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CS526: Information security

User Authentication

Readings for This Lecture

- Wikipedia
  - Password
  - Password strength
  - Salt_(cryptography)
  - Password cracking
  - Trusted path
  - One time password

1: User authentication

Three A's of Information Security

- Security is about differentiating among authorized accesses and unauthorized accesses
  - Required by all services
- Authentication
  - Check who is accessing
- Access control
  - Ensure only authorized access are allowed
- Auditing
  - Record what is happening, to identify attacks later and recover

Authentication & Access Control according to Wikipedia

- **Authentication** is the act of establishing or confirming something (or someone) as *authentic*, that is, that claims made by or about the subject are true. This might involve confirming the identity of a person, tracing the origins of an artifact, ensuring that a product is what its packaging and labeling claims to be, or assuring that a computer program is a trusted one.

- **Access control** is a system which enables an authority to control access to areas and resources in a given physical facility or computer-based information system.

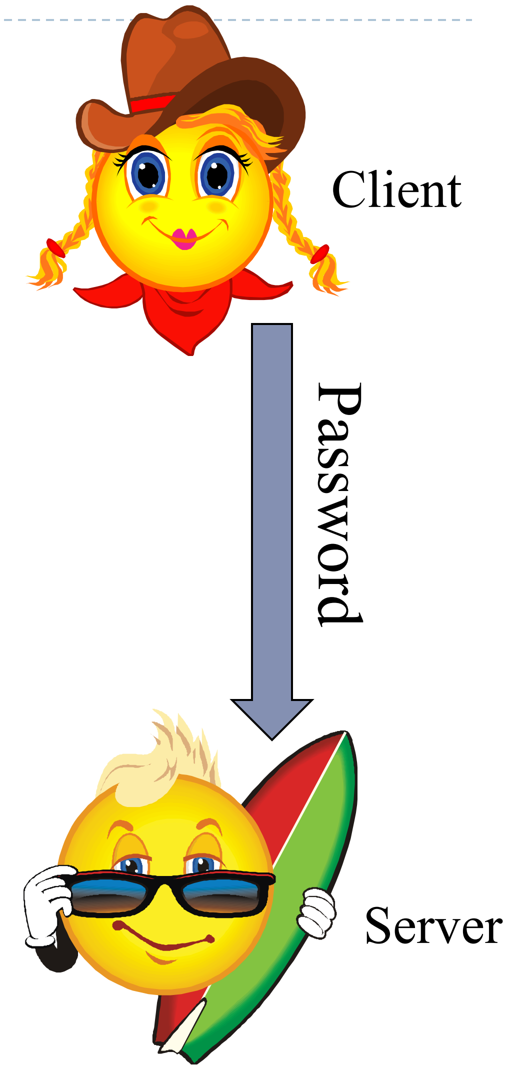
User Authentication

- Using a method to validate users who attempt to access a computer system or resources, to ensure they are authorized
- Types of user authentication
  - Something you know
    - E.g., user account names and passwords
  - Something you have
    - Smart cards or other security tokens
  - Something you are
    - Biometrics

Scenarios Requiring User Authentication

- Scenarios
  - Logging into a local computer
  - Logging into a computer remotely
  - Logging into a network
  - Access web sites

- Vulnerabilities can exist at client side, server side, or communication channel



Variants of Passwords

- Password
- Passphrase
  - a sequence of words or other text used for similar purpose as password
- Passcode
- Personal identification number (PIN)

Threats to Passwords

- Eavesdropping (insecure channel between client and server)
- Login spoofing (human errors), shoulder surfing, keyloggers
- Offline dictionary attacks
- Social engineering (human errors)
  - e.g., pretexting: creating and using an invented scenario (the pretext) to persuade a target to release information or perform an action and is usually done over the telephone
- Online guessing (weak passwords)

Guessing Attacks: Two Factors for Password Strength

- The average number of guesses the attacker must make to find the correct password
  - determined by how unpredictable the password is, including how long the password is, what set of symbols it is drawn from, and how it is created

- The ease with which an attacker can check the validity of a guessed password
  - determined by how the password is stored, how the checking is done, and any limitation on trying passwords

Password Entropy

- The entropy bits of a password, i.e., the information entropy of a password, measured in bits, is
  - The base-2 logarithm of the number of guesses needed to find the password with certainty
  - A password with, say, 42 bits of strength calculated in this way would be as strong as a string of 42 bits chosen randomly.
  - Adding one bit of entropy to a password doubles the number of guesses required.
  - On average, an attacker will have to try half the possible passwords before finding the correct one
- Aka. Guess entropy

Estimating Password Entropy

- People are notoriously remiss at achieving sufficient entropy to produce satisfactory passwords.
- NIST suggests the following scheme to estimate the entropy of human-generated passwords:
  - the entropy of the first character is four bits;
  - the entropy of the next seven characters are two bits per character;
  - the ninth through the twentieth character has 1.5 bits of entropy per character;
  - characters 21 and above have one bit of entropy per character.
- This would imply that an eight-character human-selected password has about 18 bits of entropy.

Towards Better Measurement of Password Entropy

- NIST suggestion fails to consider usage of different category of characters:
  - Lower-case letters, digits, upper-case letters, special symbols
- Orders also matter:
  - “Password123!” should have different entropy from “ao3swPd!2s1r”
- State of art is to use Markov chains to model probability of different strings as passwords
  - May rank something “yqzjx” as very secure
- Fundamental challenge: there are different attack strategies out there, which try passwords with different ordering

Example of Weak Passwords (from Wikipedia)

- Default passwords (as supplied by the system vendor and meant to be changed at installation time): *password*, *default*, *admin*, *guest*, etc.
- Dictionary words: *chameleon*, *RedSox*, *sandbags*, *bunnyhop!*, *IntenseCrabtree*, etc.
- Words with numbers appended: *password1*, *deer2000*, *john1234*, etc.,
- Words with simple obfuscation: *p@ssw0rd*, *l33th4x0r*, *g0ldf1sh*, etc.
- Doubled words: *crabcrab*, *stopstop*, *treetree*, *passpass*, etc., can be easily tested automatically.

Example of Weak Passwords (from Wikipedia)

- Common sequences from a keyboard row: *qwerty*, *12345*, *asdfgh*, *fred*, etc.
- Numeric sequences based on well known numbers such as 911, 314159, or 27182, etc.,
- Identifiers: *jsmith123*, *1/1/1970*, *555–1234*, "your username", etc.,
- Anything personally related to an individual: license plate number, Social Security number, current or past telephone number, student ID, address, birthday, sports team, relative's or pet's names/nicknames/birthdays, etc.,
  - can easily be tested automatically after a simple investigation of person's details.

Mechanisms to Avoid Weak Passwords

- Allow long passphrases
- Randomly generate passwords where appropriate
  - Though probably inappropriate for most scenarios
- Check the quality of user-selected passwords
  - use a number of rules of thumb
  - run dictionary attack tools
- Give user suggestions/guidelines in choosing passwords
  - e.g., think of a sentence and select letters from it, "It's 12 noon and I am hungry" => "I'S12&IAH"
  - Using both letter, numbers, and special characters

Balancing Password Entropy & Usability Concerns

- Forcing randomly generated passwords is often bad
  - A user needs to remember passwords for tens, if not hundreds of accounts
  - High entropy passwords are difficult to remember
- Often times, guessing passwords is not the weakest link
  - One can use various ways to reduce adversary's abilities to test password guesses
  - When a user cannot remember the password for an account, there must be a way to allow a user to retrieve it
    - The recovering method either has low security, or costs lots of money
    - It creates a weaker link
- Usability matters

Storing Passwords (UNIX Case Study)

- Old UNIX
  - The file /etc/passwd stores H(password) together with each user's login name, user id, home directory, login shell, etc.
    - H is essentially a one-way hash function
  - The file /etc/passwd must be world readable
  - Brute force attacks possible even if H is one-way
    - how to most effectively brute-force when trying to obtain password of any account on a system with many accounts?

Password Salts

- More modern UNIX
  - Divide /etc/password into two files: /etc/password; and /etc/shadow (readable only by root)
- Store [r, H(password,r)] rather than H(password) in /etc/shadow
  - r is randomly chosen for each password
  - r is public, similar to Initial Vector in CBC & CTR modes
- Benefits
  - dictionary attacks much more difficult
    - cost of attacking a single account remains the same
  - if two users happen to choose the same password, it doesn’t immediately show

Mechanisms to Defend Against Dictionary and Guessing Attacks

- Protect stored passwords (use both cryptography & access control)

- Disable accounts with multiple failed attempts
- Require extra authentication mechanism (e.g., phone, other email account, etc.)

Mechanisms to Defend Against Login Spoofing: Trusted Path

- Login Spoofing Attacks:
  - write a program showing a login window on screen and record the passwords
  - put su in current directory
- Defense: Trusted Path
  - Mechanism that provides confidence that the user is communicating with the real intended server
    - attackers can't intercept or modify whatever information is being communicated.
    - defends attacks such as fake login programs
  - Example: Ctrl+Alt+Del for log in on Windows
    - Causes a non-maskable interrupt that can only be intercepted by the operating system, guaranteeing that the login window cannot be spoofed

Spoofing & Defenses on the Web

- Phishing attacks
  - attempting to acquire sensitive information such as usernames, passwords and credit card details by masquerading as a trustworthy entity in electronic communication
- Website forgery
  - Set up fake websites that look like e-commerce sites and trick users into visiting the sites and entering sensitive info
- Defense methods
  - Browser filtering of known phishing sites
  - Cryptographic authentication of servers (will talk about in future)
  - User-configured authentication of servers
    - To ensure that the site is the one the human user has in mind
    - E.g., site key, pre-selected picture/phrases

KeyLogging

- Threats from insecure client side
- Keystroke logging (keylogging) is the action of tracking (or logging) the keys struck on a keyboard, typically in a covert manner so that the person using the keyboard is unaware that their actions are being monitored
- Software -based
  - key-stroke events, grab web forms, analyze HTTP packets
- Hardware-based
  - Connector, wireless sniffers, acoustic based

- Defenses:
  - Anti-spyware, network monitors, on-screen soft keyboard, automatic form filler, etc.
- In general difficult to deal with once on the system

Using Passwords Over Insecure Channels

- One-time passwords
  - Each password is used only once
  - Defend against passive adversaries who eavesdrop and later attempt to impersonate
- Challenge response
  - Send a response related to both the password and a challenge
- Zero knowledge proof of knowledge
  - Prove knowledge of a secret value, without leaking any info about the secret

One-Time Password

- Shared lists of one-time passwords

- Time-synchronized OTP
  - E.g., use $MAC_K(t)$, where K is shared secret, and t is current time
- Using a hash chain (Lamport)
  - $h(s), h(h(s)), h(h(h(s))), \ldots, h^{1000}(s)$
  - use these values as passwords in reverse order

Lamport's One-Time Password: Using a Hash Chain

- One-time setup:
  - A selects a value w, a hash function H(), and an integer t, computes $w_0 = H^t(w)$ and sends w_0 to B
  - B stores w_0
- Protocol: to identify to B for the i^{th} time, $1 \le i \le t$
  - A sends to B: A, i, $w_i = H^{t-i}(w)$
  - B checks $i = i_A$, $H(w_i) = w_{i-1}$
  - if both holds, $i_A = i_A+1$

Challenge-Response Protocols

- Goal: one entity authenticates to other entity proving the knowledge of a secret, ‘challenge’
- Approach: Use time-variant parameters to prevent replay, interleaving attacks, provide uniqueness and timeliness
  - e.g., nounce (used only once), timestamps

Challenge-response based on symmetric-key crypto

- Unilateral authentication, timestamp-based
  - A to B: $MAC_K(t_A, B)$
- Unilateral authentication, nounce-based
  - B to A: r_B
  - A to B: $MAC_K(r_B, B)$
- Mutual authentication, nounce-based
  - B to A: r_B
  - A to B: r_A, $MAC_K(r_A, r_B, B)$
  - B to A: $MAC_K(r_B, r_A)$

Other Defenses

- Alternatives to passwords
  - graphical passwords
- Go beyond passwords
  - security tokens
  - biometrics
  - 2-factor authentication
    - Uses two independent authentication methods
    - US Banks are required to use 2-factor authentication for online banking
  - Out of band authentication: uses a channel other than the internet
    - E.g., phone

What Are Biometrics ?

(ancient Greek: *bios* ="life", *metron* ="measure")

- ***Biometrics are automated methods of recognizing a person based on a physical or behavioral characteristic.***
- Physical Features
  - Fingerprint or fingerscan
  - Hand geometry
  - Face recognition
  - Retinal scans
  - Iris scans
- Behavioral Characteristics
  - Handwritten signature
  - Voice recognition
  - Typing
  - Gait

Biometric System

- Registration:
  - A person registers with the system when one or more of his physical and behavioral characteristics are obtained.
  - Information registered in a database (digital template), based on some algorithm.
- Use of biometrics:
  - Biometric of the user is captured and processed into a digital template
  - **Verification**: Compare a sample against a single stored template
  - **Identification**: Search a sample against a database of templates.

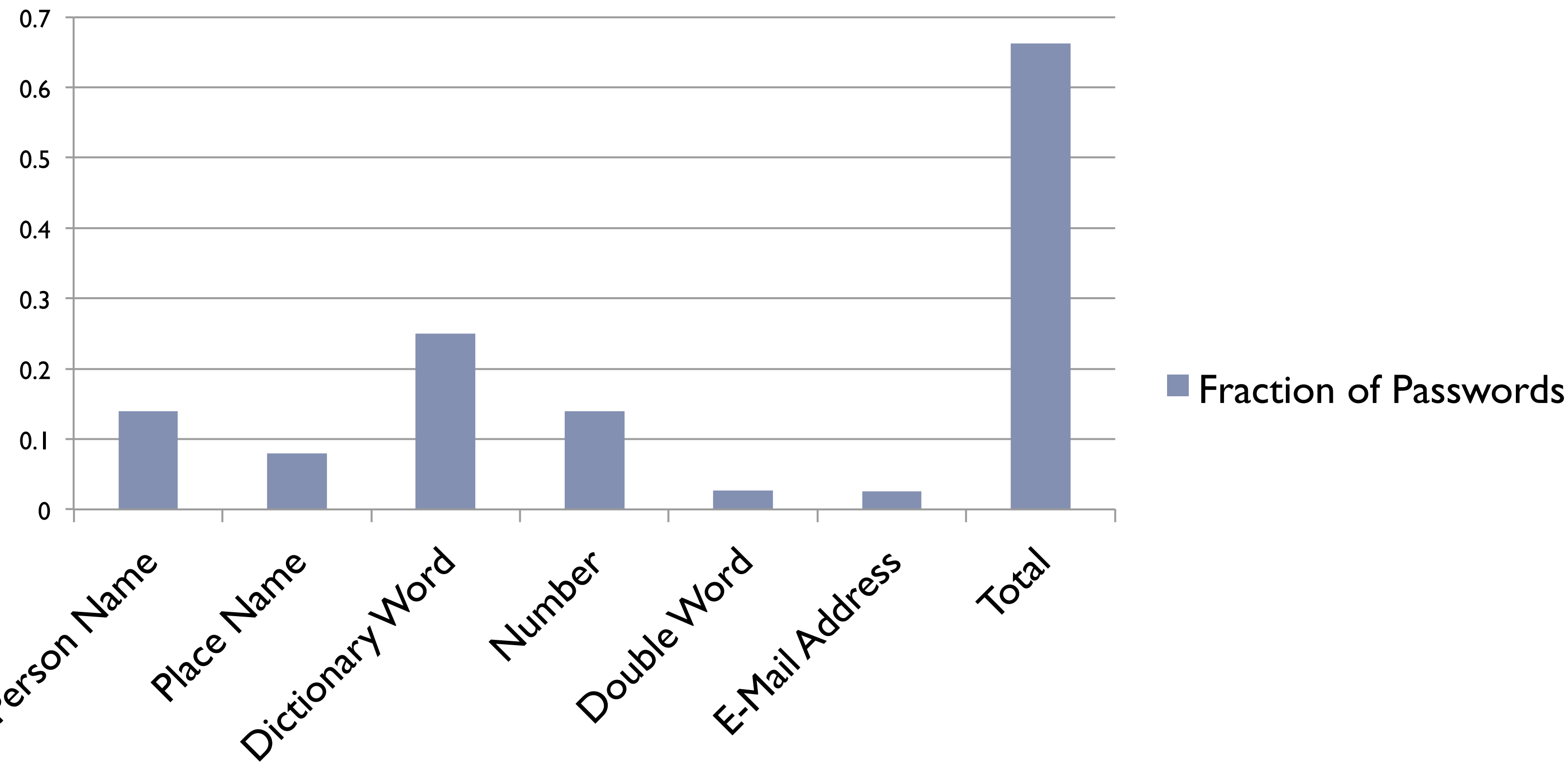
2: Human Computable Passwords
J. Blocki, M. Blum, A.Datta, S. Vempala

Slides by J. Blocki

Human Computable Passwords

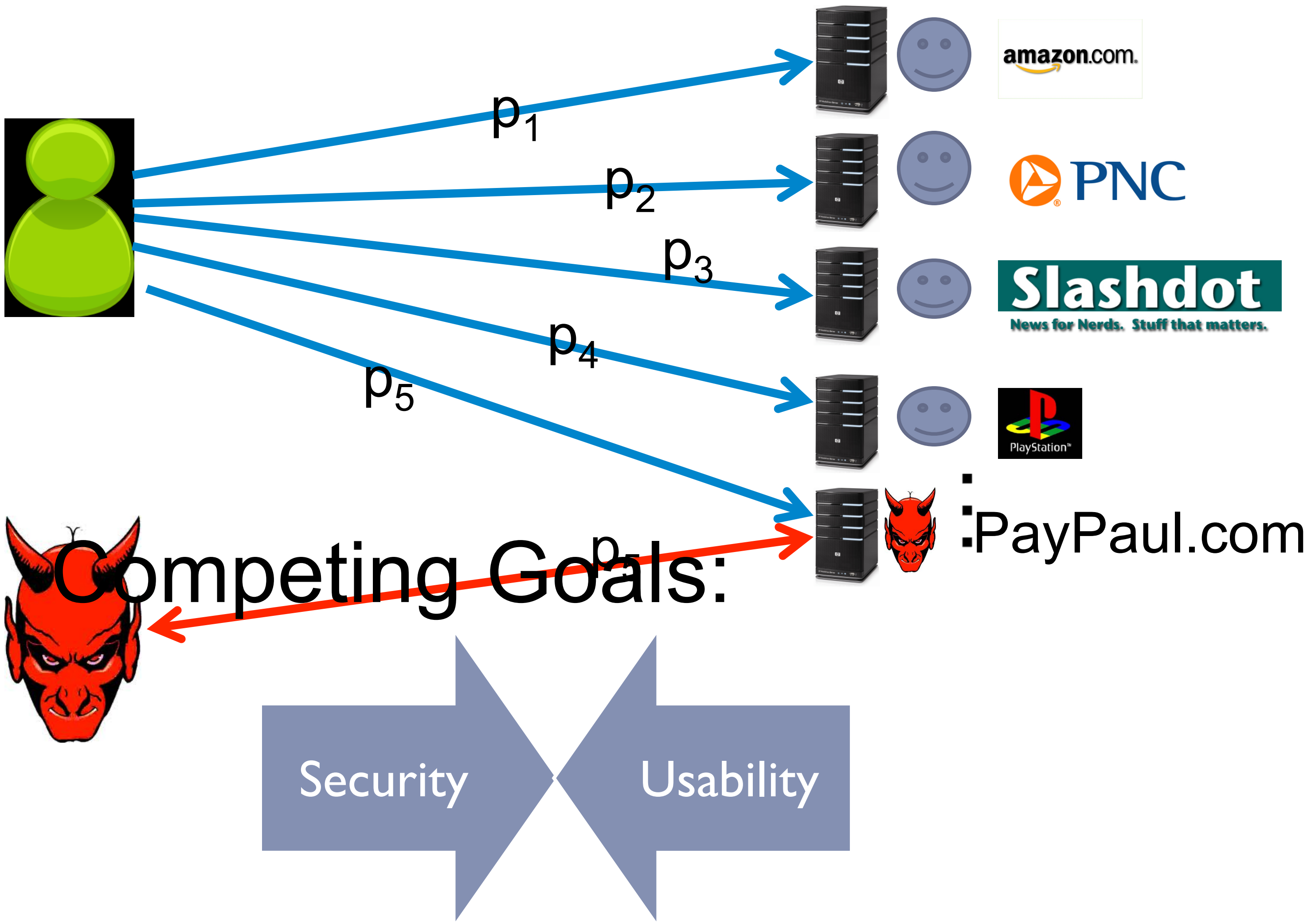
- Jeremiah Blocki, Manuel Blum, Anupam Datta, Santosh Vempala
- Slides by J. Blocki

How Do People Pick Passwords?



- Source: Science of Password Selection (Hunt, 2011)

Password Management

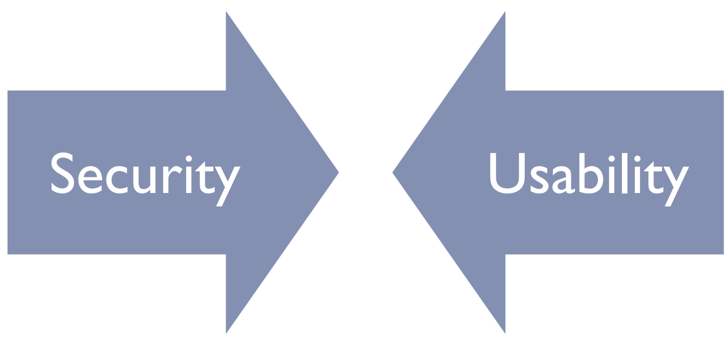


Competing Goals:

Competing Goals

- Usability – "easy" for user to create and remember his passwords

- Security – "hard" for adversary to learn passwords.
  - After many guesses
  - Even after seeing other passwords

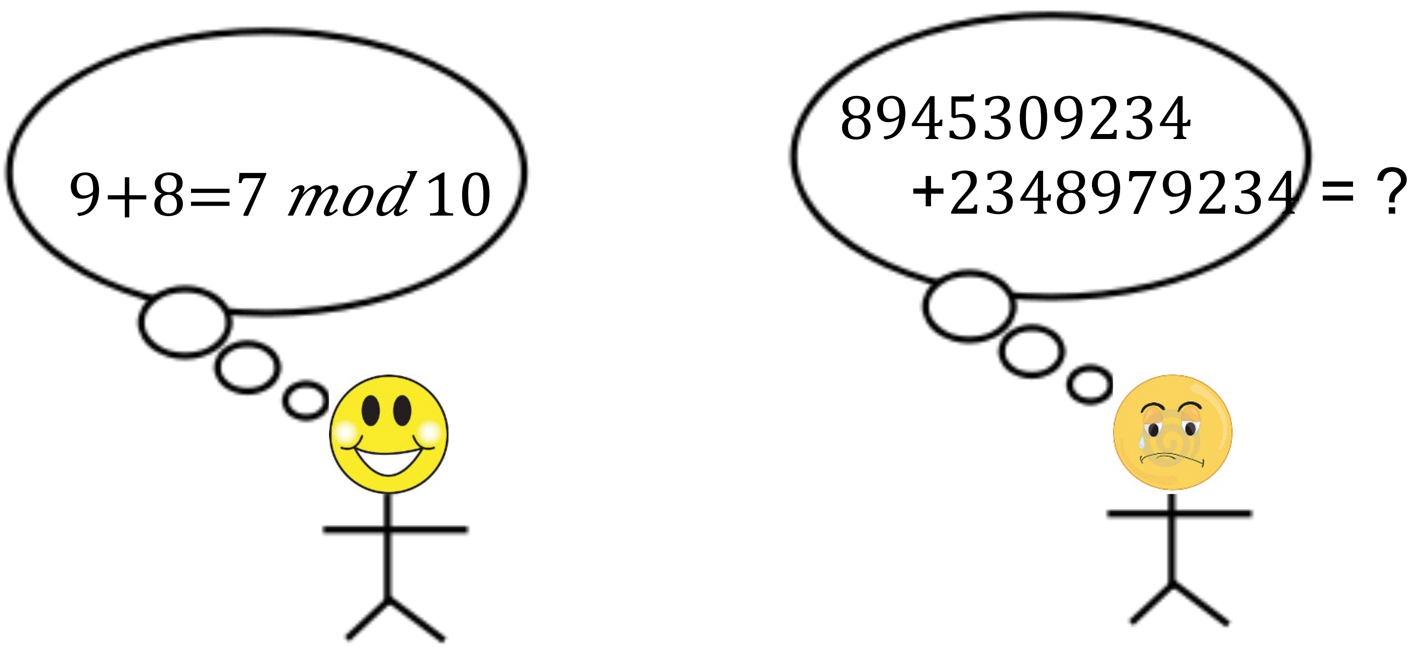


Our Scheme: Human Computable Passwords

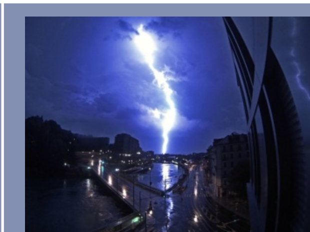
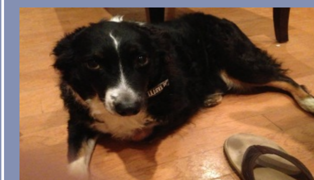
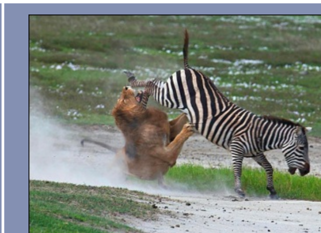
- Passwords computed by responding to public challenges
  - Computation done in user's head
- Remains secure many breaches (e.g., 100)
- Simple Operations
  - Addition modulo 10
  - Memorize a random mapping

Human Computation

- Restricted
  - Simple operations (addition, lookup)
  - Operations performed in memory (limited space)



Random Mapping

Image I			…	
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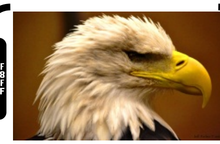
Initialization:

User Memorizes Random Mapping

$:\{I1,\ldots,In\} \rightarrow \{0,1,\ldots,9\}$

Example: n=30 images

Mnemonics

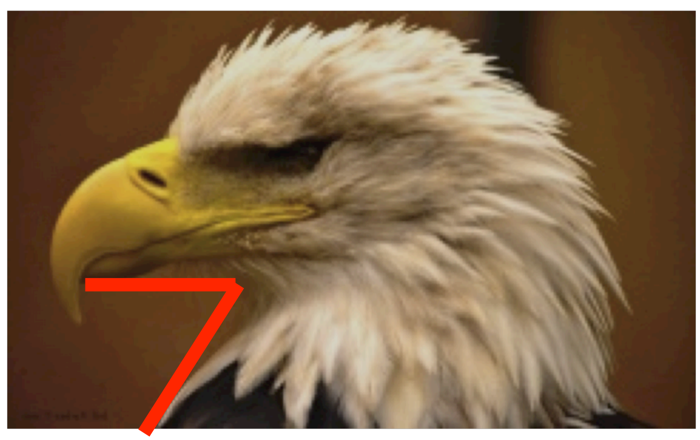
() = 4

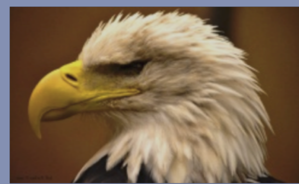
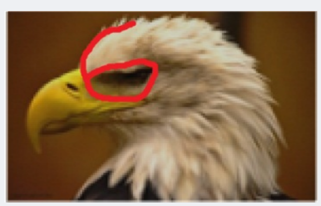
Instruction: Remember that the eagle has a gold beak. There are four letters in “gold” and “beak”.

Mnemonics

 = 7

Instruction: Trace the eagles body from the bottom of the eagle's beak down to the bottom of the picture. It looks like the number 7.

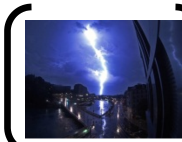


σ		• • •		• • •
…	…	…	…	…
4	The words "gold" and "beak" have four letters.	…	The words "lion" and "sand" have four letters.	…
5	The word "eagle" has five letters.	…	The words "zebra" and "grass" have five letters.	…
6		…	You can see six legs total in this picture.	…
…	…	…	…	…

Single-Digit Challenge




Computing the Response:



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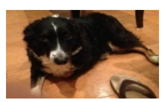

mod

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= 9+3 mod 10 = 2

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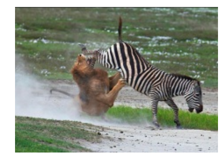
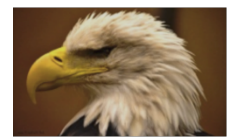
5 

1 

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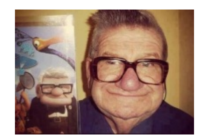
7 

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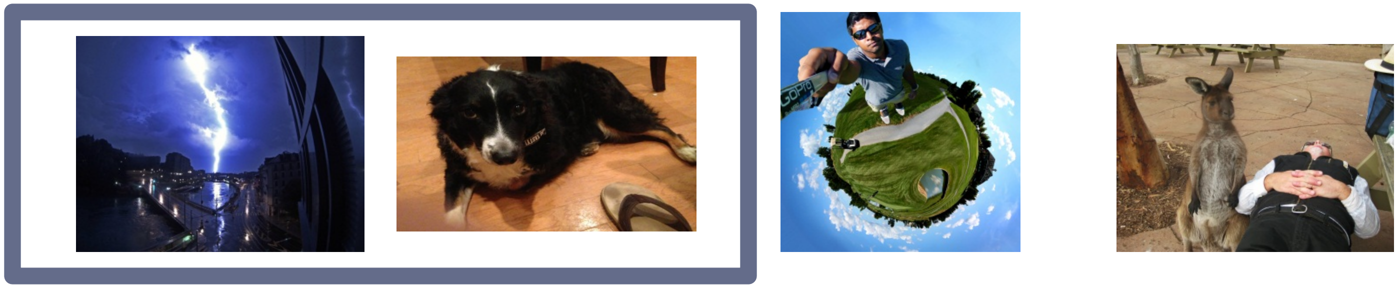
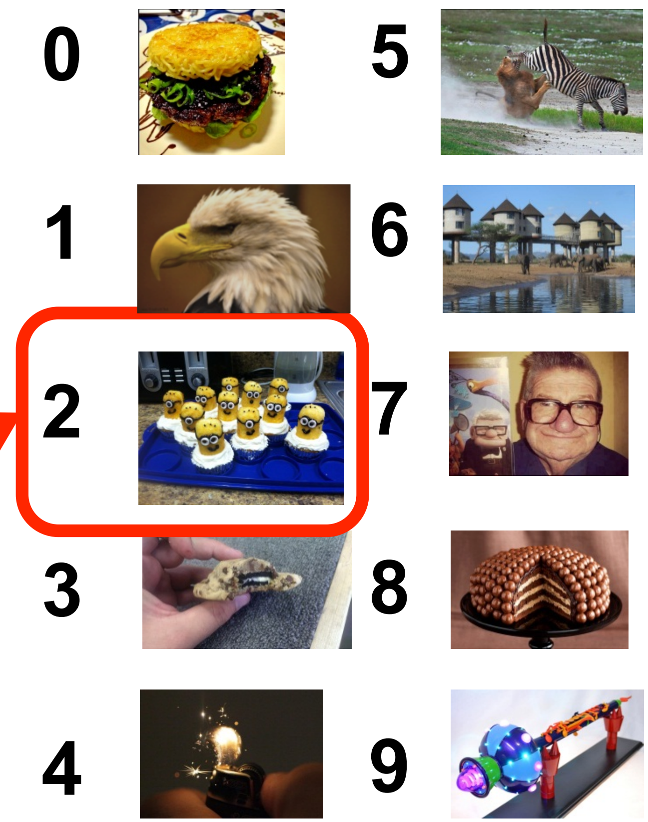
Single-Digit Challenge



Response:

mod



= 9+3 mod 10 = 2

Single-Digit Challenge

Final Response:

= 7 + 4 + 5 mod 10 =

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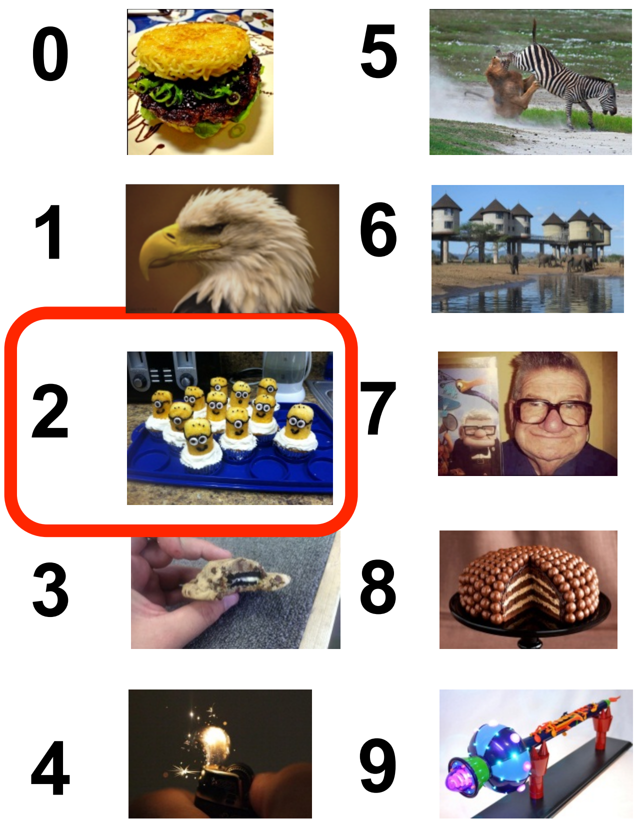

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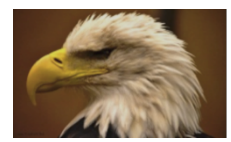
1 

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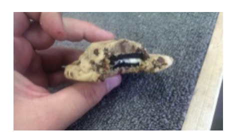
3 

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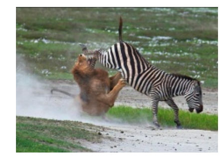
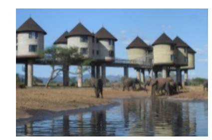
5 

6 

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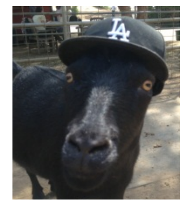
0 

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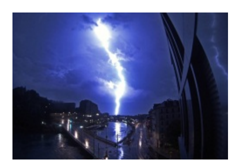
4 

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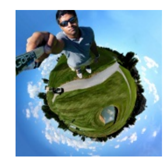
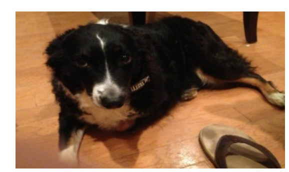
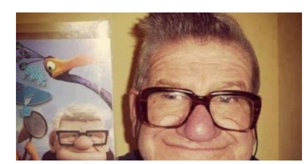
7 

8 

9 

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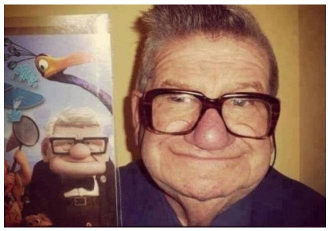


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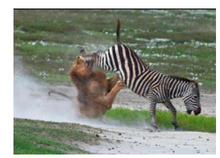
1 

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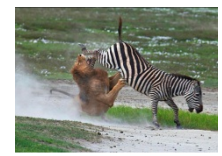
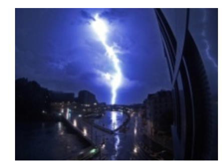
5 

6 

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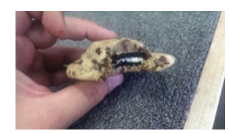
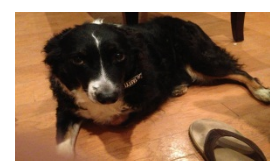
8 

9 

Usability

My Authentication Time:

- 7.5 seconds/digit
- 30 seconds for a 4-digit password
- 1.25 minutes for a 10-digit password

Memorizing the Secret Mapping:

- Memorized 100 image/digit pairs in 2.5 hours
- One Time Cost

Usability (Memorization)

	Human Computable Passwords			Shared Cues	
	N = 100	N = 50	N=30	SC-1	SC-0
Active	0.40	0	0	3.93	0
Typical	2.14	0.04	0	10.89	0
Occasional	2.50	0.05	0	22.07	0
Infrequent	70.7	22.3	6.1	119.77	2.44

E[$\mathbf{X}_{365}$]: Extra Rehearsals to maintain *all* passwords over the first year.

Open Problems

- Better measure of password quality
- Better ways to make people choose more secure passwords
- Alternatives to passwords?
  - The secret should be easy to remember, difficult to guess, and easy to enter into the system
- Better ways to make user choose stronger passwords?
- Better ways to use other devices for authentication
- Effective 2-factored and/or out of band authentication for the Web
- Phishing defense