iDecrypt
(*Eye*Decrypt)

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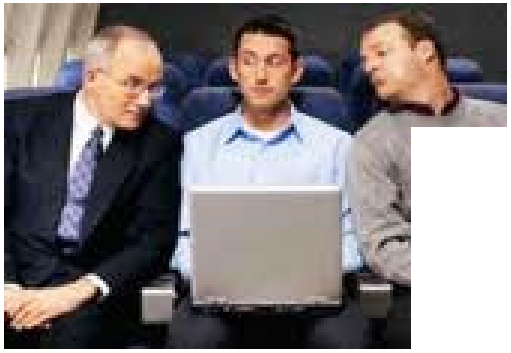
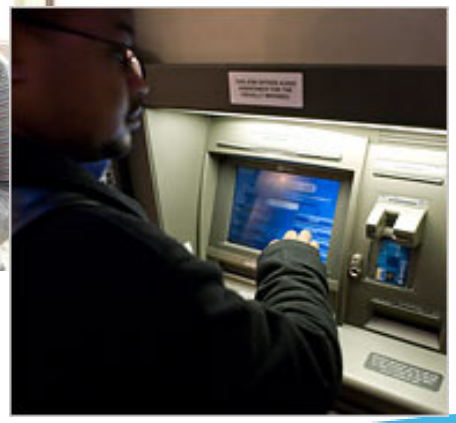
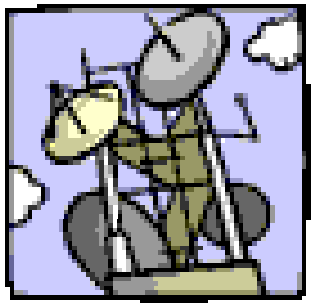
“Shoulder Surfing”



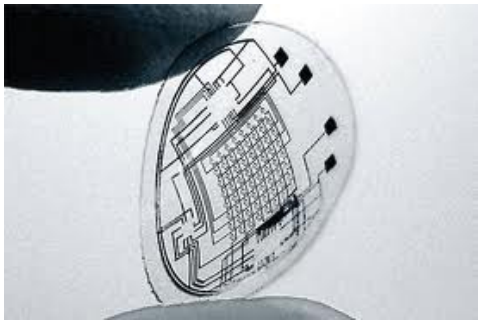


(Traditional) Content Protection

- Encryption, authentication, selective decryption
- Receiver/display devices




Realtà Aumentata - The future of education



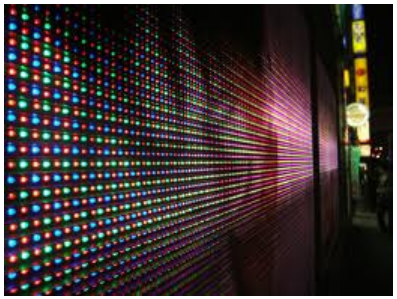
This Work

- Content protection in new setting: *public-view* rendering device (next slide)
- Content can be stored/offline or dynamically captured (streaming)
- Two main components:
  - *Visualizable* encryption scheme
  - New visual encoding technique

"For your eyes only!"

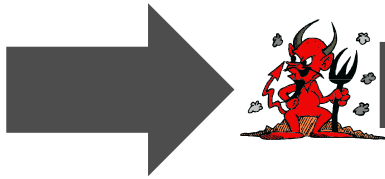
Model

Content repository/
"capturing" device



(Public) Rendering
device

$c = E_K(m)$

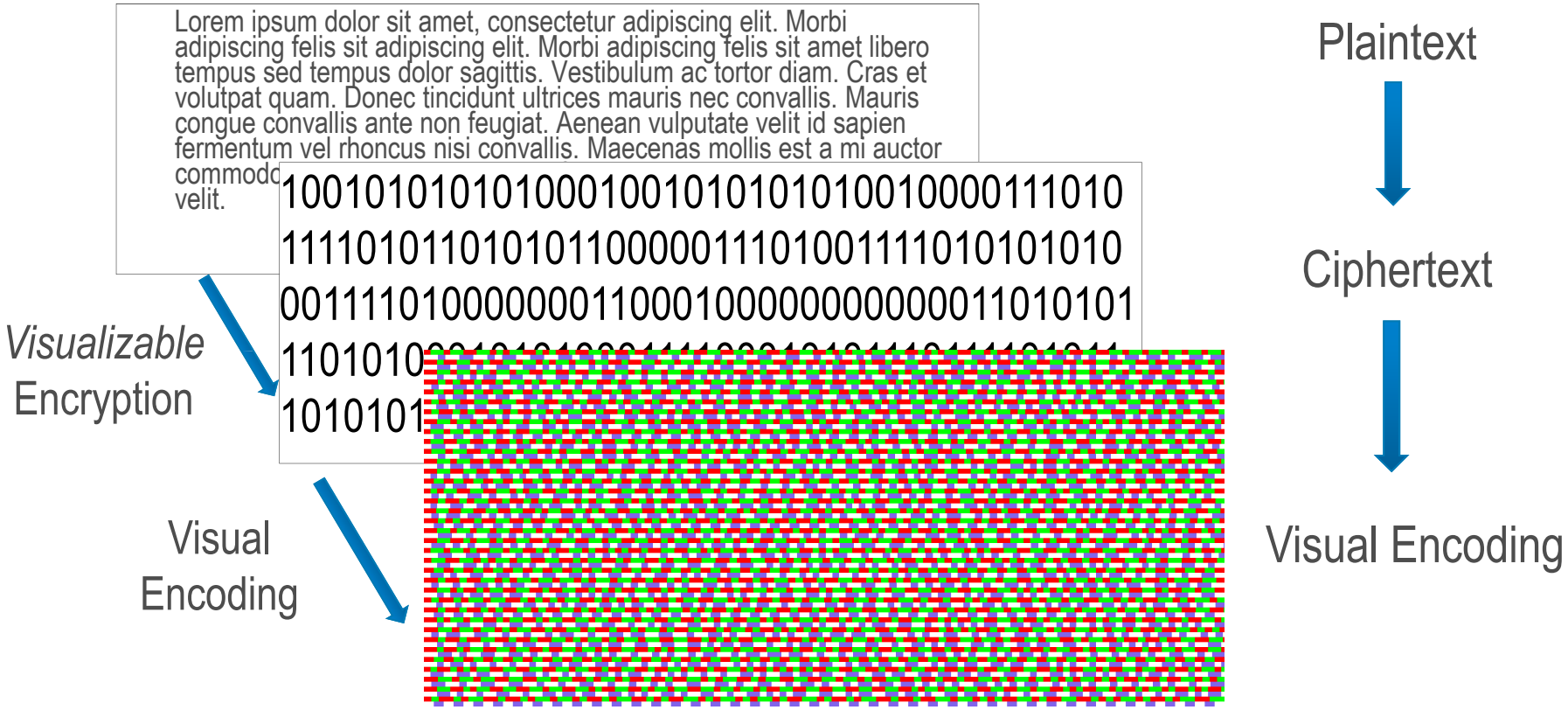


$c' = E_K(m')$

Non-malleability

R(m,m')

iDecrypt in a Nutshell



Rest of the Talk

- Introduction/Motivation
- Visualizable Encryption
- Visual Encoding
- “Demo”

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Visualizable Encryption

- Plaintext space is a matrix of text (for now)

- Encryption is performed per block:

$$\mathrm{Enc}_{K_{doc}}(M,i,j) = (\mathrm{PRF}_{K_{doc}^{enc}}(i,j) \oplus M, \tau, i, j)$$

$$\text{where } \tau = \mathrm{MAC}_{K_{doc}^{mac}}(\mathrm{PRF}_{K_{doc}^{enc}}(i,j) \oplus M)$$

- Decryption is straightforward:

$$\mathrm{Dec}_{K_{doc}}(C_{i,j}, \tau, i, j) = C_{i,j} \oplus \mathrm{PRF}_{K_{doc}^{enc}}(i,j)$$

$$\text{if } \tau \text{ is correct and } \perp \text{ otherwise}$$

Plaintext

Block

H	A	P	P	Y	
N	E	W			
Y	E	A	R		
A	L	I	C	E	!

$C_{1,1}$	$C_{1,2}$	$C_{1,3}$
$C_{1,4}$	$C_{1,5}$	$C_{1,6}$

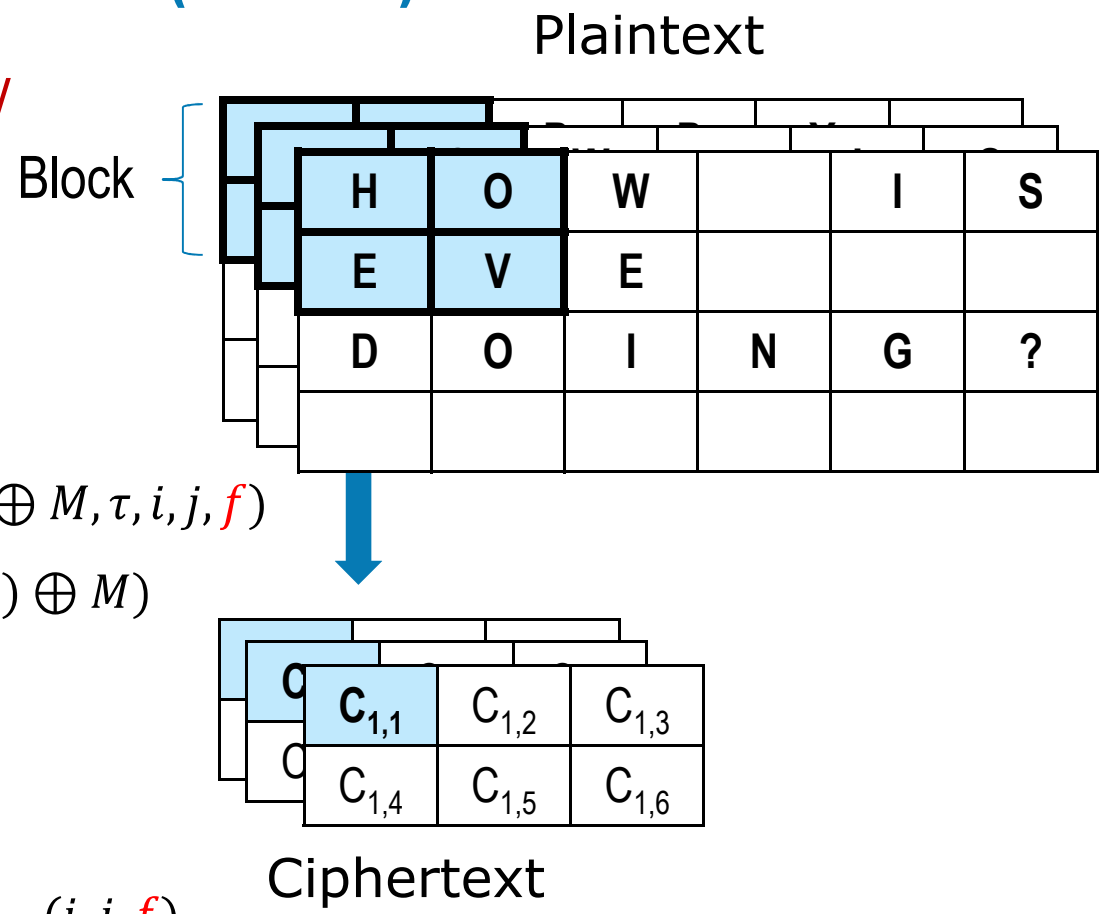
Ciphertext

Visualizable Encryption (cont'd)

- "*Frames*" — allow dynamically changing content (e.v., video, screen encryption)
- Encryption is performed per block:

$$\mathrm{Enc}_{K_{doc}}(M,i,j) = (\mathrm{PRF}_{K_{doc}^{enc}}(i,j,f) \oplus M, \tau, i, j, f)$$

$$\text{where } \tau = \mathrm{MAC}_{K_{doc}^{mac}}(\mathrm{PRF}_{K_{doc}^{enc}}(i,j,f) \oplus M)$$



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Visualizable Encryption: Security Definition

***Vis-IND-CCA* security:** A visualizable encryption scheme is secure if no efficient Adv can win the following game:

1. **Setup:** The challenger chooses a random document key K_{doc}
2. **Query Phase 1:** Adv submits encryption and decryption queries Enc(m,i,j) and Dec(c,i,j)
   - We restrict Adv from submitting Enc(m,i,j) and Enc(m',i,j) for m≠m'
3. **Challenge:** The adversary submits (m_0,m_1,i^*,j^*) that were not previously queried, and the challenger returns $c^* = Enc(m_b, i^*,j^*)$ for a random b
4. **Query Phase 2:** Same as phase 1, except Adv cannot query $Dec(c^*, i^*,j^*)$
5. **Guess:** Adv outputs a guess b' for the value of b

Visualizable Encryption: Security Def. (cont'd)

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Visualizable Encryption: Proof Sketch

- Replacing PRF with random function assigns a random pad to each block coordinates
- Each block can be queried at most once to the encryption oracle $\longrightarrow$ encrypted content is indistinguishable from random
- Non-malleability follows from MAC

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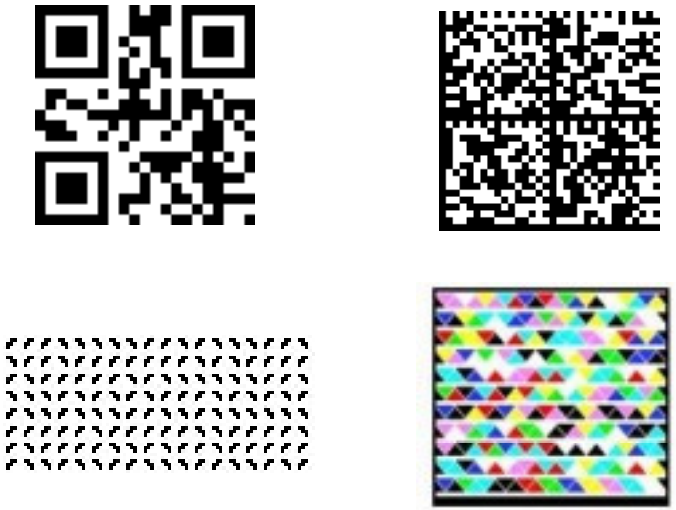
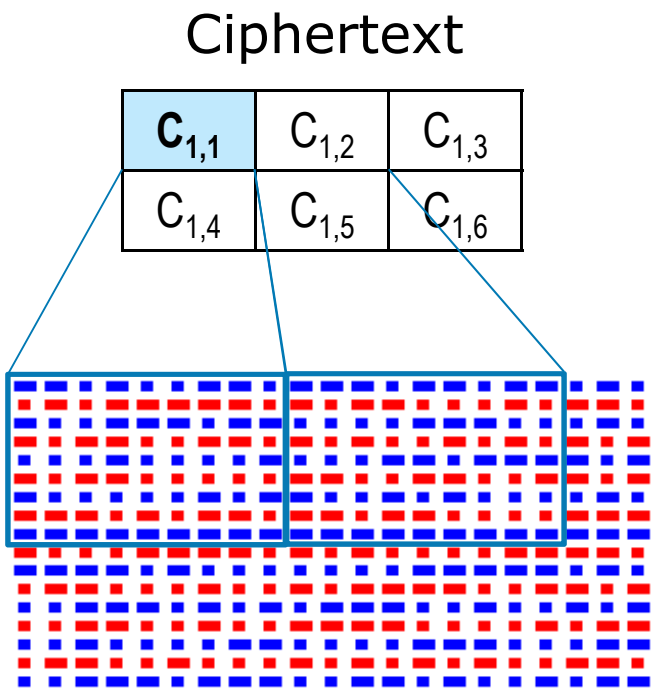
Visual Encoding

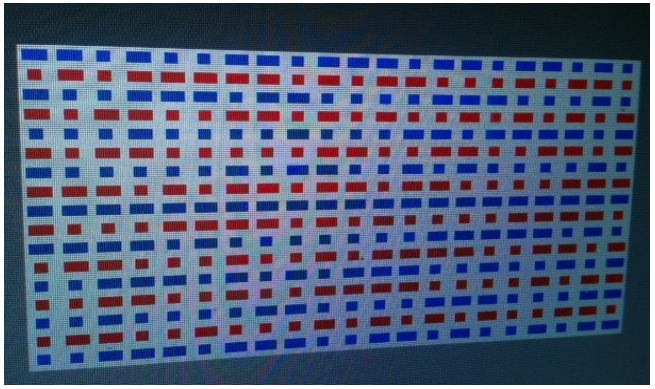
- Many existing visual encoding solutions: QR, data matrix, Dataglyphs, HCCB
- Most require capturing the entire encoding
- We require:
  - *Locality* – cropped encoding decodes to sub-matrix of input
  - *Relative positioning* – adjacent input sub-matrixes are adjacent in encoded image



Visual Encoding Scheme

- New encoding designed to meet our needs
- Bits are encoded as different-size blocks
- Distinguishing is easy regardless of distance/scale
- To encode a matrix with n-bit cells, compute an $\sqrt{n} \times \sqrt{n}$ bit matrix for each cell in input matrix
- Two colors are used to distinguish rows
- Bits can be read regardless of orientation or skew — "orientation robustness"





Visual Encoding Scheme (cont'd)

d_1, d_2 – dimensions of input matrix

t_1, t_2 – dimensions of output image

P – pixel space (e.g., RGB triples)

Definition of visual encoding:

$$Enc: (\{0,1\}^n)^{d_1 \times d_2} \rightarrow P^{t_1 \times t_2}$$

$$Dec \stackrel{\text{def}}{=} Enc^{-1}$$

Relative positioning:

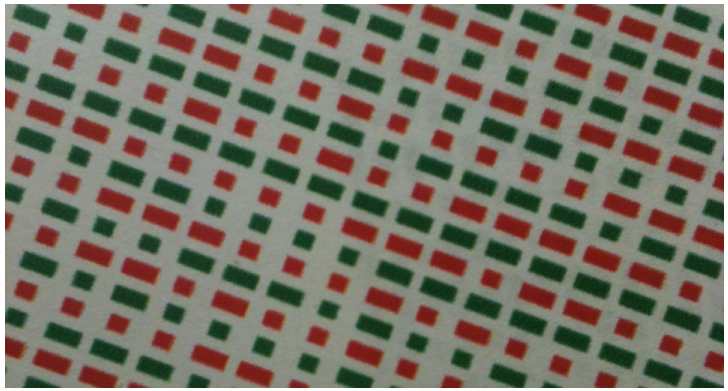
$$[r_1 \ldots r_2, c_1 \ldots c_2] \longrightarrow [r_1 \cdot t_1/d_1 \ldots r_2 \cdot t_1/d_1, c_1 \cdot t_2/d_2 \ldots c_2 \cdot t_2/d_2]$$

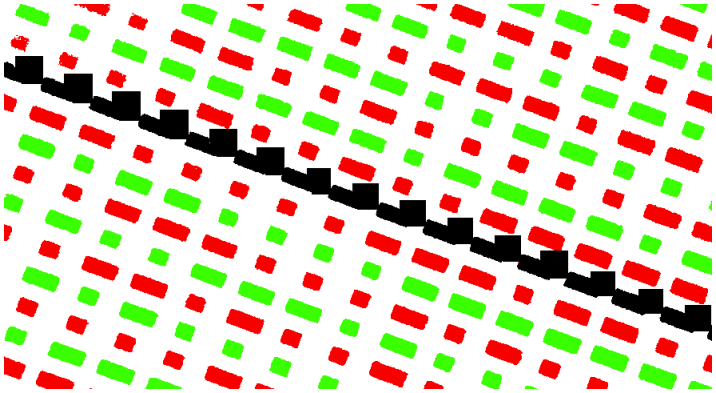
Visual Encoding Scheme (cont'd)

Decoding leverages alternating row colors and different block sizes

- First, "clean up" the image
- While reading a row, look for the closest unvisited block of the same color (e.g., using BFS)
- No need to untilt/unskew image ("orientation robustness")
- To distinguish 0/1 compare relative areas of blocks

Original image





Visualization of decoding step

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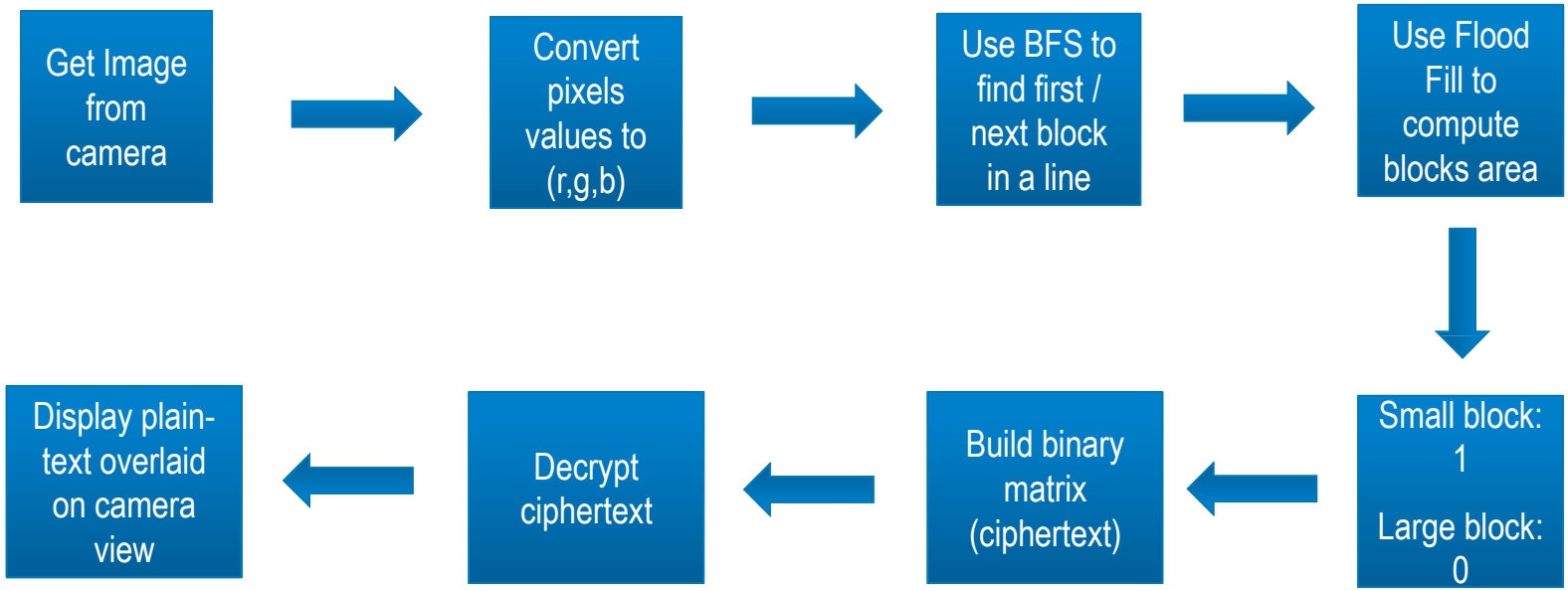
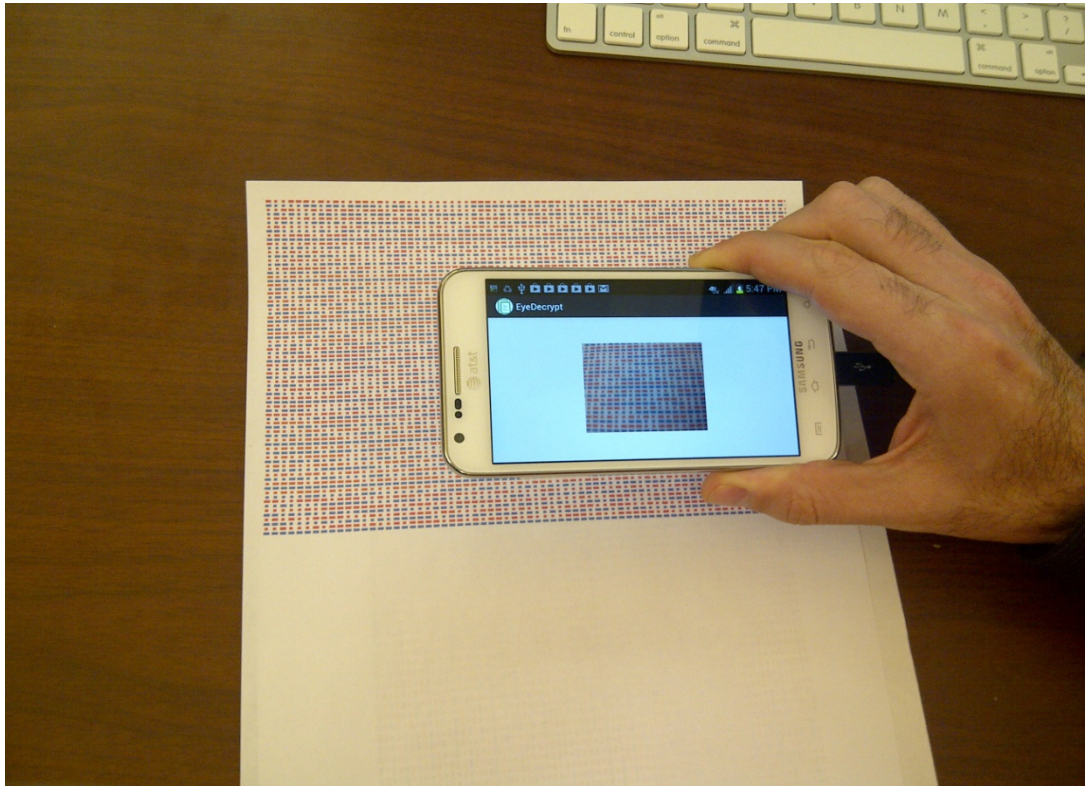
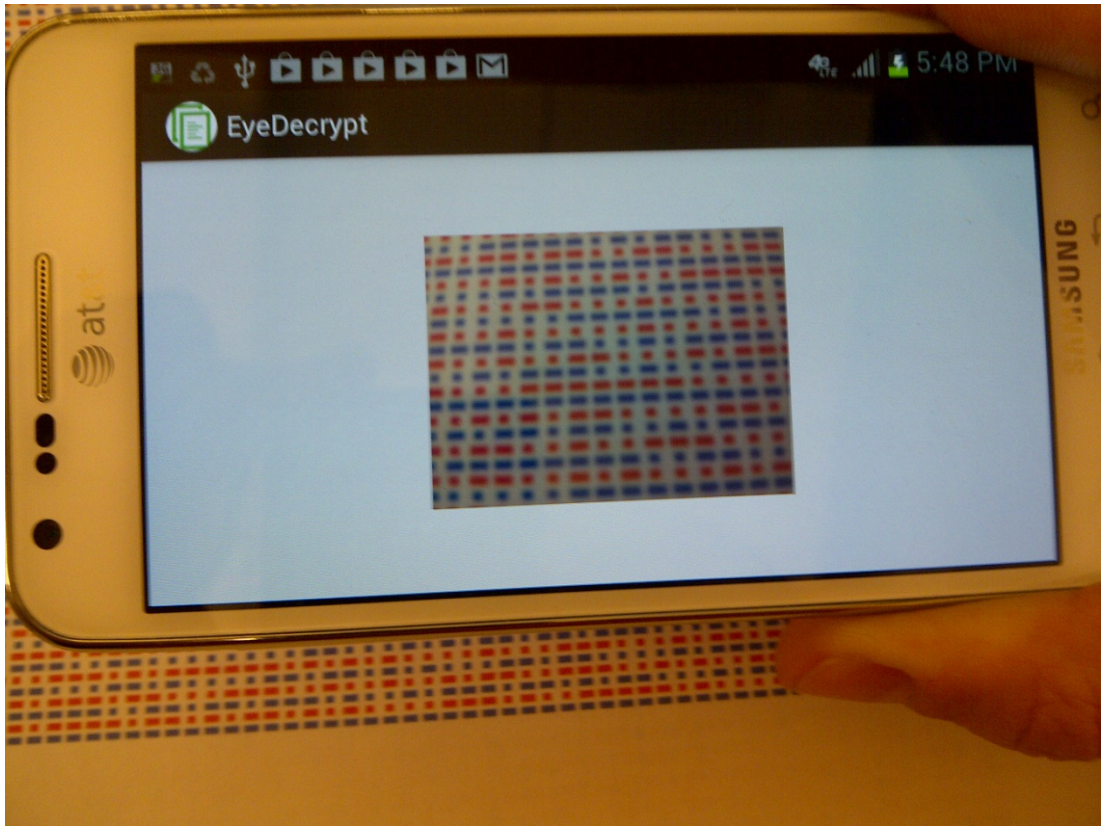
“Demo”


Get Image from camera
Convert pixels values to (r,g,b)
Use BFS to find first / next block in a line
Use Flood Fill to compute blocks area
Small block: 1
Large block: 0
Build binary matrix (ciphertext)
Decrypt ciphertext
Display plain-text overlaid on camera view

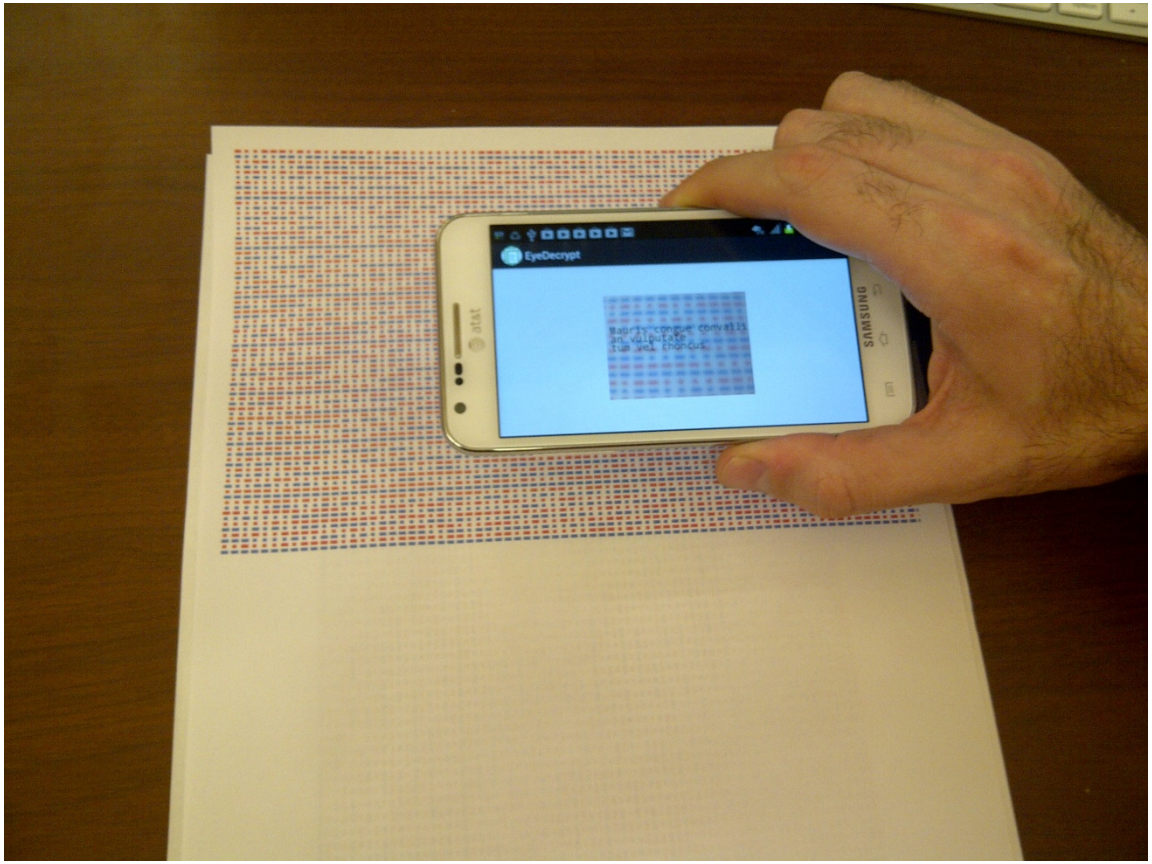
“Demo”



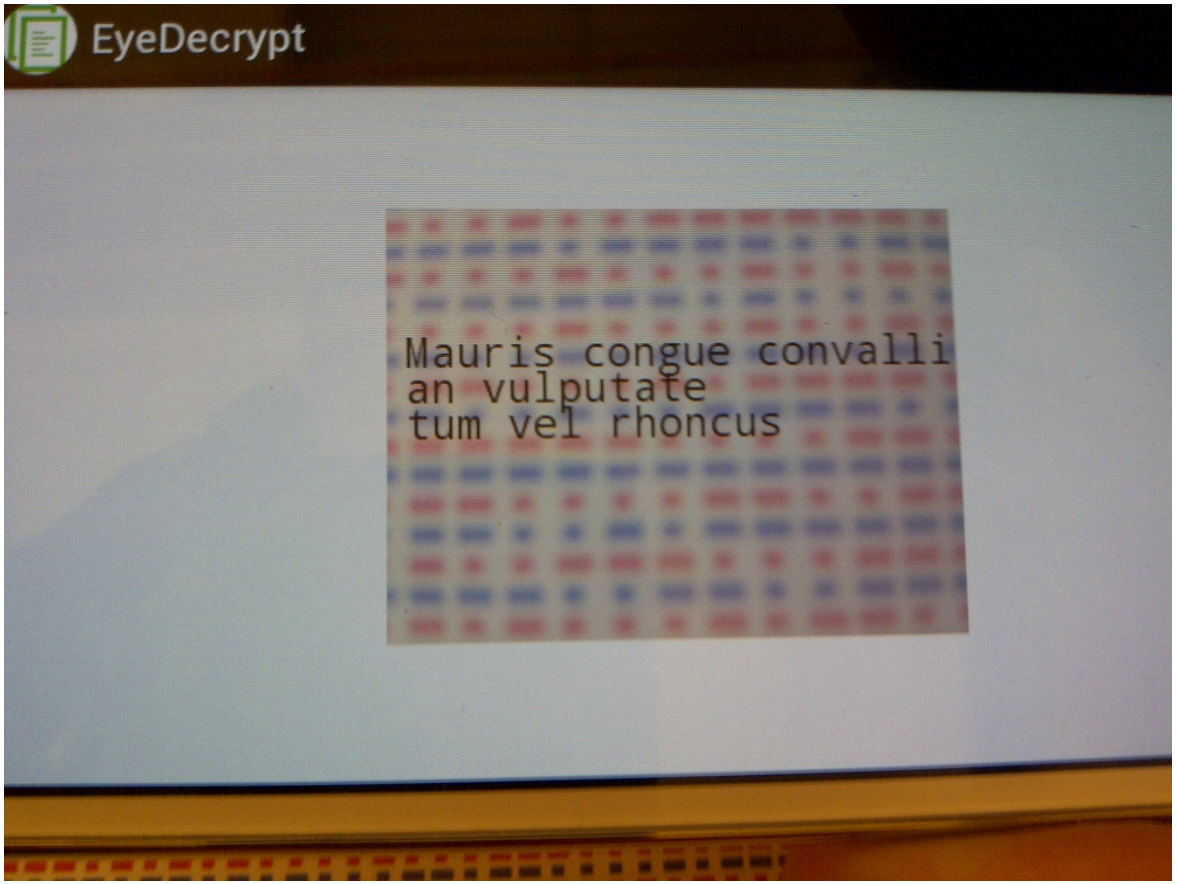
“Demo”



“Demo”



“Demo”


EyeDecrypt
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Performance and Challenges

- **Capacity**
  - Plaintext: 5184bits
  - Ciphertext: 7200 bits (overhead due to coordinates and padding)
  - Visual encoding: 1 bit / 0.25 cm^2

- **Desired properties**
  - High(er) capacity visual encoding
  - Decoding possible for different resolutions (distance, camera)
    - Can include encryption of low resolution version of neighboring blocks

- **Performance**
  - Used phone (Samsung Galaxy S2) ‘s GPU for faster rendering
  - Various algorithmic optimizations

- **Security definition(s)**

Thanks!