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| Compressive Sensing for Sparse Touch Detector on Capacitive Touch Screens |

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**Short summary**: Improved touch screen responsiveness and resolution can be achieved at the expense of the touch screen controller analog hardware complexity and power consumption. This paper proposes an alternative compressive sensing based approach to exploit the sparsity of simultaneous touches with respect to the number of sensor nodes to achieve similar levels of responsiveness. It is possible to reduce the analog data acquisitions complexity at the cost of extra digital computations with less total power consumption

# Introduction

*A. Touch Screen:*

Touch screen is used in every aspect of today’s digital products. As touch screen technologies are applied at many applications, there is an increasing demand for touch screens with **large sizes**—which need more **complex controllers**.

# Capacitive Touch Screens

*A. Self and Mutual Capacitance*

1. (Mutual) Capacitance: the term “capacitance” usually refers to the *mutual capacitance* between **two adjacent conductors**. The (mutual) capacitance of two parallel plates with area  and distance  is



where  is permittivity of free space,  is the relative dielectric constant of plates.

2. Self-Capacitance: for an **isolated conductor**, self-capacity is the **amount of electrical charge** that must be added to an isolated conductor **to raise its electrical potential** by 1V. Self-capacitance of a conducting sphere of radius  is given by:



3. Classify of Capacitive Touch Screens

If a finger or a conductive stylus is close to the touch screen, human body capacitance is added with capacitance of electrodes.



Figure 1. Typical capacitive touch screen with Indium Tin Oxide(ITO) transparent electrodes.

Capacitive touch screen can be classified into two types: self-capacitance type and Mutual capacitance type.

* Self-Capacitance Touch Screen

sensing the changes on the self-capacitance of electrode



1 2 3 4 5 6

1 2 3 4 5 6 7 8 9 10

If user touches on  point, the self-capacitance of 1st row electrode and 1st column electrode will be changed.

A drawback of self-capacitance touch screens is that they do not unambiguously detect more than one touch. If user touches on  and  points simultaneously, then  and  also can be considered as touch location.

* Mutual Capacitance Touch Screen

It overcomes the ambiguous touches problem by measuring the mutual capacitance between electrodes. For each cross point of row and column electrodes, measure the mutual capacitance between row and column electrodes. Of course, the number of measure increases than self-capacitance type.

*B. System Noise*

- Transient voltage of liquid crystal display(LCD)

- Noise from power supply

- Environmental changes, such as temperature and humidity.

*C. Sensor Requirement*

For accurate detection, space between each electrode should be half of touch object.

- Finger: roughly 5mm.

- Stylus: <2mm.

For 4.3 inch 16:9 screen, 20 rows and 10 columns are needed. (in case of finger touch)

*D. More Sensors than Touches*

In the example of part C, mutual capacitance touch screen needed 20x10=200 sensors. But simultaneous touches are much lesser than the number of sensors. Thus the compressive sensing can be applied in touch screen.

# Capacitive Sensing Techniques

*A. Comparator Based Relaxation Oscillator*

Calculate the capacitance with charging/discharging time.

*B. Charge Transfer*

First stage (Pre-charge): Charge the capacitor with known dc voltage, .

Second stage (Transfer): Connect the reference capacitor with fully charged target capacitor in parallel. Then the potential of capacitor is proportional with target capacitance.



If fully charged, the charge accumulated over  is:

.

When  is connected with , by the conservation of total charge,



which can be rearranged as

.

# Column-Based Sparse Touch Sensing

*A. Measurement Setup*

-Using Charge Transfer sensing method.

--column electrodes

--row electrodes

--times measurement



All the electrodes in a row are driven with the same voltage in the pre-charge stage

Capacitance is measured column-by-column and repeated with different set of row voltage  times.

 measurements of -th column can be combined into the following set of linear equations:

.

Without the constant , we have

.

*B. Sparsity of Touches*

If we know the background capacitance of sensors in column , , the capacitance changes caused by touches on column  can be calculated as



and because of touch input is sparse,  is a sparse vector.

Finally we can obtain



and

,

considering the calibration errors  and measurement errors .

In traditional sensing method,  is an identity matrix with . If  is  matrix with , This problem become compressive sensing problem.

*C. Hardware Implementation of the Pre-charge Matrix*

If the pre-charge matrix (=measurement matrix) is a random Bernoulli matrix, the CS problem can be solved with high probability where the number of measurements



where  is the sparsity of  and  is a small constant.

# Full Panel Sparse Touch Sensing



The set of driven voltage in a row electrode is not same anymore.

All  sensor nodes make a sparse vector.



where ,  and .

These method can decrease total measurements from  to  but increases wire connection from  to , which may be an issue for large screens.

# discussion

After meeting, please write discussion in the meeting and update your presentation file.

Appendix