Massachusetts Institute of Technology

CSAIL

Laser Speckle Photography for Surface Tampering Detection

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Research Qualifying Exam presentation

Surface tampering detection

Before image

Surface tampering detection

Before image

Surface tampering detection

Before image

After image

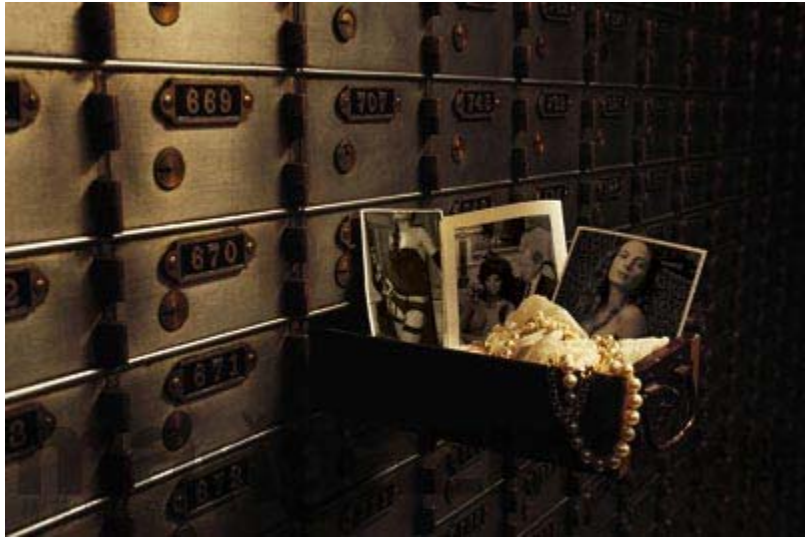
Surface tampering detection

Before image

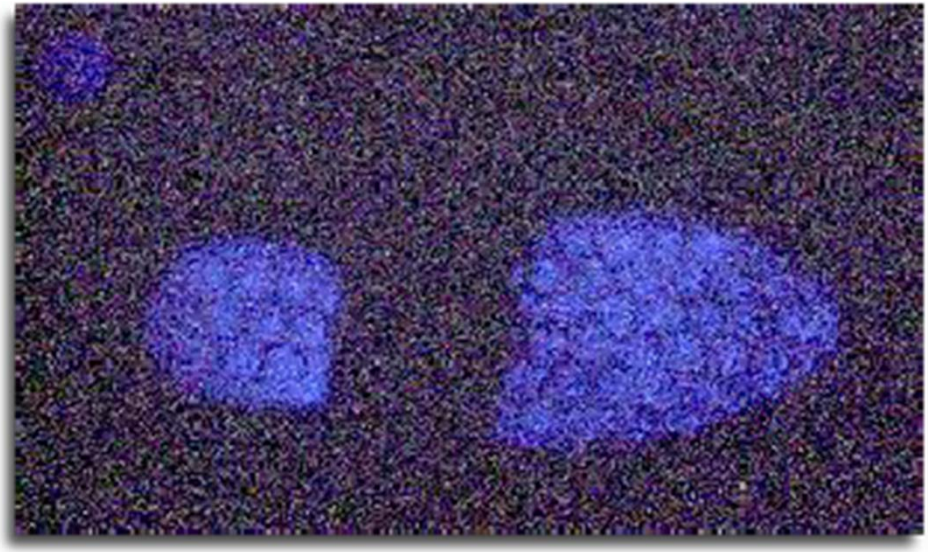
After image

Goal: detect the touched region

Security certification



Safe box



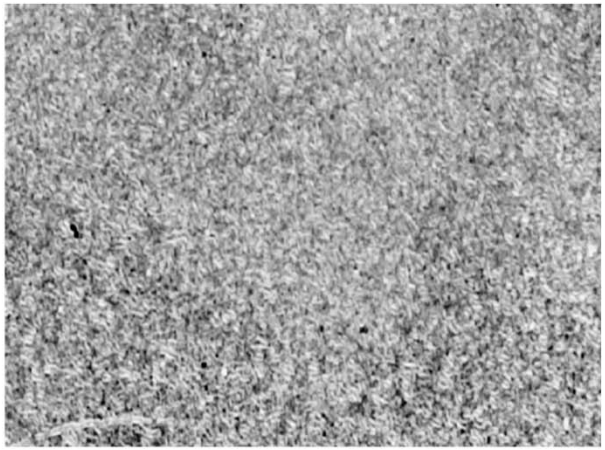
Footprint

Challenging problem

- The difference are minor and invisible

A lab wall (rock sheet)

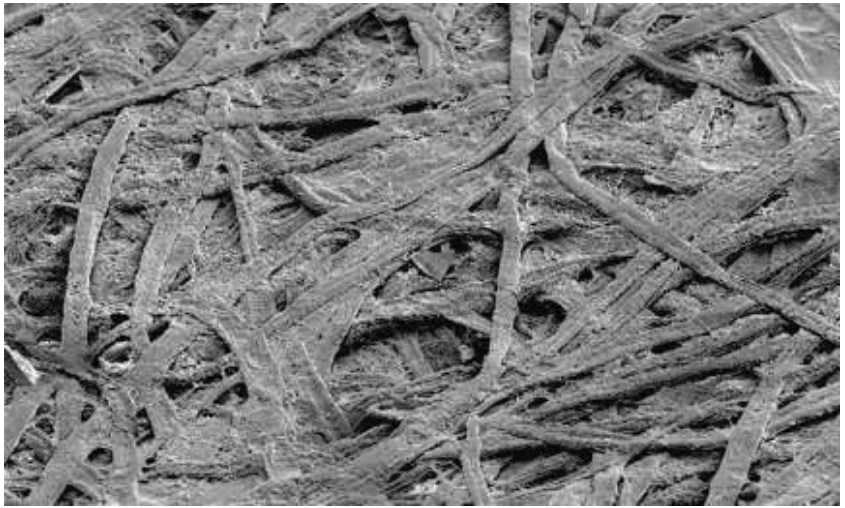
Touched by hand



Difference between before and after images (scale to [0 1]), cannot see anything

Related work: paper authentication

- Certify whether the document is original [Pappu et al 2002][Buchanan et al 2005]
- Use the micro-structure as signatures



Photographed by electronic microscope

Ingenia Techology

Related work: forensic technology

- Rely on bio footprint, eg. blood, perspiration
- Laborious works

Foot print

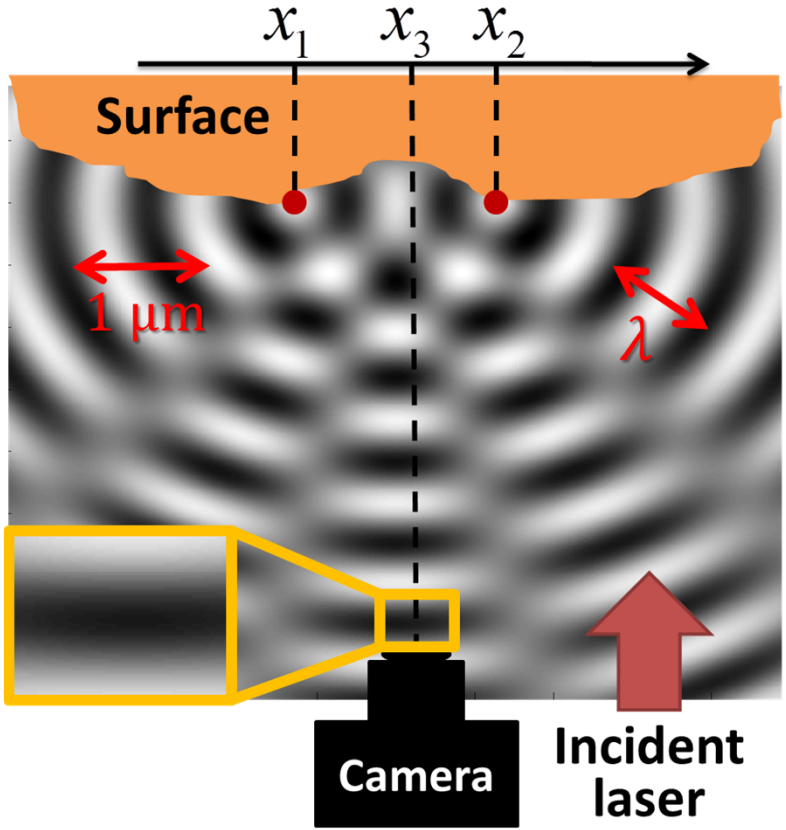
Luminol (blood)

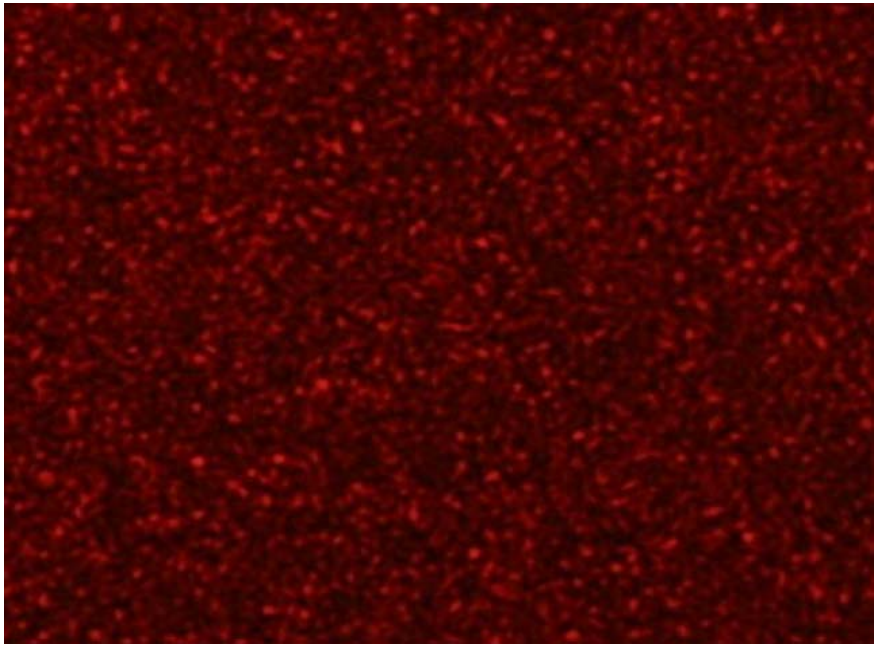
Fingerprint powder

Problem statement

- Input: before and after images
- Output: the region that has been touched
- Automatic, fast, work on various materials

Key idea: laser speckle





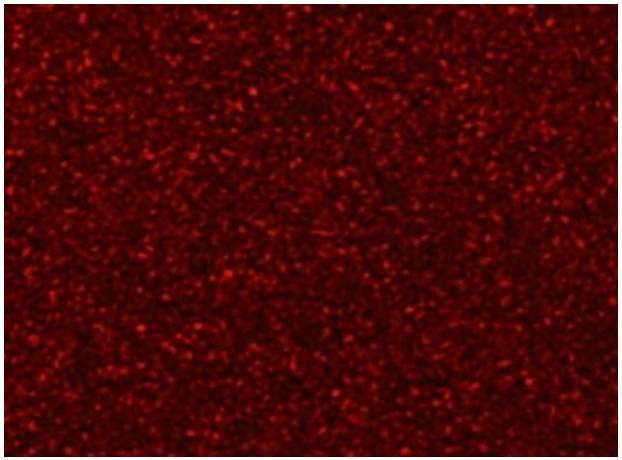
Coherent light causes interference pattern

Laser speckle

- The coherent light causes granular patterns

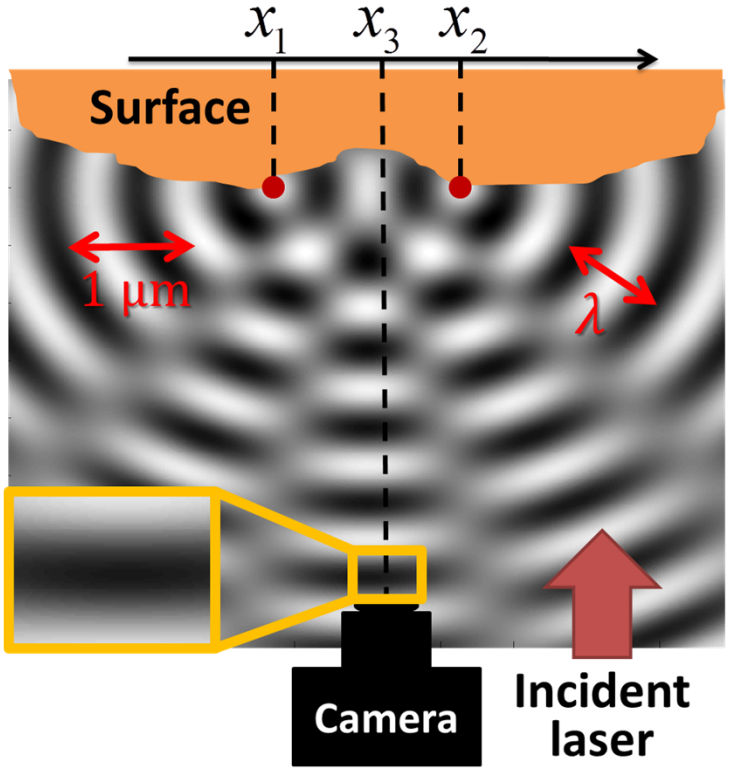
A lab wall

Without coherent light

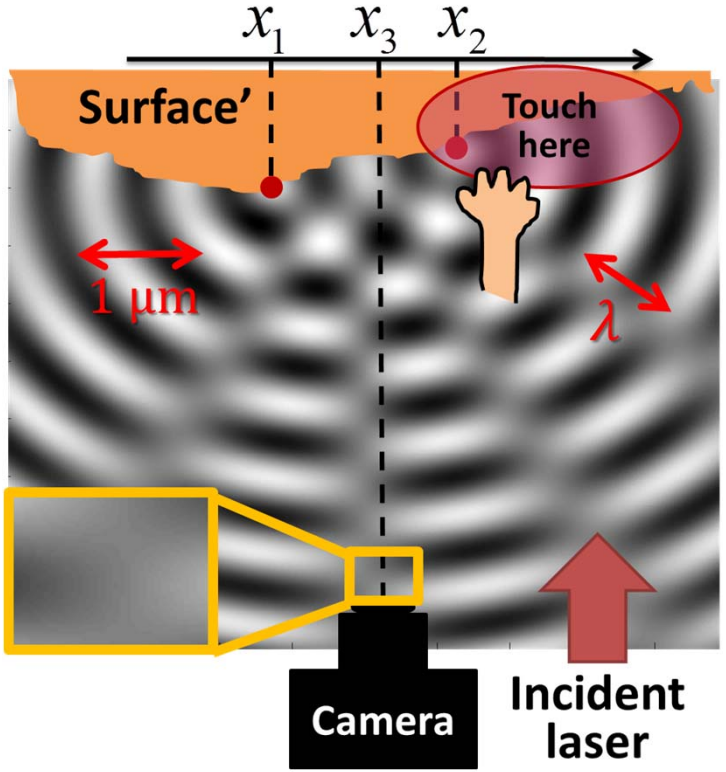


With coherent light
(laser speckle)

Tampering detection



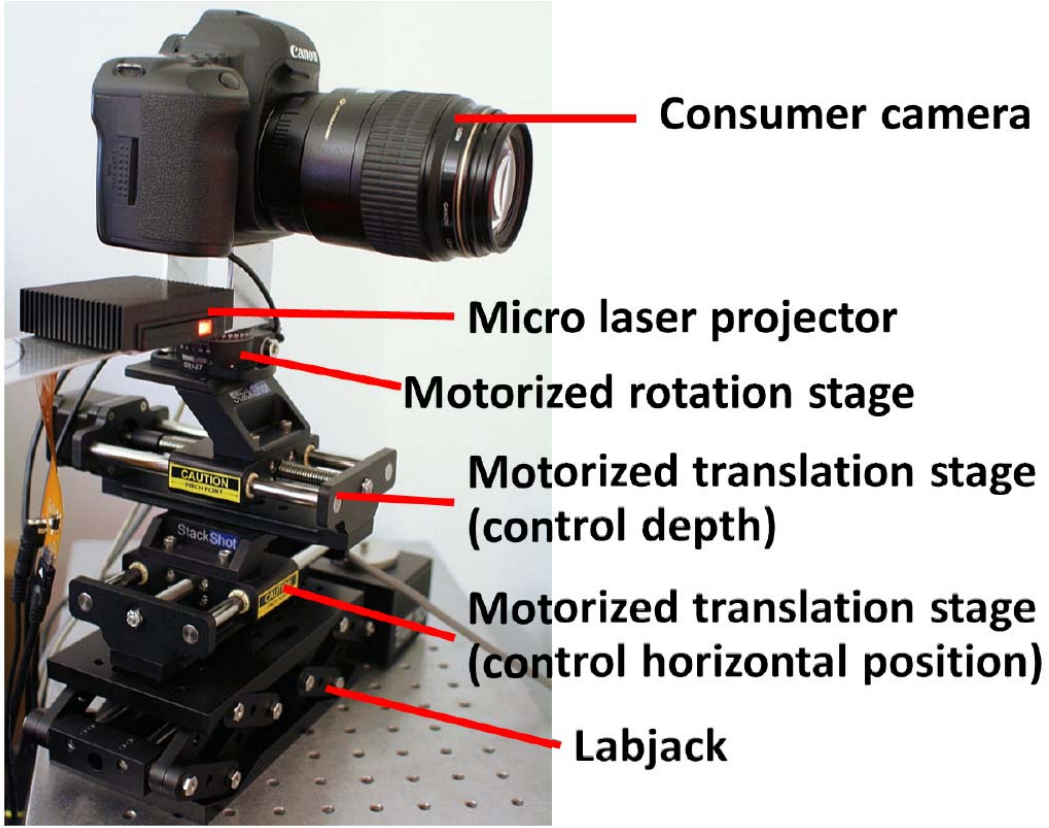
Before touch the surface



After touch the surface, the interference patterns are changed

Hardware overview

- Camera
- Laser scanner
- Controller

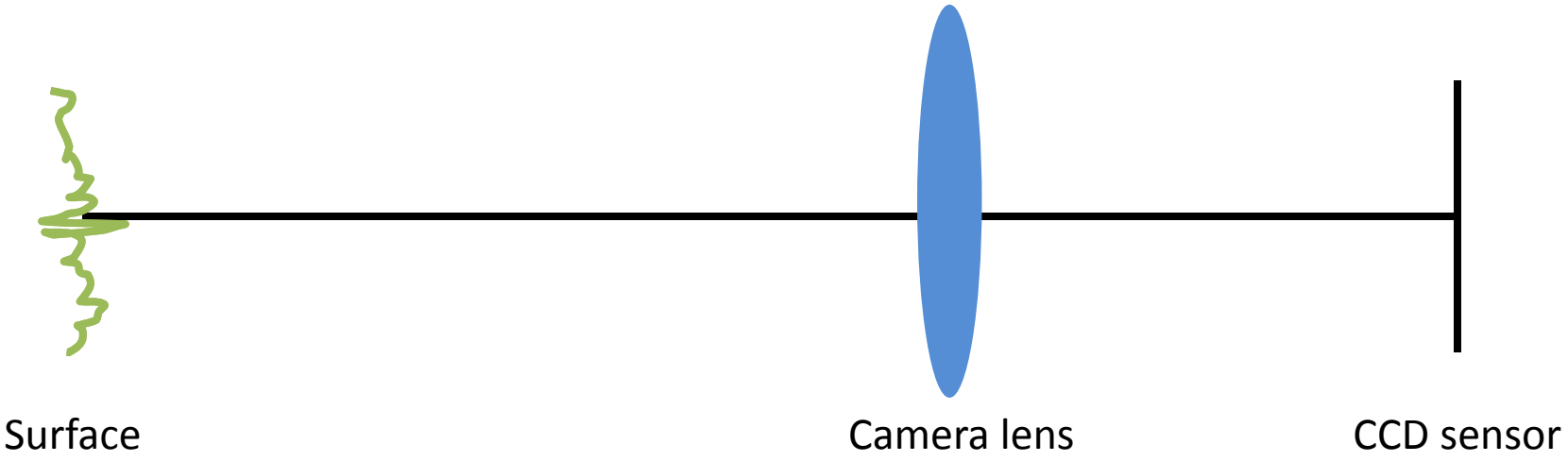


Issues that need to be concerned

- Compute the similarity map
- Camera settings
- Viewpoint alignment

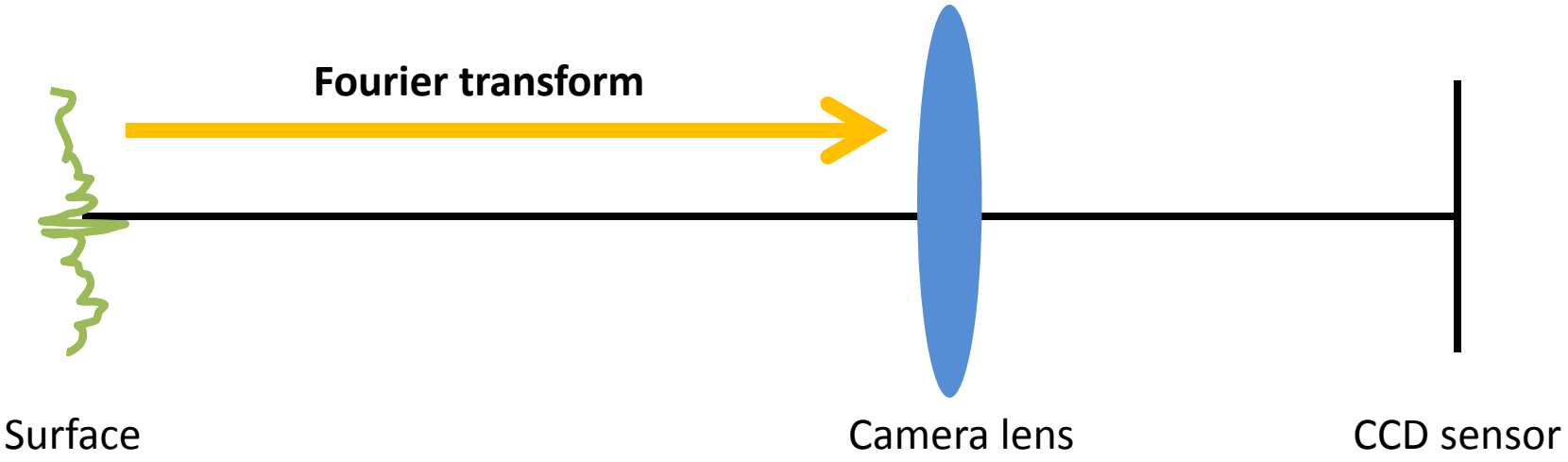
Speckle formation

- Two Fourier transform + low-pass filtering



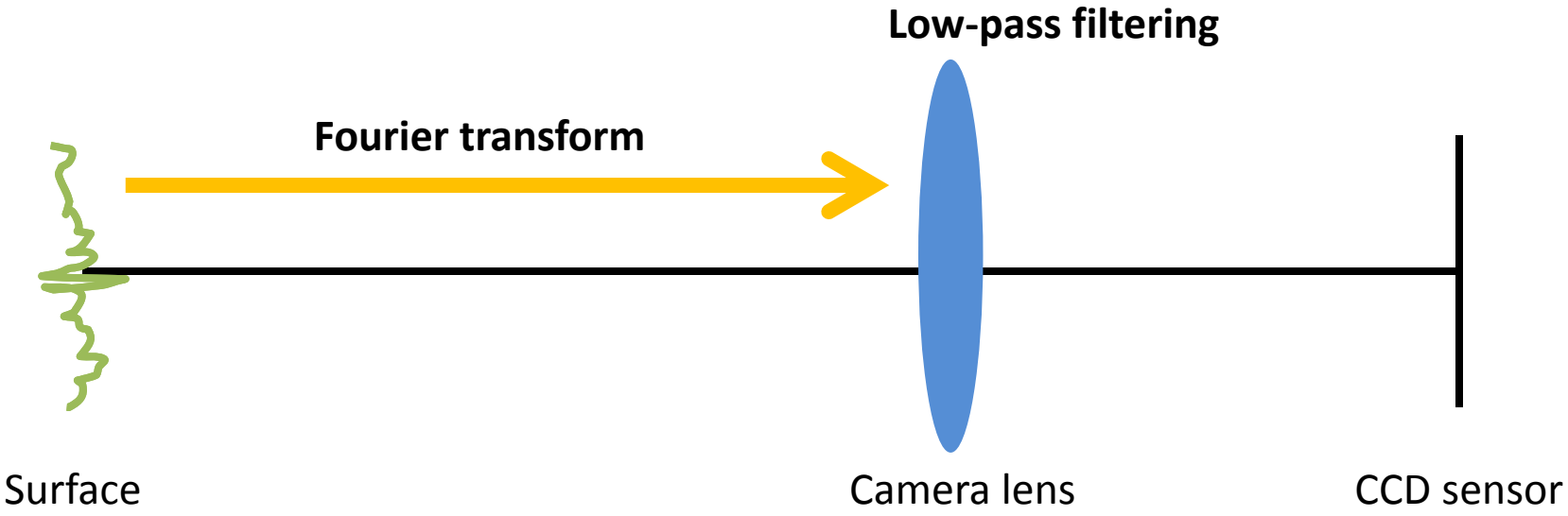
Speckle formation

- Two Fourier transform + low-pass filtering



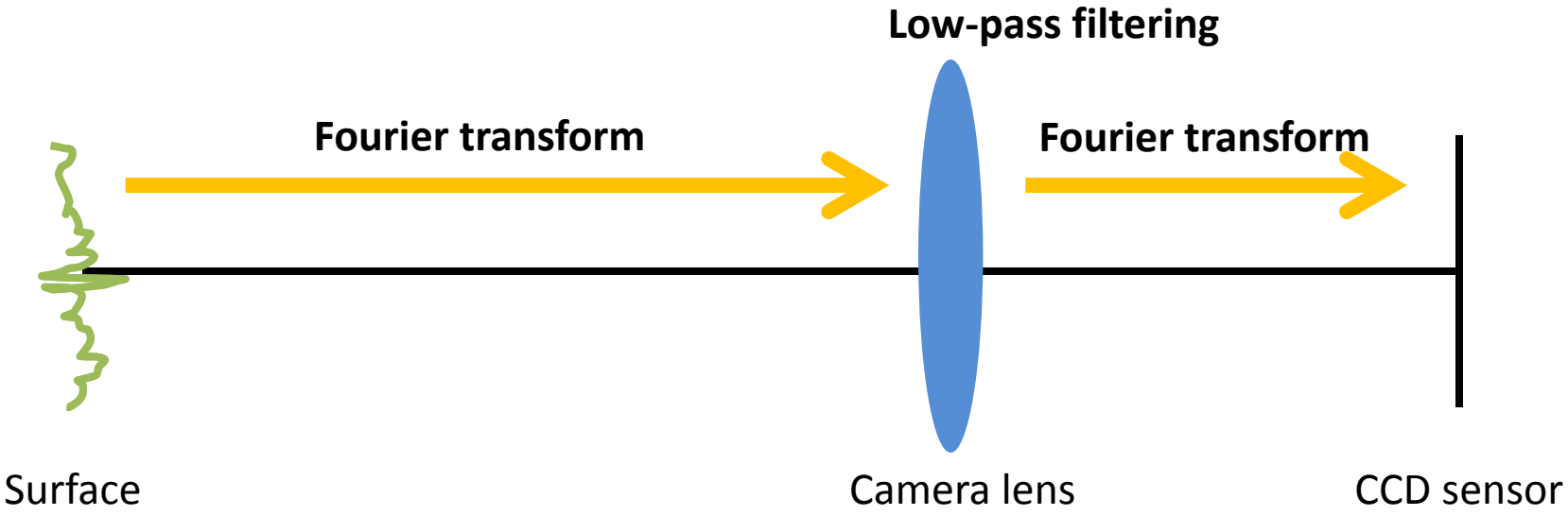
Speckle formation

- Two Fourier transform + low-pass filtering



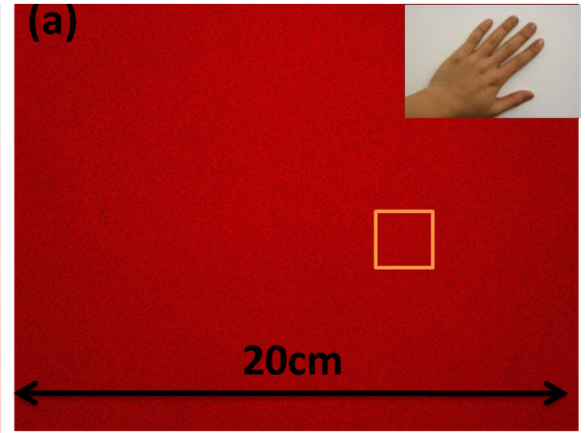
Speckle formation

- Two Fourier transform + low-pass filtering

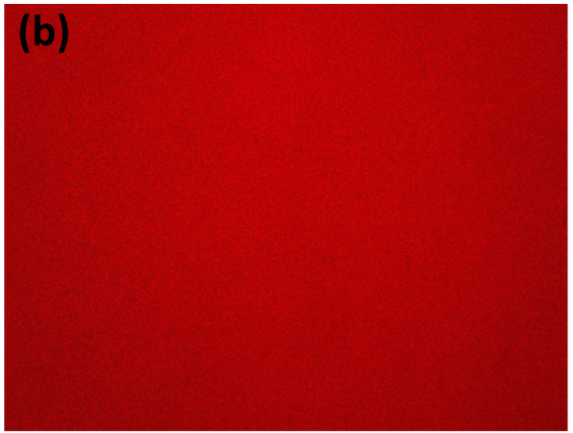


Identifying the tampered regions

- The speckle changes are local
- We use normalized cross correlation (NCC)



Before (speckle image)

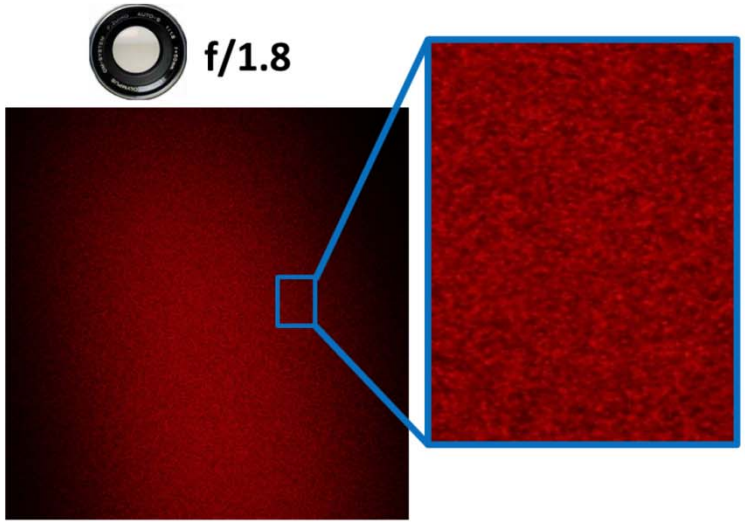


After

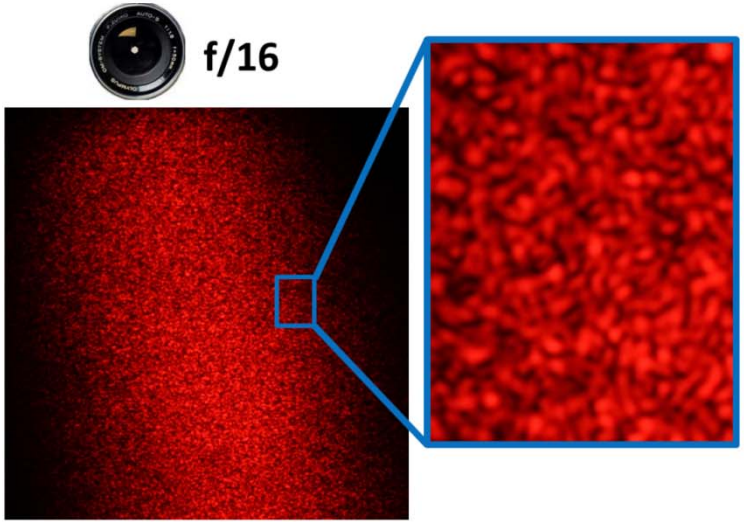
Similarity map by NCC

Camera settings

- Aperture cannot be too large or too small
- f/6.7 works best experimentally



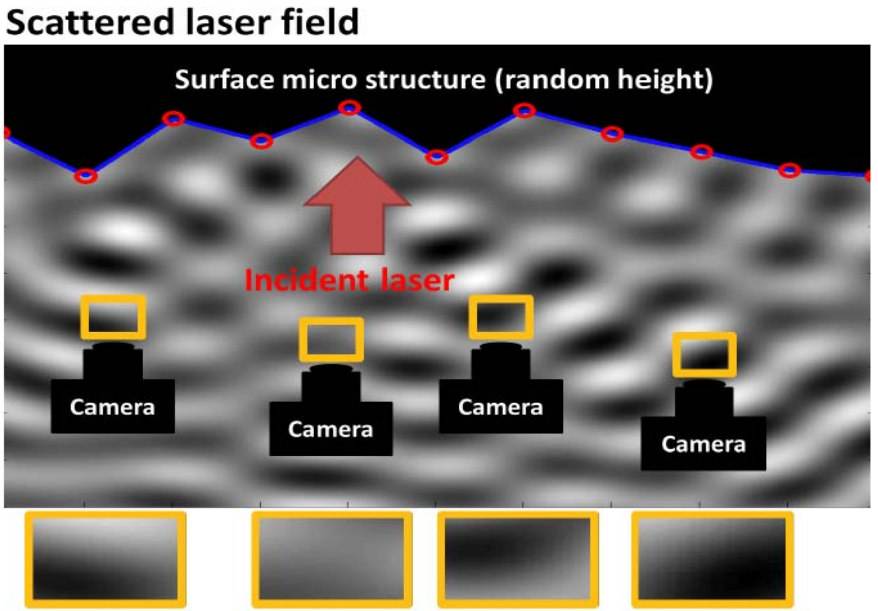
Aperture too **large**: low contrast



Too **small**: no high-frequency, lost locality

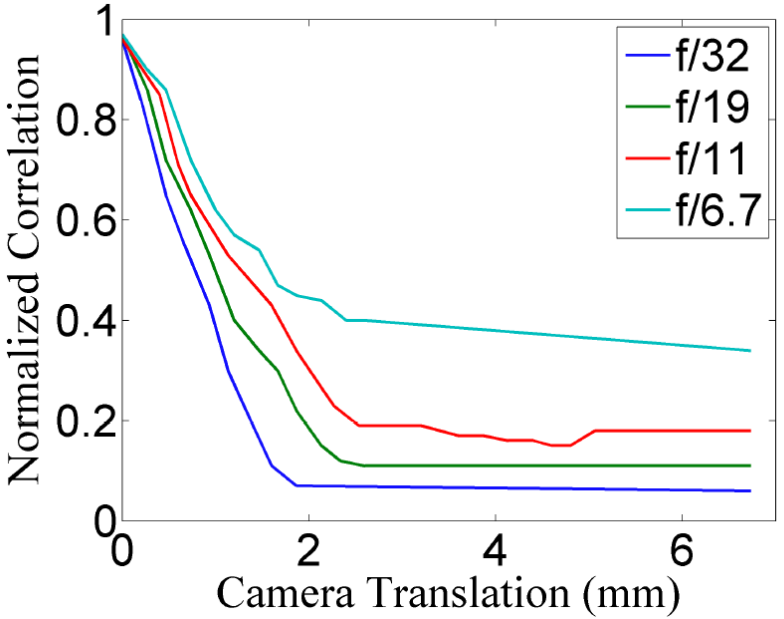
Viewpoint registration

- Challenge: speckle is very sensitive to viewpoint change



Very tight accuracy goal

- Require the distance between the two viewpoints < 1mm



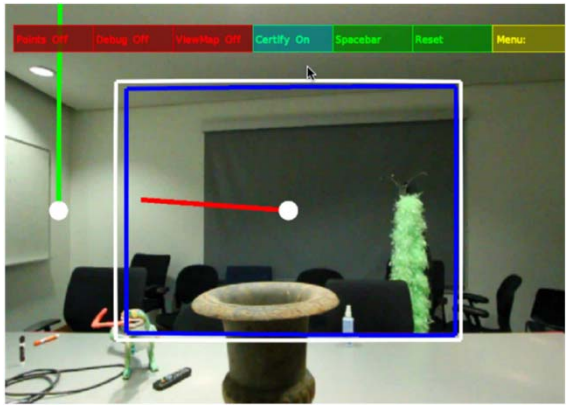
Our approach: two-step alignment

- Step 1: vision-based alignment
  - tolerance ~10 mm

- Step 2: speckle-based alignment
  - tolerance < 1mm

Coarse alignment by scene features

- Based on parallel tracking and mapping (PTAM)
- Feedbacks to guide user control
- A few minutes to reach the viewpoint with 3mm accuracy



User interface

Fine alignment by speckles

- Utilize the speckle sensitivity to viewpoint
- Densely sample between [-5mm, 5mm]
- Accurate to 0.5mm

Results

A lab wall

Touched by hand

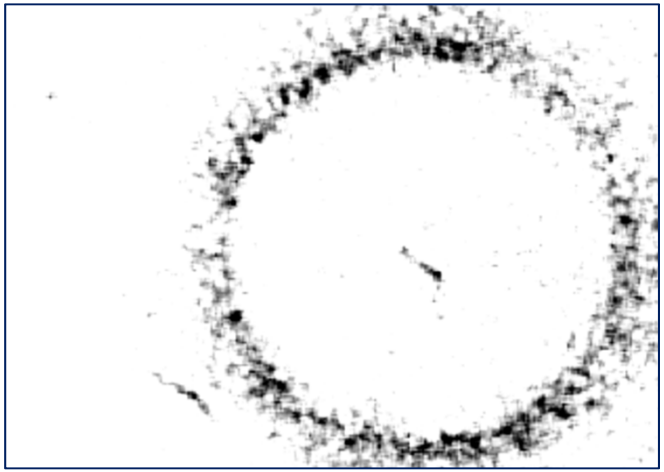
Output: the touched region

Light-weight objects

- A quarter on a card box (5.67g)

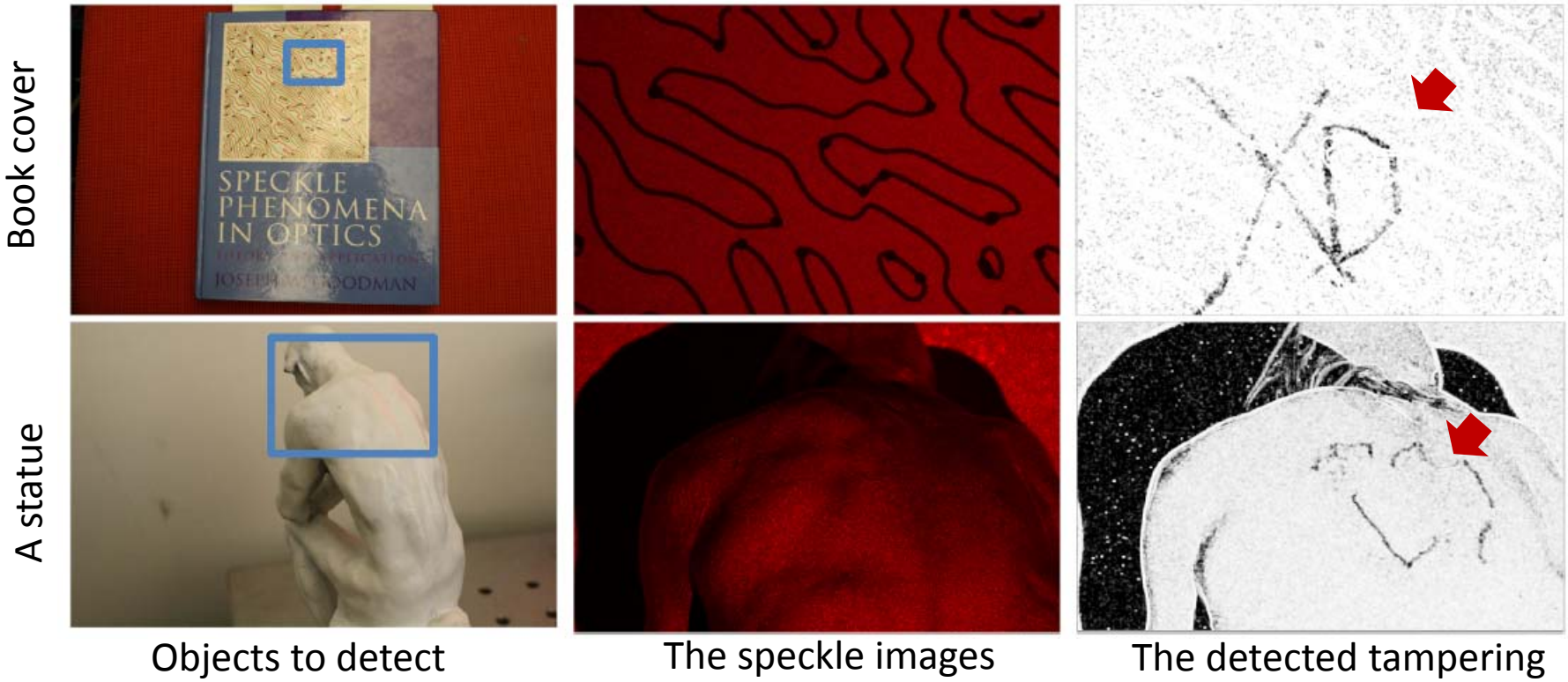
A card box

A quarter (5.67g)



Output: the detected tampered region

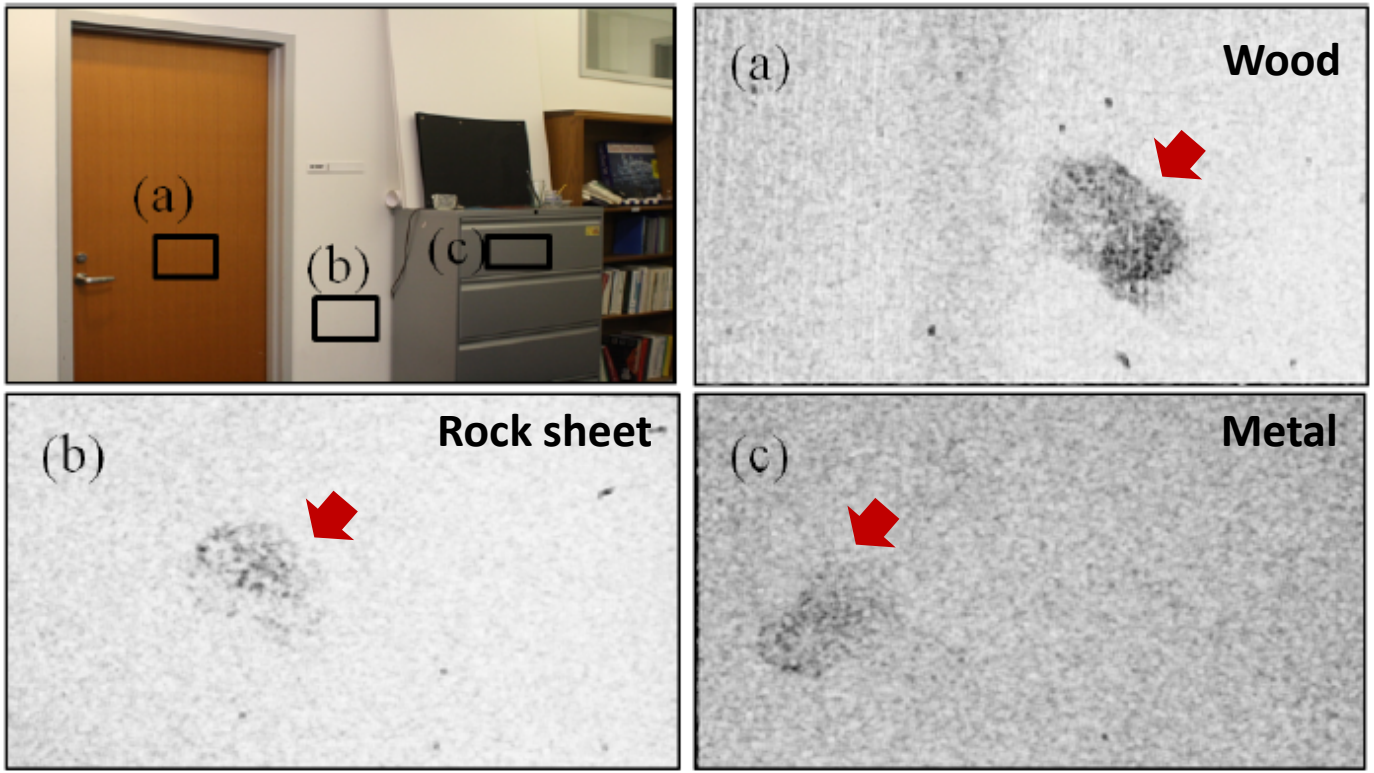
More materials



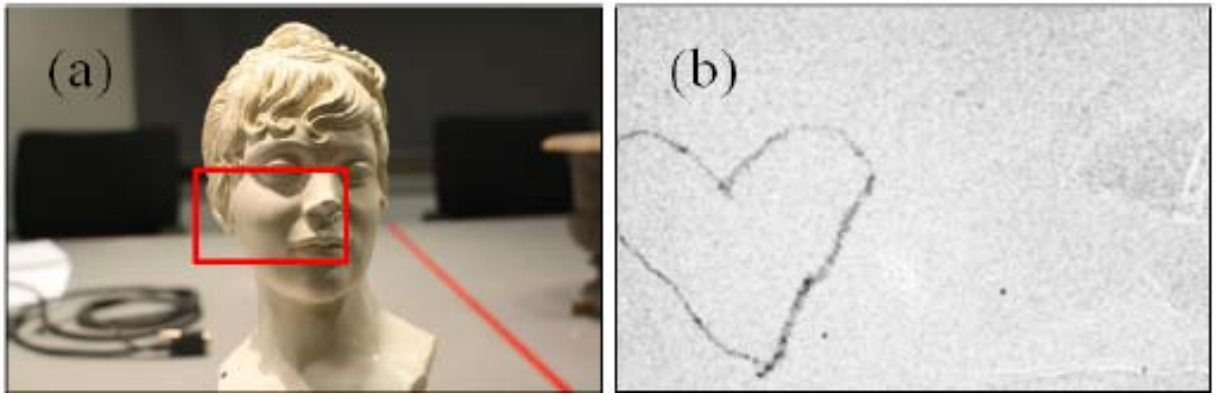

Metal case
Plastic case
Cement floor
RadioShack
FLATFOTO
Canon
Objects to detect
The speckle images
The detected tampering

Indoor scene

- Touched by a finger



Curved surface



Objects to detect

The detected tampering

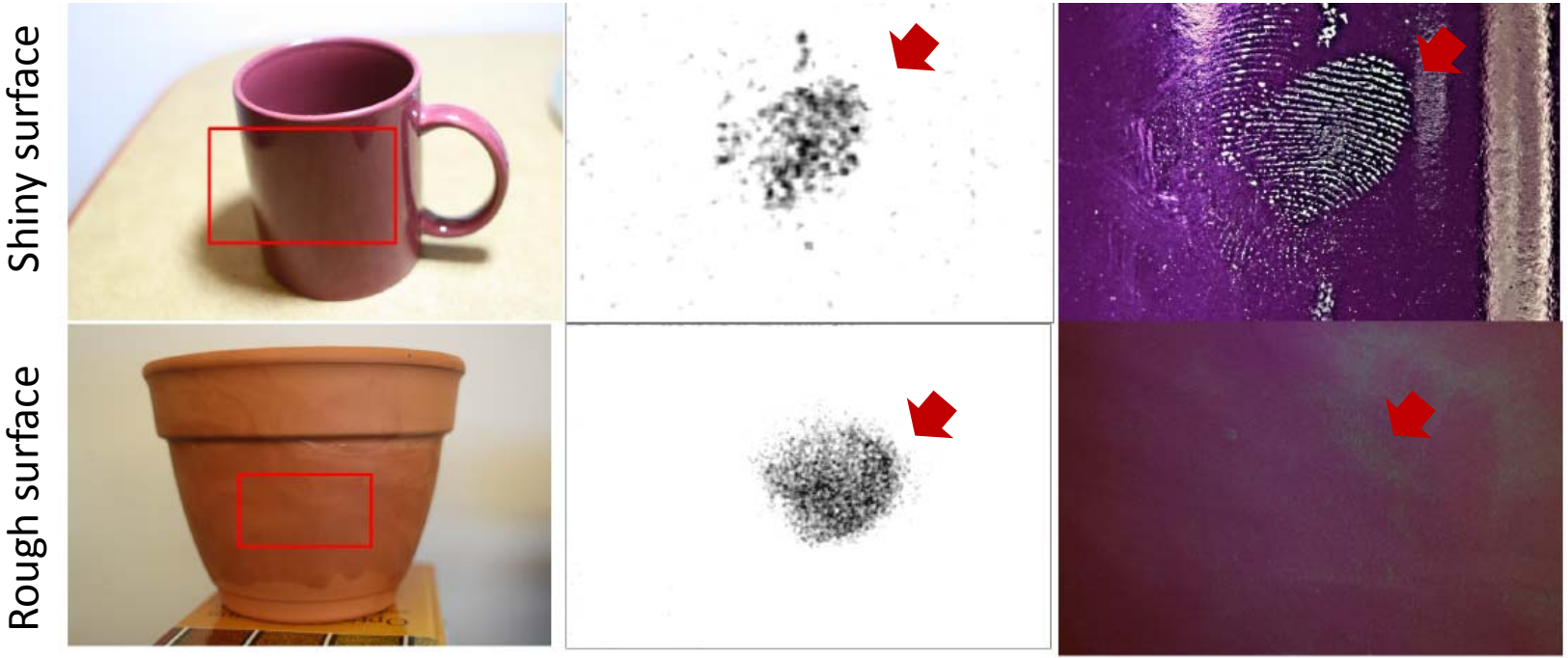
Textured surface

Objects to detect

The detected tampering

Comparisons to forensic techniques

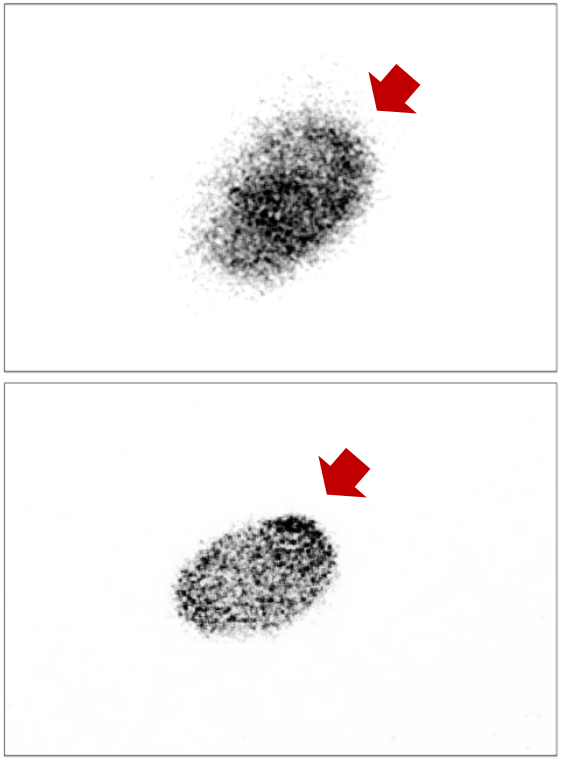
- Touched by a finger



With gloves

Without gloves

With gloves



Our speckle-based method

Fingerprint powder

Using the system

- See the video!

Demo at CVPR12

1

Take a reference laser speckle image

2

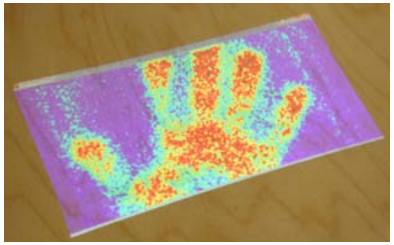
Touch the surface

3

Take an “after” laser speckle image

4

Normalized correlation reveals the tampered area



Conclusion: seeing invisibles

- Seeing the invincible difference between two images
- Key idea: using laser speckle images
- Viewpoint alignment with high accuracy

A lab wall

Touched by hand

Output: the touched region

Acknowledgements

- We thank MicroVision for donation of equipment, and acknowledge gifts from Microsoft Research and Texas Instruments, and funding from NSF CGV No.1111415.

Conclusion: seeing invisibles

- Seeing the invisible difference between two images
- Key idea: using laser speckle images
- Viewpoint alignment with high accuracy

A lab wall

Touched by hand

Output: the touched region