Pop Up! : A Novel Technology of Shape Display of 3D Objects

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1   Introduction

Pop Up! is a novel visual + tactile display for presenting touchable 3D shapes using a pin-rod matrix to convey visual depth information. Due to its dense arrangement and long range of movement, it can display large-scale, dense objects such as human faces, geographical features and architectural structures. The effect is similar to a children's "Pop up book," where a flat surface transforms into a 3D form. Each pixel is composed of a simple component shown in figure 1. The pin-rod is driven up applying voltage to the actuator, and the pin-rod is driven down by cooling the actuator with an air fan through a slit in each plastic pipe. In addition, the driving method is scalable so that displays of any size can be constructed in the same way.

For the SIGGRAPH 2004 exhibition, we developed a shape display composed of 1024 pin-rods with a 4mm pin interval. Each pin-rod has a maximum stroke of 30mm, and the height can be controlled within a 1mm accuracy.

2   Technical Details

To realize a shape display composed of many pin-rods for sophisticated applications, there are three requirements. The first requirement is speed. The pin-rod must move as fast as possible if we want to display dynamical shapes such as facial expression. The second requirement is density in order to present fine detail. For example, the pin-rod interval must be at most 4 mm to display a human face; otherwise, the displayed face could not express subtle personal characteristics. We have tested this issue through both computer simulation and with a static pin-rod matrix (see MPEG movie). The third requirement is the number of pin-rods. As the pin-rod interval must be at most 4 mm, we need at least a 32 by 32 matrix of pin-rods to display our face, which means that at least 1024 pin-rods must be actuated independently. From an engineering point of view, to achieve this number, each pin-rod must be as simple and cost-efficient as possible.

To meet these challenges, we developed the following two core technical innovations. The first is the use of Coil-type Shape Memory Alloy (C-SMA). Ordinary SMA is very small and thin, and it can produce a very strong force. Therefore, SMA has been said to be a potential realization of artificial muscle. However, ordinary SMA does not have a long stroke, and the movement is quite slow, especially when it extends back its original length, which is the main reason why it is generally avoided as an actuator. To improve its response rate, we chose to use C-SMA. The diameter of the C-SMA is only 0.85mm, yet it can lift at least 40gf. The coil can be extended to twice its original length, and shrunk to its original length by heating. The coil-form enables much faster cooling than previous SMAs, because of its large surface area. Thanks to its thinness, speed, and simplicity, it is an ideal actuator for our display.

The second innovation is the controlling actuator method and algorithm. To actuate multiple actuators at the same time is the greatest technical challenge for our display. For example, if we use servomotors, the same number of control signals and pin-rods is necessary to drive each actuator independently. As our goal is to drive displays with 32 by 32 pin-rods or more, this method is impractical. Instead, we applied a "matrix drive" method, which is commonly used in LCD display drivers. However, a simple matrix drive method by itself is insufficient for this system in speed performance. Therefore, we solve the optimization problem of time-scheduling, to determine how much time should be assigned to each pin-rod. Pop Up! is designed to display 3D objects with a custom optimized controlling algorithm we invented, which enables the display of shapes faster than a non-optimized matrix drive method.

3   Future Works

One goal of our project is the realization of the "Face Phone" (see MPEG movie and Figure 2). Such a device would display dynamic rangefinder data obtained from a human face. Conventional videoconference technology can convey vocal and visual information, but this "Face Phone" can also convey a sense of existence, which helps our daily communication with others.

The ultimate goal is for Pop Up! to become a substitute or supplement to the traditional LCD or CRT display, to enhance its quality and modality as a 3D interface.
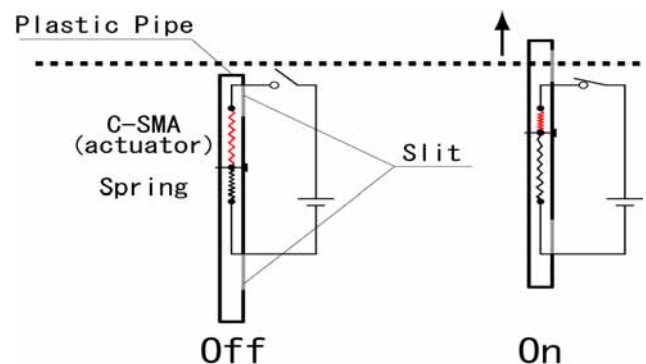

Figure 1: The configuration on single pixel.

Figure 2 : The concept of "Face Phone."

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