International Journal of Engineering & Technology, 7 (3.24) (2018) 268-272

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Development of Chameleon Surface

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Abstract

Background/Objectives: This study is about the development of chameleon surface which combines a dynamic surface with a pin-screen method and a surface projection mapping. It aims to show a higher immersion experience to the audience through physical display and projection mapping.
Methods/Statistical analysis: Due to advanced design methods and materials, we have developed a telescopic linear actuator, which is a faster, longer and lighter motion control module. We also studied material and fabric combination techniques for stretchable screens on each actuator module for projection mapping and projection mapping technology for projecting curved surfaces with multiple projectors.
Findings: The telescopic actuator has a speed of more than 1.7m/s, a travel distance of more than 1m, and weighs about 3~4kg, which is about 25% more than that of the past. Also, the stretchable screen using composite material has elastic recovery rate of 96% and maximum elongation of 180% is achieved. In the aspect of projection mapping projected on a dynamic surface, the overlapping area resulting from multiple projections is solved using 3D edge blending. This achieves an error range of 6.43 mm when projecting onto surface, maintains a speed of 24 fps or higher.
Improvements/Applications: The Chameleon surface is expected to be utilized in outdoor advertising, stage equipment, and kinetic art, and is expected to be used as a next-generation physical display after researching and optimizing the contents in the future.

Keywords: dynamic surface, physical display, projection mapping, stretchable screen, kinetic display, mechatronics display

1. Introduction

Chameleon surfaces are classified into two types: dynamic surface and curved surface projection mapping. The first is a combination of a stretchable screen with a dynamic surface of a pin-screen[1] style. Dynamic surfaces are divided into three types and are classified as flip display[2], wire display[3] and pin-screen display. Filip displays are the most commonly used display technology in public places. It is made by mechanically turning upside down, it is mainly used for electric signboards such as train station. The solenoid can be used to turn a small panel (pixel) with the power of the electromagnet, or to adjust the area reflected by the light using a servo motor. A representative example of the Wire display is the Kinetic Sculpture of ART+COM[4].The winch motors on the ceiling are arranged in a lattice to represent hundreds of small objects in space to represent physical shapes. Finally, the pin-screen display has the same shape as MIT's inform[5], in which the bars of like bars move up and down, or in and out, so that the narrow plane of the bars is represented like a pixel. However, surfaces composed of these bars are disadvantageous because they are visually over-sized pixels due to physical limitations, which may cause viewers to be segregated or discontinuous. Chameleon surfaces combine a pin-screen style and stretchable screen to prevent segmentation, aliasing, and provide a foundation for projection mapping.

The second is a technique for covering various curved surfaces, large size area and non-projection area generated by telescopic linear actuator and elastic screen with curved surface multi-projection mapping[6]. It consists of a technique of projecting an image by matching a sink to a dynamic surface, and a technique of solving the overlapping of boundaries caused by multiple projectors. Chameleon surfaces are created by surfaces that are deepened and protruded by the incoming and outgoing actuators. To solve these problems, the projector can be projected from various angles, or the number can be increased. Chameleon surfaces are being studied with the goal of providing a flexible installation environment to meet both requirements. Mechanical design, flexible fabric, and mapping technology for chameleon surfaces are a direct study of the development of physical displays[7] using mechatronics. In the future, it will be valuable as a base technology that can be used in the fields of advertising, stage, and exhibition.

2. Chameleon Surface Hardware


Figure 1: Chameleon Surface Hardware Testing

As shown in [Figure 1], the chameleon is composed of a stretchable screen and a telescopic linear actuator[8] module and an entire frame, and that has a continuous surface rather than a segmented representation. The travel distance of the actuator 1 meter to the total screen size can represent a three-dimensional shape than other pin-screen displays. For this reason, a highly resilient screen material study was carried out at the same time, named Surface Skin.

2.1. **Telescopic Linear Actuator**

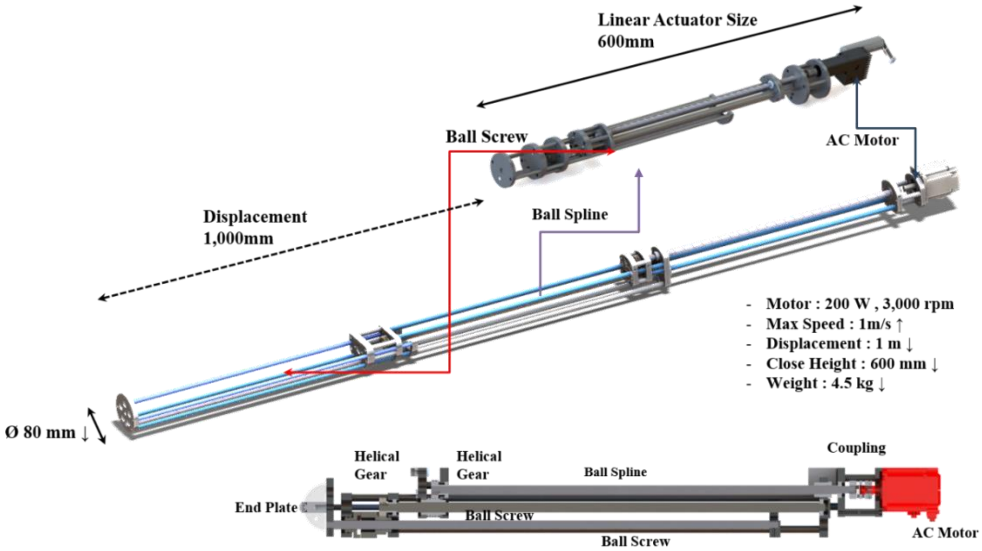

Figure 2: Telescopic Linear Actuator

It is controlled using AC motors and encoders and is designed to move in three steps in total. [Figure 2] shows that ball splines and ball screws are used to prevent vertical warpage, and helical gears are used for torque. AC motors have been changed for durability and effective control in existing DC motors, and they have been designed to be lighter instead of heavier guide rails like LM guides. With a distance of 1m and a 200W class motor, it achieves speeds of over 1.7m/s and has fast reaction speed and power.

In addition, this module has been developed as a stack structure, and it is made advantageous for disassembly, assembling, moving, and correction[Figure 3]. It is possible to see pixels that are visually richer than the grid form, which are produced in a diamond-like arrangement in consideration of the pixel structure of the projection-mapped image. The even / odd layer was constructed so that the entire shape could be formed by stacking layers.

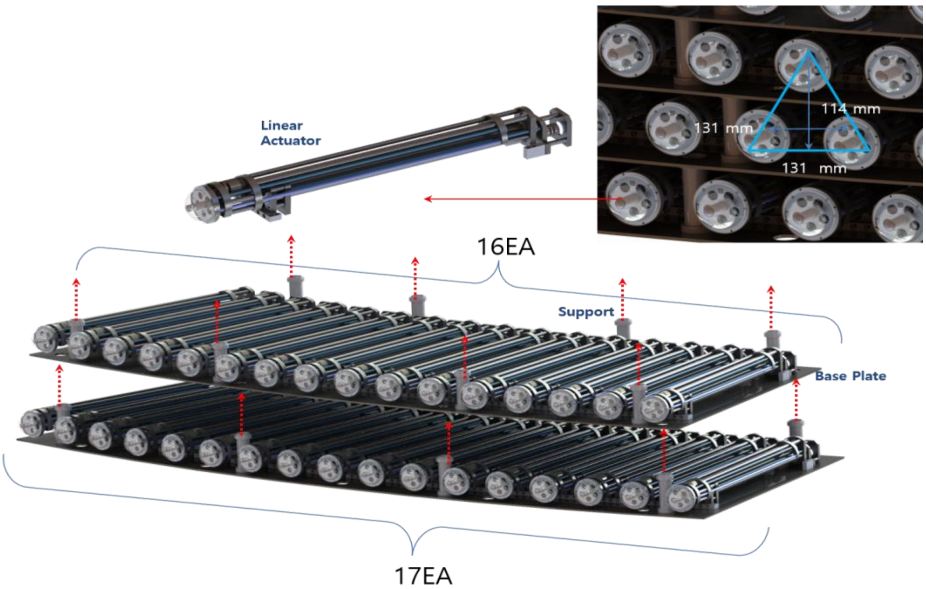

Figure 3: Structure of Telescopic Linear Actuator

In this study, we constructed 243 modules by stacking 15 times in total. It consists of 17 sets of 8 layers and 18 sets of 7 layers, and each individual layer is connected to the base plate through a support. It is a medium and large size with a width of 2200 mm and a length of 1600 mm and is designed to achieve effective size in a medium size space. Such a structure can constitute various types of screens, and it can deform a base plate to form a curved or polygonal display[9].

2.2. Surface Skin

As the performance of the actuator was improved and the curved screen was developed, the transverse elongation was about twice as long as the longitudinal elongation. To improve this, we looked for new fabrics and studied how to combine them.

For the development of a surface skin for a large screen, a polyurethane film was laminated to the fabric to produce a composite fabric. Fabric was made by weaving nylon, spandex, and polyester materials and weaving polyester 75D and spandex 20D at a ratio of 9: 1 using a circular knitting machine[10]. A polyurethane film was laminated (denoted by 32-1) to increase the modulus of elasticity and smoothness[Figure 4].

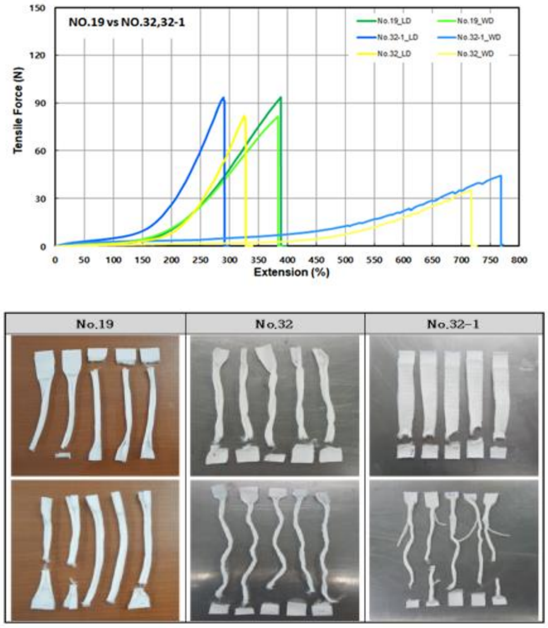

Figure 4: Surface skin fabric test

In addition, various studies have been carried out for the coupling between the fabrics and the fixing to the actuator. We tried to bond the resin by selecting the resin that can maintain the elasticity of the fabric, by physical bonding by press bonding, by physical bonding by combining two skin layers using mechanical sewing, and by physicochemical methods applied to both. As a result of this experiment[Figure 5], the physicochemical bonding method has an elongation of 260 ~ 350%, resulting in the joining method in which the coated fabric is laminated and then stitched.

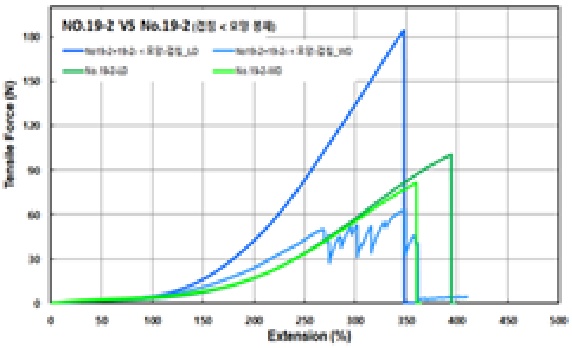

Figure 5: Surface skin bonding test

The joining strength between the actuator and the surface skin was measured using a metal button, a plastic button, a magnet, a Velcro or a screw, and it was selected as a plastic button. For the sake of aesthetics, the surface of the button is covered with the same material as the skin fabric. In addition, hemispherical plastic is attached to the end of the actuator, and the button is designed to be recessed inside the hemisphere[Figure 6], so that the button is not visible.

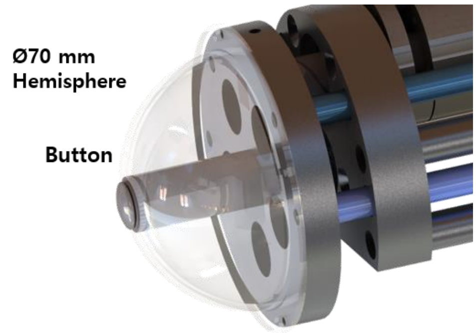

Figure 6: Design of Fixing Actuator and Button

3. Chameleon Surface Software

Dynamic curved surface projection mapping technology was developed and applied to chameleon surface hardware. For this purpose, we have developed a real - time 3D polyhedral geometric map generation technology. This is a technique of converting the surface into 3D data in real time and applying the mechanical mapping data to the image mapping software through the simulation software. When a single image is created through this technique, overlapping portions of images occur. To solve this problem, a 3D edge blending design technique is required. The software structure for this is defined in [Figure 7].

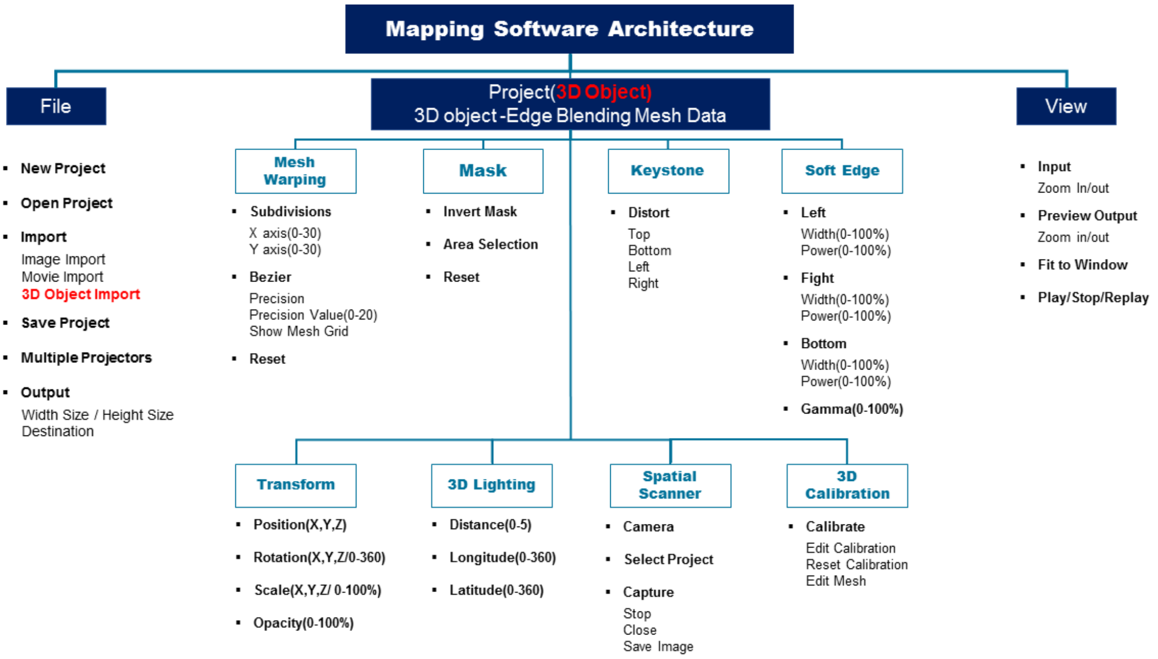

Figure 7: Dynamic 3D Projection Mapping Structure

In the past, a method of calculating the camera-based edge blending area has been applied. However, the present invention has been applied to a method of extracting three-dimensional object mesh data in consideration of a curved surface and arbitrary shape of a surface. 3D objects are inserted individually to create a basic surface grid, and the number of grids is applied to the level according to the shape of the changing 3D object to change the position values of x, y, and z on the three-dimensional surface according to the bending change of the object. And the grid is designed to be able to extract mesh data according to object shape[Figure 8].

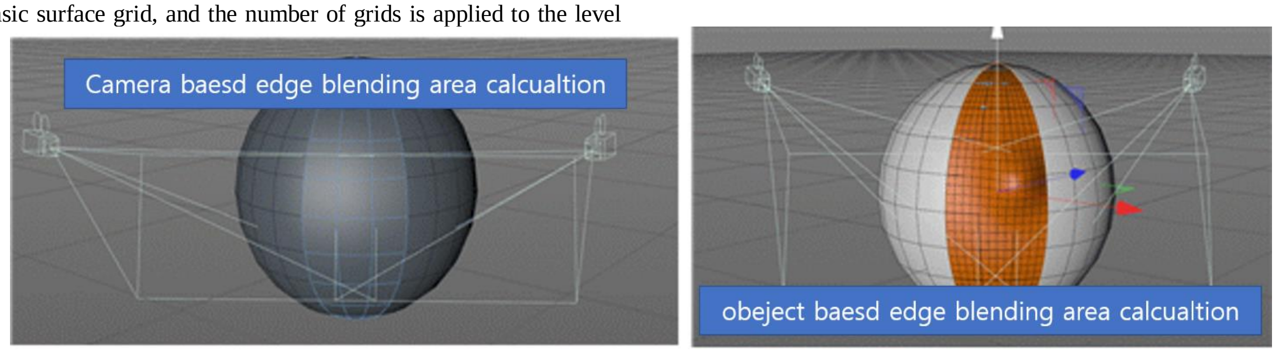

Figure 8: 3D Object based Edge Blending Mesh Data

In order to test the function of the software, a test environment was created so that the multi-faceted projection overlaps a certain part, and the multi-faceted image was adjusted to the unified image through the software using the image edge blending technology[Figure 9]. The program malfunction was checked by software repetition and the amount of change in the corrected value was measured. The execution error rate of the software is 0%. When the diagonal size of the image is compared, it is found that the error range is within 10mm and the average is 6.43mm, which is a stable structure compared to the actual environment.

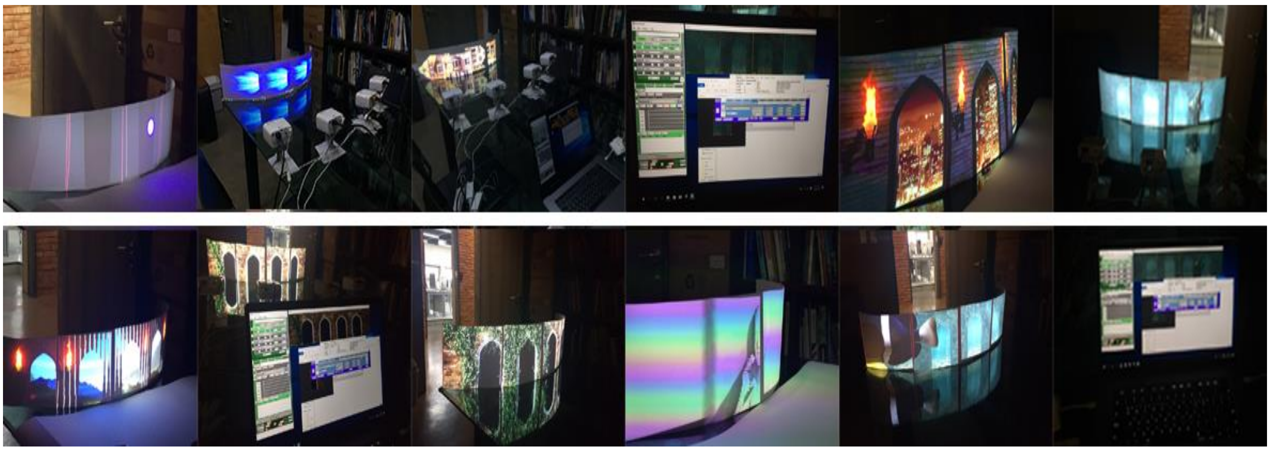

Figure 9: Software testing Environment

We have derived a schematic [Figure 10] for dynamic mapping edge blending through testing. First, feature points[11] for projector calibration were detected and calibrated. The motion of each actuator was simulated and the virtual camera was placed on the simulation software. This method has been developed by extracting the edge blending information of the corresponding geometry and projecting the image on the chameleon surface hardware.

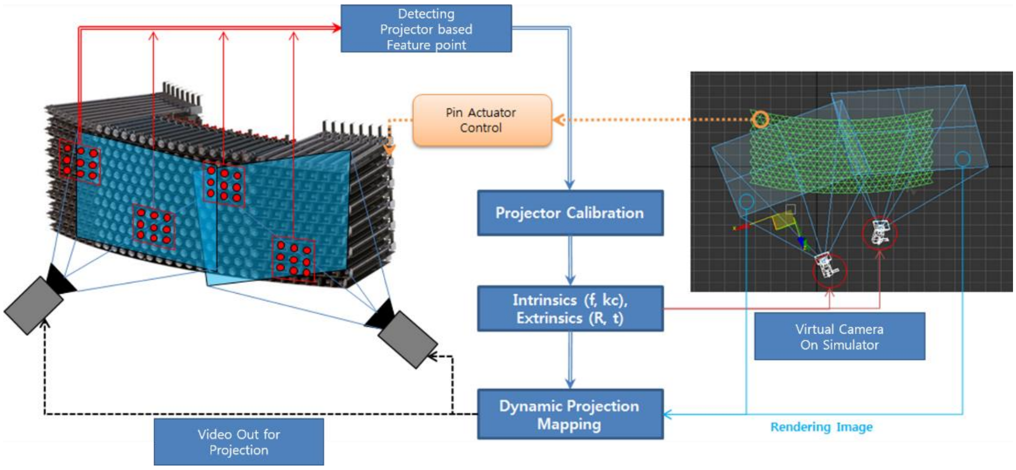

Figure 10: Real-time multi-plane projection mapping and implementation process structure

4. Conclusion

In this paper, we have divided the dynamically changing physical display chameleon surface into telescopic actuators, surface skins, and edge blending techniques in multi - projection environments for object mapping and object - based geometry generation techniques. As a result of conducting testbeds based on data obtained from actual tests and experimental studies, it became clear that the aesthetic content design using technology was important. In the next study, it should be done in order to improve the efficiency by producing content that conforms to this study. It is also expected that the integration process will be needed to improve the efficiency of the software.

The development of the chameleon surface has the potential to be applied to various elements such as architecture, advertisement display, etc. by creating a more diverse and immersive environment for the audience.

Acknowledgment

This research is supported by Ministry of Culture Sports and Tourism (MCST) and Korea Creative Content Agency(KOCCA) in the Culture Technology(CT) Research & Development Program 2017

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