Development of Capacitive Sensor for Aerial Interface

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ABSTRACT
This paper introduces our development and application of a capacitive sensor to detect hand and finger gestures based on high-sensitivity and noise-robustness sensing technology. Application of the developed capacitive sensor includes a touchless aerial interface.

1 INTRODUCTION
In recent years, mobile devices such as smartphones, automotive navigation and industrial control panels have been thinner and lighter and touch panels have been used. In touch panels, the principle of capacitive sensing is mainly used, and in general, self-capacitance detection method is mainly used as an ON/OFF switch function, and mutual-capacitance detection method is mainly used for pointing, coordinates and touch gesture recognition. In addition, as one of the measures against covid-19, the needs for non-contact interface is also increasing.

To realize non-contact detection, it is necessary to understand the principle that the difference in the presence of the detection object more than a few cm away or the sensing value in the event to detect increases.

In general, self-capacitance detection method is more sensitive than mutual-capacitance detection method if the detection electrode area is the same. However, self-capacitance detection method tends to have a parasitic capacitance between detection and the surrounding ground potential. When parasitic capacitance is provided, the detection signal contains components and impairs the detection dynamic range, which is a suppressor of sensitivity improvement [1,2].

We have developed non-contact detection touch panel that overcomes these challenges using high-sensitivity, noise-robustness sensing and noise canceling technology.

In addition, we have combined these technologies with aerial display to develop applications for touchless aerial interface. the aerial display was made by the method of AIRR (Aerial imaging by retro-reflection) system which has been proposed as suitable for mass production and cost-effective [3,4].

2 TECHNOLOGIES
2.1 High sensitivity of self-capacitance
The method of Absolute self-capacitance sensing is shown in Fig.1. To reduce the influence of parasitic capacitance in self-capacitance detection method, a guard electrode is provided on the opposite side of detection zone against the detection electrode [5]. By controlling the guard electrode potential, the inflow of static charge between the detection electrode and the surrounding ground potential is suppressed, and a shielding effect from the ground potential can be obtained, thereby parasitic capacitance can be reduced.

![Fig.1 Absolute self-capacitance sensing](image)

2.2 Both high sensitivity and noise immunity
Proximity operation is detected as a change in capacitance, because the detection uses the electric field, it is often affected by electromagnetic noise. Therefore, in non-contact detection, the balance between the increase of the detection signal and the noise immunity is the key point.

We used sine-wave to resolve these conflicting issues. Show in Fig.2. The driving waveform of a square wave contains the fundamental frequency and its odd-multiple harmonic components, while the sine wave has only a fundamental frequency component. This filters the frequency components of noise other than the drive frequency, improving noise immunity. And, this quiet drive is advantageous for electromagnetic interface from the viewpoint of radiation.
2.3 Countermeasures for display noise

In general, it is necessary to transmit light and require a transparent electrode with high transmittance, but because of the high resistance, it is susceptible to noise generated when driving display pixels.

We used noise cancellation electrodes with the time constant equivalent to that of a sensor electrode, and used the difference in output values to reduce noise. The method and its results are shown in Fig. 4.

Proximity detecting area was larger than the gesture detection electrode. Therefore, there was a problem that noises of different phases were stacked depending on the path of noise, and the effect of noise cancellation was reduced.
We divided the electrode to improve phase delay that is generated in an electrode for detecting proximity was also added. The effect is shown in Fig. 5.

![Proximity detector and gesture detectors](image)

We applied these technologies to develop a proof of concept (PoC) model that can operate non-contact detection touches and demonstrated them in 2020, as shown in Fig. 6.

![Demonstration of PoC 2020](image)

3 RESULTS

3.1 Development of non-contact detection touch panel

Self-capacitance detection method, the drive shield electrode system, and the sine wave drive are adopted as a method of both high sensitivity and robustness, and the scheme to the display noise has been described.

![Phase analysis result](image)

We divided the electrode to improve phase delay that is generated in an electrode for detecting proximity was also added. The effect is shown in Fig. 5.

![Phase analysis result](image)

3.2 Apply of touchless aerial interface

We have developed a touchless aerial interface sample for PoC in 2021. As shown in Fig. 7, our developed capacitive sensor technologies are implemented in the aerial display system with AIRR. Specifications of PoC 2021 is shown in Table 1.

![Aerial display system](image)

When a finger approaches to 50 mm, the proximity detectors detect the finger and the aerial image appears. By moving the finger closer, we can select a button with a gesture detection sensor. The aerial display and gesture detection area are adjusted to be exactly the same position, shown in Fig. 8.

<table>
<thead>
<tr>
<th>Table 1 Specifications of PoC 2021</th>
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<tbody>
<tr>
<td>Aerial display</td>
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<tr>
<td>Viewing angle</td>
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<td>Luminance</td>
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![Proof of concept on a touchless aerial interface](image)
4 CONCLUSION

We explained touchless technologies using capacitive touch panel. The high sensitivity of the touch panel allows seamless human-machine interface (HMI) through conventional contact operation and non-contact HMI, improving hygiene and operability.

Furthermore, a touchless aerial interface developed by us is very simple system, which does not require image processing, cameras or external sensors. It suggests a world where a simple aerial interface is designed, integrated into the living space and life, and appears only when needed.

HMI devices is expected to evolve by working with aerial displays and various feedback functions.

REFERENCES


Fig.8 Touchless aerial interface with PoC 2021