TDDE49
Information security concepts

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Based in part on original slides by Matus Nemec

Recommended literature

- **Computer Security and the Internet**
  - by Paul C. van Oorschot; first edition (2020)
  - https://people.scs.carleton.ca/~paulv/toolsjewels.html
  - Full text via LiU library: https://liu.se/en/library
- **Security Engineering** by Ross Anderson
  - Second edition (2008) is free from the author
  - https://www.cl.cam.ac.uk/~rja14/book.html
  - Third edition (2020) in LiU library (not online)
- **Threat Modeling** by Adam Shostack
  - 2014, in LiU library, online access for students

Information security goals

Information security goals

- Typically **defense** against **intentional** misuse
  - Protection against unintentional damage and modification also a requirement, but not the focus of computer security
    - E.g., reliability and redundancy
- Unathorized malicious actions and their consequences
  - Prevention of such actions
  - Detection and recovery from attacks
- Attacker is often a few steps ahead – unknown threats
- Main goals: **confidentiality**, **integrity**, **availability**

Confidentiality

- Goal: limiting access to non-public information, data is made available only to authorized users
- Stored and transmitted data is not revealed to unapproved (unauthorized) users

- Loss of confidentiality consequences:
  - Unauthorized data disclosure can lead to loss of trust in the organization, legal liability, fines, etc.
  - Example: Medical records available on the public Internet
- Technical means of protection:
  - Data encryption, access control

Integrity

- Goal: accuracy and completeness of information
- Protection against unauthorized data modification

- Loss of integrity consequences:
  - Data is no longer valid (reflecting reality) and reliable
  - Example: A patient is able to change their own prescription
- Technical means of protection:
  - Message authentication codes, secure hash algorithms

Note: Integrity is **not** the same as "*personlig integritet*"

- Swedish *personlig integritet* would translate roughly to "*privacy*"

Availability

- Goal: the system is accessible by authorized users when needed
- Protection against unauthorized deletion of data and disruption of services

- Loss of availability consequences:
  - Loss of productivity, inability to reach business goals
  - Example: A doctor cannot read patient’s past diagnoses
- Technical means of protection:
  - Reliability and redundancy, backup and recovery

Related goals and concepts

- Privacy
  - Confidentiality of personally sensitive information
- Authenticity of data
  - Integrity of origin – the author of the data is reliably known
- Accountability (and audit)
  - Ability to assign responsibility for past actions
  - E.g., transaction log of actions and identities
- Non-repudiation
  - Actions and commitments cannot be denied (repudiated)

Information security goals (CIA) summary

- **C**onfidentiality
  - Only authorized users can access the non-public information
  - Data in storage and transit is not undesirably revealed
- **I**ntegrity
  - Accuracy and completeness of information
  - Data remains unaltered, except by authorized users
- **A**vailability
  - The system is accessible by authorized users when needed
  - Protection against unauthorized deletion and disruption
- Sometimes includes Accountability and Non-repudiation
  - Actions attributed to users who cannot deny responsibility

Access control

Access control

- Restricts access to resources to authorized users
- Enables auditing of actions
- Possible implementation – access control list (ACL)
    - Each system resource (object) is assigned a list of permissions
    - Each list specifies which users (subjects) have access to the object and what operations are allowed on the object
    - Example: filesystem of an operating system

Role-based access control (RBAC)

- Authorization can be based on a role; each role is assigned permissions, roles are assigned to users
  - Easier to assign a single role to a user than to manage the same set of permissions repeatedly for many users
  - Easier to manage the permissions of a role than to change the same permission repeatedly for many users
  - Users can have multiple roles or groups

Example:

1. The *manager* role has access to personnel files, but not to web server configuration.
2. *IT-admin* role has access to web configuration, but not to personnel files.

But: If *manager* and *IT-admin* is the same person, he/she has access to both

Access control procedure

1. Identification – Making a claim about someone's identity
   - E.g., stating your name; presenting a username to a website
2. Authentication – Verification of a claim of identity
   - E.g., comparing a photo on your ID card to your face; checking if a username and a password match
3. Authorization – Determining the permitted actions
   - E.g., which features are accessible
   - Defined by policies (e.g., only the system administrator is allowed to install new programs), enforced by access control mechanisms (e.g., file system permissions: read, write, execute)

User authentication

User authentication

- Verification of a claim of identity
- Allows making access control decisions (authorization)

1. Something you know
   - E.g., a password, a PIN, an answer to a security question
2. Something you have
   - E.g., the LiU card, a credit card, a key to your apartment, BankID in your phone
3. Something you are
   - Biometrics, e.g., based on fingerprint/iris/face recognition
   - Something you do – behavior (handwriting, voice recognition, …)
   - Where you are – location based authentication (e.g., geolocation)

Multi-factor authentication

- Two methods used in parallel
- Typically from different categories (not 2 passwords)
- Examples:
  - Password and a one-time PIN received via SMS/from a challenge-response calculator/from a push notification
  - Payment terminals, ATM – chip-card and a PIN
  - Password and a biometric
- Mandatory with payment service providers in the EU
- Easy to setup with phone apps for web services
  - (e.g., OTP with Google, Microsoft authenticator)

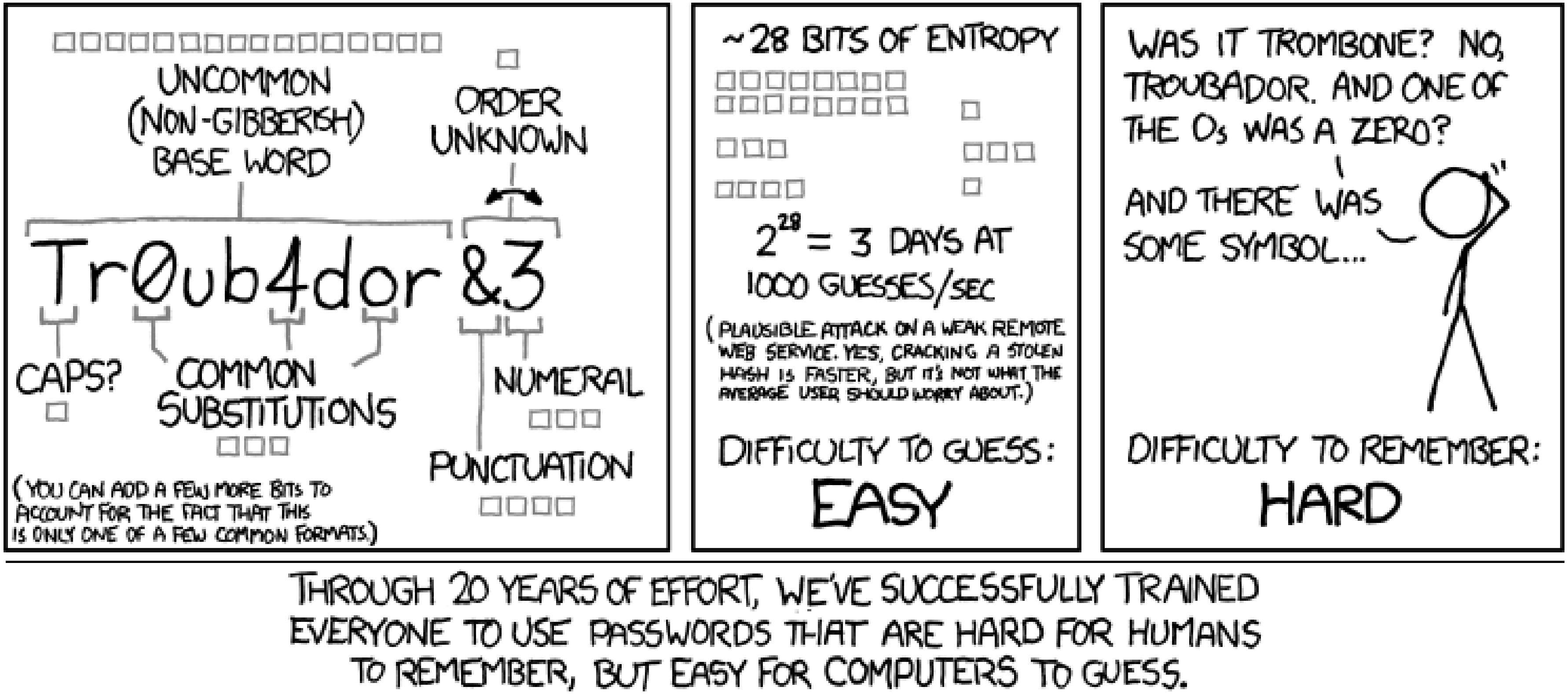
Something you know – passwords 1/2

- Typical account with a **username** and a **password**
- Some advantages:
  - Easy to use and understand
  - No extra device required – no extra cost
  - Easy to change or recover if lost
  - Quick (especially with password managers)
  - Easy to delegate (although users may forget to change the password to take back the delegation)
  - Well studied (user behavior, attacks)

Something you know – passwords 2/2

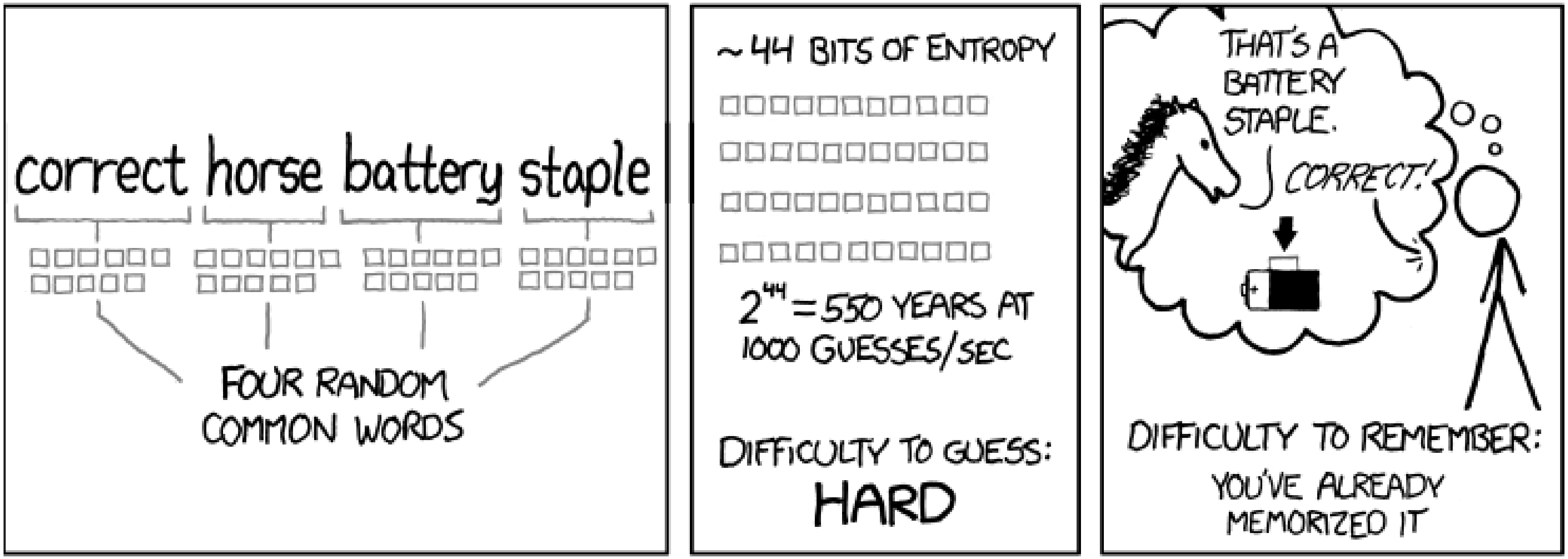
- Password disadvantages – usability issues:
    - **Password re-use across accounts is insecure**
        - Password is never more secure than the *least* secure site/system where you reused it!
    - Avoid writing down your password
    - Make it easy to remember, but difficult to guess
    - Most sites have some password complexity policies – length, special characters
    - Expiration policies (e.g., change every 90 days) – outdated and counterproductive
        - For example, users just add 1, 2, 3… to their old password

Trouble with passwords


UNCOMMON (NON-GIBBERISH) BASE WORD
ORDER UNKNOWN
Tr0ub4dor&3
CAPS?
COMMON SUBSTITUTIONS
NUMERAL
PUNCTUATION
(YOU CAN ADD A FEW MORE BITS TO ACCOUNT FOR THE FACT THAT THIS IS ONLY ONE OF A FEW COMMON FORMATS.)
~28 BITS OF ENTROPY
2^28 = 3 DAYS AT 1000 GUESSES/SEC
(PLAUSIBLE ATTACK ON A WEAK REMOTE WEB SERVICE. YES, CRACKING A STOLEN HASH IS FASTER, BUT IT'S NOT WHAT THE AVERAGE USER SHOULD WORRY ABOUT.)
DIFFICULTY TO GUESS: EASY
WAS IT TROMBONE? NO, TROUBADOR. AND ONE OF THE Os WAS A ZERO?
AND THERE WAS SOME SYMBOL...
DIFFICULTY TO REMEMBER: HARD
THROUGH 20 YEARS OF EFFORT, WE'VE SUCCESSFULLY TRAINED EVERYONE TO USE PASSWORDS THAT ARE HARD FOR HUMANS TO REMEMBER, BUT EASY FOR COMPUTERS TO GUESS.

https://xkcd.com/936/

An option for choosing a password


correct horse battery staple
FOUR RANDOM COMMON WORDS
~44 BITS OF ENTROPY
2^{44} = 550 YEARS AT 1000 GUESSES/SEC
DIFFICULTY TO GUESS: HARD
THAT'S A BATTERY STAPLE.
CORRECT!
DIFFICULTY TO REMEMBER: YOU'VE ALREADY MEMORIZED IT

https://xkcd.com/936/

Something you have

- Keys, badges, tokens, smart cards
- Can be lost, stolen
  - Difficult (costly) to replace, but loss can be quickly detected
- Some can be copied
  - E.g., credit card skimming – copy of the magnetic stripe; radio eavesdropping on RFID key cards; some car keys
- Cryptographic smartcards have more abilities (mobile phone SIM, credit card, also in ID cards, passports, …)

<- RFID card
Photo Peter Modin

ID with a cryptographic
Smartcard ->
Photo by Skatteverket

Something you have – tokens

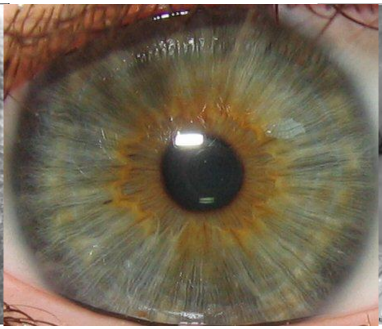
- Devices that produce one time passwords (OTP)
- Can offer strong cryptography and cannot be copied
  - Often extremely difficult to copy even with physical access
- Cryptographic functions with a secret key applied to a unique challenge and/or the current time
- Challenge-response token (e.g., bank token)
- Time-based token (e.g., RSA SecurID)
- Still vulnerable to phishing

By I. Hölscher

By A. Klink

Something you are – biometrics 1/3

- Using biological properties for identification
- Identification vs. verification of identity
  - Identification – identify a user from all possible users
  - Verification only – e.g., in a combination with a user ID/PIN
- Fingerprint, iris (visible/infrared light), face, retina



By M. Goldthwaite

By J. Daugman

By Apple

By M. Häggström

Something you are – biometrics 2/3

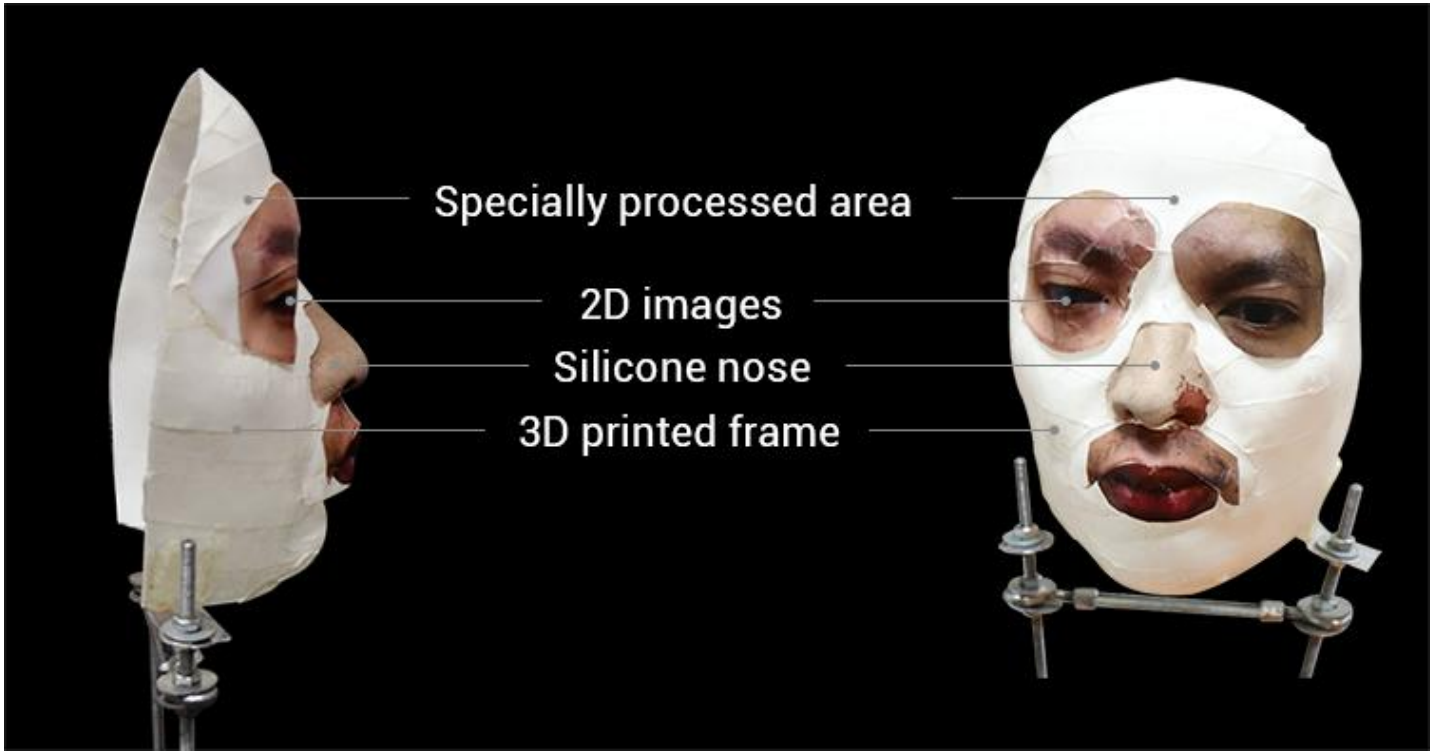
- Requirements for biometrics
    - Unique – The property is distinct for different individuals
    - Permanent – The property cannot change over time
    - Universal – Almost everyone has such property
    - Collectable – It is possible to easily measure the property
    - Difficult to circumvent – Hard to fool the system

Something you are – biometrics 3/3

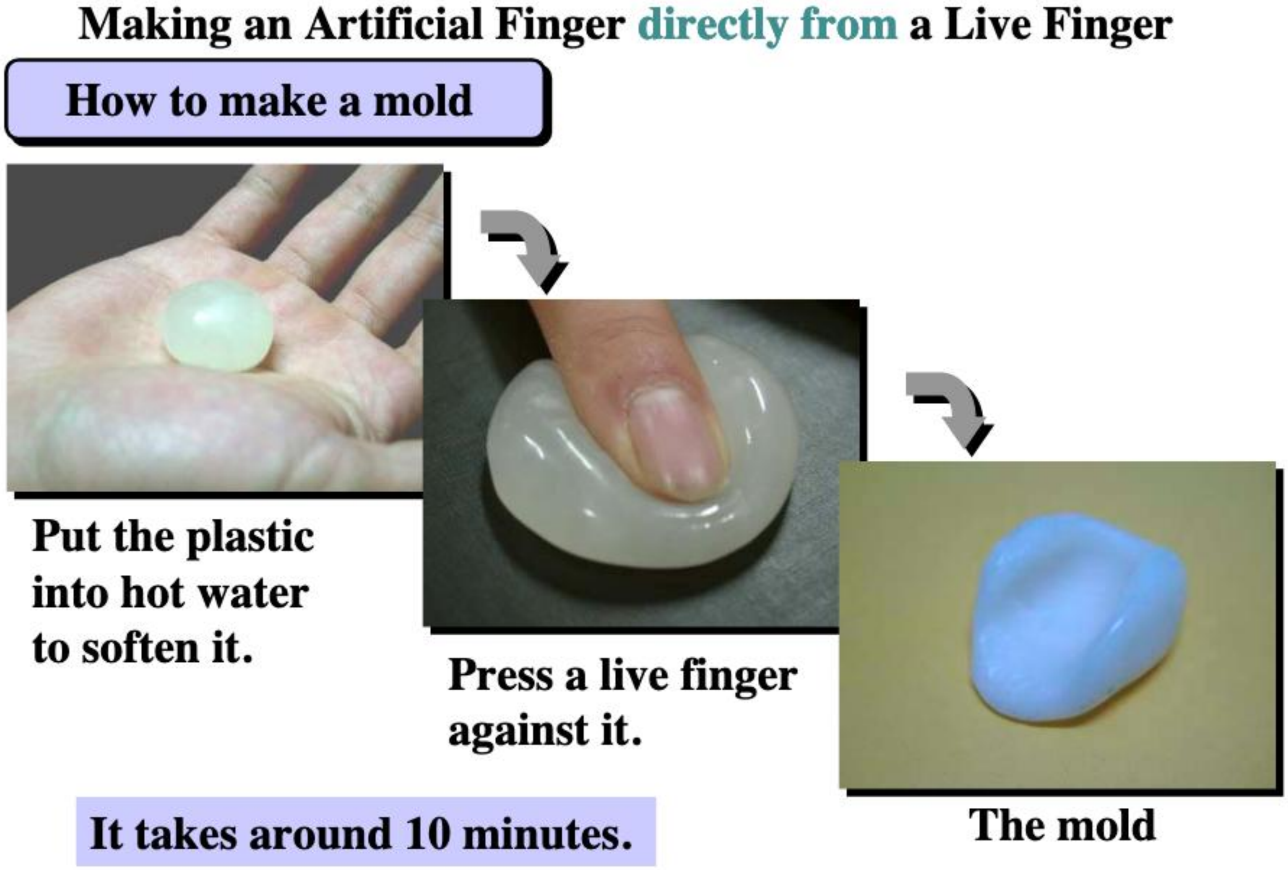
- Advantages
  - Usability – nothing to carry, no cognitive burden
  - Cannot be forgotten
- Some challenges and disadvantages
  - Variable (slightly different each time you measure)
  - Not secret and easily acquired, yet also cannot be changed
  - Failure to enroll – some users cannot use the method easily
  - Failure to capture – e.g., cannot be read with wet fingers
  - Requires a fallback mechanism for such cases
  - Can falsely reject legitimate and falsely accept ilegitimate users
- In summary, biometrics are suitable as an additional (second factor) authentication or used under supervision (e.g., security checkpoint)

Fooling biometrics

- 3D-printed mask for FaceID on an iPhone X in 2017 by BKAV



Fooling biometrics – Tsutomu Matsumoto 1/2



Making an Artificial Finger directly from a Live Finger

How to make a mold

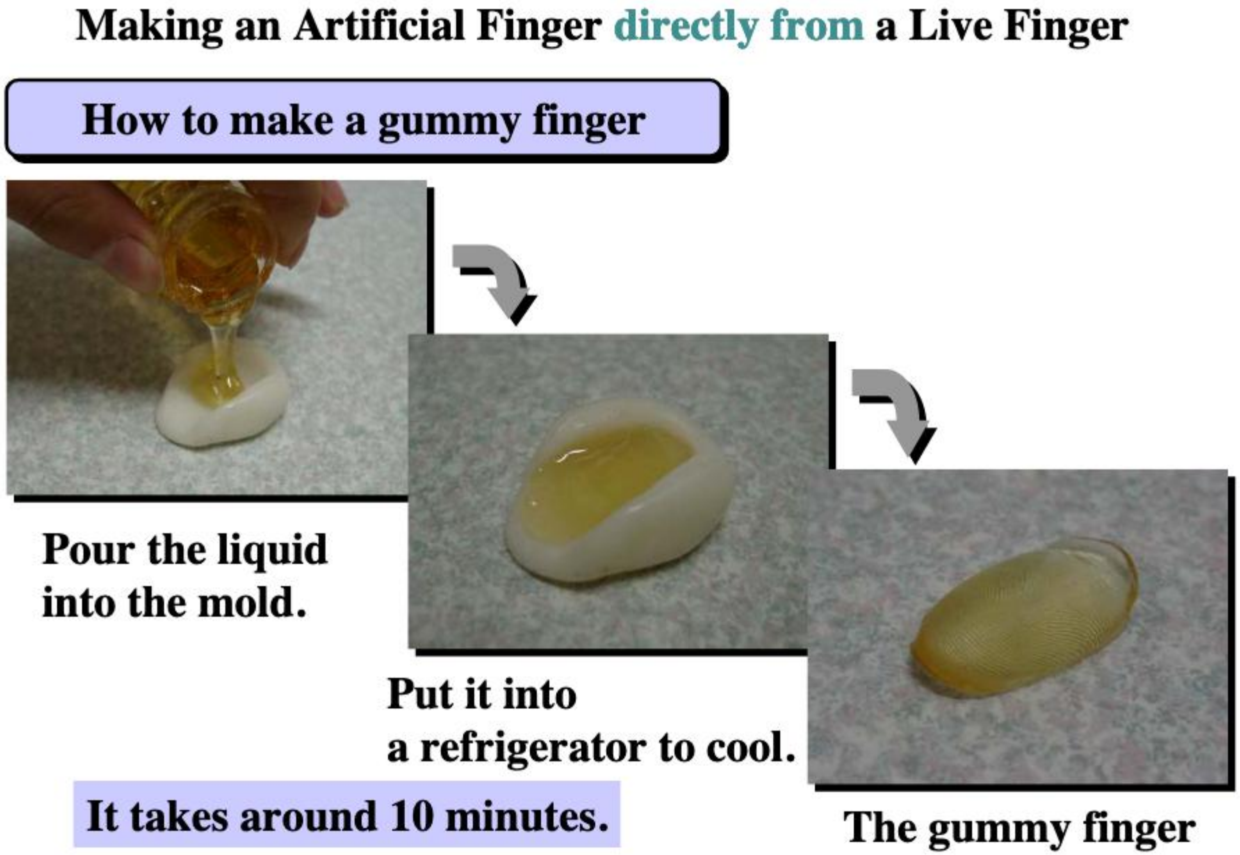
Put the plastic into hot water to soften it.

Press a live finger against it.

The mold

It takes around 10 minutes.

Fooling biometrics – Tsutomu Matsumoto 2/2



Making an Artificial Finger directly from a Live Finger

How to make a gummy finger

Pour the liquid into the mold.

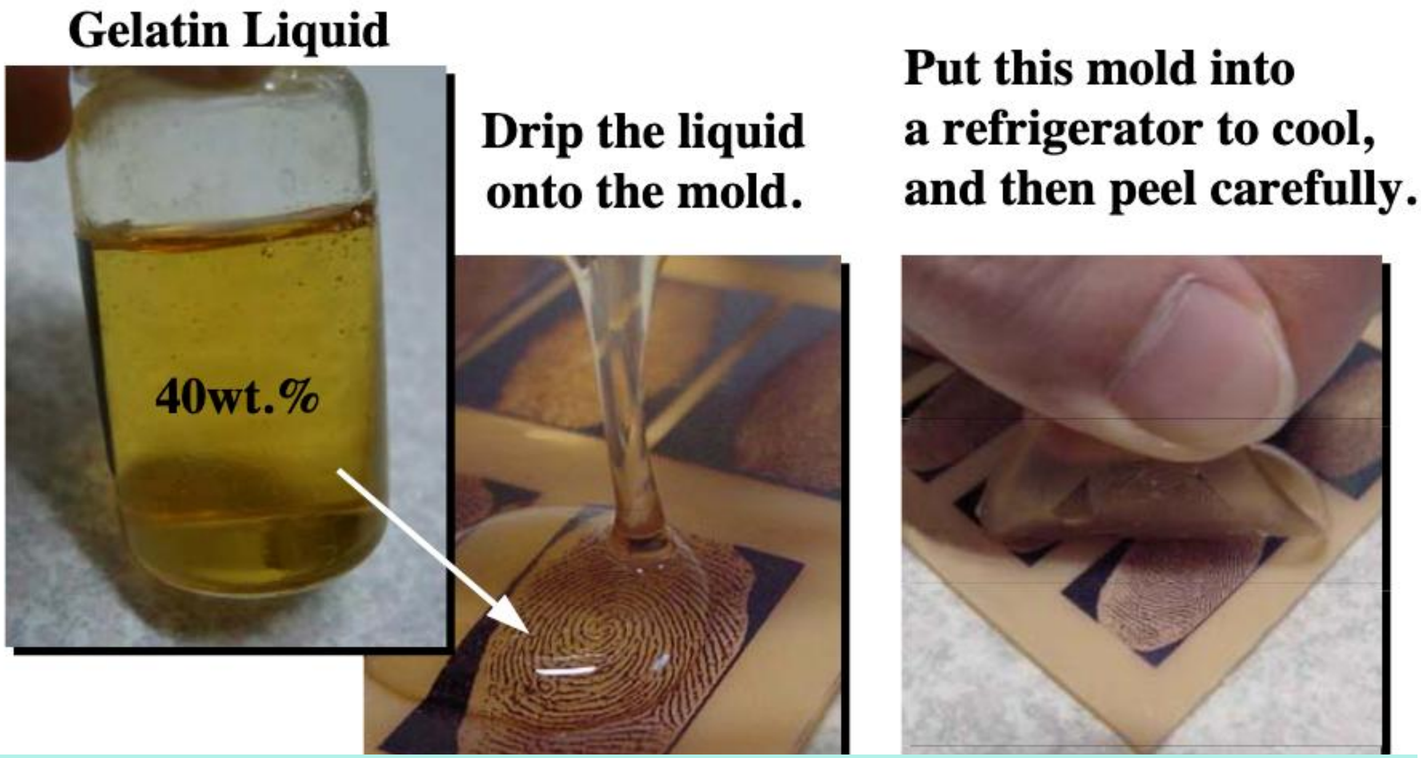
Put it into a refrigerator to cool.

It takes around 10 minutes.

The gummy finger

- Attack from 2002, can be defeated by a liveness check

Fooling biometrics – fake fingerprints


Gelatin Liquid
40wt.%
Drip the liquid onto the mold.
Put this mold into a refrigerator to cool, and then peel carefully.

- Fingerprint image, laser printer, glue; fools optical fingerprint reader; Tsutomu Matsumoto 2002

User authentication summary

- Verification of identity using different methods:

1. Something you know
    - E.g., a password, a PIN, an answer to a security question
2. Something you have
    - E.g., a passport, BankID, token device ("bankdosa")
3. Something you are
    - Biometrics, e.g., based on fingerprint/iris/face recognition

- Multi-factor authentication (MFA, 2FA for 2-factor auth.)
    - E.g., password and a one-time password from a device

Common attacks

Know Thy Enemy

A few common attack scenarios (in no particular order):

1. Password attacks
   a) Brute-force
   b) Dictionary attacks
   c) Credential stuffing
2. Social engineering – Phishing, Spear phishing
3. Malware – Ransomware, Spyware, etc.
4. Software exploits

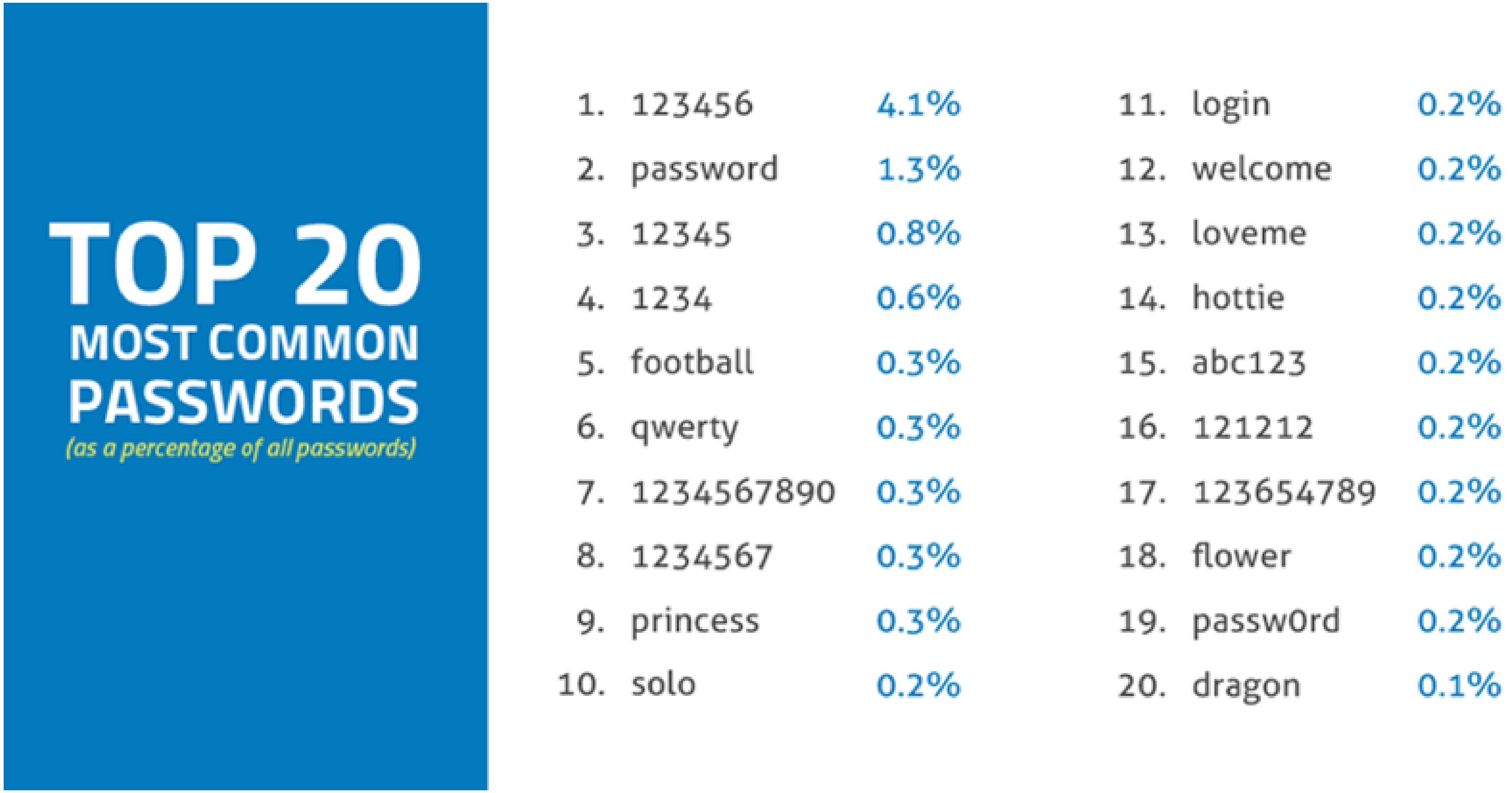
Password attacks – Brute force

- A **search attack** is the most basic form of brute force.
- Given a character set (e.g. [*abcdefghijklmnopqrstuvwxyz*]) and a password length, try every possible combination
- For example, lower case letters, 3 character password:
  - aaa
  - aab
  - aac
  - …
- Slow, but it will at some point crack the password.

Password attacks – Dictionary attacks

- **Dictionary attacks** exploit the fact that it is common for users to pick passwords that are easy to remember
  - The password “123456789ABC” is a lot more common than “frex#be!?Vu6adR”…
- Use a predetermined list of words (a dictionary) and try these as passwords
  - An actual dictionary of common words
  - Even better: A leaked set of real passwords

Password attacks – Dictionary attacks



TOP 20 MOST COMMON PASSWORDS

(as a percentage of all passwords)

1.	123456	4.1%
2.	password	1.3%
3.	12345	0.8%
4.	1234	0.6%
5.	football	0.3%
6.	qwerty	0.3%
7.	1234567890	0.3%
8.	1234567	0.3%
9.	princess	0.3%
10.	solo	0.2%
11.	login	0.2%
12.	welcome	0.2%
13.	loveme	0.2%
14.	hottie	0.2%
15.	abc123	0.2%
16.	121212	0.2%
17.	123654789	0.2%
18.	flower	0.2%
19.	passw0rd	0.2%
20.	dragon	0.1%

“Skyhigh analyzed 11 million passwords for cloud services that are for sale on Darknet…” (2015)

Password attacks – Dictionary attacks

- **Rule-based search**: make up some transformation rules that you apply to each candidate password.

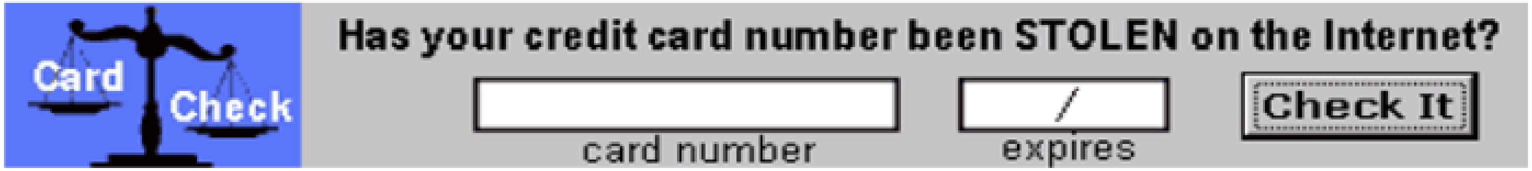
- Example: use the following transformations: ***duplicate***, ***toggle case***, ***replace e with 3***.
    - Assume we want to test the password: ***pressure***, then we would test:
        - *pressure*
        - *pressurepressure*
        - *PRESSURE*
        - *pr3ssur3*
        - *etc…*

Password attacks – Credential stuffing

- A variant of dictionary attacks
- Attacker uses a list of known username/password combinations **from an earlier breach** and tries every entry in the list on another site
- Exploits the fact that many people use the same username and password on several sites

Social engineering

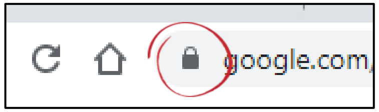
- Manipulation of people as part of a cyberattack
  - Divulge passwords or sensitive information
  - Performing actions to facilitate a break-in into IT systems
  - Very common that cyberattacks today use social engineering to get initial foothold into computer systems
- **Phishing** – for example, email to trick the receiver into, e.g.:
  - Give up passwords or personal info
  - Download malicious software



Has your credit card number been STOLEN on the Internet?

Social engineering – Spoofing

- Attackers are getting increasingly good at spoofing official-looking emails from, e.g., employers, e-commerce sites, government institutions, postal service, etc.
  - Might link to a fake login page – which steals your password
  - Common to use URLs that are similar-looking to legitimate URLs
  - Can use stolen certificates or hacked sites to have TLS encryption (“padlock symbol”)
  - Can even use tricks with *homographs:*
    - For example, the Latin letters “e” and “a” are replaced with the Cyrillic “e” and “a”: wikipedia.org



Social engineering – Spear phishing

- Instead of mass-mailing phishing emails and hoping that someone takes the bait – **use targeted attacks**
  - CEO
  - IT-admin
  - … or anyone who can (inadvertently) help attackers to get a foothold into system
- Typically entails surveilling target for an extended period of time to learn, e.g.:
  - Role and responsibilities in organization
  - Contacts
  - Interests (personal, professional)
- Send tailor-made phishing email to pique target's interest

Malware

- Software designed with the *intention* of causing some harmful effects.
  - Spyware
  - Botnet clients
  - Ransomware
  - …
- Most malware today are *trojans* – requires some action from the victim
  - Download "free" pirated software
  - Spoofed emails
    - Open malicious email attachment
    - "You need to install this important software update…"

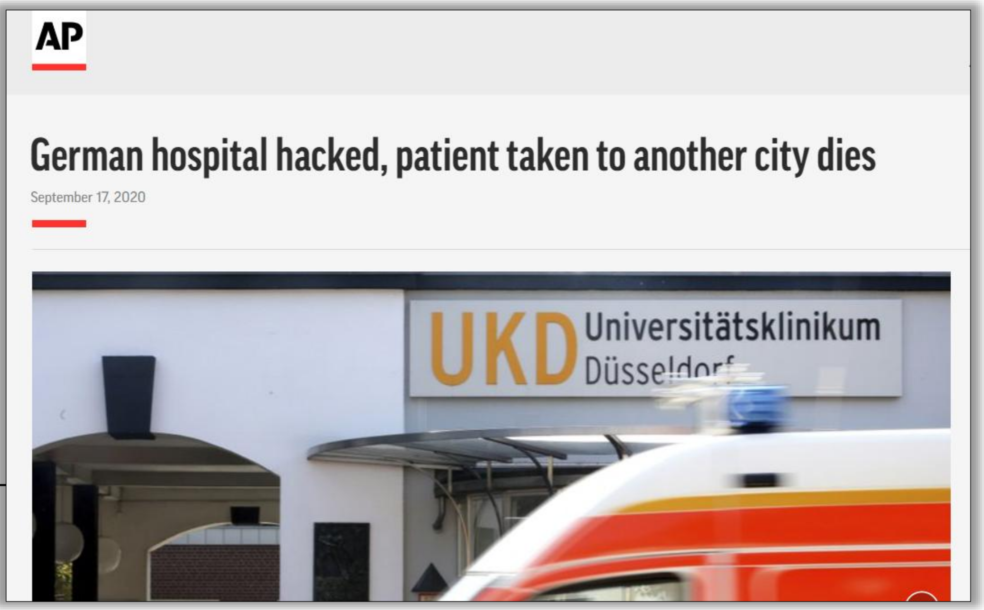
Malware

- **Spyware** is designed to steal, e.g., passwords, credit card numbers, etc.
- **Botnet clients** silently turn victim machines into a remotely controlled member of a *botnet*
  - Victim is often unaware of the infection…
  - …but the attacker can remotely instruct all infected machines to perform e.g. denial-of-service attacks against websites
    - Flood website with repeated connection attempts from thousands of hijacked computers
    - Often used for extortion or hacktivism

Malware – Ransomware

- Encrypt all files on hard drive. Demand ransom to be paid for restoring the system.
- Might also exfiltrate sensitive files – can be used as leverage to persuade victim to pay up

- Some attacks use the "shotgun approach" – send spam emails with, e.g., malicious links
  - Some will fall for it and get infected
  - Can also spread over a network to infect vulnerable machines
  - Sometimes with inadvertent disastrous effects …

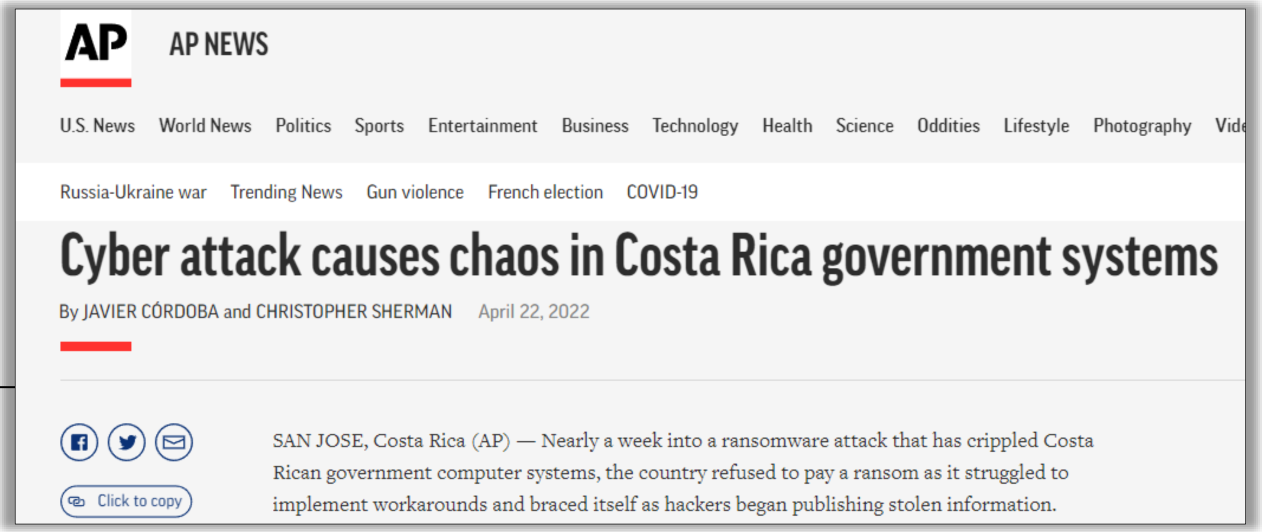

AP

German hospital hacked, patient taken to another city dies

September 17, 2020

Malware – Ransomware

- However, **targeted attacks** are becoming increasingly common
  - Carefully planned operations by professional hacker groups
  - Often executed over the course of several months
- Might use spear phishing to gain initial foothold into system
- Infiltrate other systems over an extended period of time – until attackers are ready
  - Cripple entire IT-infrastructure and demand ransom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Cyber attack causes chaos in Costa Rica government systems

By JAVIER CÓRDOBA and CHRISTOPHER SHERMAN April 22, 2022

SAN JOSE, Costa Rica (AP) — Nearly a week into a ransomware attack that has crippled Costa Rican government computer systems, the country refused to pay a ransom as it struggled to implement workarounds and braced itself as hackers began publishing stolen information.

Software exploits

- Programs can have bugs (programming mistakes) that allows manipulating their behavior
    - Such bugs are known as *software vulnerabilities*
- By providing a specially-crafted input to a vulnerable program, attackers can sometimes “trick” the program into executing the attacker’s commands
    - For example, download and install malware
- The specific procedure used to trigger a vulnerability is called an *exploit*

Software exploits

Can be used to spread malware

- Malicious e-mail attachments (PDF, Word, etc.)
  - When opened with a vulnerable document viewer, installs malware
- Malicious web page – enough to *view* the web page with an old, vulnerable version of a web browser
- Can also be used to spread malware over a network (e.g., old version of Windows with file-sharing enabled)

This is why most modern software have auto-update functionality!

- However, not all software can be updated
- For example, medical equipment – cannot modify in any way (including software) without voiding safety certification
  - These things are often PC computers “under the hood”, running an old Windows version…

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