A Novel Touch Panel Design for High Optical Transmittance for Interactive Displays

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Abstract

In this article, we propose a new sensor architecture, in which electrodes are settled at the edge of the touch panel, ensuring a very high optical transmittance. The touch event detection relies on electrical capacitance tomography (ECT) technique. The presented technique provides a feasible means to boost the optical transmittance of the touch panel layer while maintaining touch detection accuracy.

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***Abstract*—In traditional touch panels, electrodes are settled on or above the surface of displays, weakening the optical transmittance, hence resulting in high power consumption of the display for providing customers satisfied visual experience, giving rise to reduced battery's lifetime which brings users inconvenience. To address this issue, in this article, we propose a new sensor architecture, in which electrodes are settled only at the edge of the touch panel, ensuring a very high optical transmittance. The touch event detection relies on electrical capacitance tomography (ECT) technique, through which 2-dimensional location recognition is achieved, indicating the presented technique provides a feasible means to boost the optical transmittance of the touch panel layer.**

Keywords—Touch panel; high optical transmittance; electrical capacitance tomography; interactive display

I. INTRODUCTION

Touch panel has been a must-have component for interactive displays. Broadly utilized techniques in touch panels are resistive, capacitive, optical, acoustic-based architectures. Among them, capacitive touch panel dominates market [1], due to its merits such as high transparency, multi-touch support, low cost and detection by both contact and non-contact means. Recently, with the fast development of ultra-high definition display (UHD), attributes such as higher transparency and lower haze are highly desired for conventional capacitive touch panels [2-3], resulting in the use of ultra-high transmittance materials for electrodes, e.g., graphene [4-6], and nanowire-based electrodes [8-10]. Nevertheless, current techniques for high transparency electrodes require cleanroom fabrication condition [6], limiting their successful use in commercial products. Furthermore, some of them still block nearly 7% light intensity [11] during the visible spectrum, indicating the need of extra power consumption to maintain the display performance compared to their counterparts without touch panels installed, which shortens battery's lifetime for portable smart devices, giving rise to unpleasant user experience.

In this work, to achieve ultra-high transparency while maintaining low material cost and simple fabrication process, an electrical capacitance tomography (ECT) based technique is presented. Here conventional indium tin oxide (ITO) electrodes are arranged at the boundaries of the touch panel, the display and operation areas are free of electrodes, indicating a super high transparency and low haze. Through the developed touch panel, both touch and non-touch operations can be performed, with satisfied location detection accuracy.

II. METHODOLOGY

A. Sensor Design

The structure of the proposed touch panel is conceptually demonstrated in Fig. 1 (a), consisting of two layers. Above is a layer of ITO electrodes, patterned on the second layer - glass substrate. Electrodes are circular arcs spacing at 1 mm. The diameter of eight ITO electrodes formed round detection area is 40 mm. The geometry of the fabricated device is shown in Fig. 1 (b).

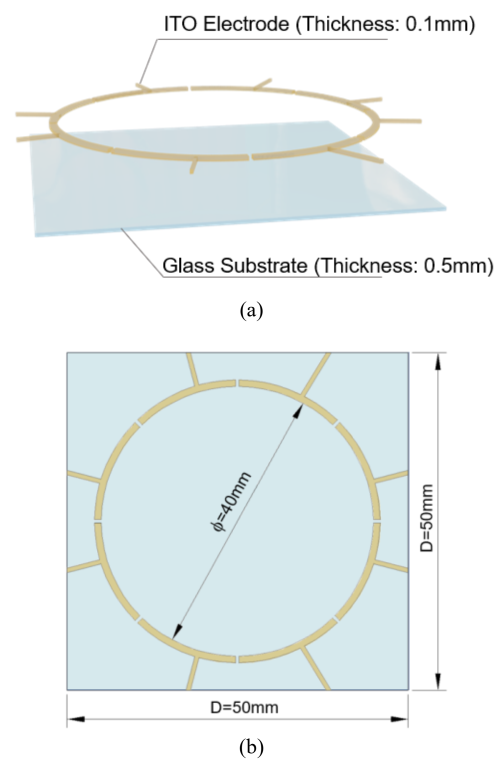


Fig. 1. (a) Structure. (b) Geometry of the proposed touch panel.

B. Touch Signal Detection

Capacitive information between different electrodes can be used to detect the presence of an object. To achieve this, capacitance values are obtained in the following steps. First, mark all the eight electrodes as 1-8, and then apply a stimulation voltage signal to electrode 1. In this test we choose 1 V. Second, the electric charges on electrodes 2-8 are measured in sequence, to obtain the capacitance between electrode 1 and the other seven electrodes [12]. Third, electrodes 2-7 are energized in turn, repeat the above steps, until the capacitive values of all single-electrode pairs are measured. Fig. 2 (a) shows the simulated capacitance vector. When an object contacts the panel, the capacitance vector will be altered. Hence, through interpreting the change of capacitance vector, the location of the object can be reconstructed by using ECT technique.

To validate the feasibility of ECT technique in detecting touch events, we created the proposed touch panel model in COMSOL to simulate the relationship between touch event and capacitance vector.

When user touches, the potential distribution and boundary capacitance values change. The distribution of potential without touch and with touch located in screen center were shown in Fig. 2 (b). The circle area represents the touch location. Obviously, in touch location, the distribution of potential is different from the condition without touch. Below, the reconstruction technique is briefly explained.

The relationship between the change in capacitance and the variance of permittivity distribution can be simplified to the linear form.

$$\Delta C_{M\times 1} = J_{M\times L}\Delta\varepsilon_{L\times 1}, \tag{1}$$

where ΔC is the capacitance change and $\Delta\varepsilon$ is the permittivity change. J is the Jacobian matrix.

In this paper, the number of electrodes is 8 and the number of independent capacitance values M = 28. The number of pixels in the imaging area is about L = 1716.

Eq. 1 is commonly written with a normalized form as Eq. 2.

$$\lambda = Sg \tag{2}$$

where λ is the normalized capacitance value, S is the normalized Jacobian matrix, g is the normalized permittivity used as the grey level of the pixels for visualization.

By using the standard Tikhonov algorithm [13-16], g can be calculated by

$$\hat{g} = (S^T S + \mu I)^{-1} S^T \lambda \tag{3}$$

where I is an identity matrix and μ is the regularization parameter.

III. Results and Discussion

To guide experiments, the reconstruction process was simulated by MATLAB. In the simulation, four different touch locations were studied as shown in Fig. 3 (a), which were represented by the high permittivity area.

The reconstruction permittivity distributions are shown in Fig. 3 (b), the dark red area represents the high permittivity area, i.e. touch location. The center of touch location and ambit of high permittivity are fit with Fig. 3 (a). The simulation results demonstrate that touch locations can be successfully reconstructed by the ECT technique. Below we will

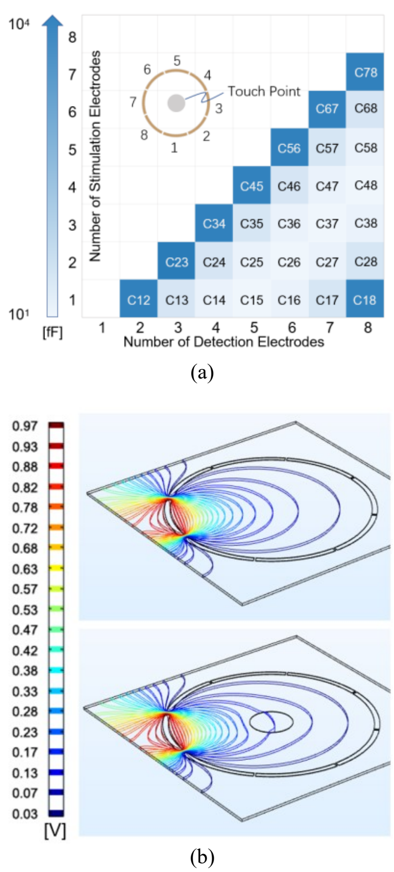


Fig. 2. (a) Simulated capacitance value. (b) Potential distribution.

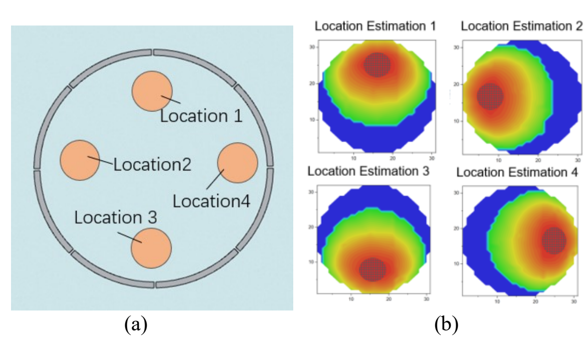


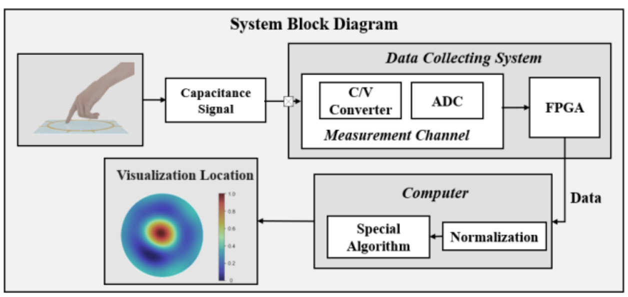
Fig. 3. (a) Simulated touch locations. (b) Corresponding reconstruction results.

experimentally examine the reconstruction effect of practical touch events.

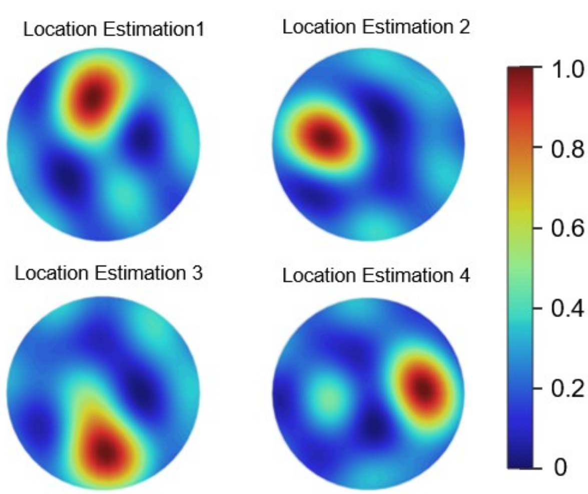
For carrying out experiments, an ECT system was built, aiming to measure capacitive information and reconstruct permittivity distribution of the measurement domain. The ECT system is constructed by three components: (1) the proposed multi-electrode sensor. (2) A data collecting system. (3) A computer for processing detected capacitive information. Fig. 4 (a) shows the block diagram of the ECT system, conceptually showing the working principle of the whole system.

Finger touches were used for performing touch event. In this experiments, the same touch locations as shown in Fig. 3 (a) are studied, and the experimental results are shown in Fig. 4 (b). The red area is approximately oval, because the shape of human finger is not standard circular. The red areas represent the reconstructed touch locations, showing that the touch events can be successfully detected.

Although promising results are obtained, two issues are waiting to be addressed. First, quantified analysis has not been performed yet, which is of significance in determination on system's 2-dimensional detection resolution. Second, environmental noise induced artifactes (shown in Fig. 4 (b)) are expected to be removed, indicating noise elimination circuit and algorithm are required to be developed for this specific application. The above explained shortages are under our research now. Future work will focus on how to further improve the reconstruction accuracy and achieve a high touch location detection resolution.



(a)



(b)

Fig. 4. (a) Block diagram of the ECT system. (b) Results of locations estimation.

IV. Conclusion

In this article, we present a novel capacitive touch panel architecture for obtaining high optical transmittance and 2-dimensional location detection. Through setting the electrodes at the edges of the touch panel, optical intensity is only weakened by the glass cover, ensuring an ultra-high transparency. Experimental results demonstrate touch location detection is successfully, potentially providing good user experience in human-machine interactivities. The work gives least optical intensity loss compared to existing techniques, lowering power consumption of the display while maintaining the visual experience for customers.

References

[1] A. Nathan, and S. Gao, “Interactive Displays: The Next Omnipresent Technology [Point of View],” *Proceedings of the IEEE*, vol. 104, no. 8, pp.1503-1507, 2016.

[2] Y. Takubo, Y. Hisatake, T. Lizuka, and T. Kawamura, “Ultra-High Resolution Mobile Displays,” *SID Symposium Digest of Technical Papers*, vol. 43, no. 1, pp. 869–872,2012.

[3] C. C. Kim, H. H. Lee, K. H. Oh, and J. Y. Sun, “Highly stretchable, transparent ionic touch panel,” *American Association for the Advancement of Science*, vol. 353, no. 6300, pp. 682—687,2016

[4] J. K. Wassei, and R. B. Kaner, “Graphene, a promising transparent conductor,” *Materials today*, vol. 13, no. 3, pp. 52-59, 2010.

[5] X. Huang, Z. Zeng, Z. Fan, J. Liu, and H. Zhang, “Graphene-Based Electrodes,” *Advanced Materials*, vol. 24, no. 45, pp. 5979–6004,2012.

[6] S. Pang, Y. Hernandez, X. Feng, and K. Müllen, “Graphene as transparent electrode material for organic electronics,” *Advanced Materials,* vol. 23, no. 25, pp. 2779-2795, 2011.

[7] L. Zhao, L. Zhao, Y. Xu, T. Qiu, L. Zhi, and G. Shi, “Polyaniline electrochromic devices with transparent graphene electrodes,” *Electrochimica Acta*, vol. 55, no. 2, pp. 491-497, 2009.

[8] T. Sannicolo, M. Lagrange, A. Cabos, C. Celle, J. P. Simonato, and D. Bellet, “Metallic Nanowire-Based Transparent Electrodes for Next Generation Flexible Devices: a Review,” *Small*, vol. 12 no. 44, pp. 6052–6075,2016.

[9] C. Mayousse, C. Celle, A. Fraczkiewicz, and J. P. Simonato, “Stability of silver nanowire based electrodes under environmental and electrical stresses,” *Nanoscale*, vol. 7, no. 5, pp. 2107–2115, 2015.

[10] T. Araki, J. M. Jaap, D. Toonder, K. Suganuma, T. Uemura, Y. Noda, S. Yoshimoto, S. Izumi, T. Sekitani, “Non-contact laser printing of ag nanowire-based electrode with photodegradable polymers,” *Journal of Photopolymer Science and Technology*, vol. 32, no. 3, pp. 429-434,2019.

[11] H. Guo, N. Lin, Y. Chen, Z. Wang, Q. Xie, T. Zheng, N. Gao, S. Li, J. Kang, D. Cai, and D. Peng “Copper Nanowires as Fully Transparent Conductive Electrodes,” *Scientific Reports*, vol. 3, no. 2323, 2013

[12] W. Yang and L. Peng, “Image reconstruction algorithms for electrical capacitance tomography,” *Measurement science and technology,* vol. 14, no. 1, pp. R1-R13, 2002.

[13] J. Nombo, A. Mwambela, and M. Kisangiri, “A review of image reconstruction methods in electrical capacitance tomography,” *Journal of Mathematical and Computational Science*, vol. 6, pp. 39-57,2016.

[14] T. Guo and S Liu and H Chen and X Wang, “Regularization iteration imaging algorithm for electrical capacitance tomography,” *Measurement Science and Technology*, vol. 29, no. 3, pp. 035403, 2012.

[15] C. Yan, D. Zhang, G. Lu and J. Dong, “An Improved Algorithm Based on Landweber-Tikhonov Alternating Iteration for ECT Image Reconstruction,” *Journal of Physics: Conference Series*, vol. 1069, pp. 012178, 2018.

[16] S. Sun, L. Xu, Z. Cao, J. Sun, W. Tian, "Selection of Truncation Radius in Calderon's Method for Direct Image Reconstruction in Electrical Capacitance Tomography," *Sensors*, vol. 19, no. 9, pp. 2014, 2019