# Computer Security

## 09. Biometric authentication

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# Biometrics

Identify a person based on physical or behavioral characteristics

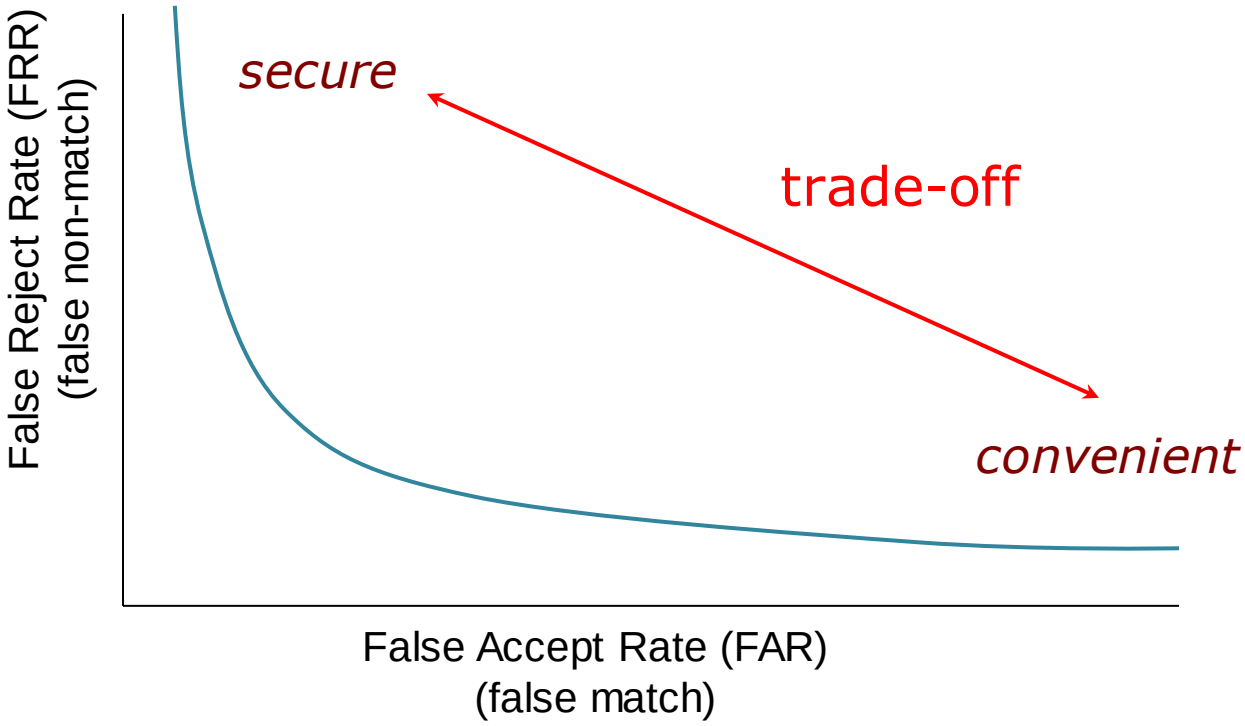
```
scanned_fingerprint = capture();
if (scanned_fingerprint == stored_fingerprint)
    accept_user();
else
    reject_user();
```

# Biometrics

- Rely on statistical pattern recognition
  - Thresholds
- False Accept Rate (FAR)
  - Non-matching pair of biometric data is *accepted* as a match
- False Reject Rate (FRR)
  - Matching pair of biometric data is *rejected* as a match

# Biometrics

- Each biometric system has a characteristic ROC curve
  - (receiver operator characteristic, a legacy from radio electronics)



# Biometrics: forms

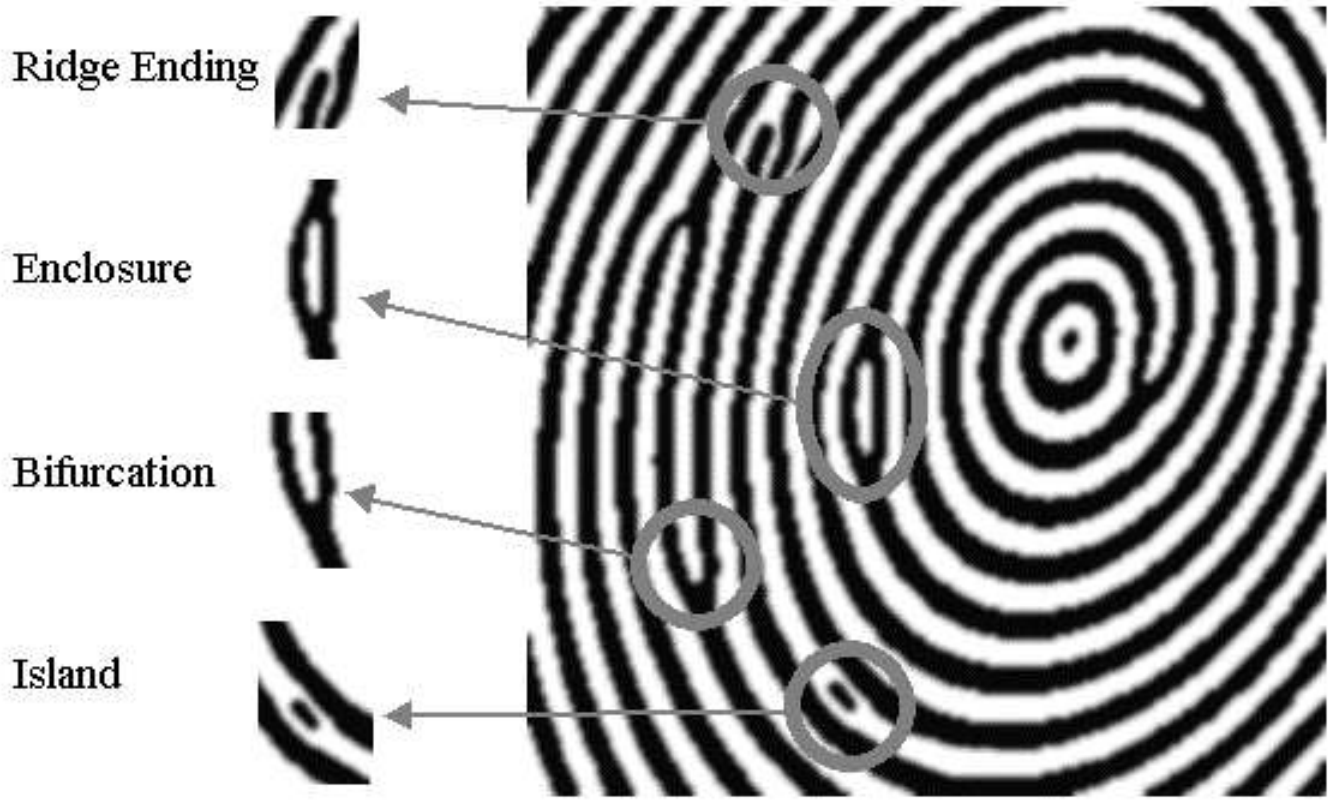
- Fingerprint
  - Reasonable uniqueness
- Iris
  - Analyze pattern of spokes: excellent uniqueness, signal can be normalized for fast matching

- Retinal scan
  - Excellent uniqueness but not popular for non-criminals
- Hand geometry: *length of fingers, width of fingers, thickness, surface area*
  - Low guarantee of uniqueness: generally need 1:1 match
- Signature, Voice
  - Behavioral vs. physical system
  - Can change with demeanor, tend to have low recognition rates
- Others
  - Facial geometry, facial thermographs, DNA, finger vein scans, palm vein scans, odor

# Biometrics: distinct features

Example: Fingerprints – identify minutia

- Arches
- Loops
- Whorls
- Ridge endings
- Bifurcations
- Islands
- Bridges




source: http://anil299.tripod.com/vol_002_no_001/papers/paper005.html

# Biometrics: desirable characteristics

- Robustness
  - Repeatable, not subject to large changes over time
  - Fingerprints & iris patterns are more robust than voice
- Distinctiveness
  - Differences in the pattern among population
  - Fingerprints: typically 40-60 distinct features
  - Irises: typically >250 distinct features
  - Hand geometry: ~1 in 100 people may have a hand with measurements close to yours.

# Biometrics: desirable characteristics

| Biometric | Robustness | Distinctiveness |
|---|---|---|
| Fingerprint | Moderate | High |
| Hand Geometry | Moderate | Low |
| Voice | Moderate | Low |
| Iris | High | Ultra high |
| Retina | High | Ultra high |
| Signature | Low | Moderate |

# Irises vs. Fingerprints

- Number of features measured:
  - High-end fingerprint systems: ~40-60 features
  - Iris systems: ~240 features

- False accept rates (FAR)
  - Fingerprints: ~ 1:100,000 (varies by vendor; may be ~1:500)
  - Irises: ~ 1:1.2 million
  - Retina scan ~1:10,000,000

# Irises vs. Fingerprints

- Ease of data capture
  - More difficult to damage an iris … but lighting is an issue
  - Feature capture more difficult for fingerprints:
    - Smudges, gloves, dryness, …

- Ease of searching
  - Fingerprints cannot be normalized
    *1:many* searches are difficult
  - Irises can be normalized to generate a unique IrisCode
    *1:many* searches much faster

# Biometric: authentication process

## 0. Enrollment

- The user's entry in a database of biometric signals must be populated.
- Initial sensing and feature extraction
- May be repeated to ensure good feature extraction

# Biometric: authentication process

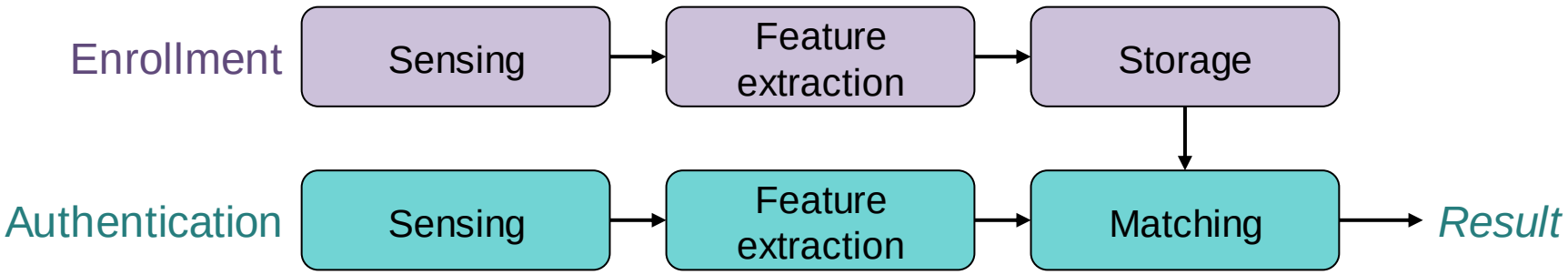
1. Sensing
   - User's characteristic must be presented to a sensor
   - Output is a function of:
     - Biometric measure
     - The way it is presented
     - Technical characteristics of sensor

2. Feature Extraction
   - Signal processing
   - Extract the desired biometric pattern
     - remove noise and signal losses
     - discard qualities that are not distinctive/repeatable
     - Determine if feature is of "good quality"

# Biometric: authentication process

3. Pattern matching
   - Sample compared to original signal in database
   - Closely matched patterns have “small distances” between them
   - Distances will hardly ever be 0 (perfect match)

4. Decision
   - Decide if the match is close enough
   - Trade-off:
     ↓ false non-matches leads to ↑false matches



# Identification vs. Verification

- Identification: *Who is this?*
  - *1:many* search

- Verification: *Is this Bob?*
  - Present a name, PIN, token
  - *1:1* (or 1:small #) search


HIGH
SECURI
Global
HD

# Biometrics: Essential characteristics

- Trusted sensor
- Liveness testing
- Tamper resistance
- Secure communication
- Acceptable thresholds

# Biometrics: other characteristics

- Cooperative systems (multi-factor)
  - User provides identity, such as name and/or PIN
- vs. Non-cooperative
  - Users cannot be relied on to identify themselves
  - Need to search large portion of database
- Overt vs. covert identification
- Habituated vs. non-habituated
  - Do users regularly use (train) the system

# Problems with biometric systems

- Requires a sensor
  - Camera works OK for iris scans & facial detection (but a good Iris scan will also take IR light into account)
- Tampering with device or device link
  - Replace sensed data– or just feed new data
- Tampering with stored data
- Biometric data cannot be compartmentalized
  - You cannot have different data for your Amazon & bank accounts
- Biometric data can be stolen
  - Photos, lifting fingerprints
  - Once biometric data is compromised, it remains compromised
    - You cannot change your iris or finger

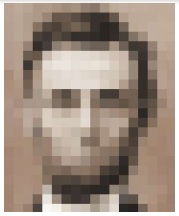
# Detecting Humanness

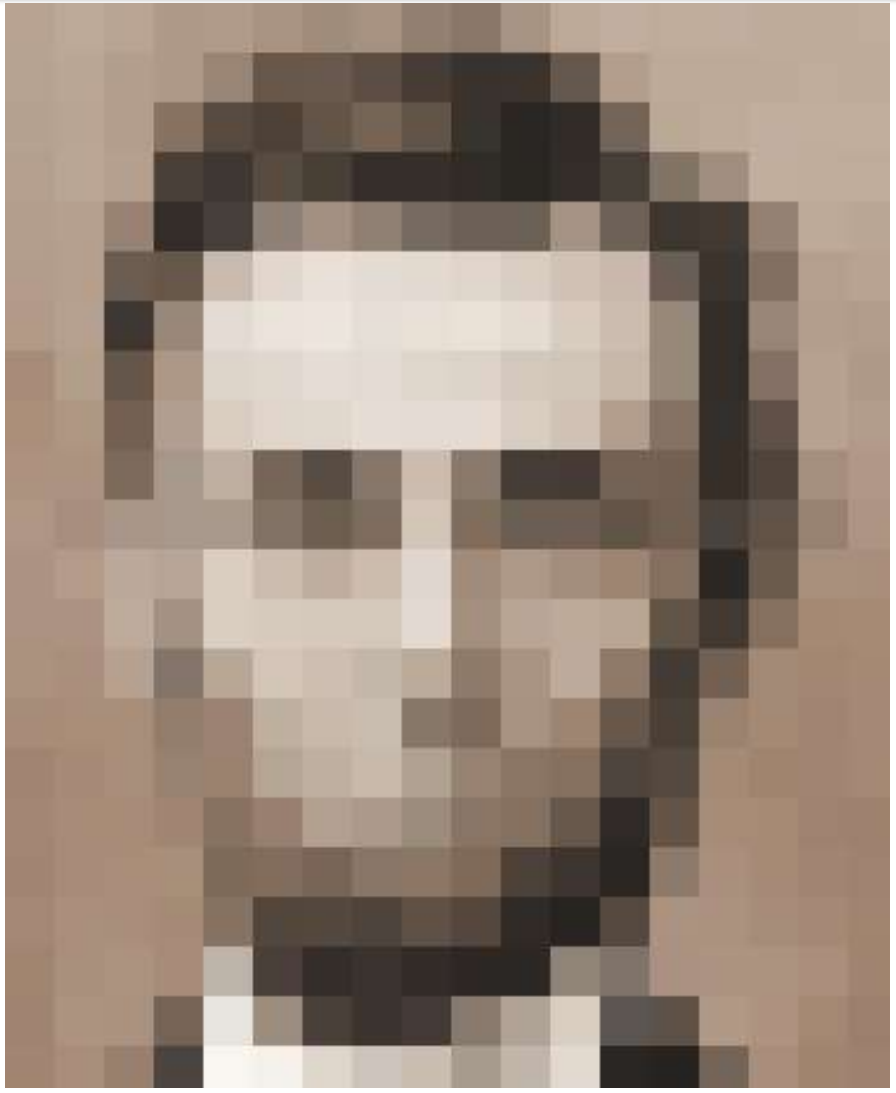
# Gestalt Psychology (1922-1923)

- Max Wertheimer, Kurt Koffka
- Laws of organization
  - Proximity
    - We tend to group things together that are close together in space
  - Similarity
    - We tend to group things together that are similar
  - Good Continuation
    - We tend to perceive things in good form
  - Closure
    - We tend to make our experience as complete as possible
  - Figure and Ground
    - We tend to organize our perceptions by distinguishing between a figure and a background

Source: http://www.webrenovators.com/psych/GestaltPsychology.htm

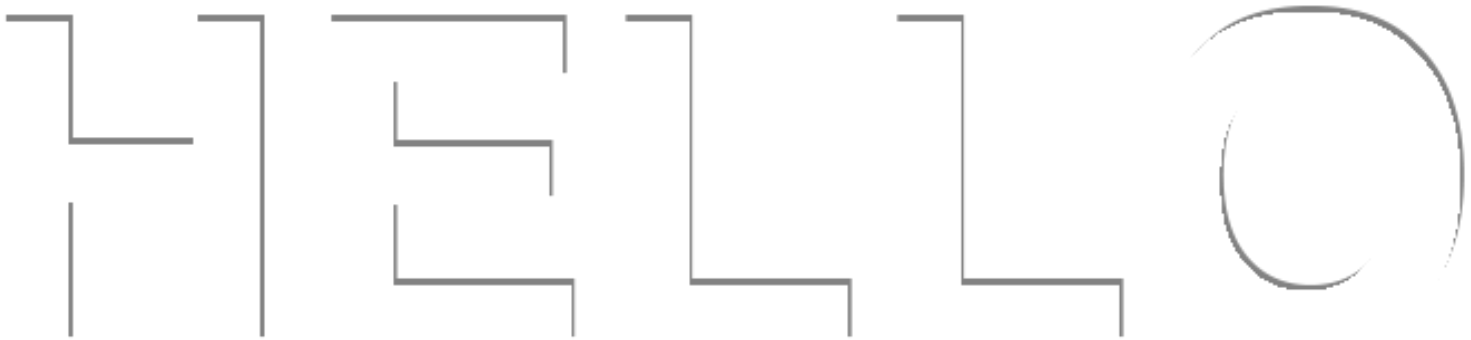
# Gestalt Psychology





18 x 22 pixels

# Gestalt Psychology



# Gestalt Psychology

# Authenticating humanness

**Battle the Bots**

- Create a test that is easy for humans but extremely difficult for computers

**CAPTCHA**

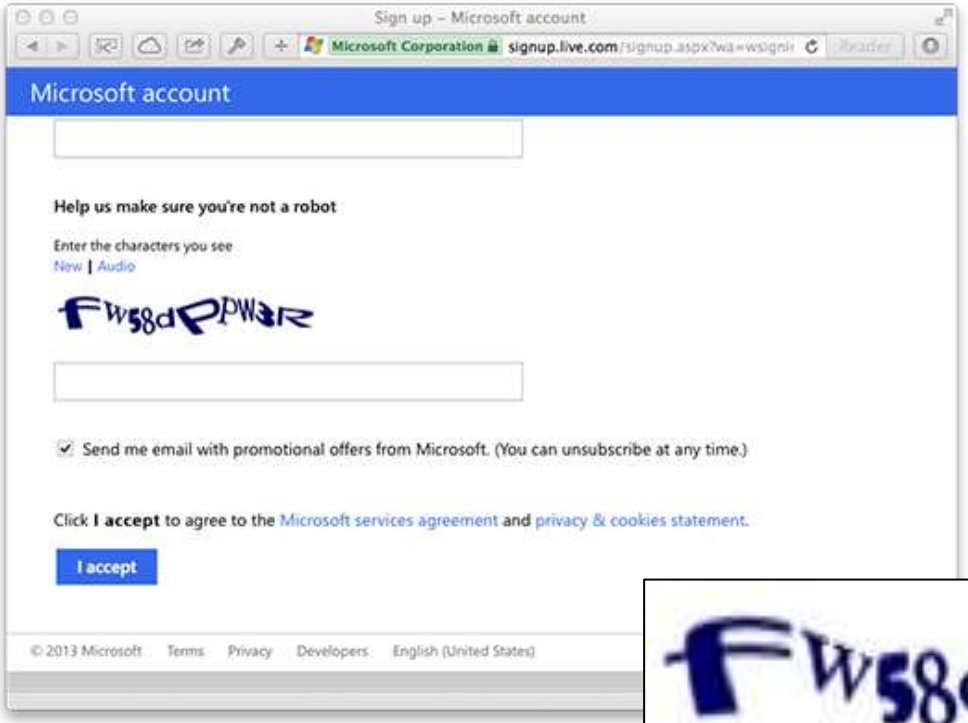
- Completely Automated Public Turing test to tell Computers and Humans Apart
- Image Degradation
  - Exploit our limits in OCR technology
  - Leverages human Gestalt psychology: reconstruction

Origins

- 1997: AltaVista – prevent bots from adding URLs to the search engine
- 2000: Yahoo! and Manuel Blum & team at CMU
  - EZ-Gimpy: one of 850 words
- Henry Baird @ CMU & Monica Chew at UCB
  - BaffleText: generates a few words + random non-English words

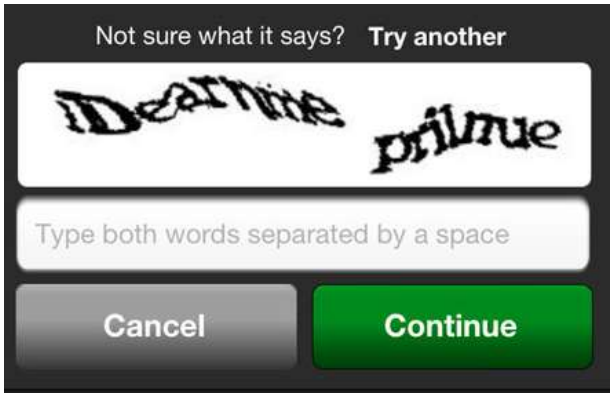
# CAPTCHA Example

Microsoft




See captchas.net

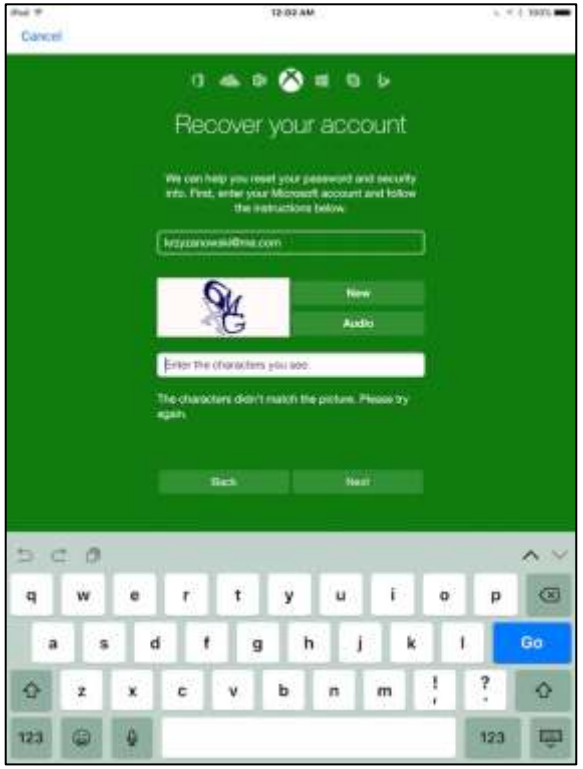
# Problems




- Accessibility
  - Visual impairment → audio CAPTCHAs
  - Deaf-blind users suffer
- Frustration
  - OCR & computer vision has improved a lot!
  - Challenges that are difficult for computers may be difficult for humans
- Attacks
  - Man in the middle (sort of)
    - Use human labor – CAPTCHA farms
  - Automated CAPTCH solvers
    - Initially, educated guesses over a small vocabulary

# Alternate approaches

- MAPTCHAs = math CAPTCHAs
  - Solve a simple math problem
- Puzzles, scene recognition


# reCAPTCHA

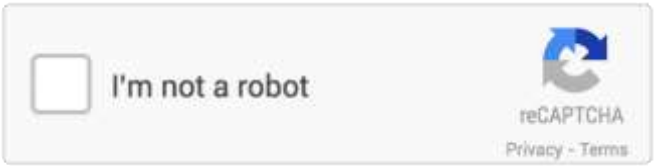
- Ask users to translate images of real words & numbers from archival texts
  - Human labor fixed up the archives of the New York Times


- Two sections
  - One for known text and the other is the image text
  - Assume that if you get one right then you get the next one correct
    - Try it again on a few other people to ensure identical answers before marking it correct
- Google bought reCAPTCHA 2009
  - Used free human labor to improve transcription of old books & street data

2014: Google found that AI could crack CAPTCHA & reCAPTCHA images with 99.8% accuracy

# NoCAPTCHA reCAPTCHA

*Ask users if they are robots*




- Reputation management
  - "Advanced Risk Analysis backend"
  - Check IP addresses of known bots
  - Check Google cookies from your browser
  - Considers user's entire engagement with the CAPTCHA: before, during, and after
    - Mouse movements & acceleration, precise location of clicks
- Newest version: invisible reCAPTCHA
  - Don't even present a checkbox

# NoCAPTCHA fallback

If risk analysis fails,

– Present a CAPTCHA

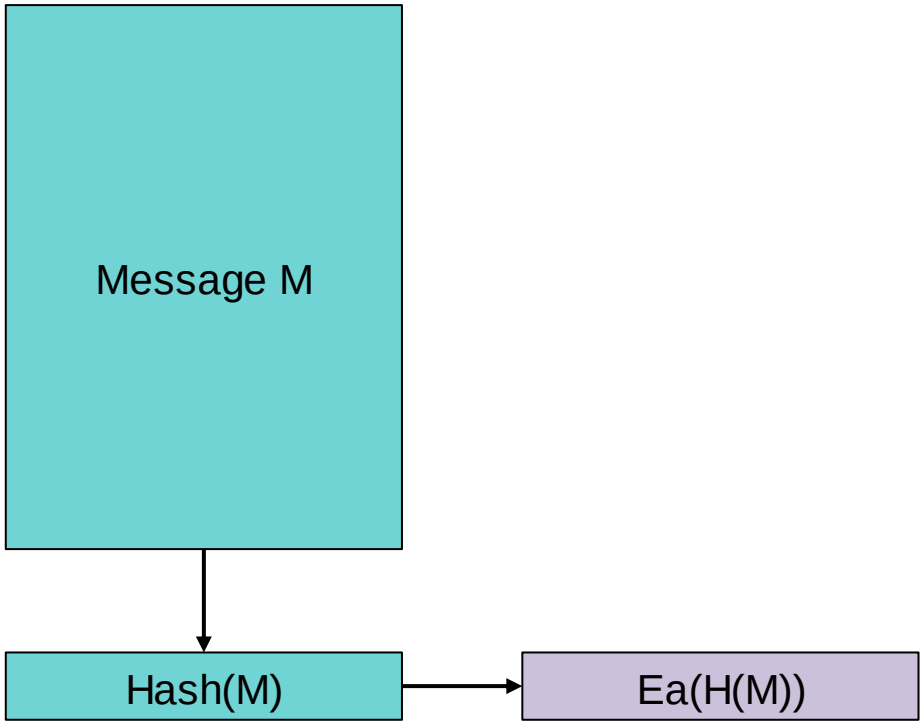
– For mobile users, present a image labeling problem


# Alternative: Text/email verification

- Text/email verification
  - Ask users for a phone # or email address
  - Service sends a message containing a verification code
    - Still susceptible to spamming
    - Makes it a bit more difficult … and slower
- Measure form completion times
  - Users take longer than bots to fill out and submit forms
  - Measure completion times
    - Bots can program delays if they realize this is being done

# Code Integrity

# Review: signed messages




Encrypt with Alice's private key
= digital signature

# We can sign code too

- Validate integrity of the code
  - If the signature matches, then the code has not been modified
- Enables
  - Distribution from untrusted sources
  - Distribution over untrusted channels
  - Detection of modifications by malware
- Signature = encrypted hash signed by trusted source
  - Does *not* validate the code is good … just where it comes from

# Code Integrity: signed software

- Windows 7-10: Microsoft Authenticode
  - SignTool command
  - Hashes stored in system catalog or signed & embedded in the file
  - Microsoft-tested drivers are signed
- macOS
  - codesign command
  - Hashes & certificate chain stored in file
- Also Android & iOS

# Code signing: Microsoft Authenticode

A format for signing executable code (dll, exe, cab, ocx, class files)

- Software publisher:
  - Generate a public/private key pair
  - Get a digital certificate: VeriSign class 3 Commercial Software Publisher's certificate
  - Generate a hash of the code to create a fixed-length digest
  - Encrypt the hash with your private key
  - Combine digest & certificate into a Signature Block
  - Embed Signature Block in executable
- Microsoft SmartScreen:
  - Manages reputation based on download history, popularity, anti-virus results
- Recipient:
  - Call *WinVerifyTrust* function to validate:
    - Validate certificate, decrypt digest, compare with hash of downloaded code

# Per-page hashing

- Integrity check when program is first loaded
- Per-page signatures – improved performance
  - Check hashes for every page upon loading (demand paging)
- Per-page hashes can be disabled optionally on both Windows and macOS

# Windows code integrity checks

- Implemented as a file system driver
  - Works with demand paging from executable
  - Check hashes for every page as the page is loaded
- Hashes stored in system catalog or embedded in file along with X.509 certificate.
- Check integrity of boot process
  - Kernel code must be signed or it won't load
  - Drivers shipped with Windows must be certified or contain a certificate from Microsoft

# The End