CSE 127 Computer Security

Stefan Savage, Spring 2020, Lecture 15

User Authentication

Today: user authentication

- Change of Focus
  - Thus far we have largely focused entirely on **computers** (i.e., how we try to protect ourselves from attacks on code or the OS or the network by an untrusted party)
  - Today, we're going to start talking about **people** too
  - Today's issue:
    - How do we determine if a process is running on behalf of a *particular* trusted party?

- The goal is to understand:
  - Common techniques for authenticating users, locally and remotely;
  - Security challenges associated with different authentication methods;
  - Mitigations designed to address some of the above security challenges.

Authentication

- Using cryptography Alice and Bob can authenticate each other by proving they know respective secret keys
  - Alice sends a random challenge to Bob. Bob signs (or MACs) the challenge.
  - Switch roles, repeat.
- What exactly did we authenticate?
  - Have Alice and Bob really committed their secret keys to memory?
  - Did they manually perform cryptographic signing operations?

Authentication

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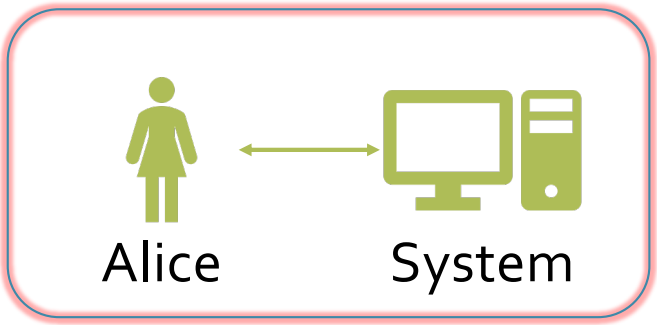
- What exactly did they authenticate?
  - Have Alice and Bob really committed their secret keys to memory?
  - Did they manually perform cryptographic signing operations?
- They authenticated each other's computers.

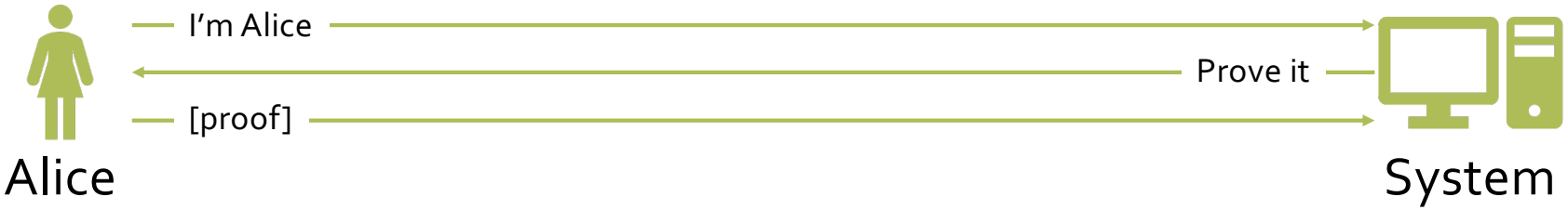
Authentication

- How do we authenticate a human user to a system?
  - System is often remote server
- Authenticate: ascertain who is interacting with the system
  - Necessary to apply appropriate security policy
  - Only the intended subject should be able authenticate to the system as that subject



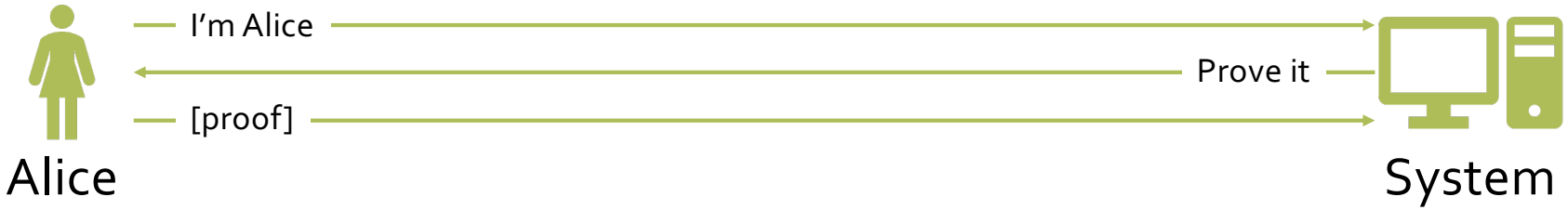
Authentication

- How do we authenticate a human user to a machine?
- Provide ***identity*** and proof of identity.
- Identity examples:
  - Name, Username, Student ID, Others?



Authentication

- How can Alice prove that she's really Alice?
- 3 types of authentication factors
  - Password: ***Something you know***
  - Token: ***Something you have***
  - Biometrics: ***Something you are***
- Each factor can be used independently, or combined for ***multi-factor*** authentication.
  - Typically 2-factor



Something You Know

Something You Know

- A secret that only the real Alice should know
  - A secret passcode
    - Examples: PIN*, password
  - A secret about Alice
    - Examples: mother's maiden name, first pet, mortgage payment
- Technically, only proves knowledge of secret, not that it's really Alice
  - Secrets leak, can be shared, guessed.

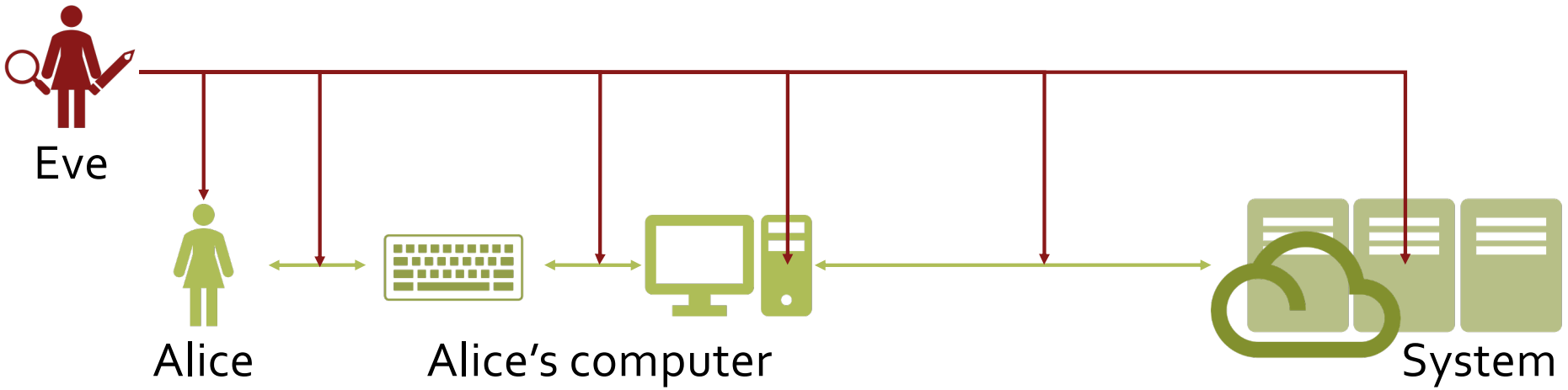
- * PIN: Personal Identification Number
  - Misnomer. Usually used for authentication, not identification.

Passwords

- How does Alice prove she knows the password?
- Simplest: Alice provides the password to the system
- Problems?
  - Passive adversary may observe password in transit
    - Need secure channel to protect confidentiality
  - Active adversary may impersonate the system
    - Alice needs a way of authenticating the system

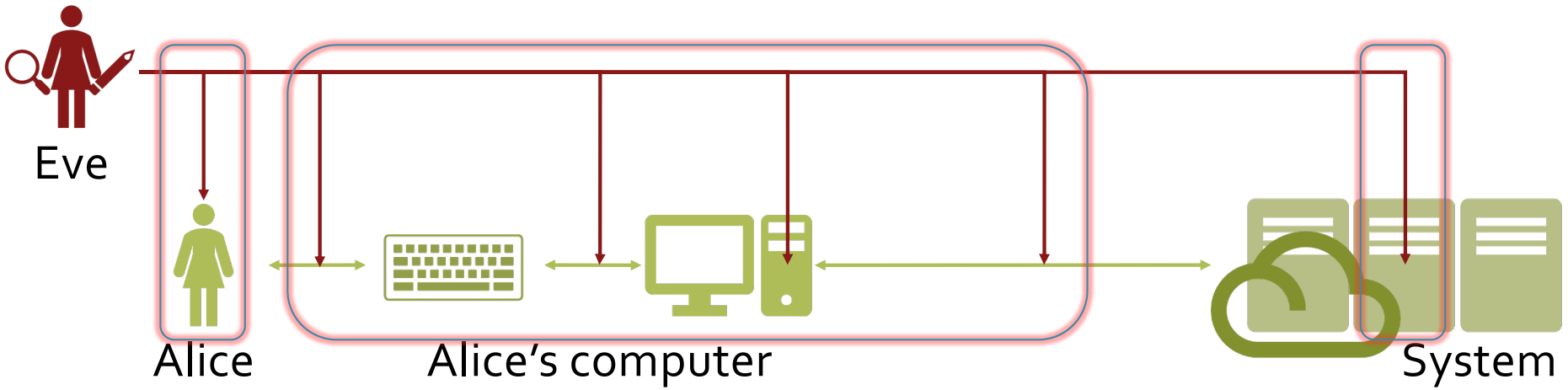
Setting

- Alice uses a keyboard to type her password into client software that sends it on to the remote system for authentication.
- Which points can Eve attack?



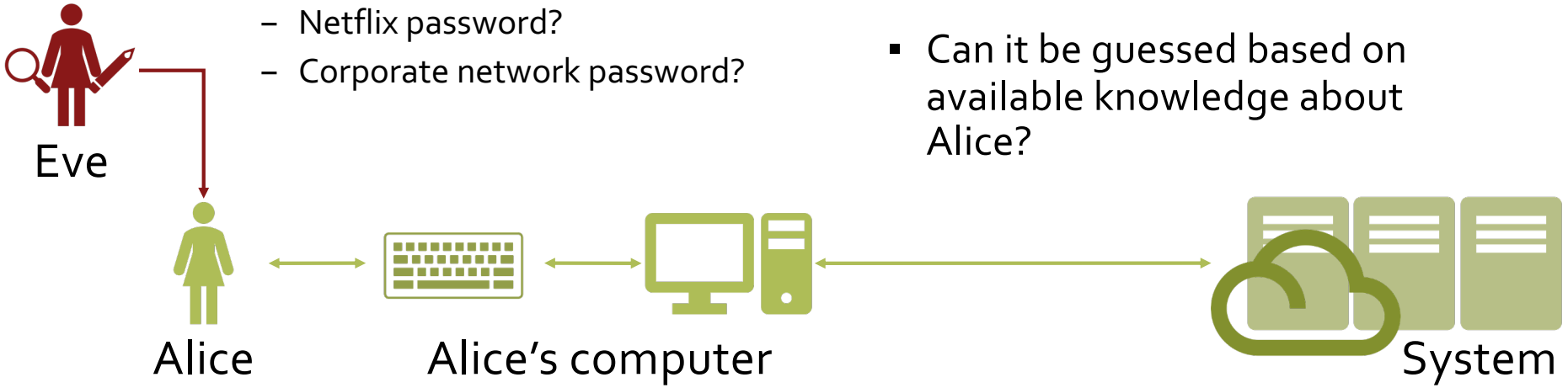
Attacking Passwords

- Get it from Alice
- Intercept it
- Get it from the system



Attacking Passwords

- $5 wrench?
- Is Alice vested in keeping it secret?
  - Debit card PIN number?
  - Personal email password?
  - Netflix password?
  - Corporate network password?
- Is it written down somewhere?
  - Good against remote attackers
  - Not good against targeted local attacks (co-workers, family, abusers)
  - Know your threat model!
- Can it be guessed based on available knowledge about Alice?



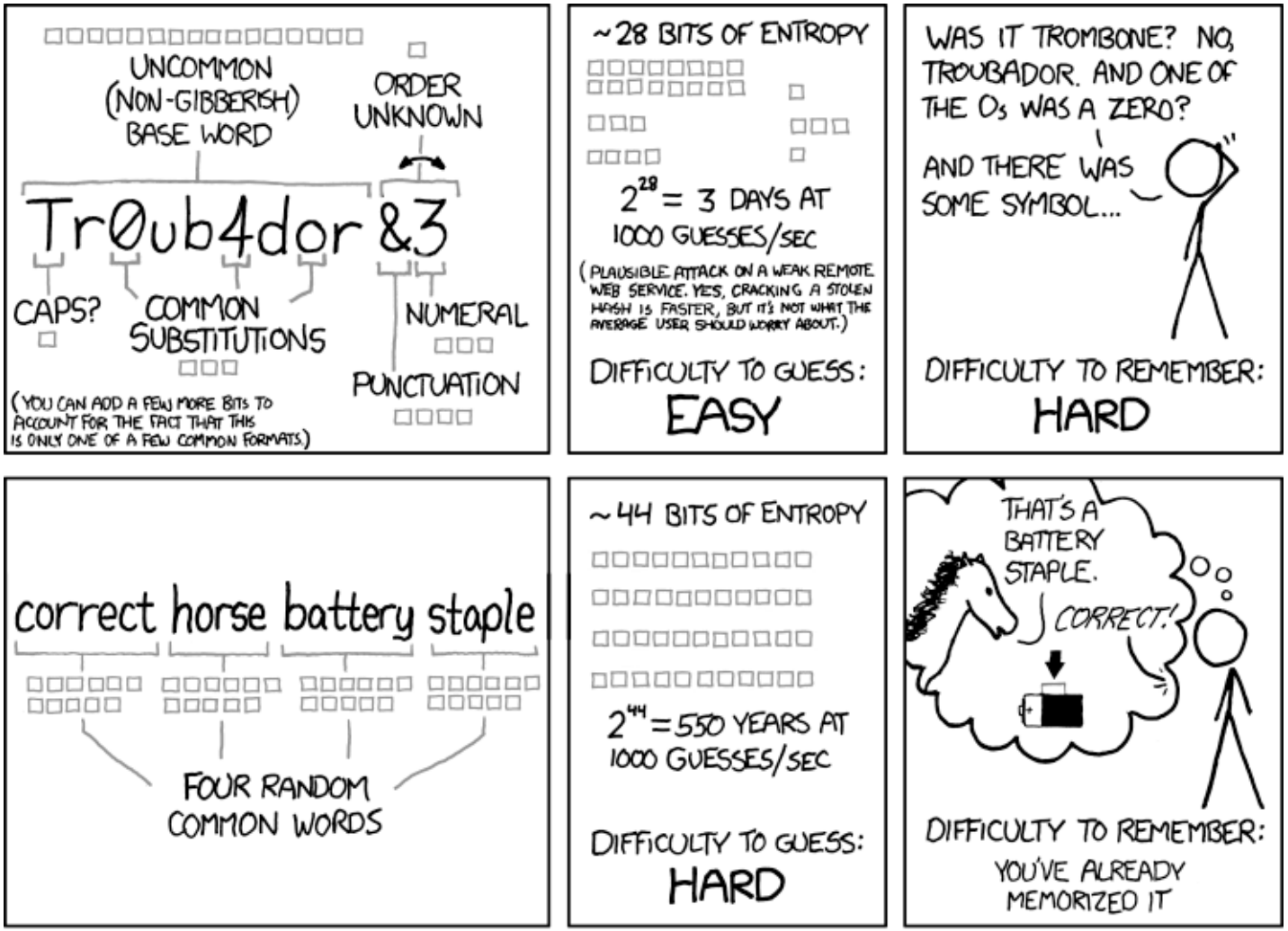
Strong Passwords

- The challenge is to come up with passwords that are hard to guess, but easy to remember.
- Common password rules:
  - Composition
    - Letters and numbers, mixed case, symbols
    - Banned dictionary
  - Length
  - Lifetime
- But… unintended consequences
  - Required letters/symbols -> ?
  - Monthly change requirement -> ?

Top 25 most common passwords by year according to SplashData

Rank	2011[4]	2012[5]	2013[6]	2014[7]	2015[8]	2016[3]	2017[9]
1	password	password	123456	123456	123456	123456	123456
2	123456	123456	password	password	password	password	password
3	12345678	12345678	12345678	12345	12345678	12345	12345678
4	qwerty	abc123	qwerty	12345678	qwerty	12345678	qwerty
5	abc123	qwerty	abc123	qwerty	12345	football	12345
6	monkey	monkey	123456789	123456789	123456789	qwerty	123456789
7	1234567	letmein	111111	1234	football	1234567890	letmein
8	letmein	dragon	1234567	baseball	1234	1234567	1234567
9	trustno1	111111	iloveyou	dragon	1234567	princess	football
10	dragon	baseball	adobe123[a]	football	baseball	1234	iloveyou
11	baseball	iloveyou	123123	1234567	welcome	login	admin
12	111111	trustno1	admin	monkey	1234567890	welcome	welcome
13	iloveyou	1234567	1234567890	letmein	abc123	solo	monkey
14	master	sunshine	letmein	abc123	111111	abc123	login
15	sunshine	master	photoshop[a]	111111	1qaz2wsx	admin	abc123
16	ashley	123123	1234	mustang	dragon	121212	starwars
17	bailey	welcome	monkey	access	master	flower	123123
18	passw0rd	shadow	shadow	shadow	monkey	passw0rd	dragon
19	shadow	ashley	sunshine	master	letmein	dragon	passw0rd
20	123123	football	12345	michael	login	sunshine	master
21	654321	jesus	password1	superman	princess	master	hello
22	superman	michael	princess	696969	qwertyuiop	hottie	freedom
23	qazwsx	ninja	azerty	123123	solo	loveme	whatever
24	michael	mustang	trustno1	batman	passw0rd	zaq1zaq1	qazwsx
25	Football	password1	000000	trustno1	starwars	password1	trustno1

https://en.wikipedia.org/wiki/List_of_the_most_common_passwords



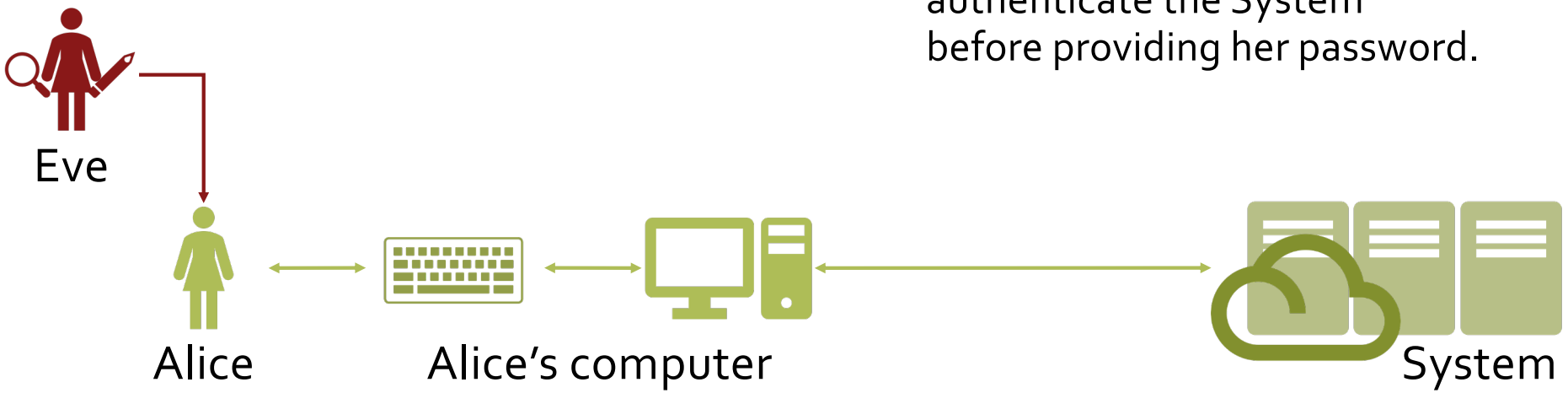
THROUGH 20 YEARS OF EFFORT, WE'VE SUCCESSFULLY TRAINED EVERYONE TO USE PASSWORDS THAT ARE HARD FOR HUMANS TO REMEMBER, BUT EASY FOR COMPUTERS TO GUESS.

https://xkcd.com/936/

Attacking Passwords

- Can Eve trick Alice into revealing her password?
- How does Alice know that she is logging into the real System?

- Phishing!
  - Tricking Alice into revealing her password by impersonating the system she is trying to access.
- Alice has to be able to authenticate the System before providing her password.



Phishing

- How can Alice authenticate the System?
- HTTPS certificates validate the URL.
- What does it really tell you?
  - That you are communicating to a server owned by UCSD?
  - No. Only that you are communicating to www.ucsd.edu and your connection is secure (confidentiality and integrity are protected) against passive and active attackers on the link.

Phishing

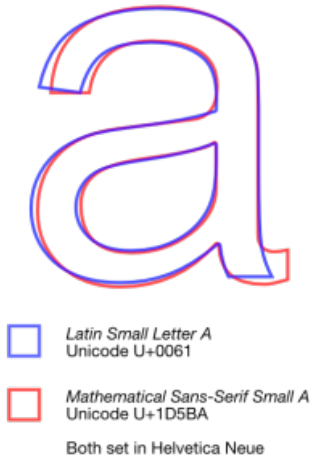
- How do you know www.ucsd.edu is a legitimate UCSD web site?
- What about:
  - www.cse.ucsd.edu
  - www.ucsd.cse.edu
  - www.cse-ucsd.edu
  - www.cs.ucsd.e.duck
  - www.cs.ucsd.education

Phishing

- How do you know www.ucsd.edu is a legitimate UCSD web site?
- A user is expected to know which domains are associated with the entity they are trying to interact with.
  - And how to properly parse the URL
    - Some browsers now highlight the domain portion

Phishing

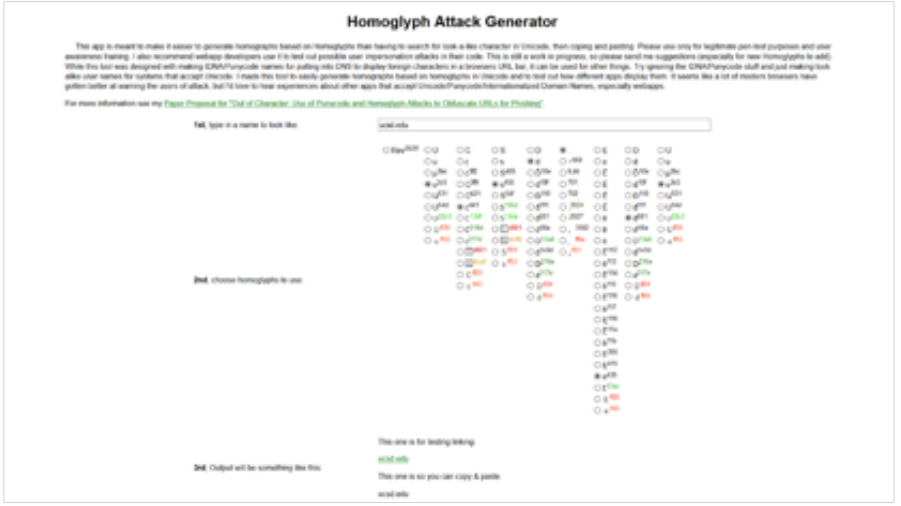
- What if the user knows which domain is real?
- ***Homoglyphs***: symbols that appear identical or very similar
- Attack: register domain names that look just like the victim domain, but using a different character set.



https://en.wikipedia.org/wiki/Homoglyph

Phishing

- https://www.irongeek.com/homoglyph-attack-generator.php
  - ucsd.edu



Homoglyph Attack Generator

This app is meant to make it easier to generate homographs based on Homoglyphs than having to search for look-a-like character in Unicode, then coping and pasting. Please use only for legitimate pen-test purposes and user awareness training. I also recommend webapp developers use it to test out possible user impersonation attacks in their code. This is still a work in progress, so please send me suggestions (especially for new Homoglyphs to add). While this tool was designed with making IDNA/Punycode names for putting into DNS to display foreign characters in a browsers URL bar, it can be used for other things. Try ignoring the IDNA/Punycode stuff and just making look alike user names for systems that accept Unicode. I made this tool to easily generate homographs based on homoglyphs in Unicode and to test out how different apps display them. It seems like a lot of modern browsers have gotten better at warning the users of attack, but I'd love to hear experiences about other apps that accept Unicode/Punycode/Internationalized Domain Names, especially webapps.

For more information see my Paper Proposal for "Out of Character: Use of Punycode and Homoglyph Attacks to Obfuscate URLs for Phishing".

1st, type in a name to look like: ucsd.edu

2nd, choose homoglyphs to use:

○ Rev 202E	○ U	○ C	○ S	○ D	◉ .	○ E	○ D	○ U
	○ u	○ c	○ s	◉ d	○ ٠ 660	○ e	○ d	○ u
	○ μ 3bc	○ c 3f2	○ S 405	○ Ď 10e	○ 6̣ d4	○ È	○ Ď 10e	○ μ 3bc
	◉ υ 3c5	○ C 3f9	◉ s 455	○ ժ 10f	○ 701 .	○ É	○ ժ 10f	◉ υ 3c5
	○ Ԛ 531	○ C 421	○ S 54f	○ Đ 110	○ 702 ˙	○ Ê	○ Đ 110	○ Ԛ 531
	○ U 54d	◉ c 441	○ Ꮪ 10bd	○ đ 111	○ .2024	○ Ë	○ đ 111	○ U 54d
	○ υ 22c3	○ C 13df	○ Ꮪ 13da	○ d 501	○ .2027	○ é	◉ d 501	○ υ 22c3
	○ U ff35	○ C 216d	○ 𖼵 d801	○ ժ 56a	○ 。 3002	○ ê	○ ժ 56a	○ U ff35
	○ u ff55	○ c 217d	○ 𖽖 dc96	○ Ꭰ 13a0	○ ． ff0e	○ ë	○ Ꭰ 13a0	○ u ff55
		○ 𖼵 d801	○ S ff33	○ ḍ 1e0d	○ ｡ ff61	○ Ē 112	○ ḍ 1e0d	
		○ 𖽖 dca8	○ s ff53	○ D 216e		○ ē 113	○ D 216e	
		○ C ff23		○ d 217e		○ Ĕ 114	○ d 217e	
		○ c ff43		○ D ff24		○ ĕ 115	○ D ff24	
				○ d ff44		○ Ė 116	○ d ff44	
						○ ė 117		
						○ Ę 118		
						○ Ě 11a		
						○ ě 11b		
						○ E 395		
						○ E 415		
						◉ e 435		
						○ E 13ac		
						○ E ff25		
						○ e ff45		

3rd, Output will be something like this:

This one is for testing linking:

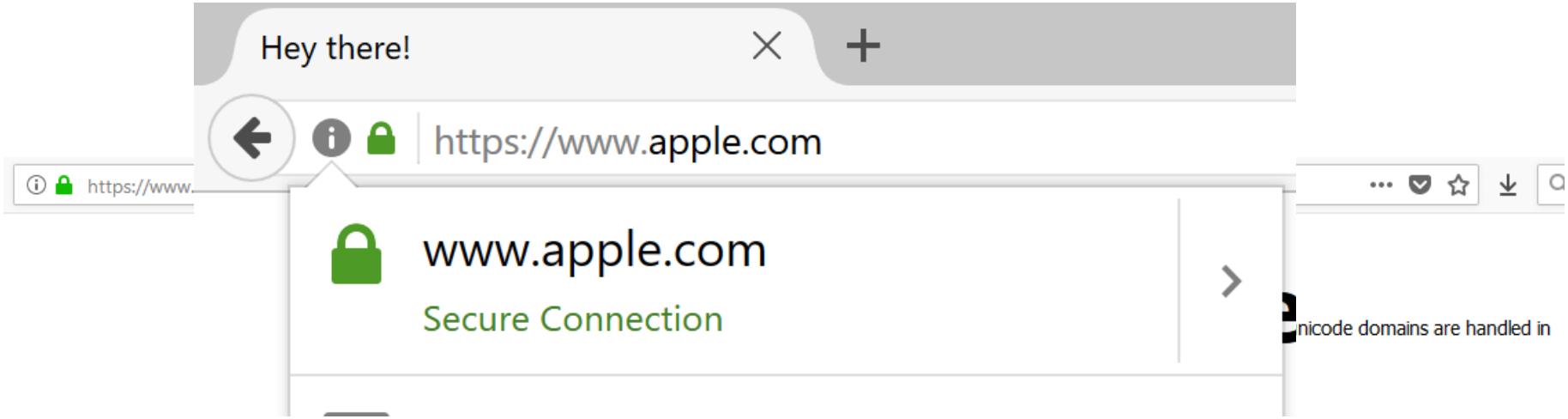
ucsd.edu

This one is so you can copy & paste:

ucsd.edu

Phishing

- Better Example: https://www.apple.com/
  - https://www.xudongz.com/blog/2017/idn-phishing/



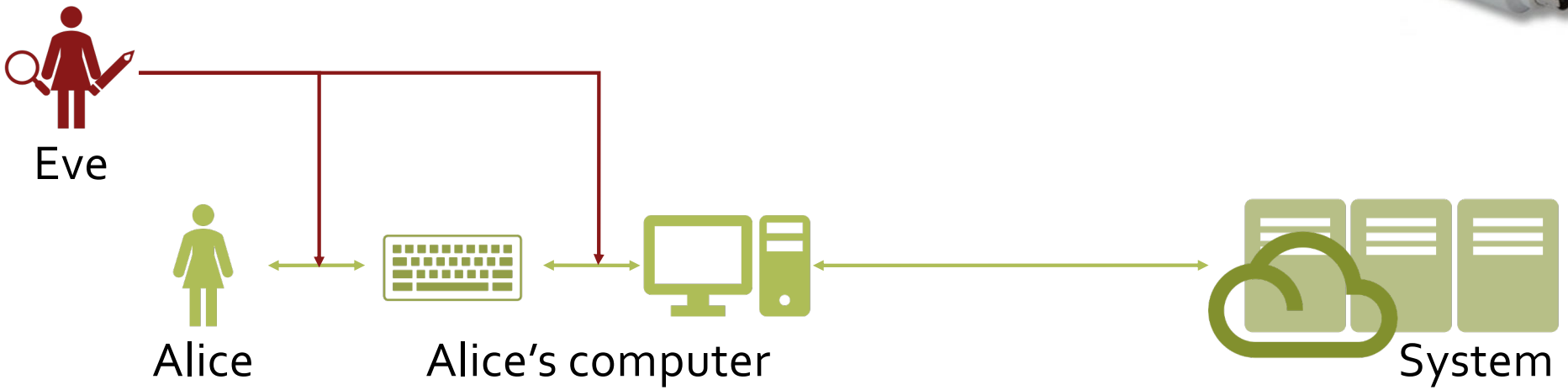
https://www.xudongz.com/blog/2017/idn-phishing/

Phishing

- Related: When logging into a machine locally, how does Alice know that she is entering the password into the **real** login program?
  - ***Trusted path***: mechanism that guarantees user is interacting with intended component
  - CTRL+ALT+DEL on Windows

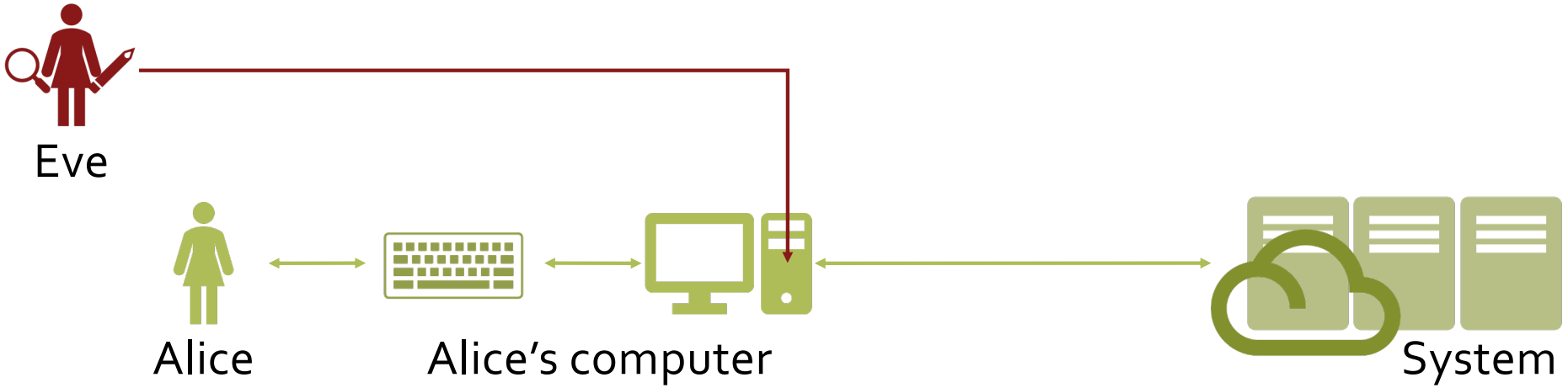
Attacking Passwords

- Shoulder-surf
- Side channels
- Hardware keyloggers



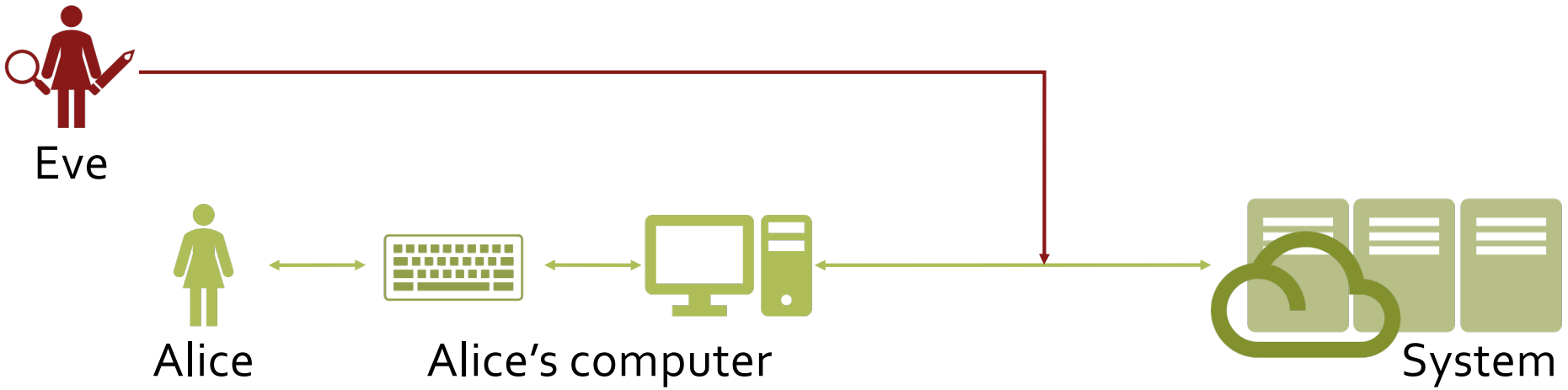
Attacking Passwords

- Software keyloggers
- Passwords in memory
  - Internal buffers
  - Clipboard
- Stored passwords
  - Cached passwords (e.g. browsers)
  - Password managers
    - Good ones are well protected by master passwords
  - AlicePasswords.txt



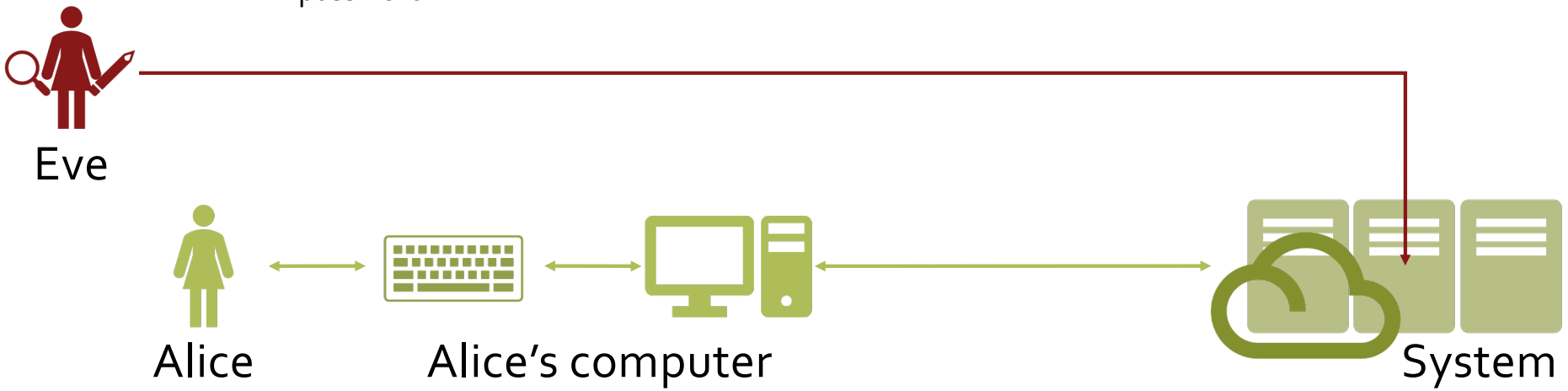
Attacking Passwords

- Monitoring the transmission channel
  - Channel should be encrypted to protect password confidentiality
  - Examples: TLS/SSH/HTTPS



Attacking Passwords

- Use system as an oracle: try to log in with different passwords
  - Defense: Minimize error information
  - Defense: Limit number of login attempts per user
  - Attack: Try different users for common password
- Compromise password database
  - Huge yield compared to user-side attacks
  - https://haveibeenpwned.com/
  - ***Password reuse issues…***



Protecting Passwords

- How can the system verify that the password Alice entered is correct?
- Naïve solution:
  - Store a copy of the password and compare provided copy to the stored one.
- Problem?
- If system is compromised, passwords are revealed.
  - Same passwords may be used on other systems.

Protecting Passwords

- Other solutions?
- Hint: System does not need to know the password, only be able to verify it is correct.
- What if the system stores a cryptographic hash of the password?
  - $H(p)$
  - Hash must be pre-image resistant.
- Better…
  - … but still problematic

Protecting Passwords

- Given a hash of a password, Eve can use it to validate guesses.
  - Also, obvious which users have identical passwords
- Dictionary Attacks
  - Dictionary: collection of possible, or likely, password strings
  - Try every string in the dictionary until the correct entry is found.
- Pre-compute hashes of all strings in the dictionary, then perform reverse look-ups by hash to find corresponding password.

Protecting Passwords

- Dictionary Attack Example:
  - Assume passwords are composed of upper or lower case letters or digits
    - 26+26+10 = 62 possible values per character (round off to 64, so we have a power of 2)
  - $64^n = 2^{6n}$ possible passwords of length n
  - For n = 6: 2^{36} possible password strings
    - ~10TB to store all possible 6-character passwords and respective SHA1 hashes

Protecting Passwords

- How do we make dictionary attacks harder?
- Note, the attacker only had to compute one dictionary of hashes that could then be used for any user's password hash from any system.
- We can parameterize, or "***salt***", password hashes with unique random numbers
  - Instead of storing $H(p)$, store $(r, H(r||p))$, where r is random salt of n bits
  - Precomputation is no-longer possible. Attacker must compute unique hashes for every target with different r.
- Better…
  - … but still problematic

Be careful about computation assumptions

- From 2012, Gosney's 25GPU password cracking cluster
  - 350B NTLM hashes (used by Windows) per sec
  - 180B MD5 hashes/sec, 63B SHA-1 hashes/sec
  - Modern rigs are even faster
- For state actors, custom hardware feasible

Remember, people don't pick random passwords

- We pick strings we can remember…
- Real dictionary attacks use password dictionaries
  - Combinations of words, numbers, letter translations, inversions, etc that are in common use
  - Can typically guess 20-50% of passwords in the first billion guesses
    - Remember how long a billion NTLM, MD5 or SHA1 hashes takes?

Protecting Passwords

- How do we make dictionary attacks even harder?
- Hint: the computation to verify a password for a given user on a legitimate system happens relatively infrequently, but an attacker attempting to crack a password hash must perform many, many attempts.
- So, we can use a deliberately slow and resource-consuming hashing function.
  - PBKDF2, bcrypt, scrypt

Protecting Passwords

- Building blocks for password protection
  - Hash
  - Salt
  - Slow down
- Use one of:
  - PBKDF2
  - bcrypt
  - scrypt

Something You Have

Something You Have

- Something only Alice should have
  - Examples: key, smartcard, RFID badge, SecurID token
- Frequently used as a second factor (in combination with a passcode)
  - 2FA token
- Technically, only proves possession of the token, not that it's really Alice
  - Tokens get shared, lost, stolen, duplicated.

Smartcards

- Idea: Put a secret key into a tiny computer that Alice can carry with her.
  - Plastic card with an embedded integrated circuit
  - Provisioned with secret key(s)
  - Interacts with readers through contact pads or short range wireless (NFC)
- Many uses beyond user authentication
  - Stored value payment and transit, SIM cards, satellite TV
- Sample authentication protocol:
  - Interrogate with a random challenge and verify signed response

https://en.wikipedia.org/wiki/EMV

One Time Passcode Tokens

- Same basic idea as smart card: a tiny computer with a secret
  - But, typically without direct computer interface.
- How to provide challenge and get response?
- Response is displayed on token screen, user types it into the authentication system.
  - Typically using current time instead of challenge (requires time sync)
    - Some versions simply generate random OTPs that can be validated (no time sync needed)
  - Some variants have keypads to allow the user to type in a challenge as well.

https://www.rsa.com/en-us/resources/rsa-securid-hardware-tokens

One Time Passcode Tokens

- Typical protocol:
  - Based on symmetric key cryptography (shared secret between token and authenticating server)
  - Periodically (e.g. once a minute) token generates a new single-use code by MACing current time.
  - To authenticate, Alice types in her password and current code (two-factor).

- Strengths:
  - Knowing the password is not enough to impersonate Alice.
  - Each code is single-use. Eavesdropping (shoulder-surfing, keylogging, etc.) does not enable Eve to impersonate Alice in the future.
  - Observing any number of codes does not help in predicting future ones.

One Time Passcode Tokens

- Weaknesses:
  - Vulnerable to man-in-the-middle and phishing attacks.
  - Server needs to know the secret key to validate token codes. Single point of failure.
    - E.g., RSA Breach
  - Does not scale well to multiple accounts.

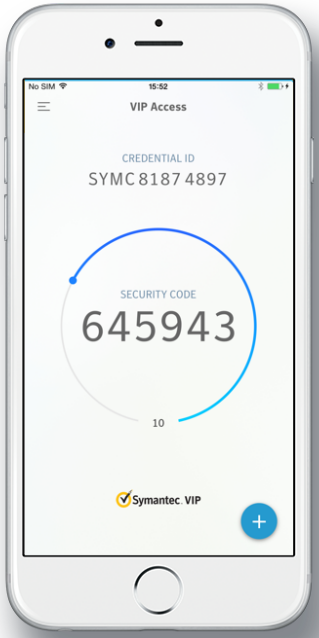
https://www.techstagram.com/2013/07/27/rsa-passban/

USB/NFC tokens

- Same basic idea but …
  - Device to device
    - User never gets to see code so can't be socially engineered
    - Compromised OS/hardware can't play MiTM without being detected
  - Interfaces to tie into a variety of authentication infrastructures
    - In principal, can avoid the "lots of tokens" problem

One Time Passcode Without Tokens

- Virtual edition
  - Everybody (in some parts of the world) already carries a tiny computer. Let's just use that.
  - Strength: better scaling, support multiple keys with the same physical device.
  - Weakness: the two authentication factors are not as isolated anymore.



https://vip.symantec.com/

One Time Passcode Without Tokens

- Extending the idea of using [possession of] your phone as an authentication factor.
- Authenticating server can send Alice a one-time code via SMS.
  - Alice logs in with her password and received code.
- Often used for step-up authentication or account recovery.
  - ***Step-up authentication***: secondary [stronger] authentication mechanism invoked based on risk level
    - Examples: when attempting to access more sensitive resources, or when behavior pattern does not match routine.
  - Similar solutions use email in place of SMS.
    - Proof that Alice has access to the email account she registered with.
- Widespread use, but weaker against range of threat models (SMS not very secure even against criminals… SIM swapping attacks)

Something You Are

Something You Are

- Something unique identifying characteristic that only Alice has (***biometrics***)
  - Physical feature: fingerprint, iris print
  - Behavioral characteristic: handwriting, typing
  - Combination thereof: voice, gait
- How do you know that I am the same person that was here last week?
  - Did I provide a password?
  - Did I provide a badge?
- Pretty much all trust boils down to biometric authentication of one human by another

Biometrics

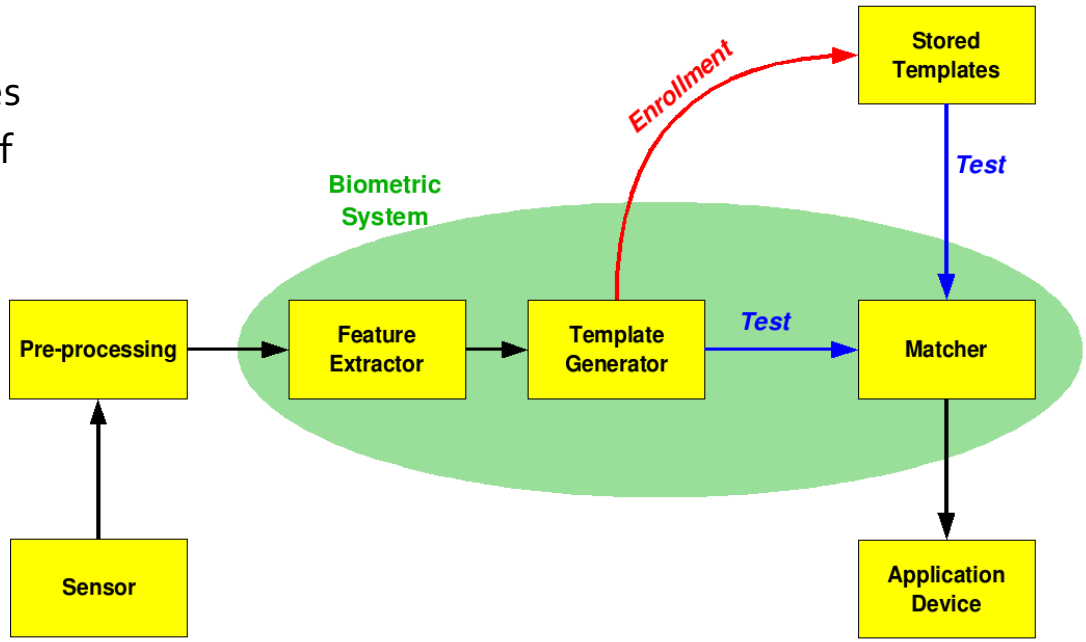
- The only authentication factor that is not designed to be transferable
  - Clear separation of authentication and authorization
- Nothing to remember, nothing to carry around
- Can be very strong differentiator
  - Unique-ish

Biometrics

- Fingerprint
- Face recognition
- Handprint
- Retina
- Iris
- Vein
  - vascular pattern in back of hand
- Voiceprint
- Signature (special pen)
- Typing
  - timing between character sequences
- Gait recognition
- Heartbeat
- DNA

Biometrics

- General approach
  - Scan an analog sample
  - Convert to set of digital features
  - On enrollment save template of identifiable features
  - On authentication, attempt approximate match against saved features



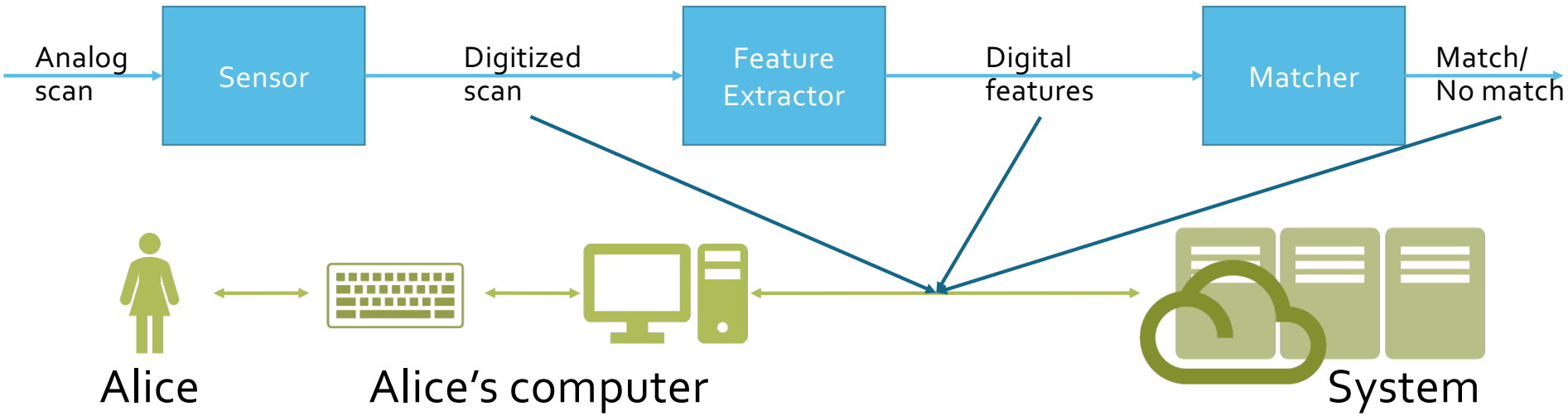
https://en.wikipedia.org/wiki/Biometrics

Biometrics

- Simplified flow

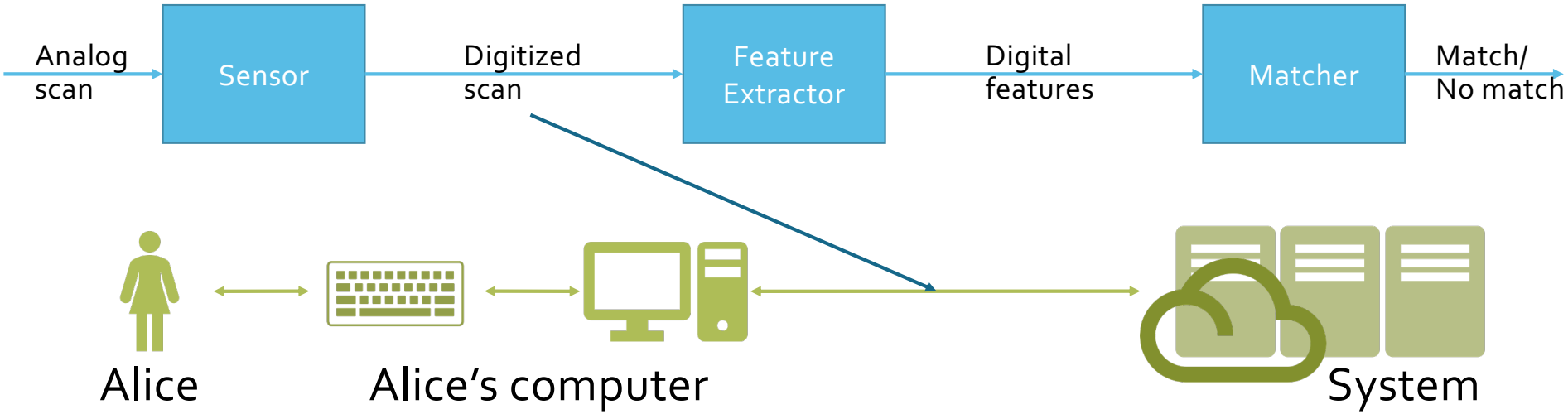
Biometrics

- What happens in a remote authentication setting?
- What does the authenticating system actually get?



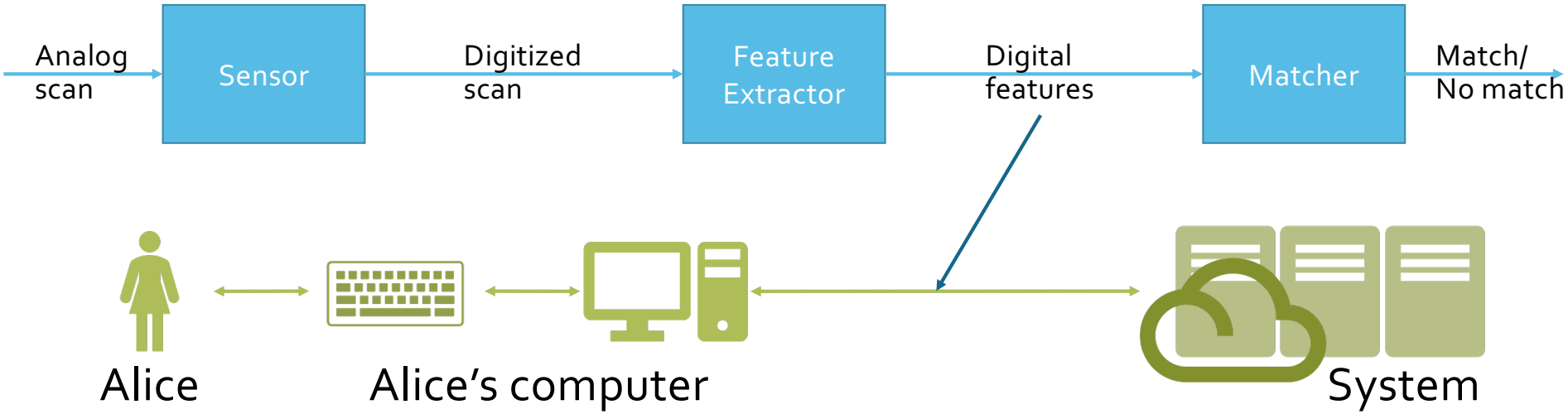
Biometrics

- Scenario A: only the sensor is local to user. Feature extraction and matching happen on authenticating system.
  - Authenticating system has to trust Alice's computer to provide fresh, unspoofed sensor data.
  - All biometric features and template data are on a central server.



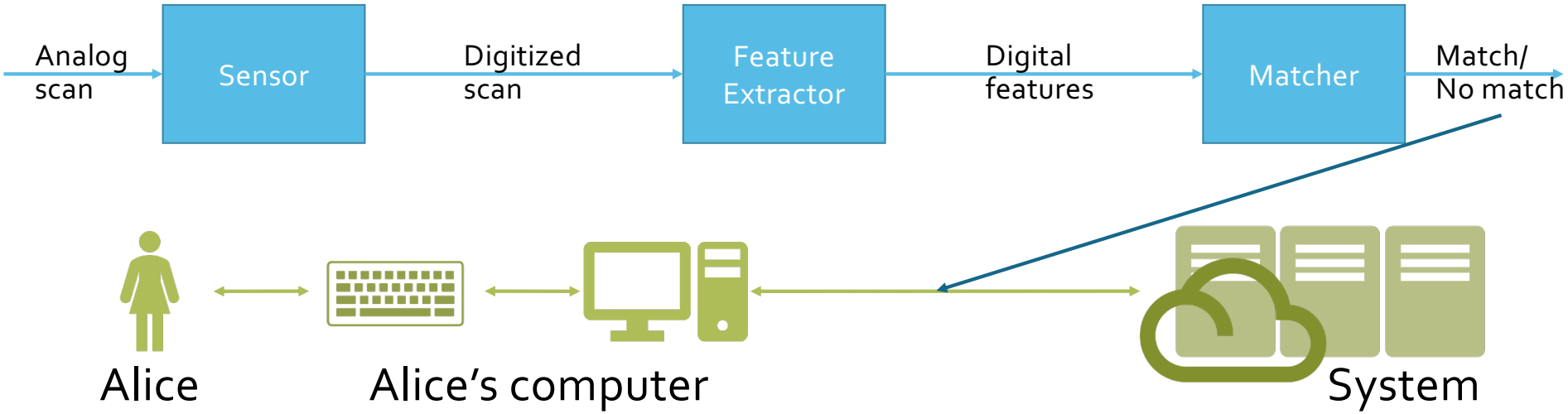
Biometrics

- Scenario B: Sensing and feature extraction are local to user. Matching happens on authenticating system.
  - Authenticating system has to trust Alice's computer to provide authentic, fresh, unspoofed feature data.
  - All biometric features and template data are still on a central server.



Biometrics

- Scenario C: Sensing, feature extraction, and matching are local to user. Only the result is communicated to the authenticating system.
  - Authenticating system has to trust Alice's computer to perform authentication.
  - All biometric features and template data are isolated on end users' devices.



Biometrics

- Use in distributed systems requires biometric scanner to be trusted and to have secure channel (authenticity, privacy, integrity, no-replay) to the server.

Biometrics

- Challenges
  - Accuracy
  - Ease of use (particularly enrollment)
  - User acceptance
  - Feature stability

Enrollment issues

- Unlike passwords, hard to pre-enroll user
- Users must be enrolled interactively
- For many biometrics, getting good accuracy requires multiple readings
  - Build templates and test against registration
  - Repeat
  - Some templates simply tough (e.g., smooth fingerprint); "goats"

How strong is a biometric?

- Non-adversarial
  - False accept rate
  - False reject rate

- Adversarial
  - Intercept
  - Spoofing

Non-adversarial testing

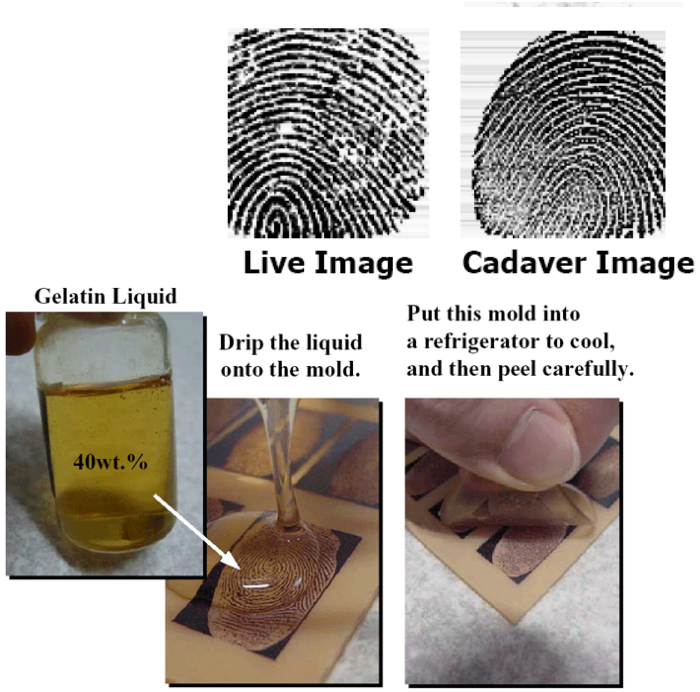
- False accept rate
  - How many random trials before expectation of false accept > 0.5
- False reject rate
  - How many random trials before expectation of false reject > 0.5
- Lower FAR = less tolerant of close matches
  - Harder to attack
  - Necessarily increases FRR
- Lower FRR = more tolerant of close matches
  - Easier to use
  - Necessarily increases FAR
- Since match is approximate can almost always tune for one or other
- Equal error rate: point where FAR= FRR
- Note, huge difference between a **single false accept** and **system-wide false accept** (more templates means more things you can accept against)

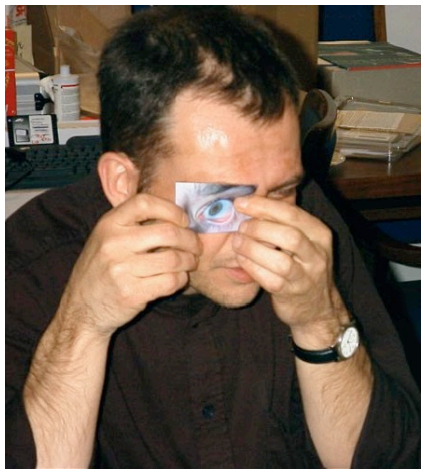
Biometrics Spoofing

- Biometrics are private, but not secret
- Users expose biometric instances everywhere
  - Fingerprints, hand geometry, face, handwriting, iris, gait, etc.
- Allows attacker to create biometric forgery
- Very hard to replace a biometric identifier

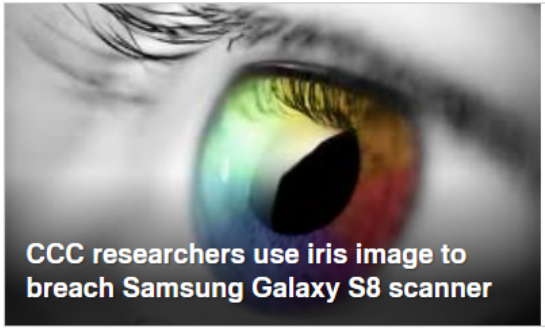
Biometrics Spoofing

- There are spoofing techniques for virtually all biometrics.





Chaos Computer Club



May 23, 2017

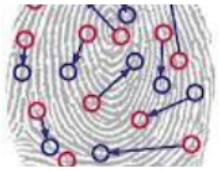
Researchers from the Chaos Computer Club (CCC) have successfully breached the Samsung Galaxy S8's iris recognition system to unlock the...

Continue Reading

Spoofing iris recognition technology with pictures

Mar 9, 2015

In a recent report by Forbes, Chaos Computer Club security researcher Jan "Starbug" Krissler highlighted the vulnerabilities behind some iris-scanning...



German researcher reverse-engineers a fingerprint using photos

Dec 30, 2014

A German researcher from European hackers association Chaos Computer Club recently demonstrated a method to fool standard biometric security software...

Chaos Computer Club claims Touch ID fake fingerprint spoof

Sep 23, 2013

Well that was fast. German hacker collective, Chaos Computer Club, has claimed that it has already spoofed the iPhone 5S's Touch...

Biometrics Spoofing Mitigations

- Replay prevention
  - Save previous image and reject if identical
  - Tricky: can pick up print and rotate to fool
- Improved validation precision
  - Verifier should have higher precision than forger
    - Examples: pore detection, perspiration detection
  - “Liveness” detection
    - Examples: temperature, pulse, blood flow

Biometrics Spoofing Mitigations

- Multi-modal
  - Multiple biometric factors

- Multi-factor
  - Biometric plus password
  - Biometric plus token

Privacy Issues

- Biometric identifier can track your physical activities as well as your virtual activities
  - Some with crisp legal standing (fingerprint, DNA)
- Easy to match (even if can't spoof)
- Very hard to obscure

Review

- 3 types of authentication factors
  - Password: ***Something you know***
  - Token: ***Something you have***
  - Biometrics: ***Something you are***
- Each factor can be used independently, or combined for ***multi-factor*** authentication.
  - Typically 2-factor
- Use a ***slow salted hash*** to store passwords
  - PBKDF2, bcrypt, or scrypt
  - Don't make up your own!