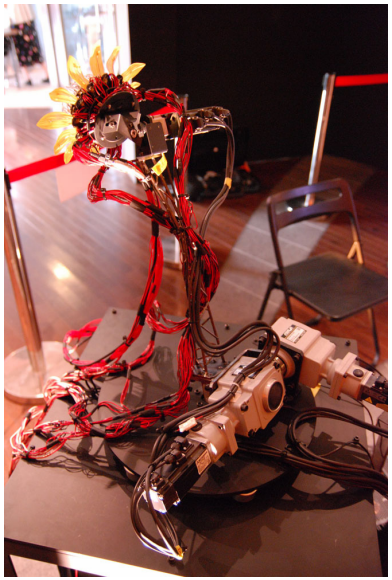

figure 4. The stalk of Himawari

figure 5. The head of Himawari

and blooming toward the sun looks as if they are trying to convey some message.

Designing

Himawari is based on the sunflower plant. To add movements to plants that in principle do not move, we made Himawari by thinking more freely to add creature-like existence, for example by adding creature-like tentacles and expression of swaying petals. Himawari uses an infrared camera placed at the center of the head as its eye, and slowly moves toward the direction that someone has moved. The stalk (Fig. 4) is actuated by four servo motors. The head (Fig. 5) has 48 white LEDs, an infrared LED, an infrared camera, 68 SMAs for tentacles, and 12 SMAs for petals. The petals are made from artificial sunflowers. The infrared LED is used to analyze human movement using the infrared camera. The white LEDs light up reacting to human movement. The SMAs for tentacles and petals also bend and straighten with human movement. The wriggling of tentacles and slow movement of petals give creature-like expression and the look of Himawari as a mechanical life form.

Engineering Himawari

We explain the technology used in controlling Himawari in four sections: overview of system, flow of control, structure of SMA actuators, and SMA voltage control methodology.

System Overview

Images obtained by the infrared camera on the head are analyzed with a program developed on Cycling'74 Max/MSP/Jitter (Windows). Based on the analyzed data, signals controlling servo motors are sent via serial transmission to a servo motor control unit (Linux). The SMA and LED control commands are converted into DMX signals used in stage lighting and transmitted to a voltage control unit.

Control Flow

Fig. 6 shows the flow of control from input to output. First, images from the infrared camera are analyzed, and mosaic processed. The images are converted into signals by the grayscale level of mosaic dots, and used as triggers to control voltage applied to LEDs and to control SMAs. The position of dots in the mosaic image is reproduced as SMA actuators and LEDs in the actual Himawari flower. The SMAs and LEDs simply react to the human movement by bending and flashing.

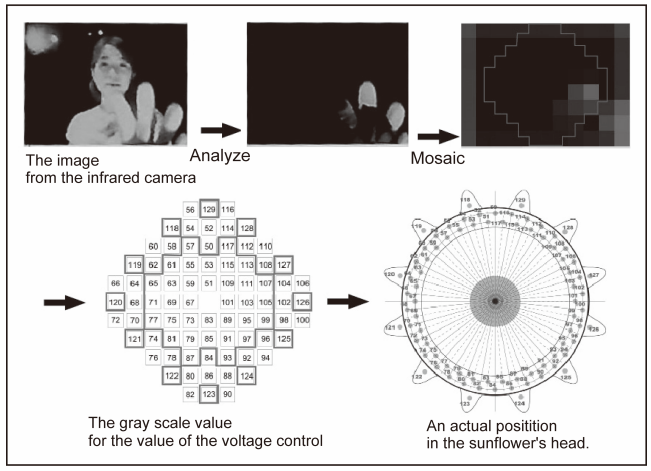

figure 6. The flow of control

Mechanical SMA

Fig. 7 is a drawing of the SMA actuator structure. The actuator has a simple structure; a curved SMA for actuation, a superelastic SMA as a return spring, and enamel wire for conduction are inserted in a silicone

tube. We can apply voltage to the SMA for actuation by connecting the SMA and enamel wire. The actuator is slightly bent in the initial position. The actuator bends further when voltage is applied, and returns to the initial position when the voltage is removed.

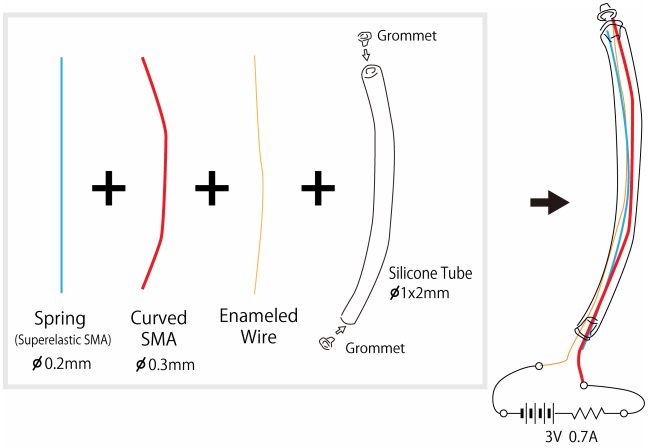

figure 7. The structure of SMA actuators

Electronic Control

The SMAs are controlled by a PIC microcontroller, which controls pulse width modulation of large current using field effect transistors to regulate the voltage applied to SMAs. One SMA requires maximum electric current of 0.7A at 3V. The problem with SMA actuators is that response is slow. Fig. 8 shows the voltage control profile of a SMA. The SMA bends over three seconds by increasing the voltage, and returns to the initial shape over four seconds by natural cooling. The slow response speed makes SMA actuators look as if they are always wiggling randomly, even though they are operating interactively, reacting to human movement. This is an important issue regarding interactivity of SMDs, and must be resolved.

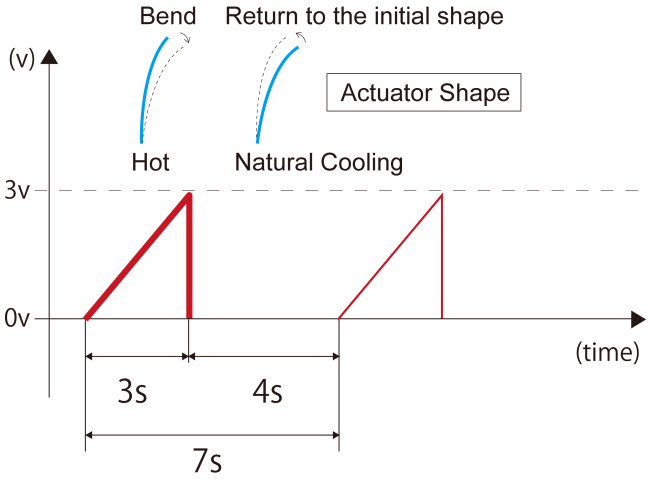

figure 8. The voltage control profile of a SMA

Discussion

We received much feedback on Himawari through exhibition in MACHIJYU ART in Kitakyushu 2008 [3] and ACM SIGGRAPH ASIA 2009 Emerging Technologies [6]. The movement of tentacles and petals using SMA actuators were perceived as life-like, realistic movement, and gained surprised looks and high level of attention. However, the movements did not appear to be reacting to human movement. There may be two reasons. First, the movements did not correspond to real-time human movement because the actuators react slowly, thus appearing to be moving randomly. Second, the expression of movement over actuators did not reach the resolution that humans can perceive due to the small number of actuators.

Furthermore, there was feedback that the plant-shaped robot Himawari was more interesting compared to humanoid or animal-shaped robots. People want higher levels of communication with humanoid or animal-shaped robots because of their human or animal look. If the communication did not go well, people might feel stressed. On the contrary, people may feel comfortable interaction with lower levels of communication with plant-shaped robots because plants are fragile existences anyway. Therefore, wiggling expressions such as sea anemone tentacles, in addition to expressions inspired by plants, have not have gained much interest but may be very effective depending on the application.

Conclusion and Future Work

We have discussed the possibility of SMD through making a plant-shaped robot Himawari as a piece of art. The plant-like, creature-like expressions received surprise and high interest. However, the low functionality and number of actuators did not fully demonstrate the expressions. We believe a higher degree of interaction allows presentation of expressions that are easier to understand. We will resolve these issues in the future, and will develop devices with more expressional capabilities and reproducibility through fundamental experiments on SMD. Furthermore, we will also explore human interaction with organic life-like movements.

Acknowledgements

We thank Kiyoshi Tomimatsu, Yoshikawa Kogyo Co., Ltd, Kyushu University Challenge & Creation Project, Yoshimi Inc., NPO Arts and Technology Association Kitakyushu, and ADCDU.

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