# User Authentication

- **Identification**
  - Present an identifier to a security system
  - Example: username
- **Verification**
  - Verify the claimed identity
  - Example: password
- An authenticated identity provides the basis for both *access control* and *accountability*

**User Authentication**

- Identification
- Verification

- Do not confuse **user authentication** and **message authentication**
  - **User authentication:** Establishing the validity of a claim
  - **Message authentication:** Verify integrity and source authenticity of a message

# Means of Authentication

- **Something you know**, e.g., passwords, passphrases, PINs
- **Something you have**, e.g., smart card, physical key, smartphone

**Drawbacks**

Can be forgotten, lost or stolen

- **Something you are (static biometrics)**, e.g., fingerprint, retina, iris, hand geometry, facial characteristics
- **Something you do (dynamic biometrics)**, e.g., voice recognition, handwriting, typing rythm

**Drawbacks**

Errors, problems with acceptance, cost

**Multifactor authentication:** Use of more than one of the above

# Common Passwords

- Stolen from Rockyou.com 2009 (SQL-injection)
- Stored in clear text (32 Million passwords)
- **Note:** People may or may not regard Rockyou.com as a place where you need complex passwords.

**Password length**

| | |
|---|---|
| 5 | 4% |
| 6 | 26% |
| 7 | 19% |
| 8 | 20% |
| 9 | 12% |
| 10 | 9% |
| 11 | 4% |
| 12 | 2% |
| 13 | 1% |

**Characters used**

| | |
|---|---|
| Numbers | 16% |
| Letters | 43% |
| Alphanumeric | 37% |
| Other | 4% |

**10 most common**

1. 123456
2. 12345
3. 123456789
4. Password
5. iloveyou
6. princess
7. Rockyou
8. 1234567
9. 12345678
10. abc123

# 9 years later…

- Data taken from public sources with data breaches from 2018. 5 million passwords in total.

| | |
|---|---|
| 1 | 123456 |
| 2 | password |
| 3 | 123456789 |
| 4 | 12345678 |
| 5 | 12345 |
| 6 | 111111 |
| 7 | 1234567 |
| 8 | sunshine |
| 9 | qwerty |
| 10 | iloveyou |
| 11 | princess |
| 12 | admin |
| 13 | welcome |
| 14 | 666666 |
| 15 | abc123 |

- 3% used 123456
- Top 25 constitute over 10% of the total 5 million passwords

# The Password File

- System needs to verify password
- Password needs to be stored somewhere
  - file, database,…
- Users should not be allowed to see other's password

  → Password file must be protected

**Protection:**

- One-way (hash) function is used so passwords are not in clear
- Additional cryptography and/or access control is possible

*password* → Hash function → Hash value

*We will improve this further soon!!!*

# Password File Protection

- We want to protect the hashed passwords
- Access control – Only priviliged users can access the file
  - In Unix (and Linux) hashed passwords are usually stored in a file only readable by root (shadow password file)
  - Windows NT used a proprietary binary format of the file. (Security by obscurity)
  - In Windows 2000 and later, the SAM file is (optionally) encrypted with SysKey
  - The SAM file cannot be moved or copied when windows is running.
    - Still, there are tools to dump the content, see Laboratory 1

# Obtaining Passwords

- Spoofing Attacks
- Obtaining file with hashed passwords
  - Brute force
  - Dictionary attack
  - Time-memory tradeoff
- Social engineering
- Guess password online
- Guess answer to secret question

# Spoofing Attacks

- Username and password give *unilateral* authentication
  - System authenticates user but user does not authenticate system

**Spoofing Attack:**

- The attacker runs a program that presents a fake login screen.
- User enters username and password, and is then directed to the real login screen.

**What to do?**

- Prevention
  - Trusted path (CTRL+ALT+DEL in Windows)
  - *Mutual authentication*
  - One-time passwords
- Detection
  - Information about previous logon session
  - Display number of failed logins

# Obtaining Hashed Passwords

- There are tools to dump the password database (SAM) in Windows
- Security vulnerabilities in other programs may allow you to read a password file in Unix or Linux
- Online forums, social networks, webmail providers, etc often have databases with hashed passwords. These can be obtained from security bugs
  - Some methods will be discussed in the course ”Web Security” in HT1

| **Username** | **Password** |
|---|---|
| Alice | g6F4fdsg8h...h5NHa |
| Bob | dsjk7H5dg0...d2a5V |
| Charlie | KJ7YtrcZa2...l9j7G |
| David | p09J7h6bD3...73Dnt |

# Brute Force

- Go through all possible passwords
  - Will take a long long time.
  - Can restrict to only test common characters (alphanumerical).
- 26+26 letters + 10 numbers
  - **Example:** Testing all alphanumerical passwords up to length 7 requires

$$\sum_{i=1}^{7} 62^i = 3579345993194 \approx 2^{42}$$

hash invocations

- Is this computationally possible?
  - Depends on which hash function is used, how many computers you have and how much time you have, but basically, yes.

# Dictionary Attack

- Passwords are often based on words – try common words
- Consider *Oxford English Dictionary*
  - Contains about 200000 words

- **Complexity**
  - Trying 100 variations of each word require about $2^{24}$ hash invocations.
  - Doing the same thing for 50 languages require $2^{30}$ hash invocations
  - → Still about 4000 times faster than trying all alphanumerical passwords up to 7 characters

- ”Easy” passwords can also be included in dictionaries
  - qwerty, q1w2e3r4t5, zaxscdvfbg, qwaszx, etc...
  - …and the 32,000,000 from Rockyou.com and similar

# Time-Memory Tradeoff Attack

- In some sense a brute force attack
  - Done in a clever way and partly in advance
- Require lots of memory
- Attack introduced by Hellman in 1980
  - Explained for block cipher but works equally well for any one-way function
- Attack consists of two stages

**Preprocessing**
- Build tables
- Takes a long time

Capture hashes

**Realtime (or online) phase**
- Use tables
- Relatively fast

The two phases have **different** complexity

# Preprocessing Phase

- Let $N$ be the search space
  - **Example:** alphanumerical passwords with length $\leq 7$ gives $N = 2^{42}$
- Let $h$ be the one-way function to invert
  - $y = h(x)$
- Let R be a reduction function mapping an output to a new password
  - $x_2 = R(h(x_1))$
- Idea:
  1. Pick random password $x_{1,0}$
  2. Compute $x_{1,1}=R(h(x_{1,0}))$, $x_{1,2}=R(h(x_{1,1}))$,…,$x_{1,t}=R(h(x_{1,t-1}))$
  3. Save $x_{1,0}$ as starting point and $x_{1,t}$ as ending point for this chain
  4. Pick new starting point $x_{2,0}$ and compute ending point $x_{2,t}$
  5. Do this for $m$ starting points → we cover $mt$ passwords

# The Table

$$x_{1,0} \xrightarrow{h} h(x_{1,0}) \xrightarrow{R} x_{1,1} \xrightarrow{h} h(x_{1,1}) \xrightarrow{R} x_{1,2} \xrightarrow{h} \quad \xrightarrow{h} h(x_{1,t-1}) \xrightarrow{R} x_{1,t}$$

$$x_{2,0} \xrightarrow{h} h(x_{2,0}) \xrightarrow{R} x_{2,1} \xrightarrow{h} h(x_{2,1}) \xrightarrow{R} x_{2,2} \xrightarrow{h} \quad \xrightarrow{h} h(x_{2,t-1}) \xrightarrow{R} x_{2,t}$$

$$x_{3,0} \xrightarrow{h} h(x_{3,0}) \xrightarrow{R} x_{3,1} \xrightarrow{h} h(x_{3,1}) \xrightarrow{R} x_{3,2} \xrightarrow{h} \quad \xrightarrow{h} h(x_{3,t-1}) \xrightarrow{R} x_{3,t}$$

$$\vdots$$

$$x_{m,0} \xrightarrow{h} h(x_{m,0}) \xrightarrow{R} x_{m,1} \xrightarrow{h} h(x_{m,1}) \xrightarrow{R} x_{m,2} \xrightarrow{h} \quad \xrightarrow{h} h(x_{m,t-1}) \xrightarrow{R} x_{m,t}$$

Save startpoints

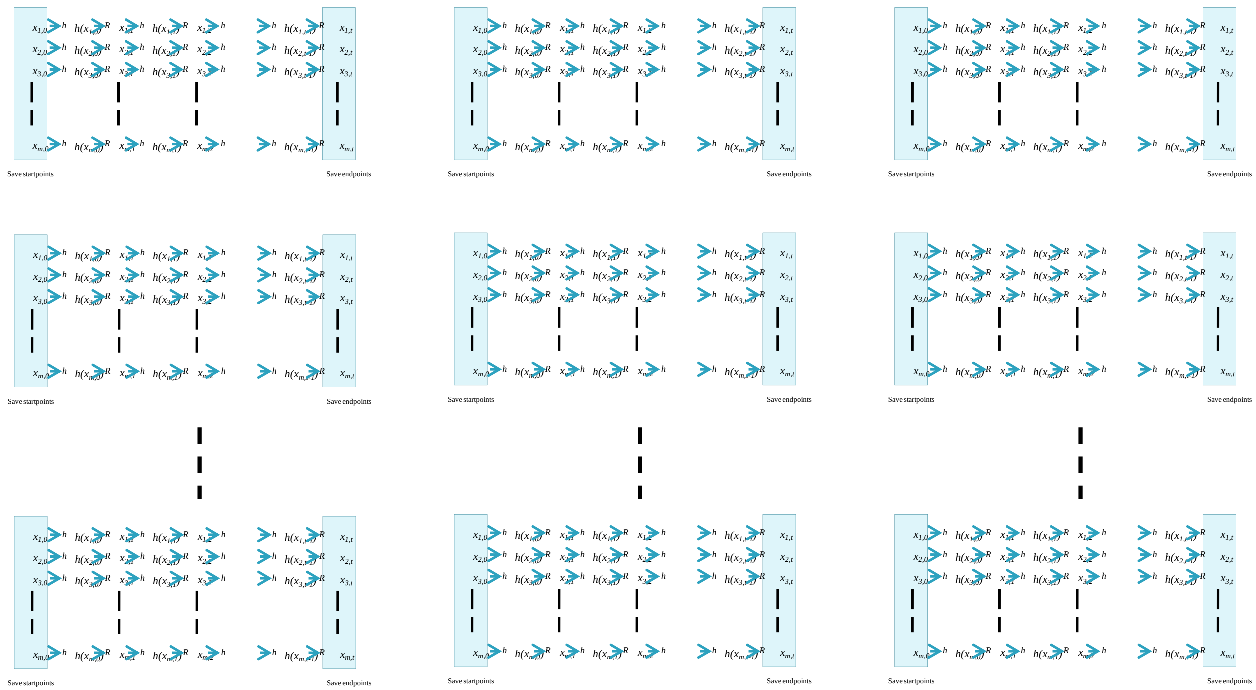
Save endpoints

# Table Coverage

- We cover *mt* points
- If $x_{i,j} = x_{u,v}$ the two chains will merge and we will not cover any new points
- Avoid merging: stop when $mt \cdot t = N$
  - Intuitive explanation: We have *mt* different points. If we add *t* points there are $mt \cdot t$ possibilities of collision
- We only cover a fraction mt/N = 1/t of the search space
  - We need *t* tables, each with different reduction function *R*

- Cost for preprocessing phase $P \approx N$ ← **NOTE!!!**
  - All points are processed
- Memory usage $M \approx mt$
  - *m* points saved for each table, and there are *t* tables

Actually 2m, but we do not care about small constants (and we did not specify unit anyway)




In total $t$ tables, each with new reduction function

# Realtime Phase

- Goal: Find $x$ when we know $h(x)$
- Do the following for each of the $t$ tables
  1. Apply reduction function $R$
  2. If $R(h(x))$ is a saved endpoint, then go to 4.
  3. If $R(h(x))$ is not a saved endpoint, find $R(h(R(h(x))))$, etc... until endpoint is found. Then go to 4.
  4. When endpoint is found, take corresponding startpoint and iterate until $h(x)$ is found. Then $x$ is the password!

- Cost for realtime phase $T \approx t^2$

# Summary of Attack

- Realtime computations: $T = t^2$
- Preprocessing time: $P = N$
- Memory needed: $M = mt$
- Matrix stopping rule: $N = mt^2$

$\Rightarrow$

$N^2 = M^2 T$
$P = N$

- Example: $T = N^{2/3}$ and $M = N^{2/3}$
  - $N=2^{42}$ can be broken with table of size $2^{28}$ and $2^{28}$ computing steps
  - Thus after producing the table ONCE with cost $2^{42}$, any password can be broken with cost $2^{28}$. You just need to have the table.
  - Any parameters satisfying the tradeoff curve can be chosen
    - More memory → less time
    - Less memory → more time

# Improvement: Rainbow Tables

- Oechslin 2003
- Practical improvement, but asymptotic complexities are the same as in Hellman's attack
- Idea: Use different reduction function for each computation of the hash function
- Collisions will merge chains with probability *1/t*
  - Only collisions in the same column will merge chains
- Only one large table needed
  - In practice, a few tables
- Realtime speedup factor approximately 2-10 (debated)
- See Laboratory 1 for more info

# Downloadable Rainbow Tables

- Examples from *http://www.cryptohaze.com/*

| | |
|---|---|
| *Algorithm:* MD5 | *Algorithm:* MD5 |
| *Number of characters:* 1-6 | *Number of characters:* 1-8 |
| *Characters:* !"#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_`abcdefghijklmnopqrstuvwxyz{\|}~ | *Characters:* !"#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_`abcdefghijklmnopqrstuvwxyz{\|}~ |
| *Size of table:* 1.0 GB | *Size of table:* 1.5 TB |

Does the choice of hash function matter to table size?

# In the news, December 2009



## Tysk forskare har knäckt gsm-koden

Publicerat 2009-12-29 20:25

**En tysk forskare säger sig ha knäckt gsm-algoritmen, en kod som utvecklades 1988 och som fortfarande används för att skydda integriteten för omkring 80 procent av världens mobilsamtal.**

Den 28-årige forskaren Karsten Nohl har tillsammans med andra

Skriv ut

## Din mobil kan avlyssnas – av vem som helst

Koden ... hjälp av ett gratisprogram

"Säl... ...ande nätet är bristfällig" 6

## GSM-kod knäckt av tysk forskare

Publicerad: 29 december 2009, 09.41. Senast ändrad: 29 december 2009, 13.16

**En tysk forskare säger sig ha knäckt GSM-koden – därmed ... avlyssnas. Men avslöjandet kritiseras.**

Läs vidare | Textstorlek: A A A | Skriv ut

ANNONS

**Cirka 80 procent av världens mobilte...** nät som den 28-årige forskaren Karsten N... rapporterar New York Times. Intrånget s... ...att visa på den sårbarhet han menar finns i systemet.

– Det här visar att säkerheten i det nuvarande GSM-nätet är bristfällig. Det är därför vi försöker få operatörerna att hitta bättre säkerhetslösningar för mobilsamtal, sade Nohl igår vid en presskonferens på datahackerkonferensen i Berlin som just nu pågår.

**Men GSM-organisationen med säte** i London tillbakavisar kritiken och menar att Nohls agerande är olagligt. Dessutom anser man att han överdriver riskerna.

Tipsa andra

Vad är det här?

IT | Mest lästa

- Nokias N900 ska visa vägen
- GSM-kod knäckt av tysk forskare
- Ny teknik kan fria nätpirater
- Okonventionella kompaktkameror
- Får prövningstillstånd i Pirate Bay-mål

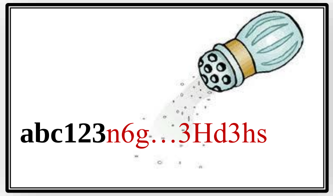
## Så lätt avlyssnas samtal i gsm-nätet

SÄKERHET En säkerhetsforskare har visat hur enkelt det är att avlyssna mobiltelefonsamtal på gsm-nätet.

(36 kommentarer)

# Password Salting

- Add some extra info, **salt**, to the password before hashing.
  - Username
  - Randomly generated characters
- Salt stored with hashed password.




| Username | Salt | Password |
|---|---|---|
| Alice | Gfgh5 | g6F4fdsg8h...h5NHa |
| Bob | kd6sd | dsjk7H5dg0...d2a5V |
| Charlie | dsfjh | KJ7YtrcZa2...l9j7G |
| David | J7Fj2 | p09J7h6bD3...73Dnt |

- **Three advantages:**
  1. Two users with same password will have different hash.
  2. Slows down dictionary attacks when trying to break several passwords at once.
  3. One Rainbow table for each salt needed.
- Not possible to know if same user has same password on two different systems.

# Guess Passwords Online

- Possible targets: webmail, forums, communities, web shops
- Enter username + password and see if it works
  - Takes a long time
- Better
  1. Write program that sends the correct HTTP requests (username + password) and analyses the response
  2. Wait...

- **Protection:**
  - Do not allow many automated login attemps in a short time
  - Force user to verify that he/she is human after some failed attempts

# Example, Online Password Guessing

- ”Twitter” was compromised in the beginning of January 2009
  - Dictionary attack used to try passwords online for a specific account
  - Password was ”happiness”
  - Account turned out to belong to a staff member
- **Consequence:** Attacker had control over all accounts on ”Twitter”
  - Fake comments from e.g., Barack Obama, Britney Spears and Fox News were sent out.
- Article: http://blog.wired.com/27bstroke6/2009/01/professed-twitt.html


# ”Improved” Twitter

- Some time after the Jan 2009 attack Twitter decided to make improvements
  - The ”brute force” dictionary attack no longer worked
- In Sept 2012 another Twitter account was online brute forced?!?
- Turned out the login attempt **limitations was per IP**, not per account
- Article: http://www.buzzfeed.com/jwherrman/security-flaw-lets-hackers-steal-twitter-accounts
- Perhaps now ”improved Twitter” can be called improved Twitter?

On the positive side, but completely unrelated, Twitter uses bcrypt to hash passwords

# Guess Answer to Security Questions

- Security question common to allow users that forgot their password to recover it
  - In some cases the right answer will give you immediate access
- But obviously:
  - Password difficulty is upper bounded by the problem of answering the question
- Makes no sense to pick ”Hd#6%5Sue!7s” as password and ”What is my mother's name?” as question.

Surely no one would do that.....or?

# Example, Guessing Password Question

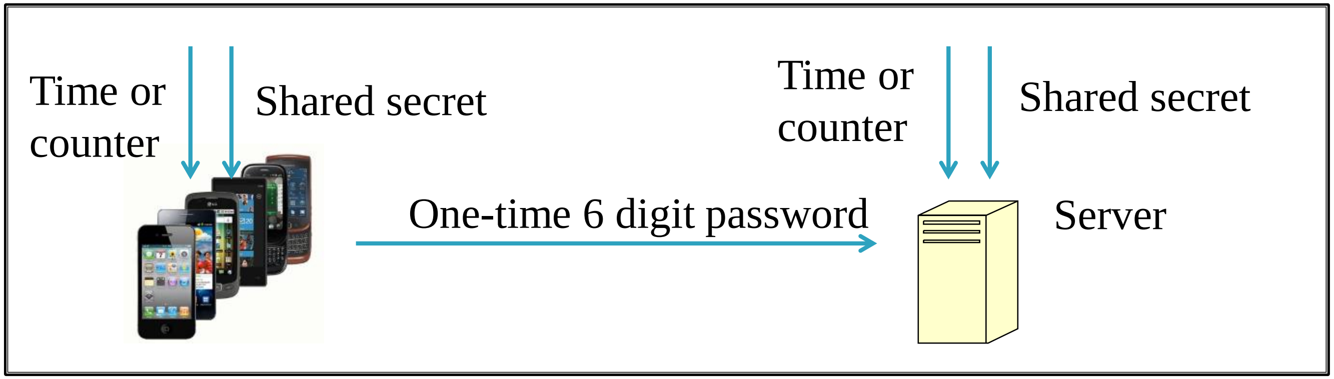
- Sarah Palin's Yahoo account was compromised in Sept 2008
- **Required info:** Her birthday, her zip code and answer to security question
- **Security question:** ”where did you meet your spouse?”
  - **Answer:** Wasilla High (the high school where she studied)
- According to attacker:
  - It took about 45 minutes in total
  - He found nothing of interest

## System Help Mechanisms

- Password checkers
  - Proactive checking
  - Reactive checking
- Automated password generation
- Password ageing
  - Require user to change after some given time
- Limit login attempts
  - Lockout user after a number of failed logins
- Show audit information
  - Inform user about number of failed logins after each login

# HOTP and TOTP (Something You Have)

- Use a device ”we all have” – the smart phone

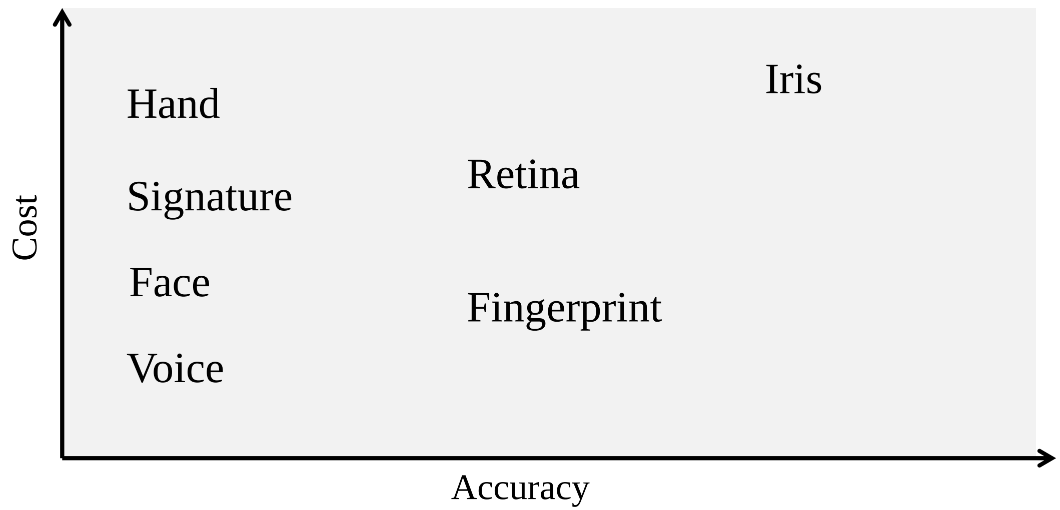



- See RFC 4226 for HOTP specification (HMAC-based one-time password algorithm)
  - Based on counter
- See RFC 6238 for TOTP specification (time-based one-time password algorithm)
  - Based on time
- See e.g., Google authenticator for implementation of TOTP

# Something You Are (Static Biometrics)

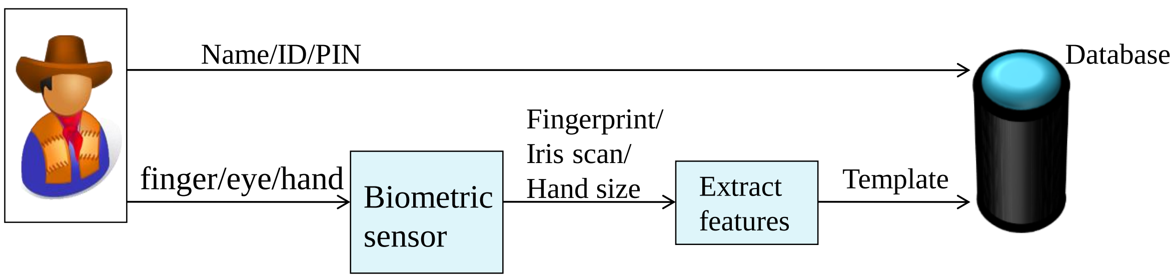
- Examples:
  - Fingerprint
  - Iris
  - Facial characteristics
  - Hand geometry
  - Retinal pattern
  - Voice
- **Requirements:** Uniqueness, Universality, Permanence, Measurability, User friendliness
- Can be used for both identification and verification

# Cost vs. Accuracy



# Biometric Systems

- Enrollment, create reference templates

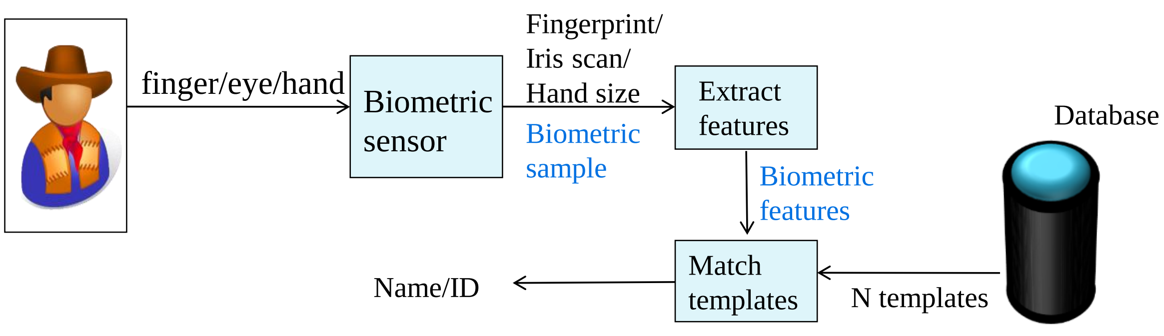



Several templates can be collected for one person

FER – Failure to Enroll Rate

# Biometric Systems

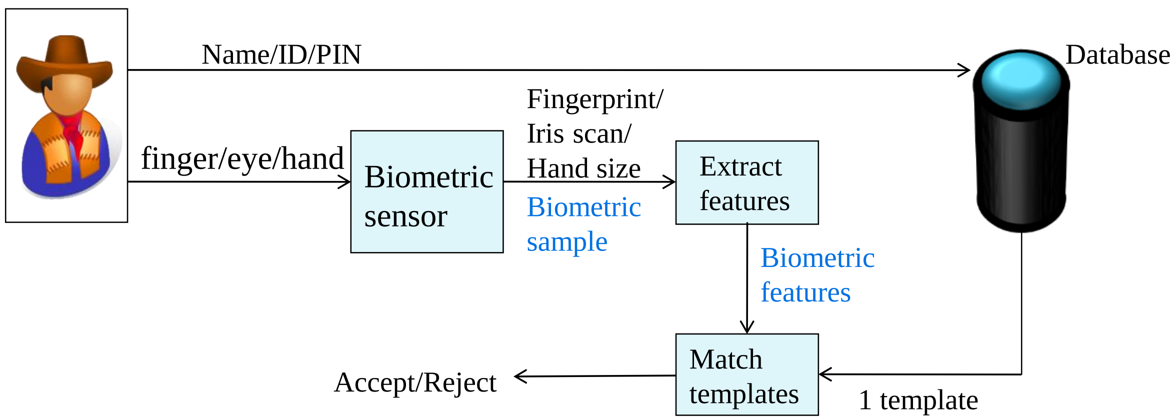
- Identification, *1:N* comparison




Identify a user from a database of *N* people

# Biometric Systems

- Verification, 1:1 comparison



# Errors

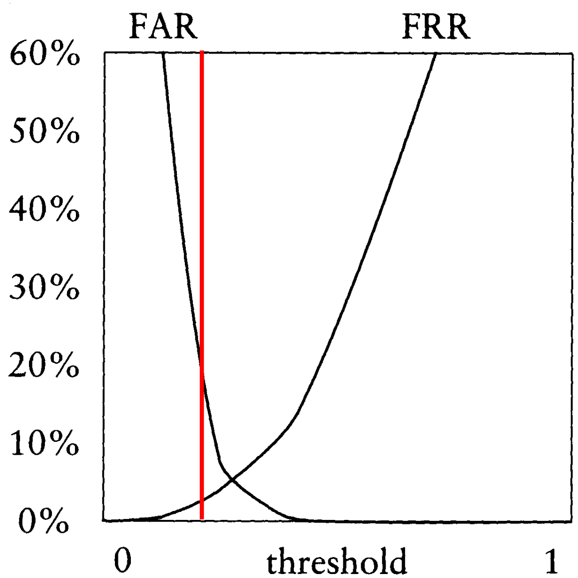
- Measurement will not exactly match reference template. (Different from passwords)
- Two kinds of errors
  - False positives or false matches (Accepting wrong user, security related)
  - False negatives or false nonmatches (Rejecting legitimate user, comfort related)
- Matching algorithm used to compare with templates
- The matching is converted to a *score*. Better match gives higher score
- A threshold will determine what the minimum score must be to accept user as valid

# FAR & FRR

FAR – False Acceptance Rate
FRR – False Rejection Rate

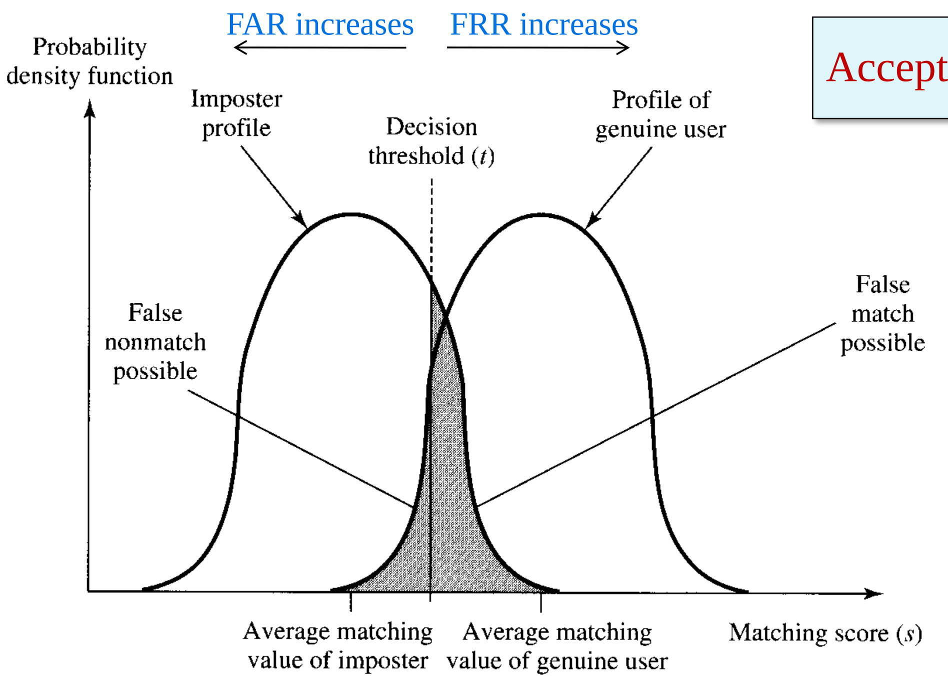
Equal Error Rate (EER) when FAR=FRR

**Graph for typical system**




Normalized score on x-axis

# Another View




Accept if s > t

**Placement of threshold *t* provides a tradeoff**