Saddle Shape Intelligent Cockpit Display Solution

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Abstract

This paper presents a novel saddle-shaped display solution for intelligent cockpits, leveraging stretchable microLED technology to enable freeform designs. The dual-axis curved display (R_H1300/R_V-700) is optimized for center information display (CID) applications, offering enhanced ergonomics for both drivers and passengers.

The solution integrates Insert Molding Electronics (IME) for touch functionality, along with under-display camera (UDC) and knob display technologies, achieving a highly compact and functional design. This innovation not only enhances design flexibility for automotive applications but also ensures safer driving, a more immersive user experience, and highly sophisticated design possibilities.

Author Keywords

Stretchable displays; RGB micro-LEDs; island-bridge; dual-axis curved; intelligent cockpit

1. Introduction

Since the milestone of autonomous driving achieved by Google X in 2010 **[1-2]**, the automotive industry has made significant strides in automation technologies, aiming to enhance safety and redefine user experiences. A key aspect of this evolution is the ability to present critical information in a clear, intuitive manner within the cockpit. Larger displays are often employed to achieve this; however, conventional flat or single-curved displays limit design flexibility and can sometimes obstruct the driver's view, posing challenges for ergonomic and aesthetic integration.

The advent of stretchable display technology provides an innovative solution. Unlike traditional single-axis curved panels, stretchable displays can conform to complex, dual-axis surfaces, enabling freeform designs that seamlessly integrate into the vehicle interior. This not only enhances ergonomics for both drivers and passengers but also opens up new possibilities for immersive and intuitive interactions.

In this paper, we introduce a saddle-shaped center information display (CID) featuring stretchable MicroLED technology with R_H1300/R_V-700 specifications. The proposed design integrates advanced features such as Insert Molding Electronics (IME) for seamless touch functionality and an under-display camera (UDC) for unobtrusive interaction and monitoring. Additionally, the design incorporates a knob display, further enhancing usability while maintaining a compact and functional layout.

This novel approach not only addresses the limitations of traditional display technologies but also ensures safer driving, a more immersive user experience, and unprecedented design flexibility. The following sections discuss the mathematical basis of dual-axis curved surfaces, the innovative features of the proposed display, and its potential impact on intelligent cockpit design.

2. Definition of Dual-Axis Curved Surface

In differential geometry, a surface is defined by its principal curvatures (k_1 and k_2) at a specific point, describing how it bends along orthogonal directions **[3-4]**. Gaussian curvature (K_g) is calculated as:

$$K_g = k_1 k_2$$

Based on the value of K_g, surfaces are classified as follows:

- Developable surfaces ($K_g = 0$): Planes or cylinders.
- Non-developable surfaces ($K_g \neq 0$): Spheres ($K_g > 0$) or saddle shapes ($K_g < 0$).

For dual-axis curved surfaces, both k_1 and k_2 are non-zero. These surfaces, as illustrated in **Figure 1**, enable designs to conform to complex shapes, making them particularly suitable for ergonomic applications. This adaptability is ideal for automotive displays, as it enhances both functionality and aesthetics.

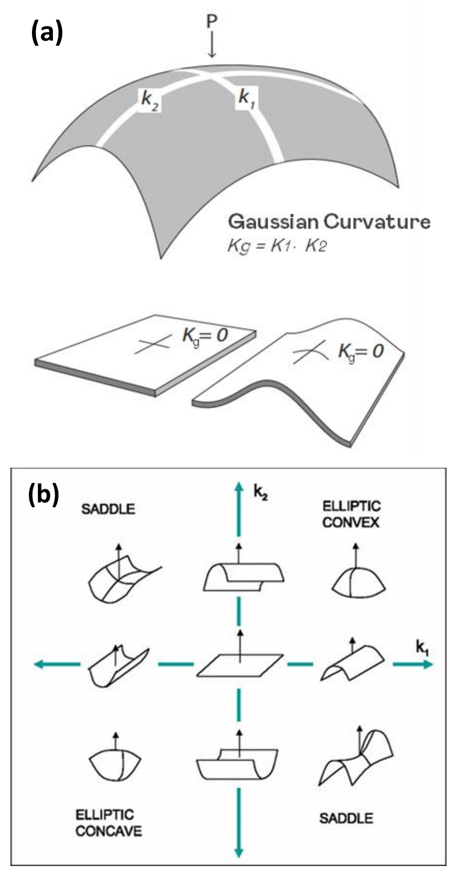

Figure 1. The definition of dual-axis curved surface by (a) Gaussian curvature and (b) the shape of surface.

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3. The Stretchable MicroLED Display

According to the mathematical model and physical properties of Gaussian curvature, a surface with zero Gaussian curvature must undergo stretching, compression, wrinkling, or fracturing to conform to a non-zero Gaussian curvature surface. Thus, a display must be stretchable to fit a saddle-shaped surface.

Kirigami [5], or so-called island-bridge structure, the concept of dividing elements to create stretchable configurations from non-stretchable surfaces, can be applied to display design. When integrated into display technology, kirigami transforms a display into a stretchable format and reduces strain by allowing the elements to rotate, as shown in Figure 2.

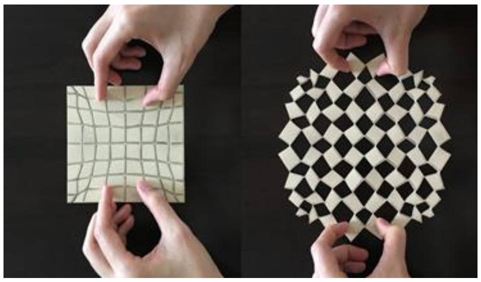

Figure 2. The concept of Kirigami

Based on the kirigami-inspired slit-type design, all panel components are positioned on "islands," while connecting lines form "bridges." When the display is stretched, each island rotates according to the kirigami concept. This slit-type design has been implemented in a 3.5-inch MicroLED display with 141 PPI to demonstrate on-demand display adaptability [6], as illustrated in Figure 3. The 3.5-inch MicroLED display demonstrates the potential of a stretchable display that can switch between a conventional display and a three-dimensional button as needed by the driver. This dynamic switching minimizes driver distraction while operating controls, and also enhances the aesthetic of the interior design.

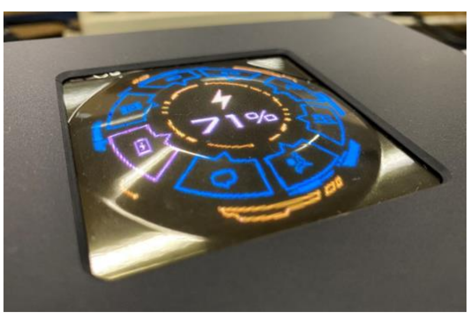

Figure 3. 3.5" stretchable MicroLED display with 141PPI

In this paper, a 13.8-inch MicroLED display maintains the kirigami concept, enabling stretchability while improving resolution to 163 PPI. The larger panel size and higher resolution ensure adequate quality for displaying driving information, aligning well with the role of a center information display (CID).

4. Dual-Axis Curved Center Information Display

The center information display (CID) serves as a crucial interface for displaying multiple types of information, such as navigation, multimedia, and car status. To minimize driver distraction while ensuring visibility, the CID must feature a convex surface in the horizontal axis, curving around the driver for easier access and readability. Simultaneously, the vertical axis of the CID should follow a concave curvature, creating a smooth, ergonomic shape that enhances interaction for both the driver and passenger. An ideal smart cockpit design that follows these principles is illustrated in Figure 4.

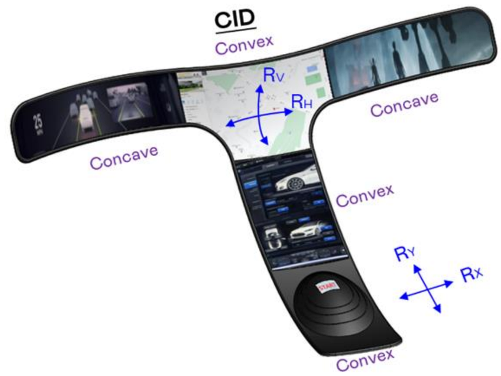

Figure 4. The ideal smart cockpit design

To ensure a practical and user-friendly cockpit design, ergonomic reach guidelines [7] are followed:

• Primary Zone (<460mm): Frequent operations (e.g., steering wheel).

• Secondary Zone (460-600mm): Less frequent operations (e.g., CID).

• Tertiary Zone (600-720mm): Occasional operations requiring body tilt.

These zones, illustrated in Figure 5, emphasize that the Secondary Zone (460-600mm radius) is optimal for the CID. This positioning allows the display to remain within easy reach while minimizing driver distraction, creating a balance between functionality and safety.

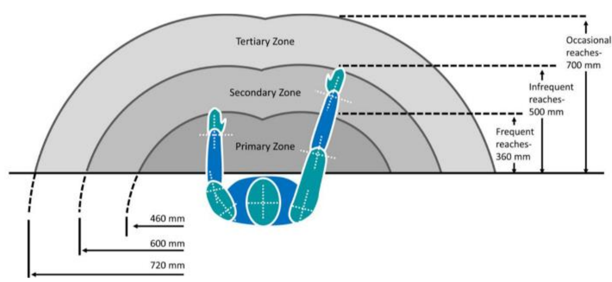

Figure 5. The ergonomic reach guidelines

Given the average cockpit width of approximately 1500mm, the CID is optimally designed with a horizontal curvature radius of 800mm to 1500mm. In the vertical direction, the CID curvature radius is designed between 700mm to 1000mm, aligning with the passenger's viewing angle of -14° to -30°, as shown in Figure 6.

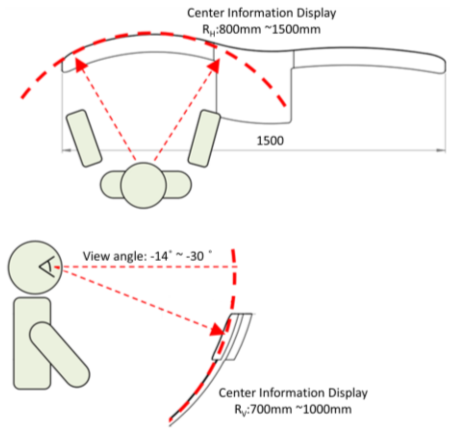

Figure 6. The radius design and view angle for center information display

Following these design guidelines, the 13.8-inch stretchable MicroLED display is developed with R_H1300/R_V-700 dual-axis curvature. This saddle-shaped CID leverages the advanced stretchable display technology to conform seamlessly to the dual-axis curved surface, ensuring an immersive, ergonomic experience for both drivers and passengers. The renderings of this innovative display are illustrated in **Figure 7**, showcasing its integration into the smart cockpit design.

This approach not only enhances the aesthetic and functional aspects of the cockpit but also provides a safer and more engaging user experience.

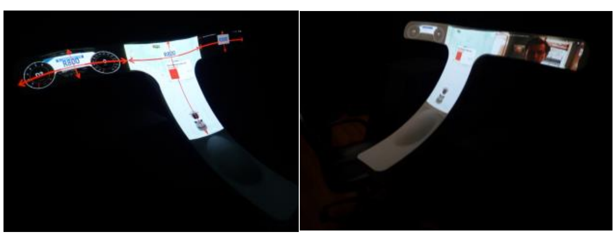

Figure 7. Proof-of-concept of a smart cockpit.

5. UDC Integration for Driver Monitoring System

The Driver Monitoring System (DMS) monitors driver behavior to ensure safety, particularly in Level 2 and Level 3 vehicles. Conventional DMS designs with visible cameras (e.g., Tesla Model 3) are often intrusive and less aesthetically appealing.

The 13.8-inch MicroLED display provides a highly innovative platform for integrating DMS through UDC technology. This approach eliminates the need for external cameras in visible locations, seamlessly embedding the camera behind the display. The integration is made possible by the kirigami structure of the stretchable MicroLED display, which features numerous micro-holes that:

1. Improve transmittance: Allowing sufficient light to reach the camera behind the display.

2. Enable invisibility: Hiding the camera from view while maintaining its functionality.

By combining the 13.8-inch stretchable MicroLED display with UDC technology, this solution represents a significant step forward in DMS integration, aligning functionality with the demands of modern smart cockpit designs. It ensures safety while maintaining an immersive and driver-friendly environment.

6. IME and Knob Display Integration

The integration of Insert Molding Electronics (IME) and Knob Display into the 13.8-inch MicroLED display enhances functionality and interaction within the cockpit, as illustrated in **Figure 8**.

Figure 8. Photograph of a 13.8" stretchable MicroLED display.

IME: Embeds touch-sensitive circuitry directly into the display, offering seamless design, durability, and responsive touch input (**Figure 9**).

Figure 9. Photograph of an IME.

Knob Display: Combines tactile controls with real-time visual feedback beneath the knob, enhancing interaction while saving space (**Figure 10**).

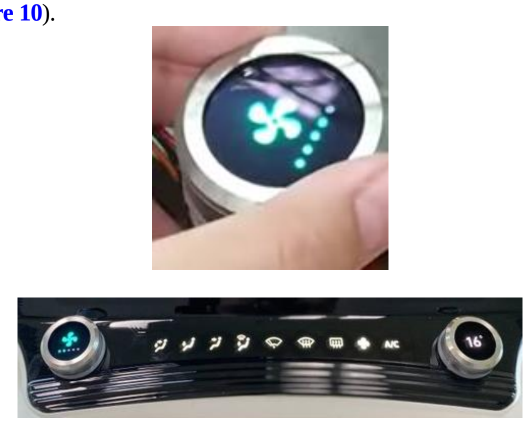

Figure 10. Photographs of a knob display.

The IME and Knob Display integration transforms the MicroLED panel into a versatile, ergonomic, and visually appealing centerpiece for modern automotive interiors.

7. Summary

This paper reports on the development of a 13.8-inch stretchable MicroLED display, with key specifications detailed in **Table 1**.

Table 1. The specifications of a 13.8" stretchable MicroLED display.

Resolution (pixel)	1980 x 1080
Pixel Density	163 PPI
Substrate	Stretchable LTPS Backplane
Curvature	Dual-axis curved R_H1300/R_V-700 mm
Color Gamut	>100% NTSC
Compensation	6T1C
LED Size	<30μm

The implementation of the 13.8-inch stretchable MicroLED display demonstrates significant advancements in automotive cockpit design:

1. Dual-Axis Curved Surface Integration: The R_H1300/R_V-700 saddle-shaped design achieved seamless integration with the cockpit, providing a more ergonomic layout for drivers and passengers.

2. Enhanced Visibility and Interaction: The kirigami structure enabled precise curvature adaptation while maintaining high resolution (163 PPI), excellent brightness, and clarity, even in varying light conditions.

3. Advanced Features:

• UDC Integration: Successfully captured driver gestures and behavior through the display without compromising aesthetics or functionality.

• IME and Knob Display: Delivered intuitive and durable touch and tactile control within a compact design, enhancing user experience and operational safety.

4. Ergonomic Design: The display adhered to ergonomic guidelines, positioning key interfaces within the primary and secondary reach zones, minimizing driver distraction and maximizing accessibility.

The 13.8-inch stretchable MicroLED display combines dual-axis curvature, UDC, IME, and Knob Display technologies to enhance safety, functionality, and design flexibility. This innovation sets a new benchmark for ergonomic and interactive smart cockpit solutions, paving the way for future automotive designs.

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