Biometrics; Authentication as a Systems Problem

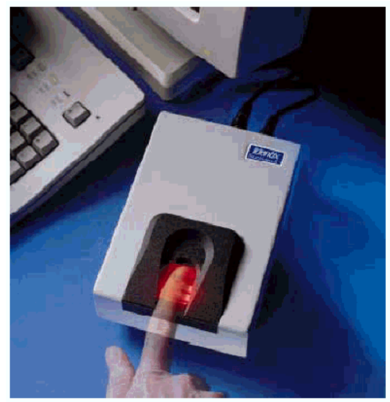
Biometrics

- Something you are
- A characteristic of the body
- Presumed unique and invariant over time

Metanote: biometrics is an area of rapid progress; some of the limitations I describe here are likely to change in the near future. Exercise: which of the problems are likely to remain difficult issues for system designers?

Common Biometrics

- Fingerprint
- Iris scan
- Retinal scan
- Hand geometry
- Facial recognition

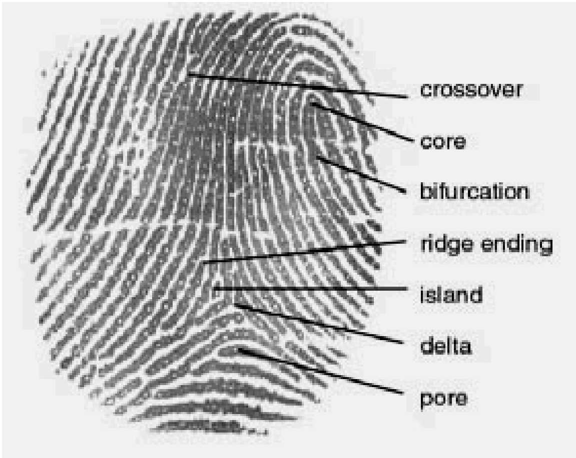


Fingerprints

- Uniqueness well-established (not an idle issue; Bertillon measurement were once thought unique)
  ☞Fingerprints are *congenital*, not genetic
- Lots of backup fingers
- Commodity hardware available; built into most new phones

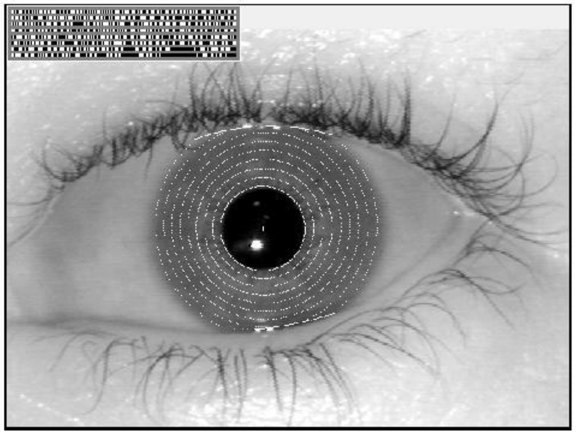
Fingerprint Recognition

- Image recognition technology
- Find significant features
- Does *not* match entire image
- Matching isn't as easy as you see on television
- New automated systems have improved scanning speed, but there can still be accuracy issues



Iris Scans

- Considered one of the most accurate biometrics
- Uses patterns in the iris of the eye that form after birth
- Hard part in some applications: finding the eye
- People do not like to stare into scanners



Retinal Scan

- Looks at patterrn of blood vessels inside the eye
- Must put eye up to laser scanner
- Most people *really* dislike scanners that shine things into their eyes. “You’re going to shine a *what* into my eye?!”
- Falling out of favor compared to iris scans

Hand Geometry

- Requires somewhat fussy hand-positioning
- Relatively easy to use; few acceptability issues
- Formerly used at Disney World and by U.S. Immigration. Disney has switched to finger geometry; Immigration has switched to fingerprints

Facial Recognition

- Not very accurate yet, but getting better
- Relies on geometry of key features—eye spacing, ears, etc.
- Major target market: walk-through authentication (and detection)
- ☞ Also: finding suspects in a crowd. (Gov. Cuomo plans to deploy it at Penn Station and probably elsewhere.)
- Some countries (US, UK, Germany, probably others) now prohibit smiling for passport pictures, to aid (future) automated recognizers

Other Biometrics

- Voiceprint
- ☞ New research shows how computers can imitate someone's speech from comparatively small amounts of recorded samples
- Typing rhythm

Human Voice Recognition

- Press the red button to "go secure"
- Crypto magic happens, followed by the display of some hex digits
- Each party reads the hex digits to the other
- You must recognize the other party's voice speaking those digits

☞ Computers be able to fake that soon...

(Photo courtesy Matt Blaze)

Advantages of Biometrics

- You can’t forget your fingers
- You can’t lend your eyes to a friend
- You can’t fake a fingerprint
- Why aren’t they used more?
- Maybe they’re not that secure…

Lenovo’s Statement on Fingerprint Recognition

“Non-Embedded Security Subsystem models can be configured for fingerprint only authentication that does not also require typing in a password. *This configuration offers convenience, but security is not significantly better than using typed passwords only* [emphasis added].”

(Note: “Embedded Security” models, which use a tamper-resistant chip, are more secure; more on that later.)

Some Problems with Biometrics

- False accept rate
- False reject rate
- Fake (or “detached”) body parts
- Computer-synthesized voices
- “Bit replay”
- Non-reproducibility
- Many biometrics are *public*

False Accept Rate

- No biometric system is perfect
- Reducing false accept rate increases false reject rate
- Usual metric: what is the true accept rate for a given false accept rate?
- Substantial difference between different products
- For fingerprints, best is .994 TAR @ 10^{-4} FAR; .999 TAR @ 10^{-2} FAR (NIST, 2004)
- For faces, .72 TAR @ 10^{-4} FAR; .90 TAR @ 10^{-2} FAR. (Lighting matters a lot for facial recognition.)
- All systems work much better for one-to-one match than “does this biometric match something in the database?”

False Reject Rate

- People change
- Cuts, scars, glasses, colds, bandages, etc.
- Problems in original image acquisition

Fake Body Parts

- Thieves cut off someone’s finger to steal his fingerprint-protected car (`http://news.bbc.co.uk/2/hi/asia-pacific/4396831.stm`)
- Biometric sensors have been fooled by “Gummi Bear” fingerprints, close-up pictures of face
- One solution: use “liveness” detectors—temperature, blood flow, etc.
- Another solution: use biometrics only when under observation

Bit Replay

- Ultimately, a biometric translates to a string of bits
- If the biometric sensor is remote from the accepting device, someone can inject a replayed bit stream
- What if someone hacks a server and steals a biometric? You can't change your fingerprints...

☞ Note: this happened with the OPM database breach

- Encryption helps; so does tamper-resistance
- Relying on human observation may help even more

Non-Reproducibility

- Biometric matching compares an image to a template or set of templates
- It is hard (but not impossible) to reduce a biometric to a reproducible set of bits, suitable for use as a cryptographic key
- This makes it difficult to use a biometric to protect locally-stored keys; you're really relying on the operating system

iPhone Fingerprint Recognition

- New iPhones have a fingerprint recognizer in the Home button: replace the PIN to unlock the phone
- Uses advanced technology; claimed to be immune to fake fingerprints, detached body parts, etc.
- Apple says the odds on a random finger matching are 1 in 50,000—and only five tries are allowed

☞ $1 - (1 - 50,000)^5 \approx \frac{1}{10,000}$ — the same as one guess at a 4-digit PIN

- The Chaos Computer Club has already shown that those claims are incorrect: use a high-resolution camera, a suitable printer, and some white glue. . .

Is That Secure?

- Lossy mapping of fingerprint images to template; cannot reconstruct fingerprint from it
- Templates stored in physically and logically secure coprocessor; communications from sensor to coprocessor are encrypted
- You can't even replace the sensor without the phone noticing and refusing to listen to it
- Data is *not* backed up in cleartext to iCloud
- The PIN is used to encrypt sensitive data on the phone (more detail on that later)
- PIN reentry is required after 48 hours, after failed authentication attempts, or after rebooting

What is "Secure"?

- What is being protected?
- What is the threat model?
- We can't answer "is it secure?" without defining what we're trying to protect!

☞ Fingerprint logs into phone: probably secure enough

☞ Can the fingerprint data be protected? Harder

☞ Fingerprint processor is vouching for user's identity: hardest of all

Using Biometrics

- Biometrics work best in public places or under observation
- Remote verification is difficult, because verifier doesn't know if it's really a biometric or a bit stream replay
- Local verification is often problematic, because of the difficulty of passing the match template around
- Users don't want to rely on remote databases, because of the risk of compromise and the difficulty of changing one's body
- Best solution: use a biometric to unlock a local tamper-resistant token or chip; store keys there

☞ This is what the iPhone does

- Another solution: put the template on a mag stripe card in the user's possession; that supplies it to a local verification station. But how is the template authenticated?

Signed Templates

- Can digitally sign a biometric template
- Medium doesn't matter; signed template is self-authenticating
- Verifier can operate offline
- But—which digital signatures should it trust?
- How do you revoke *authorization*?
- (This is a *capability*)

Systems Considerations

- The last two issues illustrate an important point: authentication doesn't stand by itself
- Whether or not biometrics are suitable depends on the situation
- How you set up your biometric authentication matters, too
- In fact, all authentication schemes are situation-dependent
- Authentication is a *systems problem*

Certificates as a Systems Issue

- The basic concept—a digitally-signed binding of a name to a public key—is simple enough
- (Just as we signed a biometric template)
- But—it's more complicated than that

Issuing Certificates

- Typically, user generates key pair, and presents public key and proof of identity
- CA signs the certificate and gives it back
- Note: certificates are also self-secured; they can be verified offline

Who Issues Certificates?

- Identity-based: some organization, such as Verisign, vouches for your identity
  ☞Cert issuer is not affiliated with verifier
- Authorization-based: accepting site issues its own certificates
  ☞Cert issuer acts on behalf of verifier
- Identity-based certificates are better when user has no prior relationship to verifier, such as secure Web sites
- Authorization-based certs are better when verifier wishes to control access to its own resources—no need to trust external party
- See CS dept and university web certificates at `https://www.cs.columbia.edu/~smb/classes/f16/cs-cert.txt` and `https://www.cs.columbia.edu/~smb/classes/f16/cu-cert.txt`

Things to Notice About Certificates

- Signer (the university didn't issue the department's certificate)
- Validity dates
- Algorithms (RSA, SHA256)
- (See older certificates at . . . /f07/. . .)
- They both use 2048-bit keys: modern standard
- They used to use SHA-1, which is deprecated
- Certificate usage—encryption and authentication, but *not* for issuing other certificates
- Certificate Revocation List (CRL)
- OCSP server: Online Certificate Status Protocol

How Do You Revoke a Certificate?

- Revocation is hard! Verification can be done offline; revocation requires some form of connectivity
- Publish the URL of a list of revoked certificates
  ☞One reason for certificate expiration dates; you don't need to keep revocation data forever
- Online status checking
- STU-IIIs use flooding algorithm—works well because of comparatively closed communities

Why Revoke Certificates?

- Private key compromised
- Cancel authorization associated with certificate
- Note the difference between identity and authorization certificates here
- CA key compromised, e.g., DigiNotar

What Certificates Do You Accept?

- Browers and (some) mailers have built-in list of CAs
- What were the listing criteria?
- Do you trust the CAs?
- What are their policies? Symantec's *Certification Practice Statement* (CPS) is at `https://www.symantec.com/content/en/us/about/media/repository/relying-party-agreement-user-authentication.pdf`. Have you read it?
- All certificate verification has to start from *trust anchors*; these must be locally provisioned. (Firefox trusts about 200 CAs; Windows IE trusts > 300—and at least 10% are agencies of some government)

The Risks of Built-in CAs

AOL Time Warner Root Certification Authorit...	Builtin Object Token
▿ Autoridad de Certificacion Firmaprofesional CIF...	
Autoridad de Certificacion Firmaprofesional ...	Builtin Object Token
▿ Baltimore	
Baltimore CyberTrust Root	Builtin Object Token
Baltimore CyberTrust Code Signing Root	Software Security Device
Baltimore CyberTrust Mobile Root	Software Security Device
▿ BankEngine Inc.	
bankengine	Software Security Device
▿ BelSign NV	
BelSign Object Publishing CA	Software Security Device
BelSign Secure Server CA	Software Security Device

It's amusing to read Baltimore's complex corporate history

Historical Note on Passwords

- The Unix password scheme was designed for *time-sharing systems*
- Users logged in from dumb terminals, with no local computing power
- It was intended for an environment with little or no networking
- Do these assumptions still hold?

Scenarios

- Parties: Prover (P), Verifier (V), Issuer (I)
- Issuer supplies credentials; Prover tries to log in to Verifier
- How many verifiers?
- How many different provers?
- What sort of networking is available?
- What sort of computer is P using?
- What is the relationship of P, V, and I?
- What are the adversary's powers?

Example: Large Enterprise

- Comparatively homegenous computing environment
- P trusts his/her own computer
- Centralized I, many Vs
- Perhaps use Kerberos
  - Uses password as cryptographic key
  - Uses centralized database of plaintext keys (but not passwords)
  - Little risk of keystroke loggers
  - Use management chain to authorize password recovery

Example: Wireless Consumer ISP

- Unsophisticated user base
- Low cost is very important
- Trusted, high-speed internal network
  - Separate login and email passwords
  - Store the wireless login password on the user's machine; maybe email password, too—must avoid help-desk calls
  - Use password hints; maybe even let customer care see part of the password or hints
  - Reasonably low risk of password file compromise: file theft may be less of a risk than keystroke loggers
  - Many Vs for login; several Vs for email. Use centralized back-end database, with no crypto

Example: University Computer Center

- Central V database
- Wireless networking
- Very heterogenous client computers
  - Kerberos not usable; too many different client machines
  - Serious danger of eavesdropping; use encrypted logins only
  - Use back-end process to distribute password database, or use online query of it
  - Classical password file may be right

Example: Consumer Web Site

- Low-value logins
- Can't afford customer care
- Use email addresses as login names; email new password on request (but why not send out old password?)
- Don't worry much about compromise

Example: Mailman Mailing List Server

- Use of password is rare (and often non-existent)
- Solution: auto-generate passwords; email them to users in the clear
- No serious resources at risk, especially for public mailing lists
- Better choice than asking users to pick a password—people *will* reuse some standard password
- But—the password may give access to the archives for closed mailing lists

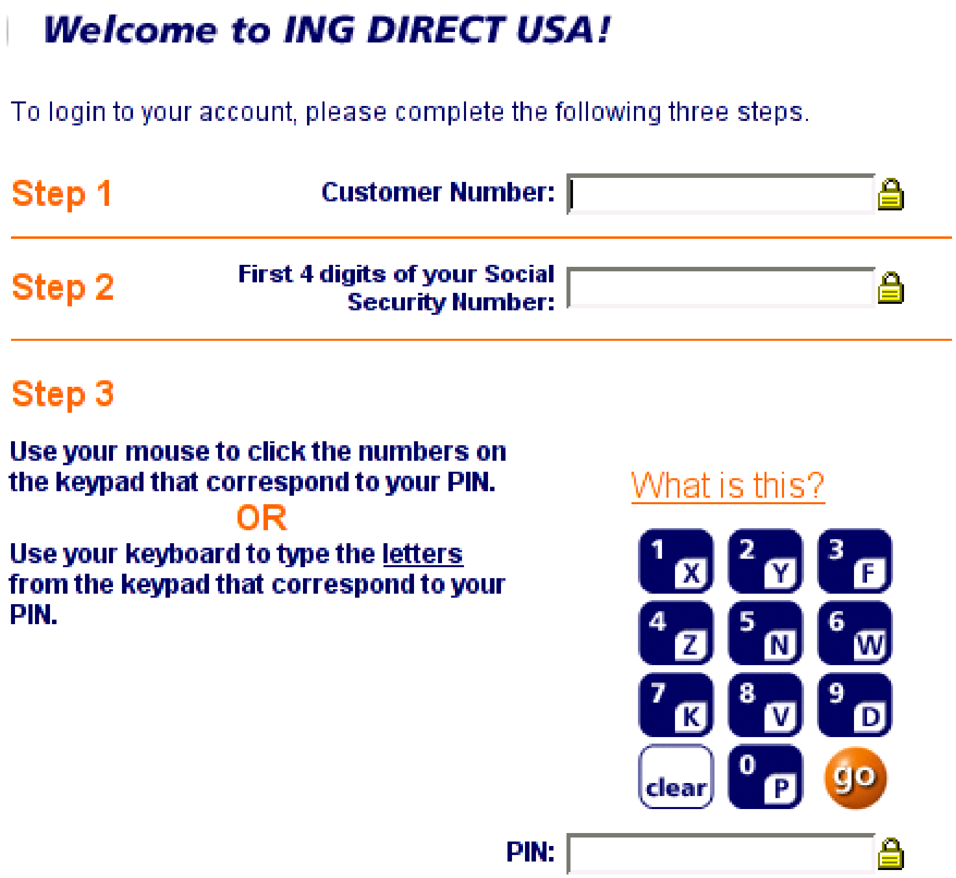
Example: Financial Services Web Site

- High-value login
- Protecting authentication data is crucial
- Customer care is moderately expensive; user convenience is important, for competitive reasons
  - Perhaps use tokens such as SecurID, but some customers don't like them
  - Today, perhaps use smart phones as second factor
  - Do not let customer care see any passwords
  - Require strong authentication for password changes; perhaps use physical mail for communication
  - Guard against compromised end-systems

iPhones

- My fingerprint, my phone
- Fingerprint database backed up via iTunes—but it's encrypted to the phone
- More convenient than (short) PIN; security is probably comparable
- Spoofing seems possible—but does it matter? What is the threat model? The attack is *targeted*; most phone locks are designed to protect against casual thieves.

A Previous ING Direct Login Screen

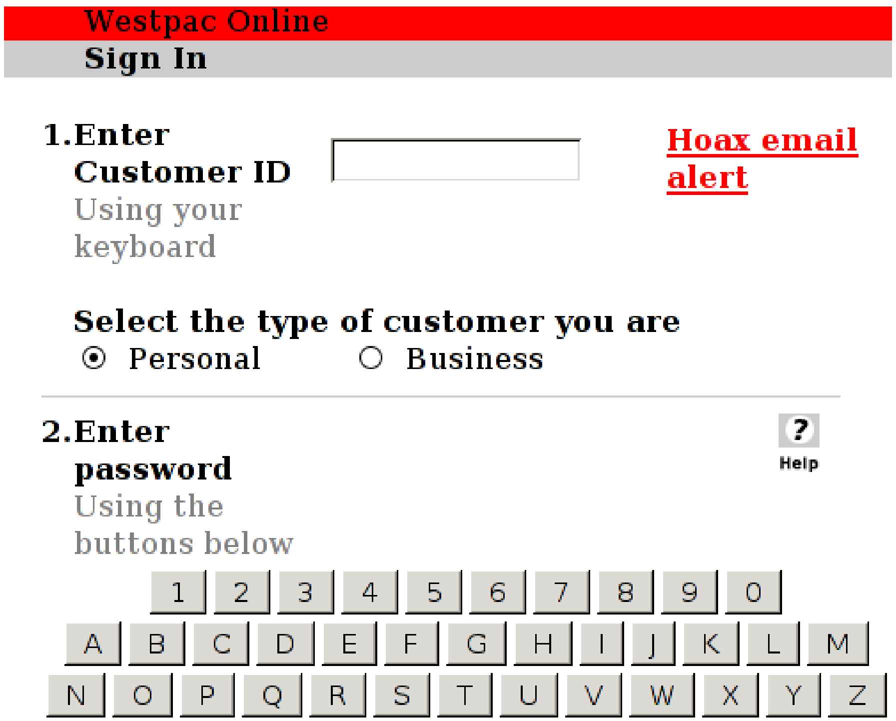


The keypad letters are randomly chosen and change each time, to guard against keystroke loggers

It’s Gone Now. . .

- Too complicated?
- Bypassed by the hackers?
- That happened to a similar scheme in Turkey within 24 hours. . .

Some Sites Still Use It



Hmm—letters and number keys only; no punctuation. Other sites *require* punctuation in passwords. . .

Example: Military Computer and Email Systems

- Captive user population—and they'll be there for a few years
- User training possible
- High value in some situations
- Everyone has to carry ID anyway
  - Convert dog tag to smart card containing public/private key pair
  - Use it for physical ID (Geneva Convention) and for computer login
  - Use PIN to protect private key

The Threat Model Wasn't Right

- Prisoners of war *must* show their dog tags
- That same device can provide access to sensitive computer systems
- POWs can be "pressured" to disclose their PINs
- Result: some pilots in Iraq in 2003 destroyed the chip before missions
- The designers forgot one thing: the risk of physical capture of the device *and* the device owner

Authentication as a Systems Problem

- The many different forms of authentication have a great deal in common:
  - Secondary authentication
  - Dealing with server compromise
  - Credential loss
  - Susceptibility to guessing attacks
  - Administrative infrastructure
- These pieces interact

Properties of Authentication Mechanisms

	Guessing	Forgetting	Device loss	Server file compromise	Temp access	External trust
Passwords	✗	✗	✓	✗	✓	✓
Chall/resp	✓	✓	✗	✗✗	✗	✓
SMS	✓	✓	?	✓	✗	?
Time-based	✓	✓	✗	✗✗	?	✗
Crypto	✓	✓	?	✗, ✓	?	✓
Biometric	✓	✓	?	✗	✗	✓
Federated	?	?	✓	✓	?	✗

✓ No particular problem; strength of this mechanism OK

? Some trouble or implementation-dependent

✗ Significant risk

✗✗ Very serious risk

There Are No Perfect Solutions

- All mechanisms have their shortcomings
- Most of the effort thus far has focused on eliminating passwords, because of the problem of guessing

☞ But other schemes have different shortcomings (including cost)

Passwords Aren't Going Away

- They're simple; everyone understands them
- They're low-cost
- Well, the cost isn't that low, when you account for recovery from forgotten passwords
- Other types of authentication have their own challenges
- We have to learn to handle them properly