FACE FLASHING:
A SECURE LIVENESS DETECTION PROTOCOL BASED ON LIGHT REFLECTIONS

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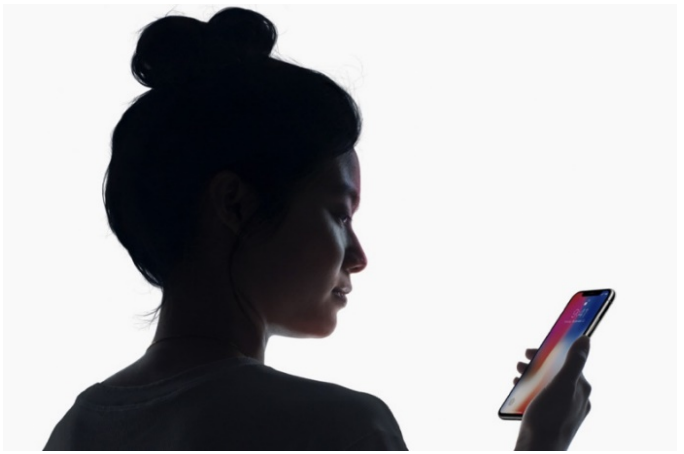
Face-based Authentication Will Become Popular

Online payment

ATM withdraw

Door entrance

Phone unlock



Face Recognition Is Not Enough

Easy-obtained faces

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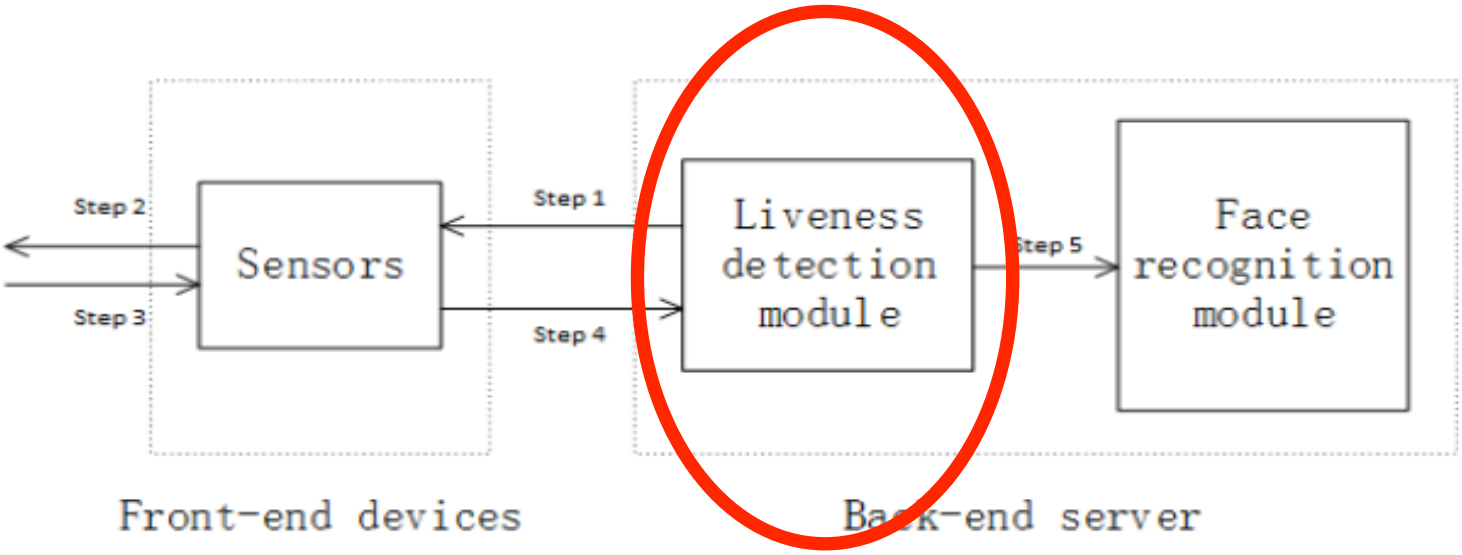
Easy-obtained faces

High-resolution printers/screens

Powerful CPUs/GPUs

Developed technologies

Liveness Detection Is Necessary



Detect whether
the subject under authentication
is a real human

Liveness Detection Is Hard to Be Done Right

Texture extraction methods:

- Local Binary Pattern (LBP)
- 2D Fourier Spectra
- …

High-resolution screen will fail it.

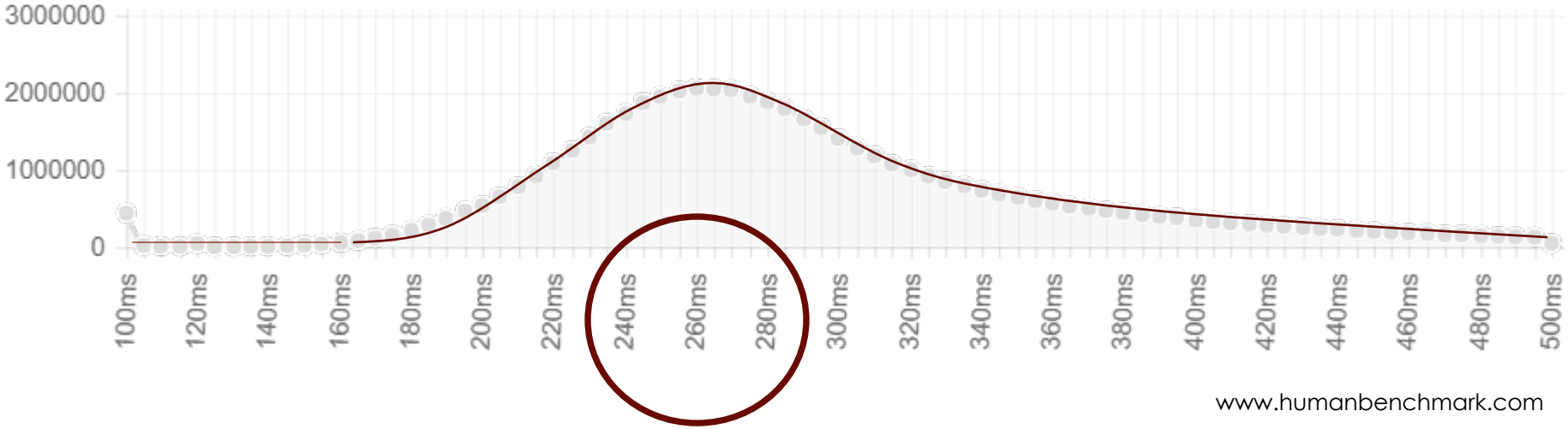
---- It can outputs any patterns you want

Liveness Detection Is Hard to Be Done Right

Challenge-response protocols:

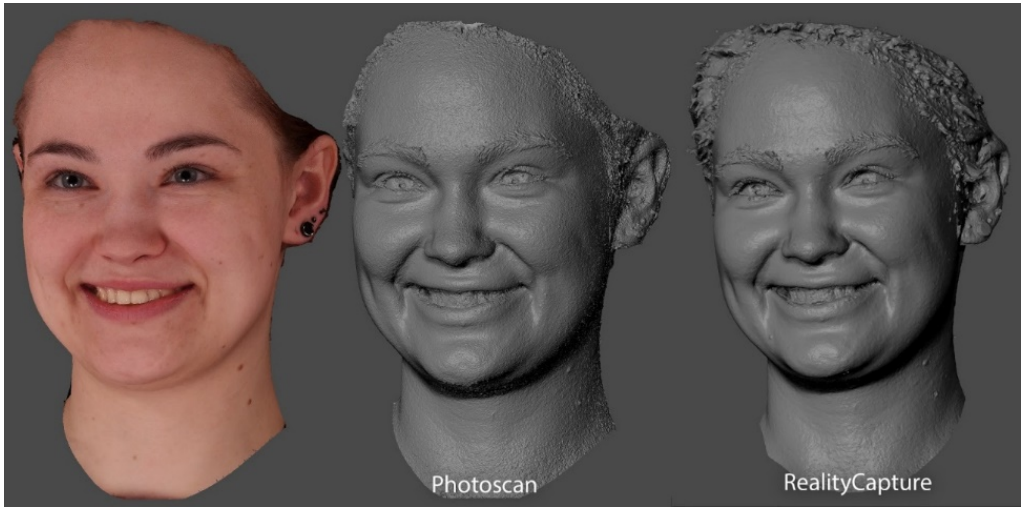
- Eye blink
- Expression
- Head movement
- Speaking

Human Reaction Time

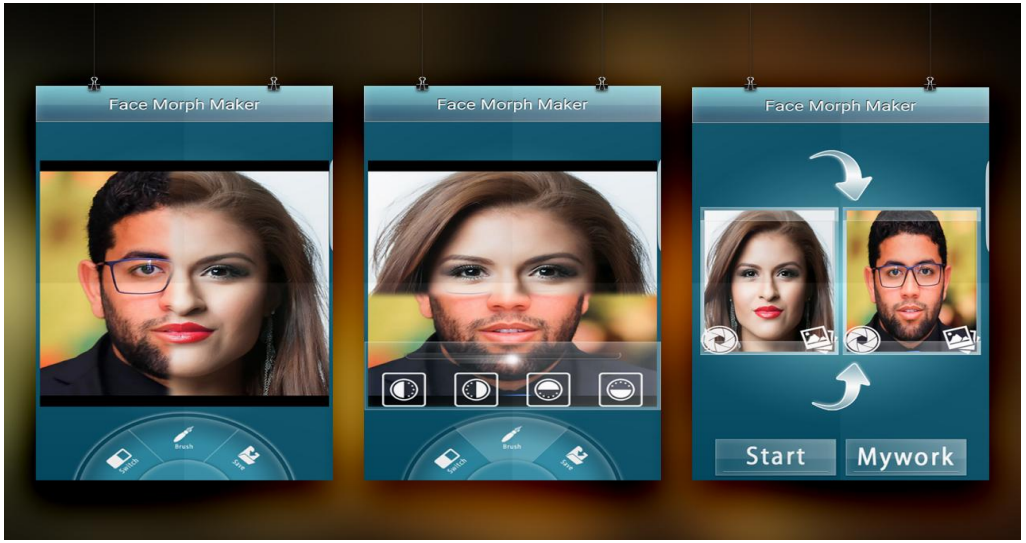


Machines can do10^9 flops, in 260MS

Machines Are Powerful



3D reconstruction



Face morphing

Machines Are Powerful

Expression synthesizing

Fundamental Problem ?

Fundamental Problem ?

No strong security guarantee!

~~Details~~ ~~Precision~~

~~Trembling~~ ~~Ability~~

Weakness of Human Reactions

Limited speed

Uncertainty

Smart device + Screen can fail it

- 2D dynamic attacks (e.g., Media-based Facial Forgery)

What We Want to Do?

Solid stone
to build a secure protocol

~~Human reaction~~

Relieve threats
from 2D dynamic attacks

Non-digital
physical

Light reflection

Features of Light Reflection

Fastest in the universe

-- No computers can generate fake responses at the same speed, no matter how powerful it will be

Without human reaction

Can capture rich information

-- 3D shape -> eyes, nose

-- Texture -> skin vs. non-skin

Reflection Model

$$I_c(x) = \int_{\Omega} E(x,\lambda) R(x,\lambda) S_c(\lambda) d\lambda, c \in \{r, g, b\}$$

E: Illumination
R: Reflectance
S: Sensor response function
λ : Wave length
x : position of a given point

We will separately consider R,G,B channels.
There are no inter-effect among them,
if we use the raw data (before AWB).

Reflection Model

$$I_c = E_c \times R_c, c \in \{r, g, b\}$$

E: Incoming light
R: Reflectance

Get reflectance:

To check face

$$\frac{I_c(x)}{I_c(y)} = \frac{R_c(x)}{R_c(y)}, c \in \{r, g, b\}$$

Get illumination:

To check time

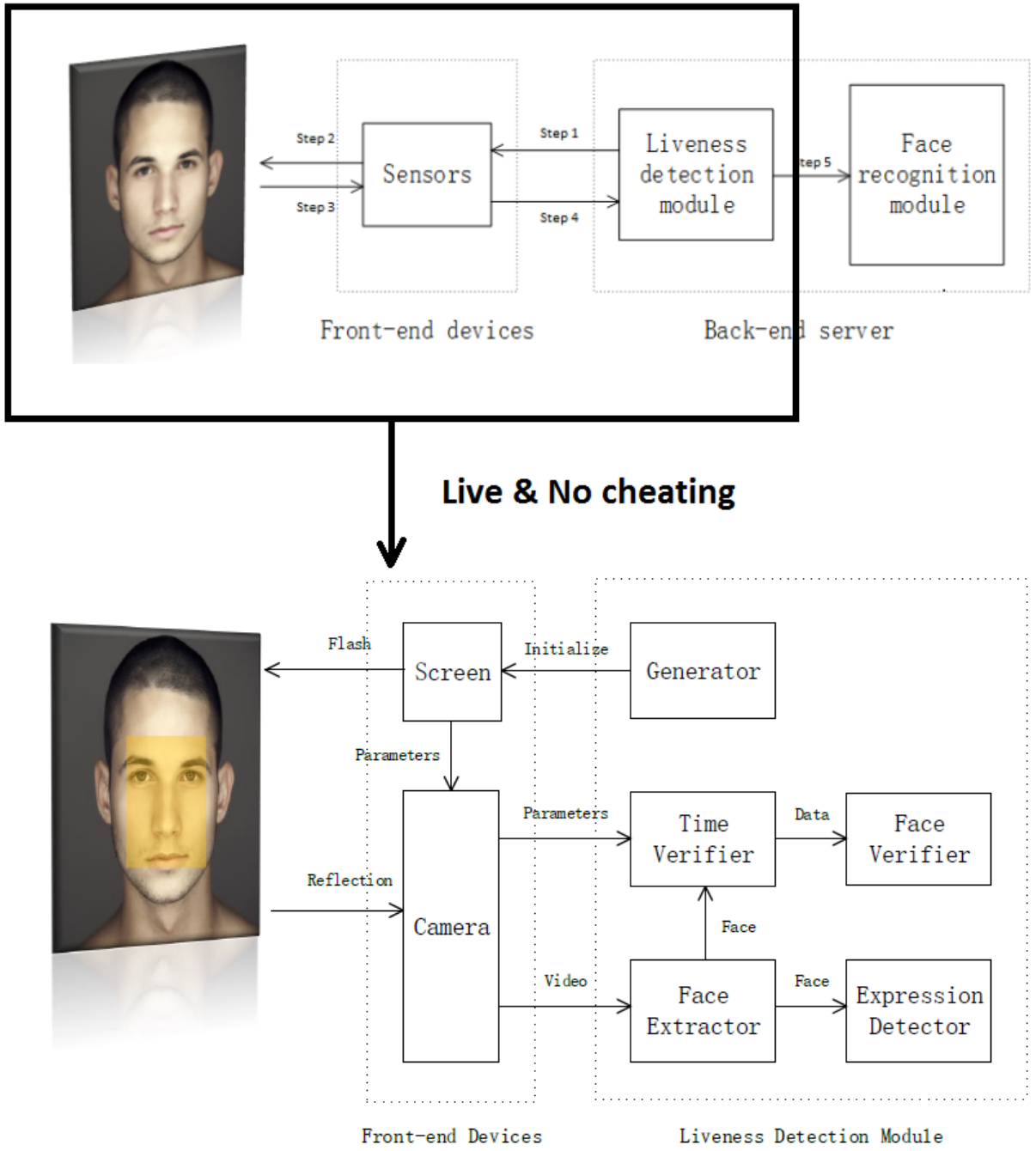
$$\frac{I_{c1}(x)}{I_{c2}(x)} = \frac{E_{c1}(x)}{E_{c2}(x)}, c1, c2 \in \{r, g, b\}$$

The reflections is determined by incoming light
Without knowing the incoming light, it is impossible to pre-calculate the reflected light.

Design

Things to verify:

1. **Response time**
2. **Face information**
3. **Expressions**



Verifying the Timing is Difficult

Challenging!!

Reflections happen at speed of light

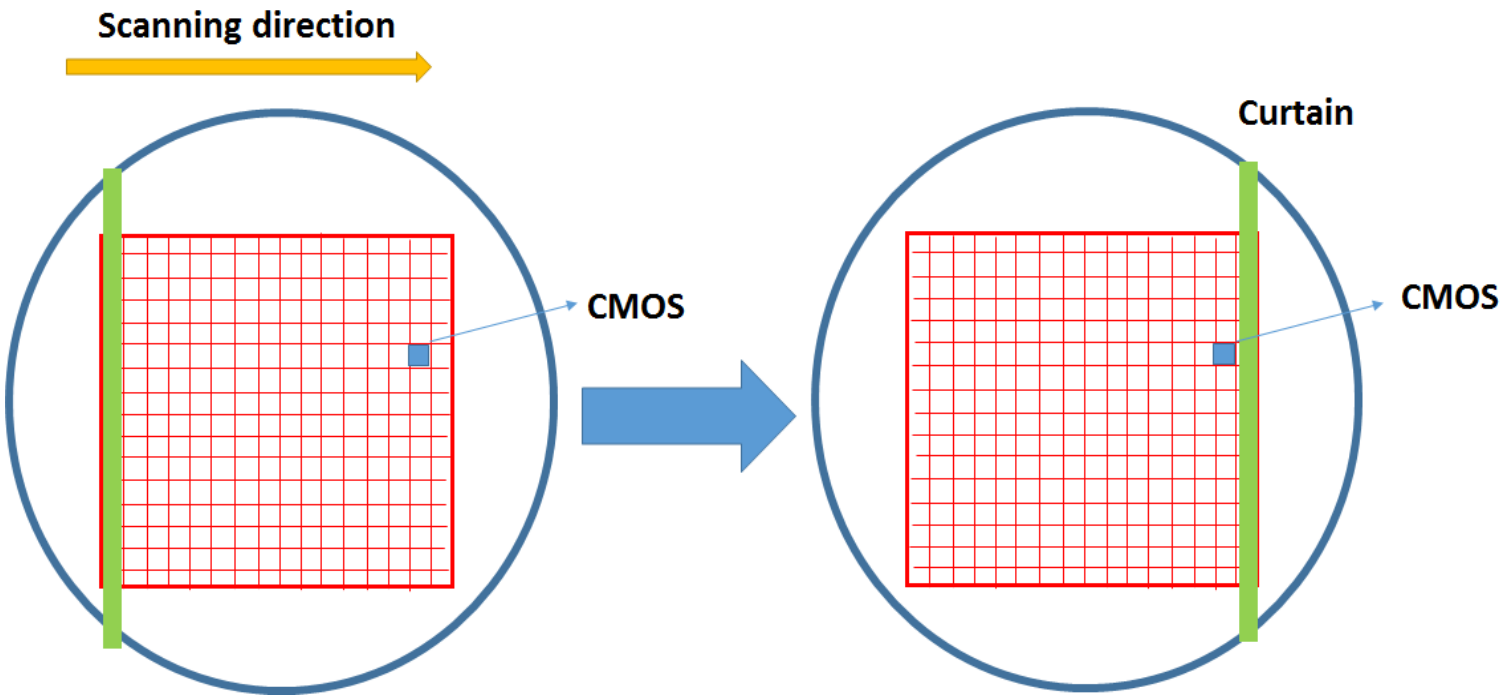
But camera is not

Limited by the refreshing speed

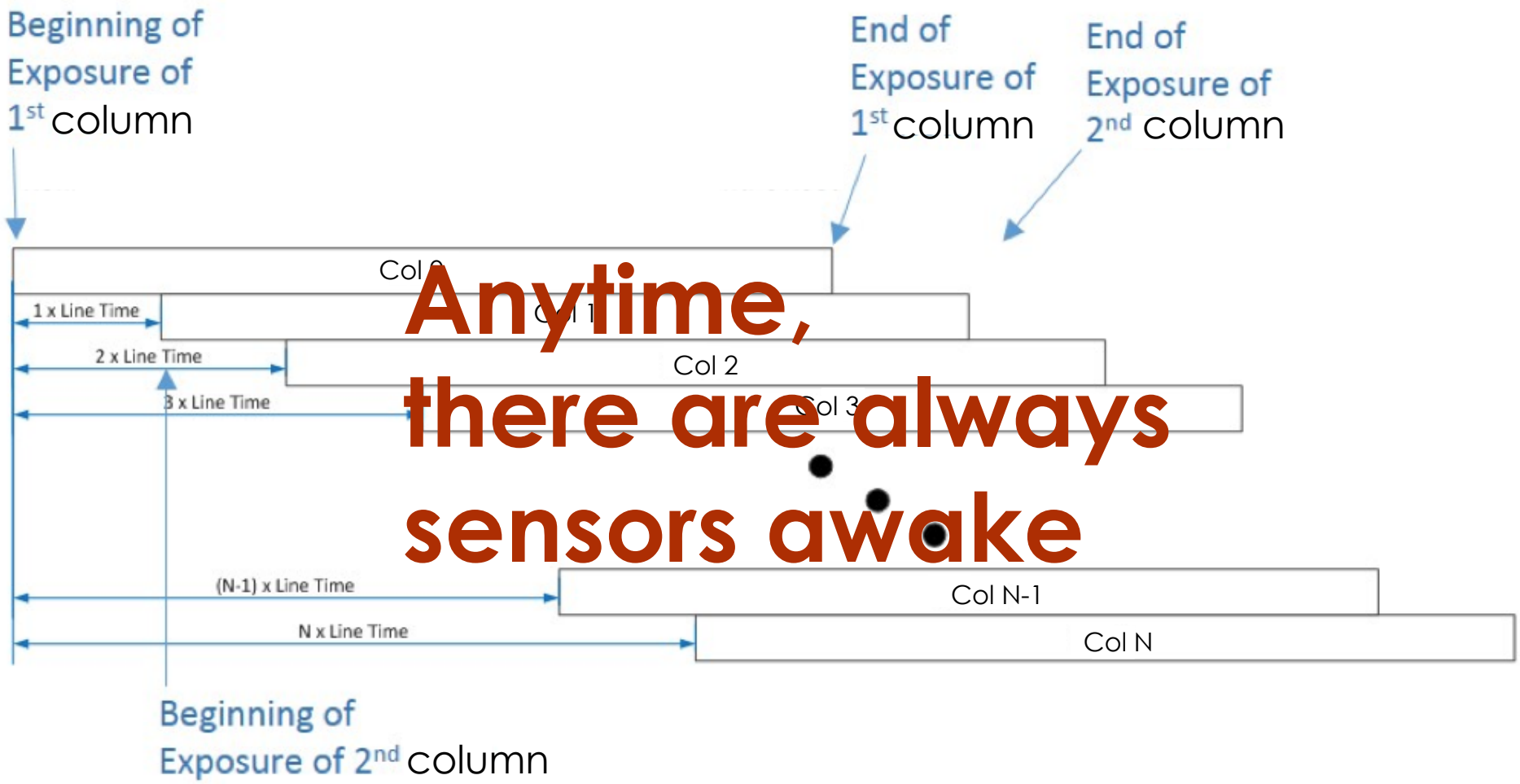
→ around 30 fps

Does it mean powerful attackers with high speed camera and displaying devices can bypass?

Working Details of Camera



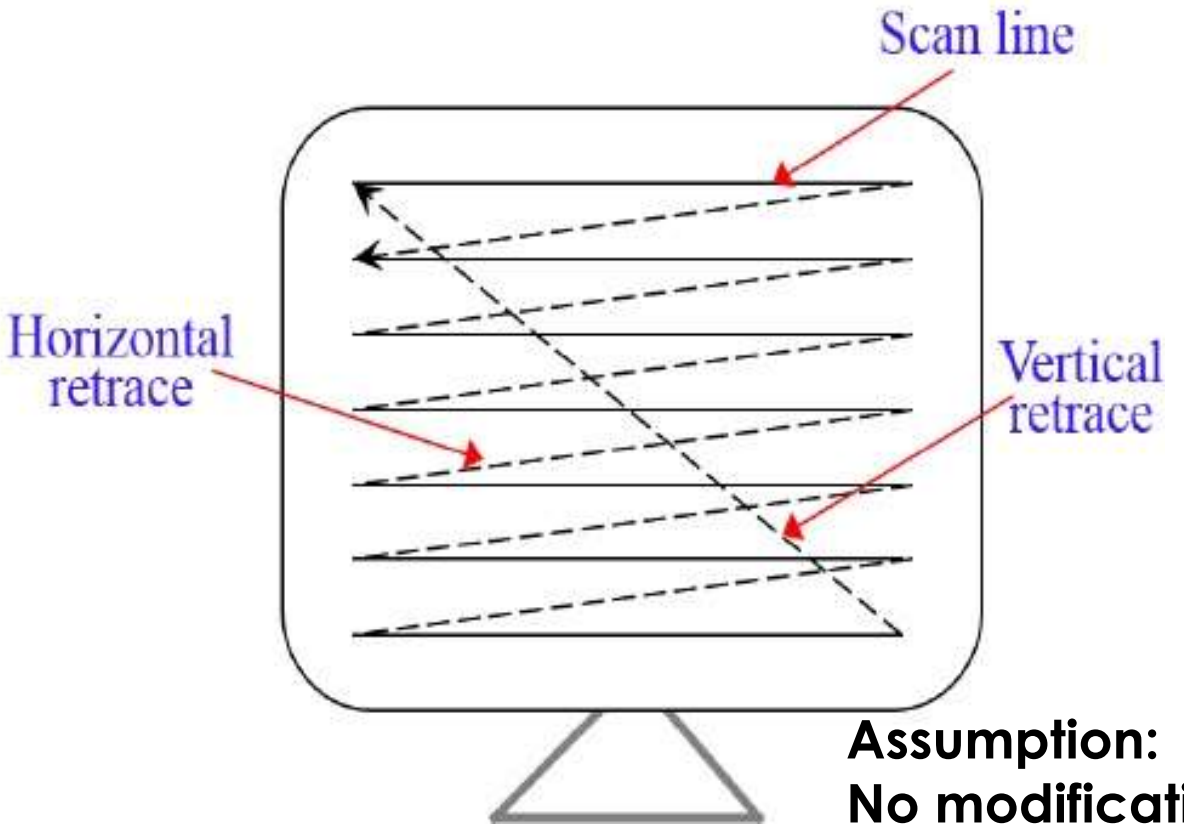
Working Details of Camera



Anytime, there are always sensors awake

Detecting tiny differences in time is possible

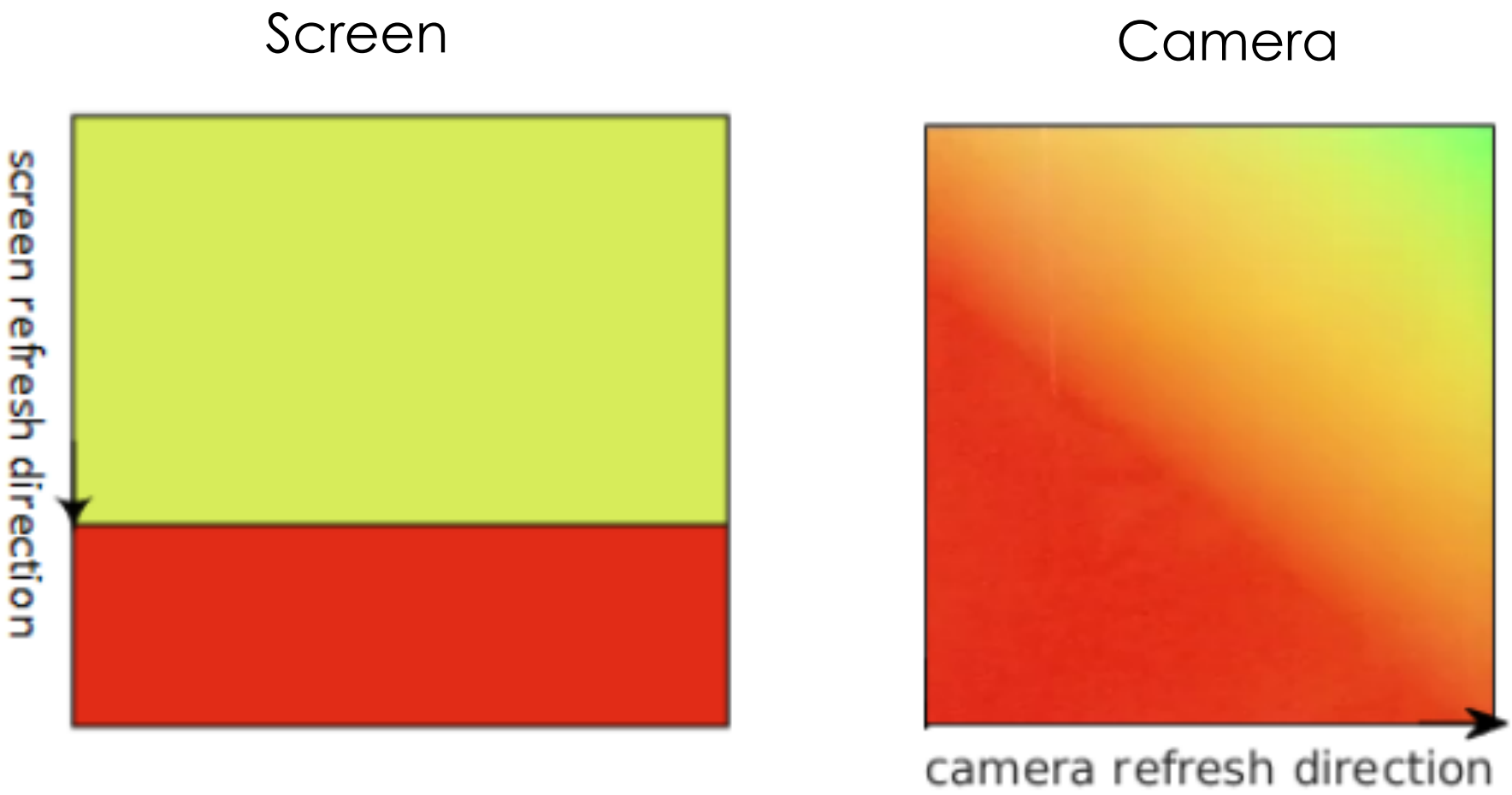
Working Details of Screen



Assumption:
No modification can be added to the buffer that is being displayed

Both camera and LCD monitor work in a scanning pattern. So what will happen?

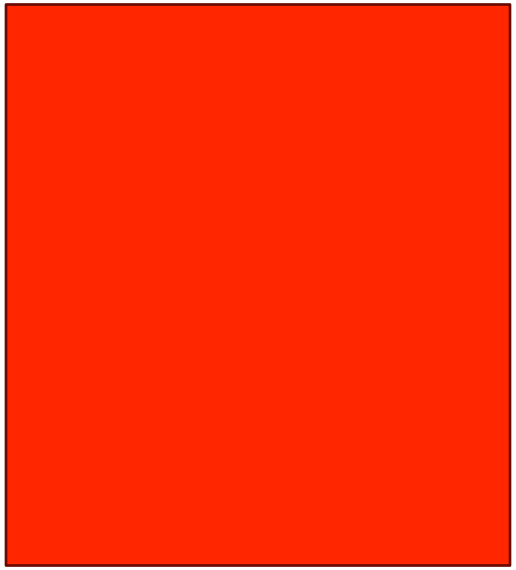
Partially Captured Images



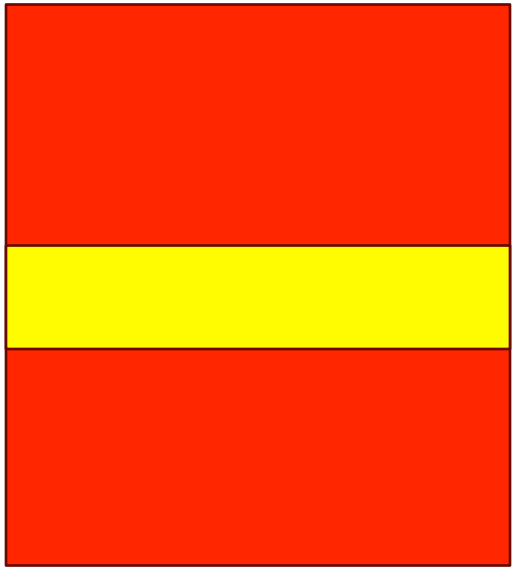
How to verify?

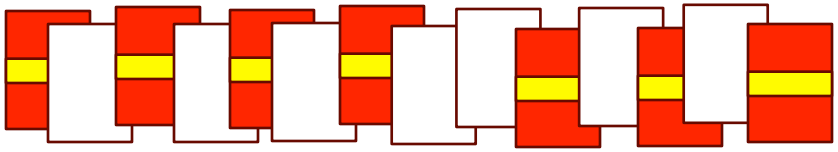
Challenges

Background challenge

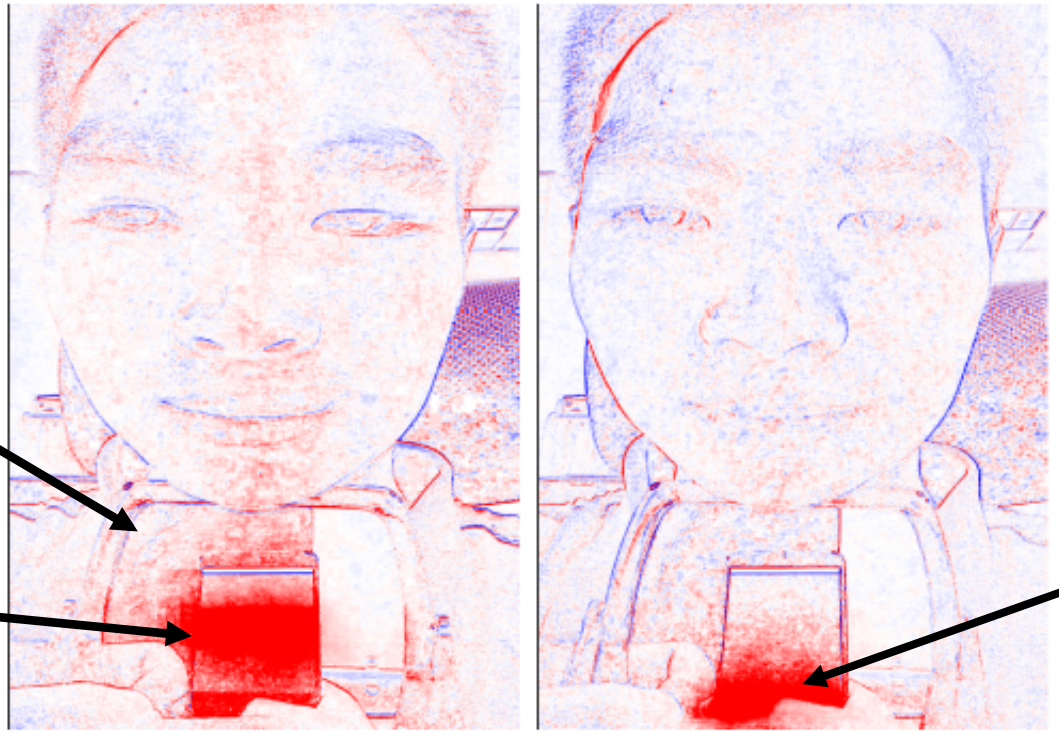


Lighting challenge





Response and Challenge



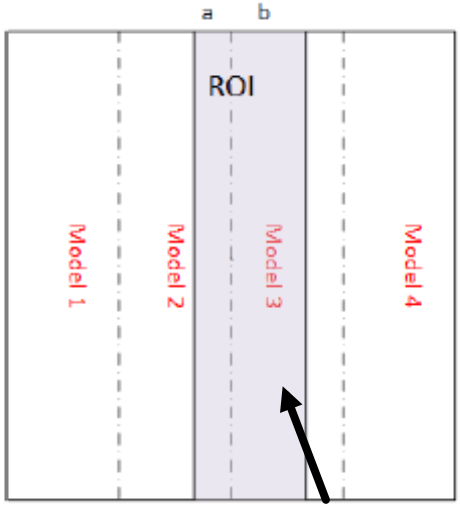
Get challenges:

$$\frac{I_{c1}(x)}{I_{c2}(x)} = \frac{E_{c1}(x)}{E_{c2}(x)}, c1, c2 \in \{r, g, b\}$$

Calculate the Location

The Challenge image
(with lighting area)

Camera



Corresponding region

Forgery -> Delay -> Wrong location

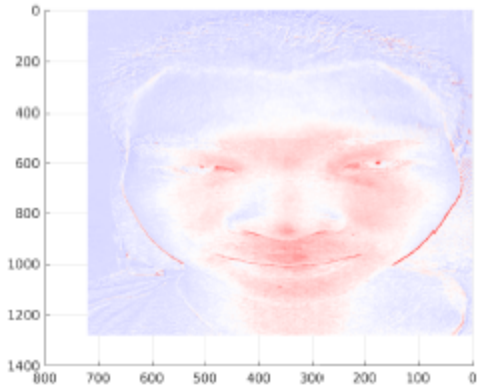
Accumulation:

$$d_i = \hat{y}_i - \frac{u_i + d_i}{2}$$

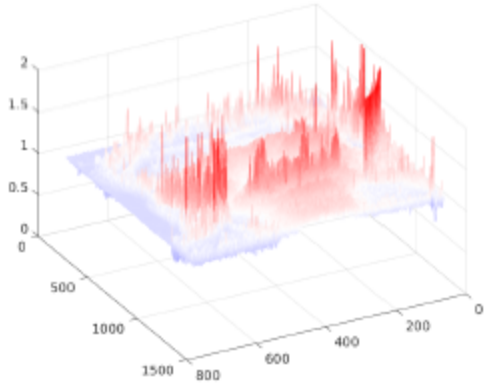
$$mean_d = \frac{\sum_{i=1}^{n} d_i}{n}$$

$$std_d^2 = \frac{\sum_{i=1}^{n} (d_i - mean_d)^2}{n-1}$$

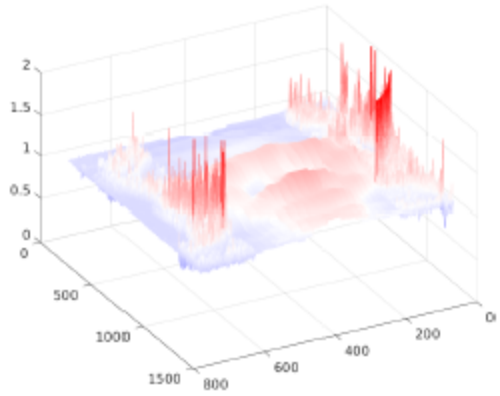
Face Feature Verification



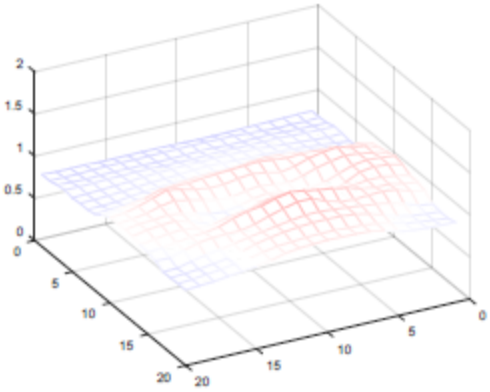
(a) midterm result



(b) midterm result



(c) abstract result



(d) resize result

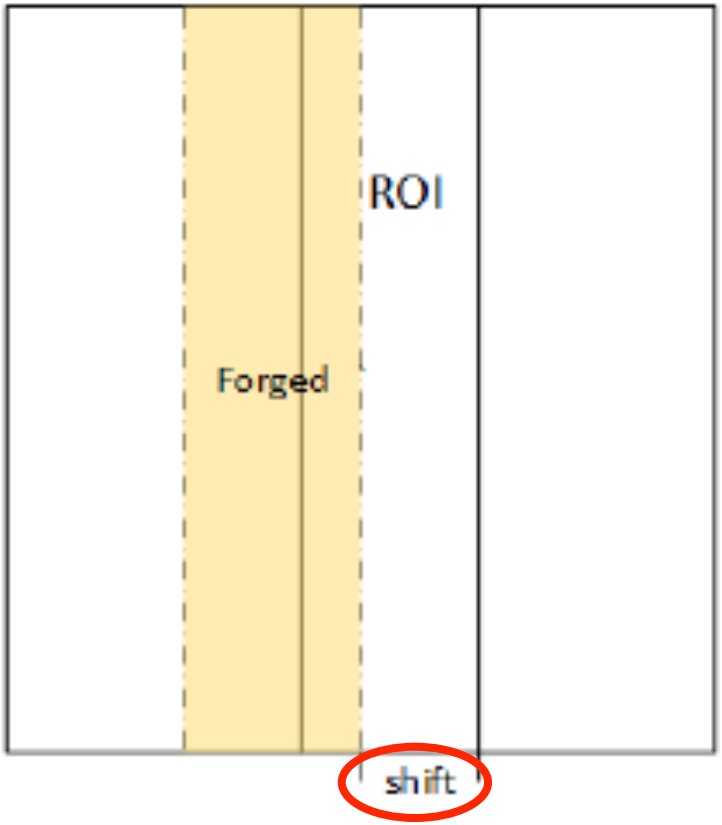
Get reflectance:

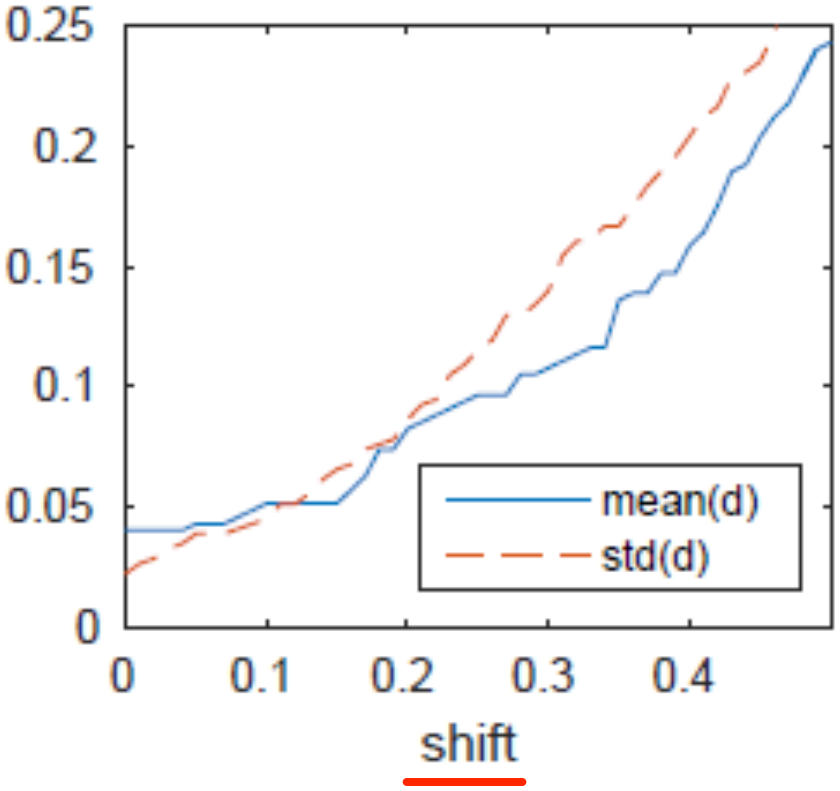
$$\frac{I_c(x)}{I_c(y)} = \frac{R_c(x)}{R_c(y)}, c \in \{r, g, b\}$$

Put it into a Neural network for classification

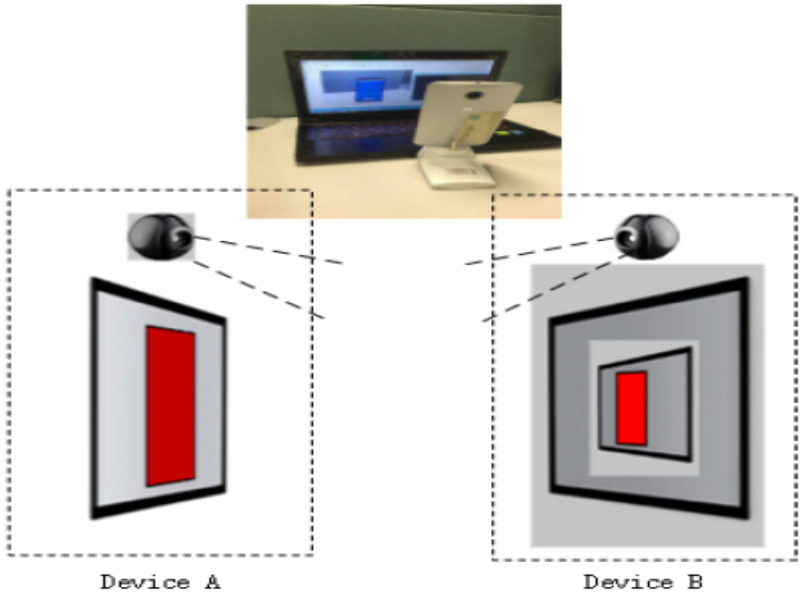
Evaluation

Sensitivity to Forged Responses

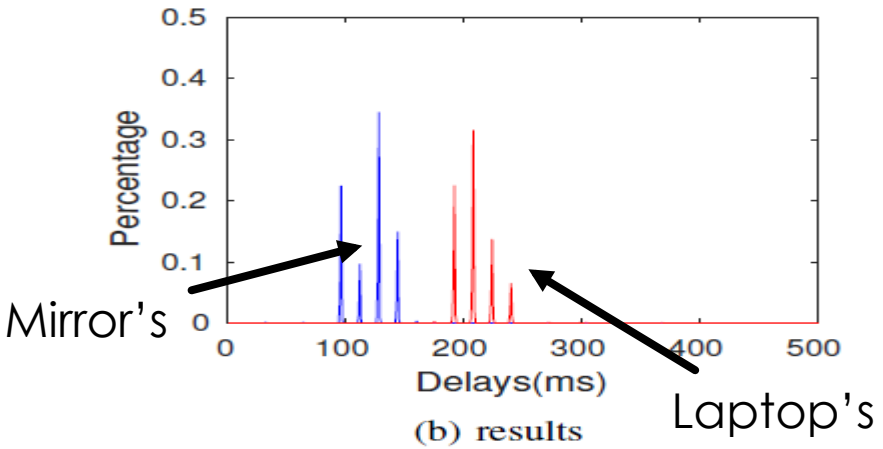




Timing: Camera VS. Mirror



(a) scenario



(b) results

Face Feature

TABLE II: Four different screens.

	Screen	Resolution	Pixel Density
1	HUAWEI P10	1920*1080	432(ppi)
2	iPhone SE	1136*640	326(ppi)
3	AOC Monitor (e2450Swh)	1920*1080	93(ppi)
4	EIZO Monitor (ev2455)	1920*1200	95(ppi)

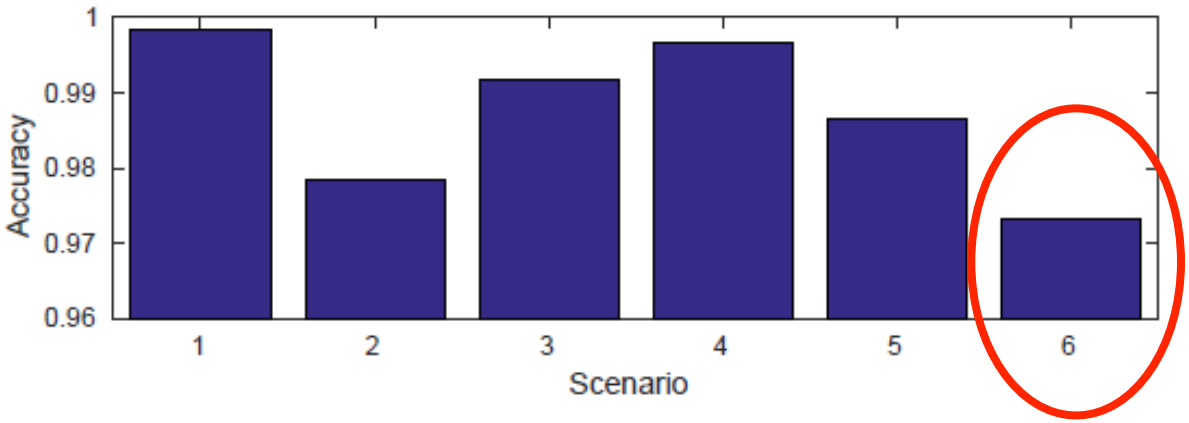
TABLE III: Experimental results of face verification.

	Training Ps	Training Ns	Testing Ps	Testing Ns
Total	20931	20931	3000	3000
Incorrect	329	0	75	0

Robustness

TABLE IV: Features of scenes.

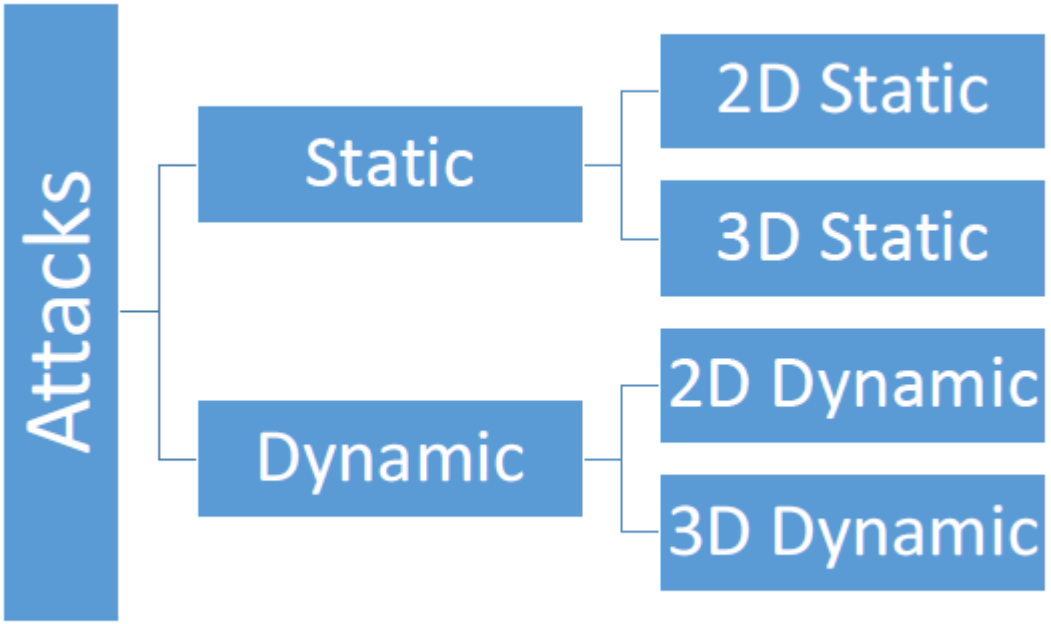
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Illumination	good	varying	intense	normal	normal	dark
Vibration	no	intermittent	normal	normal	intense	intense



Discussion

Our method will force adversaries to use “3D Dynamic Attack” which is more expensive

Our method could not handle 3D dynamic attack twins, silicone masks



Discussion

Our implementation just used 8 different colors

Our implementation needs several seconds
to accomplish once authentication

Using ‘albedo curve’ may handle 3D dynamic attacks

Combine with face recognition algorithm
could enhance efficiency and effectiveness

Summary

Face Flashing protocol

Effective and efficient method
on timing and face verifications

Prototype and empirical evaluations

Q & A

Thanks