Rethinking Passwords

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OAG password rules

*** The password must be at least seven characters long and cannot exceed fifty characters.**
*** The password is case sensitive and must include at least one letter and one numeric digit.**
*** The password may include punctuation characters but cannot contain spaces or single or double apostrophes.**
*** The password must be in Roman characters**

World of Warcraft Wizard Rules

*** Your Account Password must contain at least one numeric character and one alphabetic character.**
*** It must differ from your Account Name.**
*** It must be between eight and sixteen characters in length.**
*** It may only contain alphanumeric characters and punctuation such as A-Z, 0-9, or !"#$%.**

United Airlines rules

Passwords may be any combination of six (6) characters and are case insensitive.

Your password will grant you access to united.com, as well as other United features such as our wireless flight paging service, EasyAccess.

For security, certain passwords, such as "united" and "password" are not allowed.

Passwords are case insensitive; please remember how it is entered

Minimum password length is six (6) characters and must include characters from at least two (2) of these groups: alpha, number, and special characters.

New Password ••••••••••••••••

Verify Password ••••••••••••••••

Secret Question – Select Secret Question –

Secret Question Answer

* New Password must be minimum 7 alpha/numeric characters.

* New Password must contain at least 1 numeric symbol.

* Answer to Secret Question needs to be from 2 to 32 characters.

Passphrase Rules:

It must be a minimum of 4 words separated by blanks, at least 1 word must be 5 characters or longer.

It is case sensitive and cannot be less than 11 characters or more than 50 characters long including blanks.

It cannot contain single quotes, double quotes or ascii newline characters.

It cannot contain 3 or more consecutive identical characters.

You may NOT reuse any of the last 6 previously used passphrases

- The password may not contain your user name.
- The password must contain a minimum of six characters although eight characters are recommended since future complexity parameters will require an eight-character minimum.
- The password must contain three of the following characteristics:
  - Uppercase alphabet characters (AZ)
  - Lowercase alphabet characters (az)
  - Arabic numerals (09)
  - Non-alphanumeric characters (for example, !,$,#,%)

- Passwords shall not contain any proper noun or the name of any person, pet, child, or fictional character. Passwords shall not contain any employee serial number, Social Security number, birth date, phone number, or any information that could be readily guessed about the creator of the password.
- Passwords shall not contain any simple pattern of letters or numbers, such as "qwerty" or "xyz123".
- Passwords shall not be any word, noun, or name spelled backwards or appended with a single digit or with a two-digit "year" string, such as 98xyz123.
- Pass phrases, if used in addition to or instead of passwords, should follow the same guidelines.
- Passwords shall not be the same as the User ID.

Create a password between 8 to 15 characters.
Your password must contain at least:

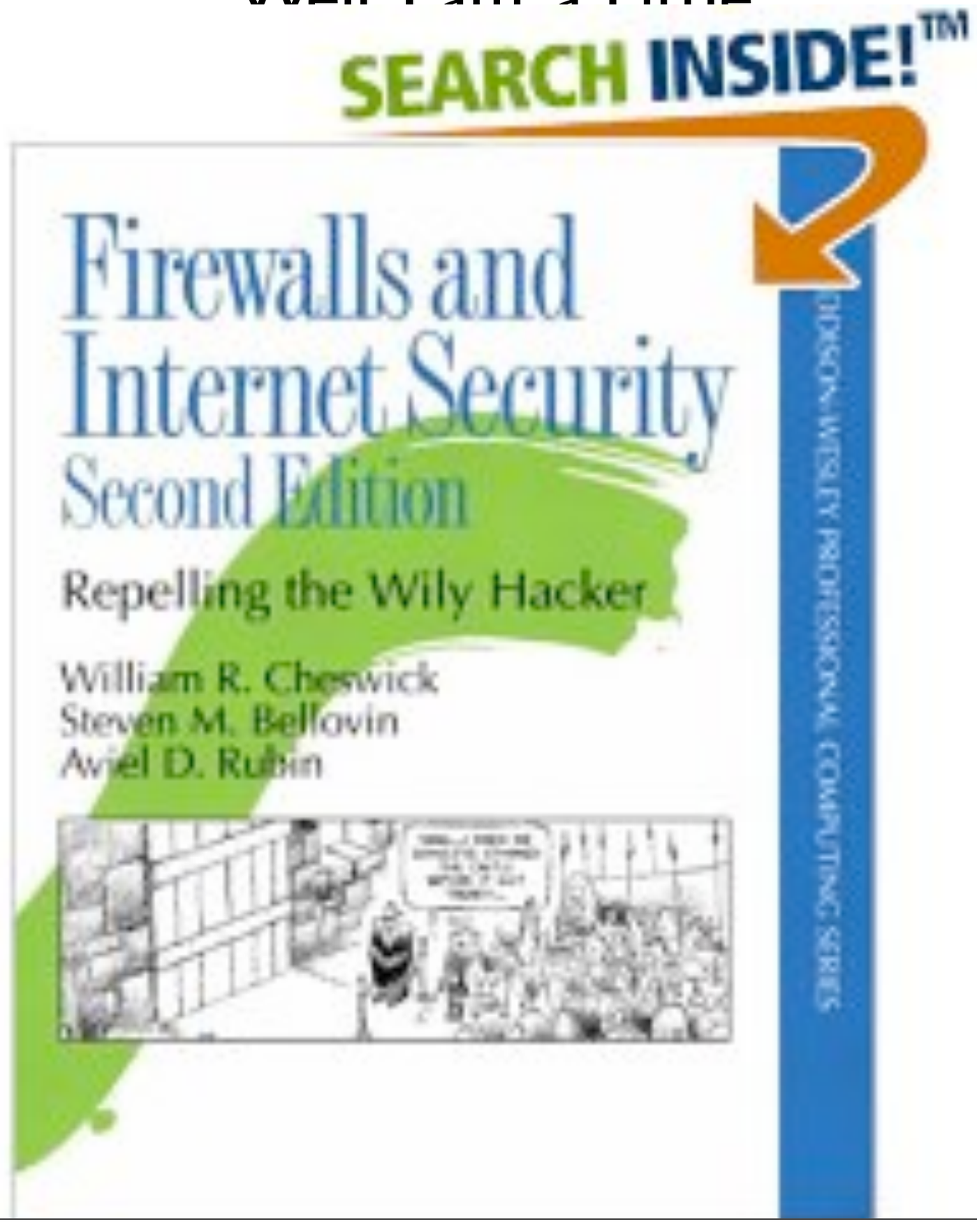
- one special character (shift-number)
- one uppercase character
- one lowercase character
- and NOT contain any spaces

Also....

- Use a Different Password on each target system
- Change your password frequently
- Don’t Reuse Passwords
- Don’t write your password down

Who is Responsible For This Eye-Of-Newt Password Fascism?

Well, I am a little



What are these rules for?

Dictionary Attacks

How many times can I try to guess your password?

How Many Guesses? History of passwords

- A: a lot
- A: jillions
- A: zillions (>> jillions)
- A: three
- A: three, and the correct answer changes each time you try

A: A lot of guesses

- Late 1970s, when Unix passwords were hashed with a salt (Morris and Thompson)
  - That made pre-computation impractical
- Access is mostly timesharing

A: Jillions

- Moore's Law carries on, people don't pick better passwords
- Networked services offer access to password files on misconfigured sites
- WAYWYT?

A: Today: Zillions

- Clouds, botnets, screen savers are all perfect for dictionary attacks
- If brute force doesn't work, use more.

The Dictionary Attack Arms Race

- Moore's Law: 12 doublings since 1990
- And multi-core CPUs are perfect for password cracking
- Can a human choose and remember a password that a computer can't guess when limited only by computer speed and time available?

Evolution of the bad guys

- academics
- teens without girl friends
- governments
- organized crime, drug lords, terrorists

We Knew People Pick Weak PWs by 1990

- Klein, D. V.; *Foiling the Cracker; A Survey of, and Improvements to Unix Password Security*, Proceedings of the United Kingdom Unix User's Group, London, July 1990.

bout 120

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It is simply poor engineering to expect people to select and remember passwords that are resistant to dictionary attacks

Results

- People violate many of these rules routinely, for usability reasons
- Stringent rules increase use of fall-back systems, which are usually less secure, or more expensive
- The rules don't make most things more secure in the face of most current threats

A: Three guesses

- Lock the account for a while or forever if there are too many wrong guesses in a row, or too many wrong guesses forever
- A locked account is a pain, but much better than illicit access
- Any non-moronic password can now be used

Non-moronic password rule

- Pick something a friend, colleague won't guess in a few tries.

Summary solution

- Limited guesses and lock the account
- Non-moronic passwords

The threat model has changed!

- Dictionary attacks are not used very much any more
- Keystroke loggers and *phishing* beat any strong password
- If I watch (or listen!) to you type, I can get the full password regardless of complexity!

A: three, and the correct answer changes

- This is done with one-time passwords
- The answer is based either on the time, or the response to a changing challenge
- Usually requires hardware, or a piece of paper (but see below)

SecureID

SecureNet Key
SNK-004

- Why is this better?
- PIN does not travel through the computer or over the network, or reside in the server
- In fact, the issuer never knows the PIN!
- Easy server software

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A login from my distant past

RISC/os (inet)

Authentication Server.

Id? ches
Enter response code for 70202: 04432234

Destination? cetus
$

Challenge/Response passwords

- Gets us out of the game
- Sniffing is not useful
- Man-in-the-middle can still be used
- Pretty much nothing to forget
- A PIN is helpful to make two-factor
- Surprisingly cheap

Why aren't these ubiquitous?

- Cheap devices available before 1990
- People hate:
  - Having to carry the device
  - Entering the challenge (why SNK lost)
  - Entering the response
  - Carrying multiple devices

Further password criteria?

- Text-only is most general
  - The web isn't the only place we need these solutions
  - But maybe iPhone-like interfaces will be ubiquitous enough
- Memorability? Shoulder-surfing?

Password Properties

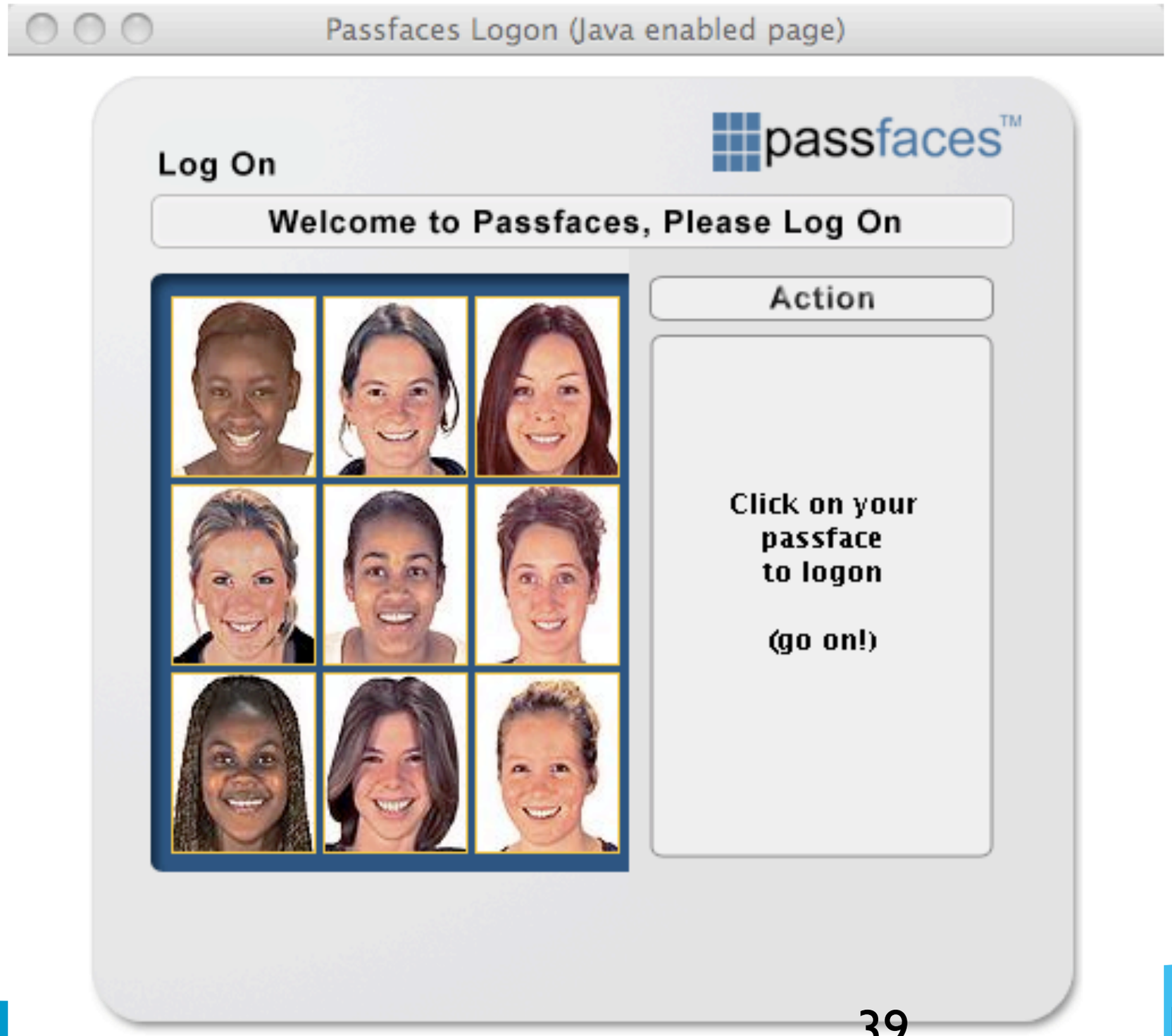
- Memorable?
  - Daily, monthly, yearly?
  - Cost if forgotten
- Hardware needed?
- Training steps needed
- User selected?
- Single use?
- Changeable?
- Easy to write down?
- Easy to describe or transmit?
- Authentication speed
- Text, graphical, bio, other

Some Password Ideas

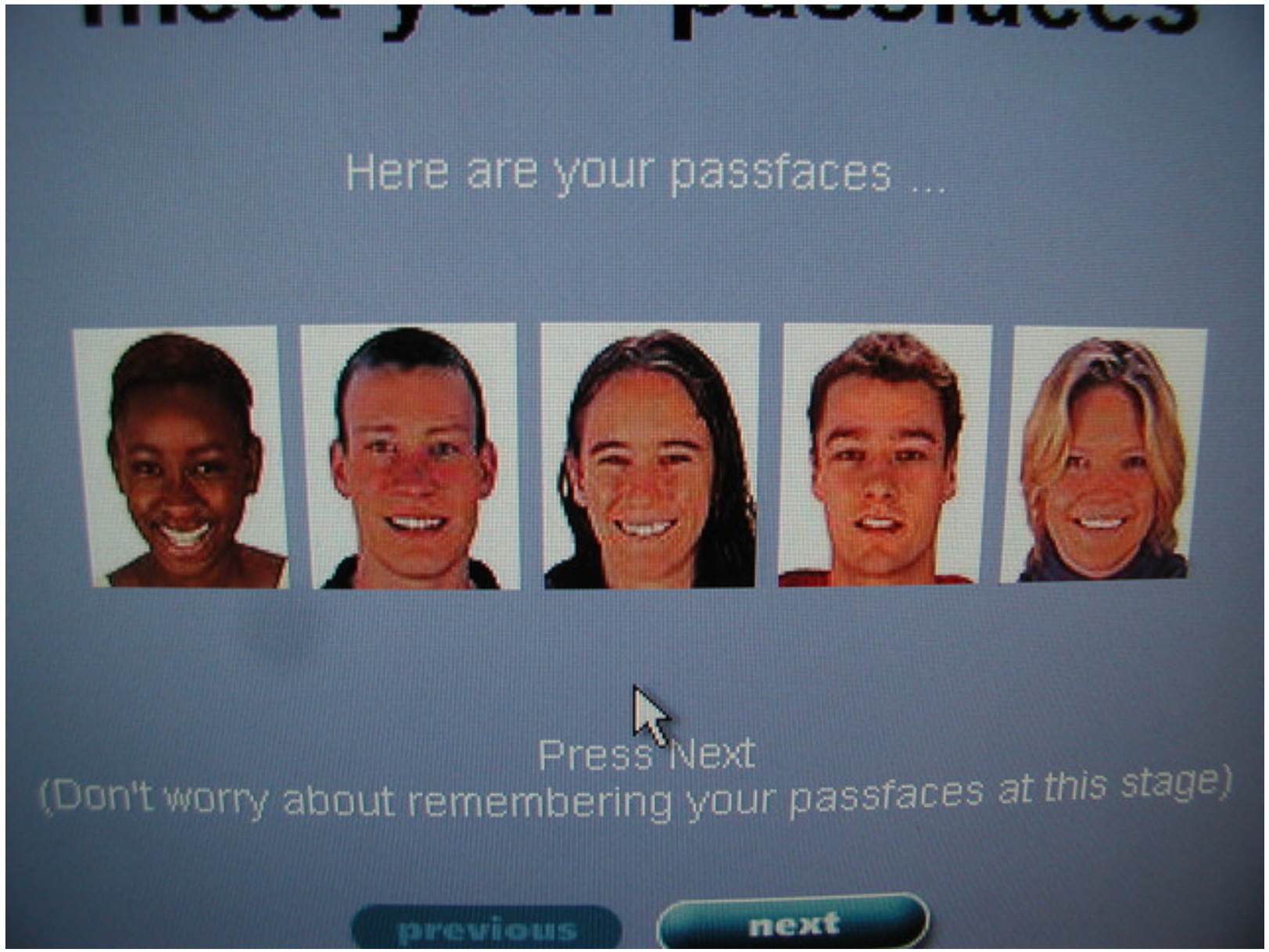
Passpoints

from *Dirik, Memon, Birget*; SOUPS 2007

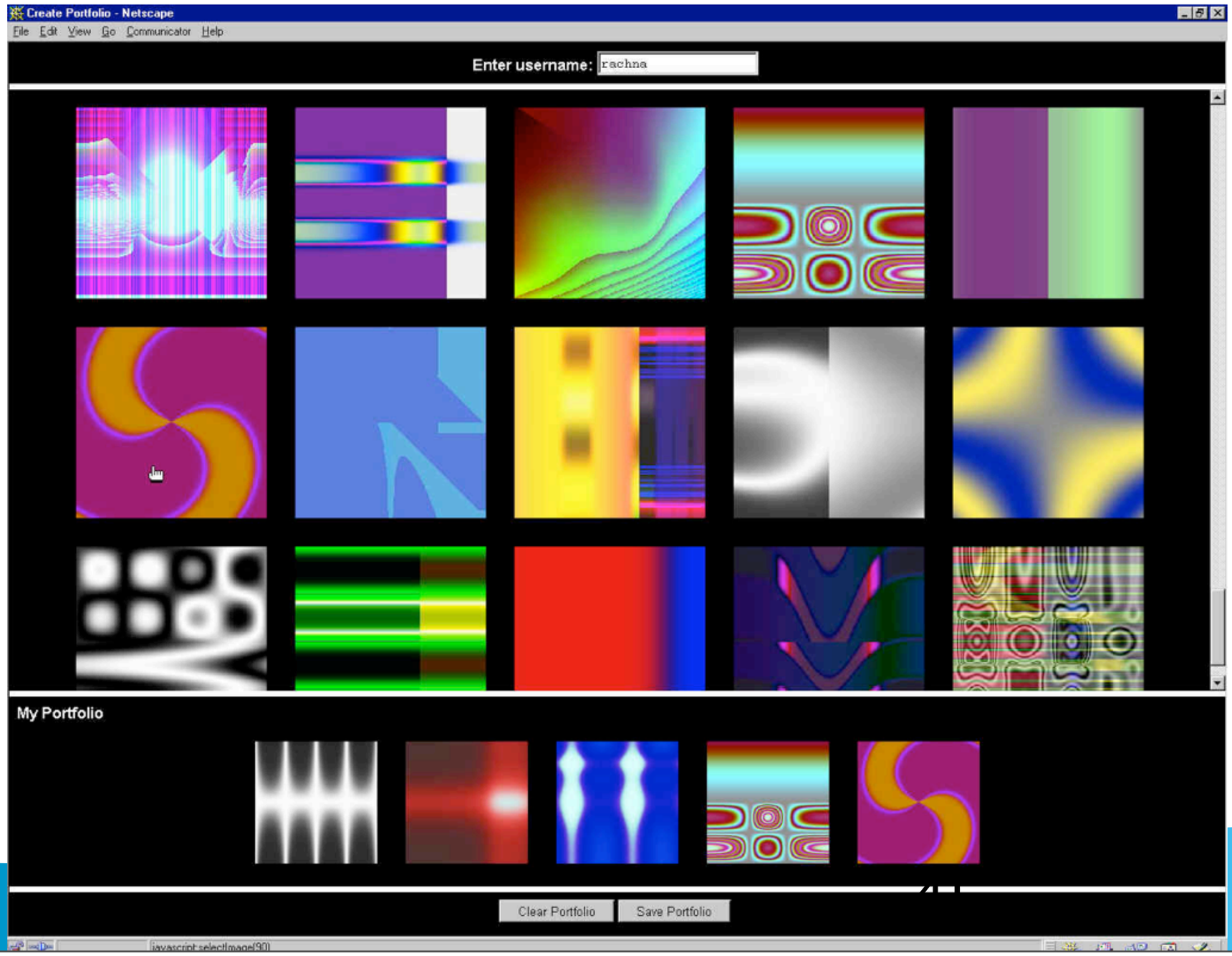
Passfaces


Passfaces Logon (Java enabled page)
Log On
passfaces™
Welcome to Passfaces, Please Log On
Action
Click on your passface to logon
(go on!)

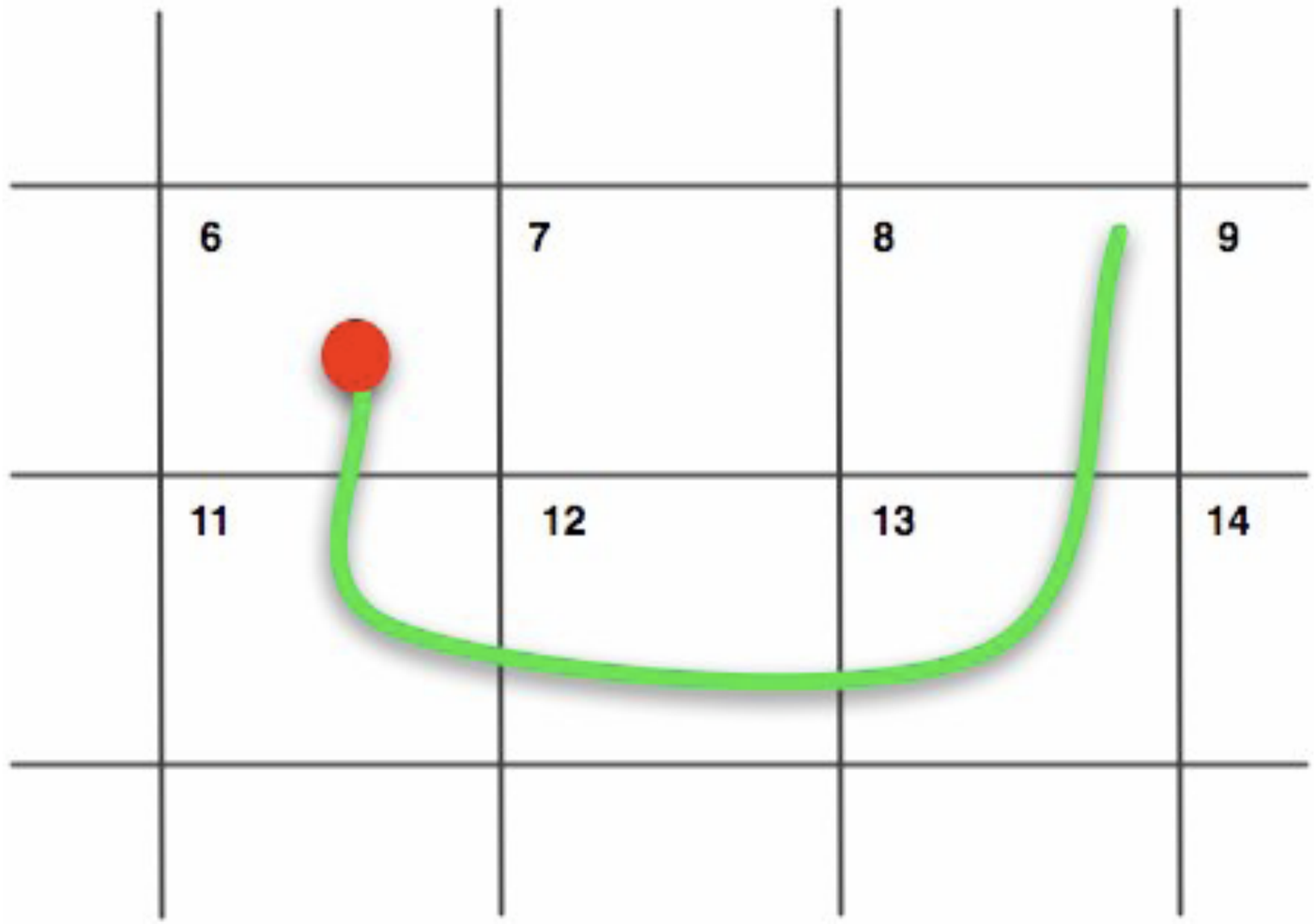
Passfaces


Here are your passfaces ...
Press Next
(Don't worry about remembering your passfaces at this stage)
previous
next

Deja Vu (Recognition-based)



Draw a Secret



Lin, Dunphy, *et al.* SOUPS 2007

Use Your Illusion (SOUPS 2008)

about 120

Some Whacko Ches Ideas

Passmaps

TODO: Find a point in New York State

Adirondacks are nice

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South Dundas
Massena
Malone
56
11
Norwood
Potsdam
Canton
Ogdensburg
Cardinal
11
Gouverneur
3
812
Star Lake
Tupper Lake
3
Saranac Lake
9N
Lake Placid
73
87
Dannemora
Plattsburgh
St Albans
Milton
Peru
Keeseville
Burlington
Jericho
Shelburne
Essex
Hinesburg
Vergennes
Bristol
Middlebury
Adirondack Park
Ticonderoga
Brandon
Rutlan
Whitehall
Fair Haven
Warrensburg
22
Poultney
7
Lake George
149
Granville
Glens Falls
Hudson Falls
Saratoga Springs
Lowville
Boonville
Rome
90
Utica
Little Falls
Gloversville
29

Lakes have interesting shapes,
let's zoom in on the middle

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Upside down dog in the upper left

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Dogs bark, check out the voice box

PW is lat/long of the center island

Passmaps?

- Reproducibly zoom in on a remembered set of map features?
- Lots of bits
- Maybe hard to shoulder surf
- Not challenge/response
- memorable over a year?
- Nice for a touch screen?

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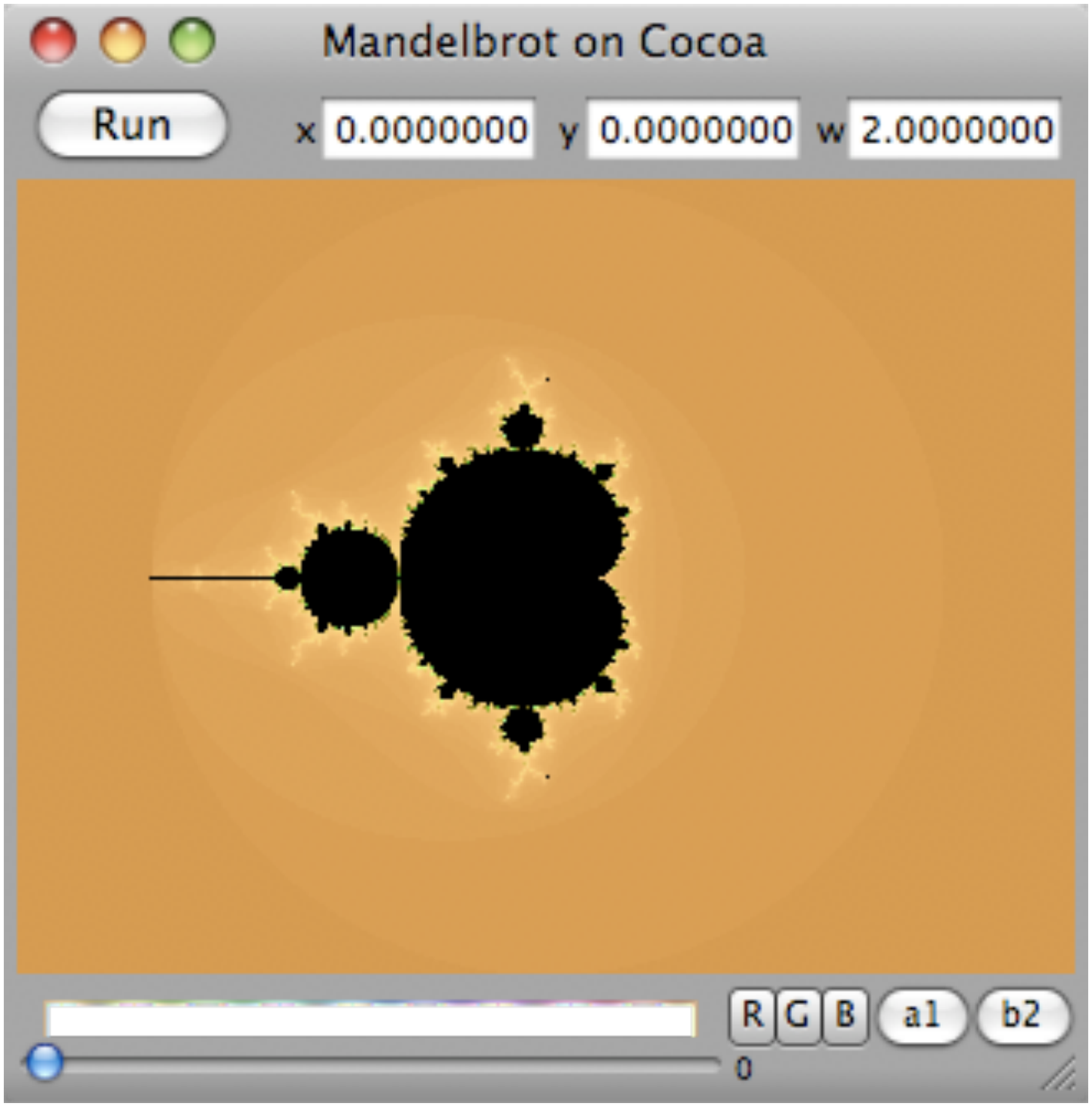
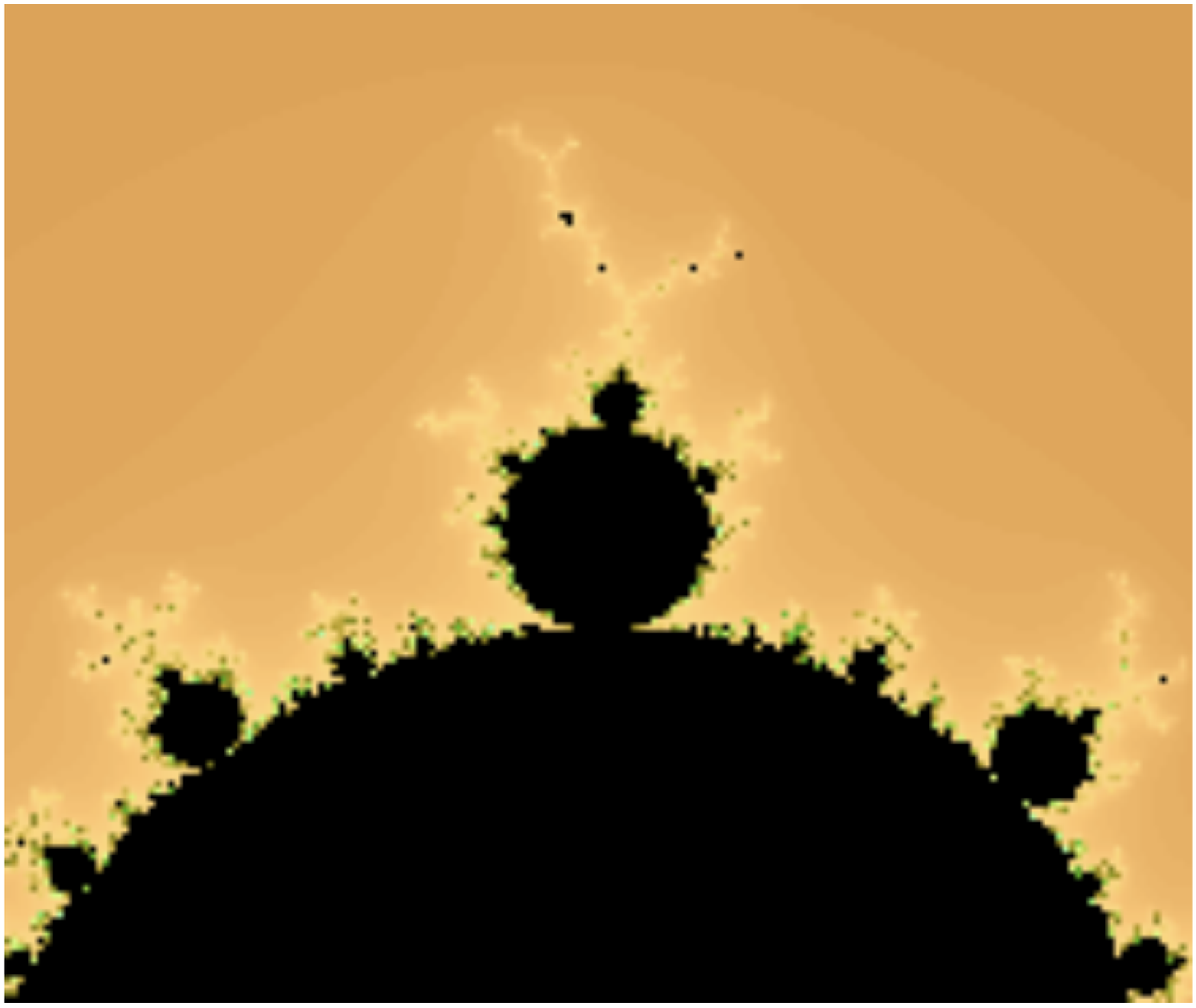
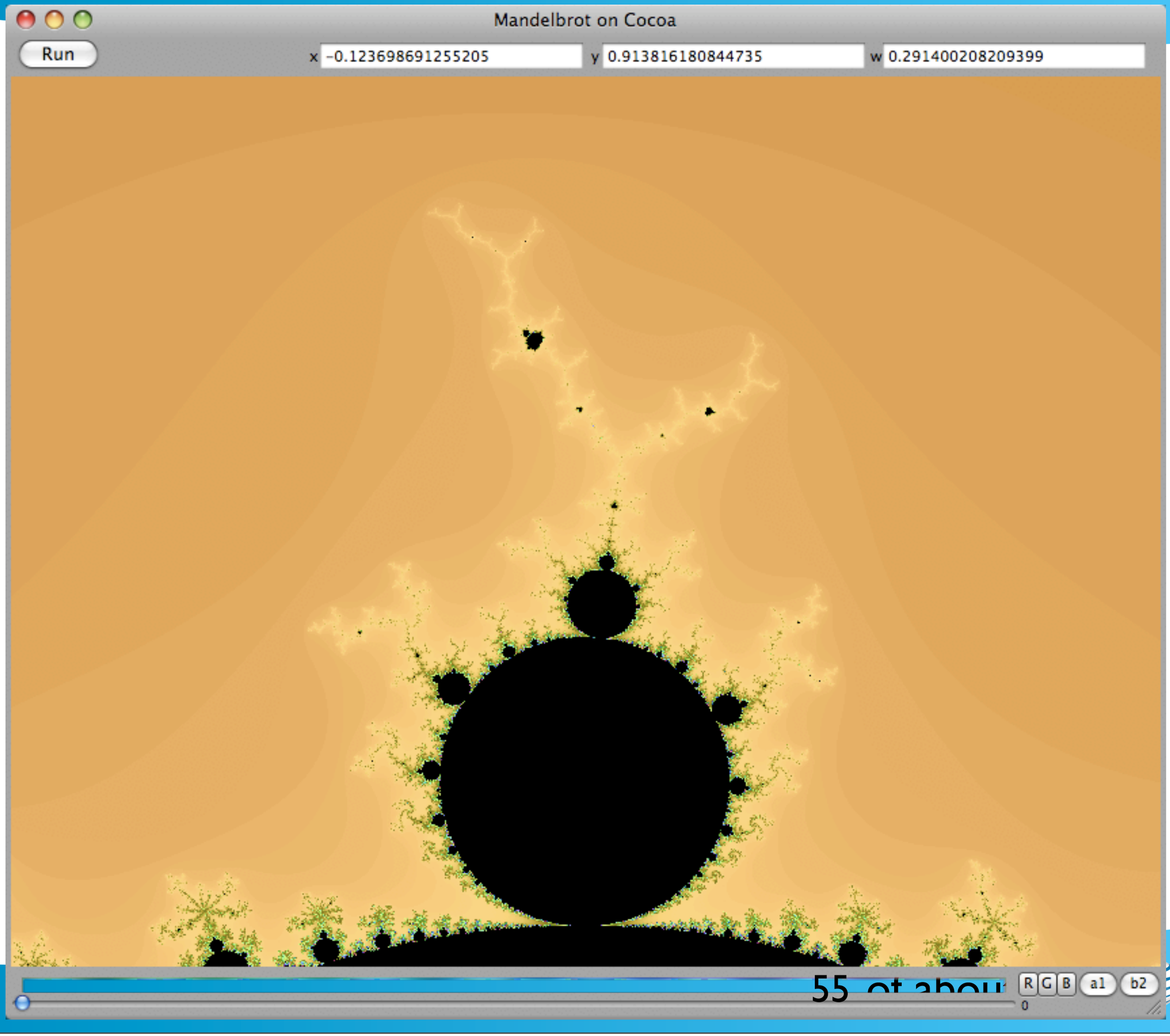
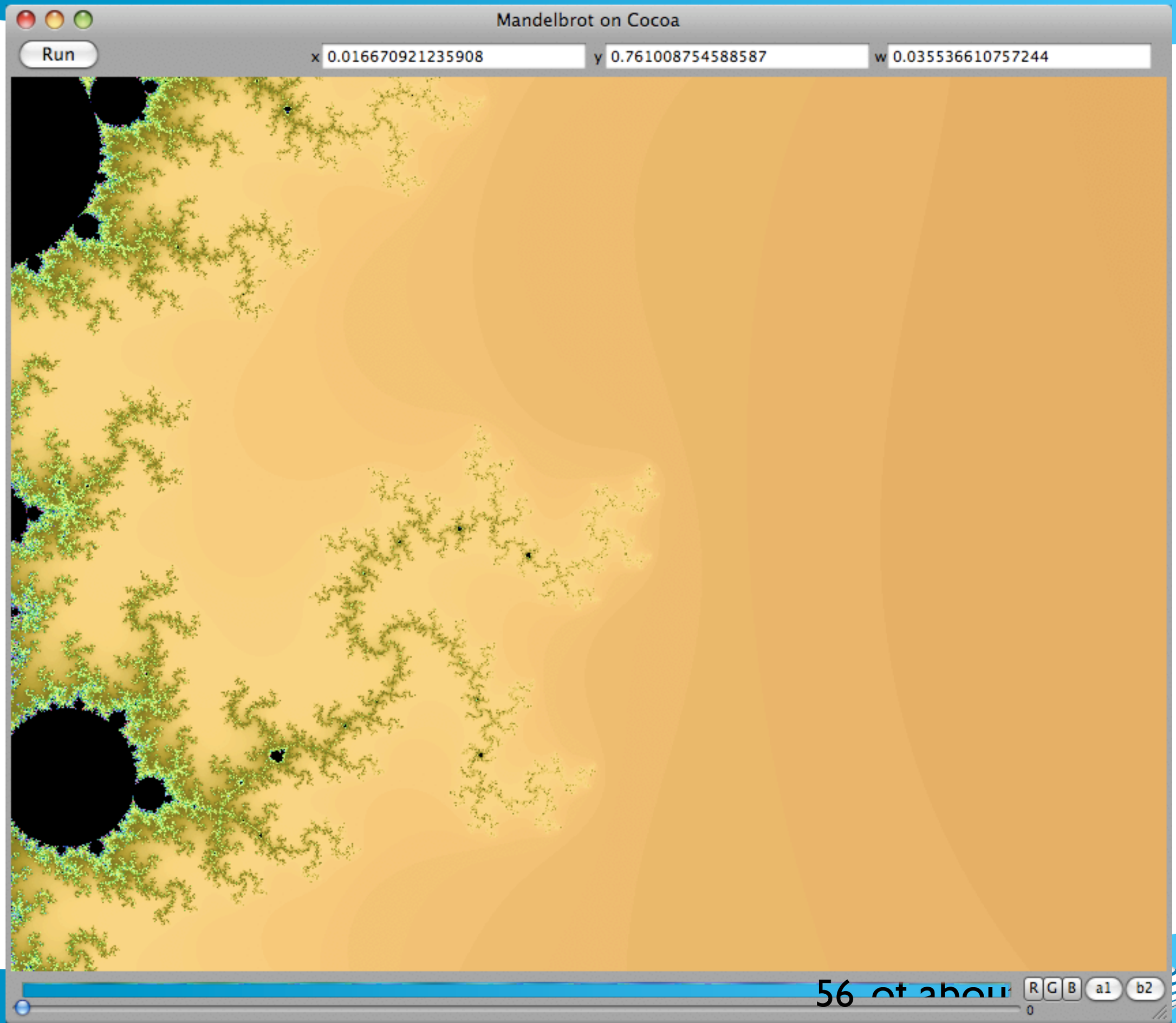
Some Whacko Ches Ideas

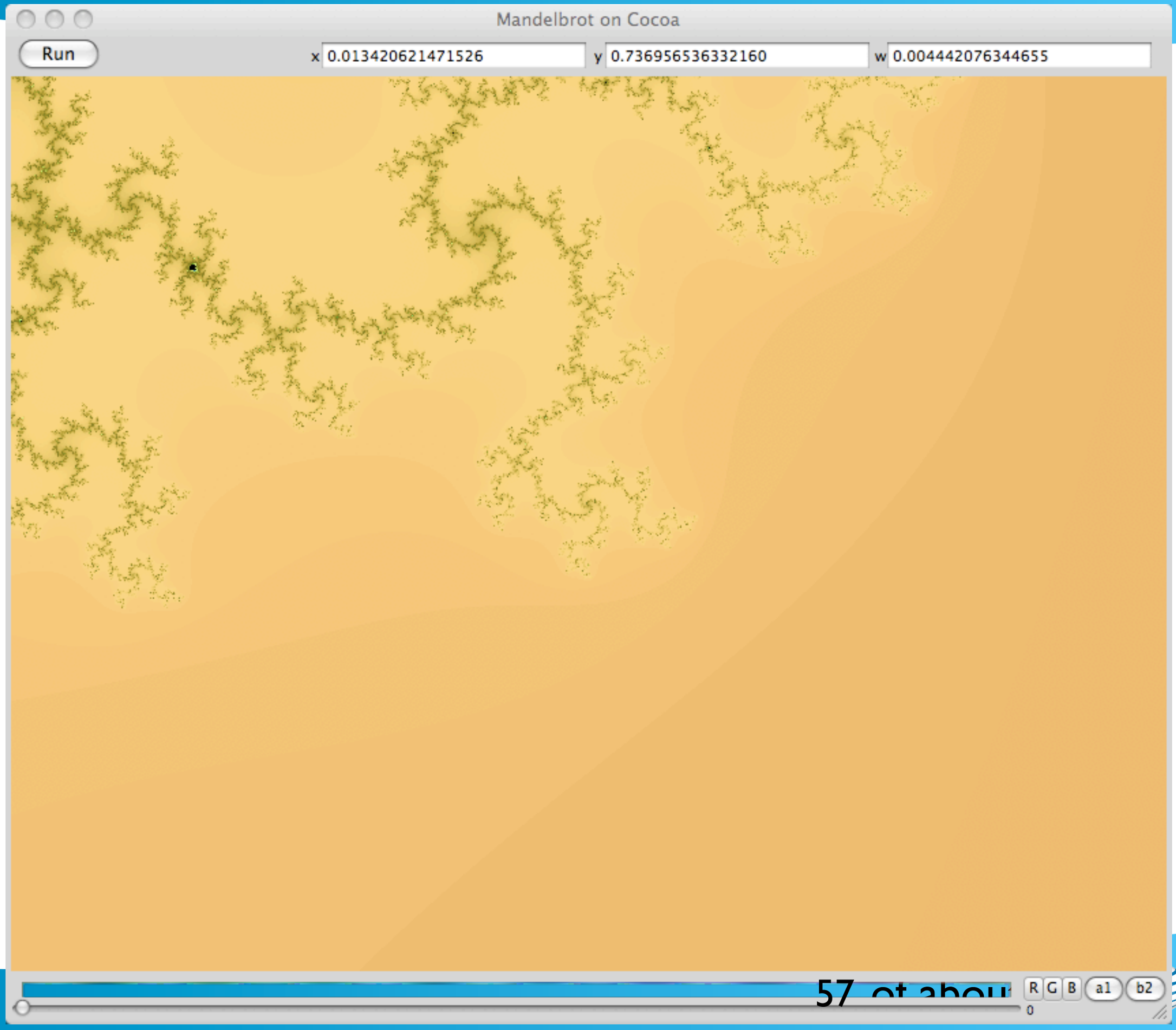
How about passgraphs? Get Google out of the loop

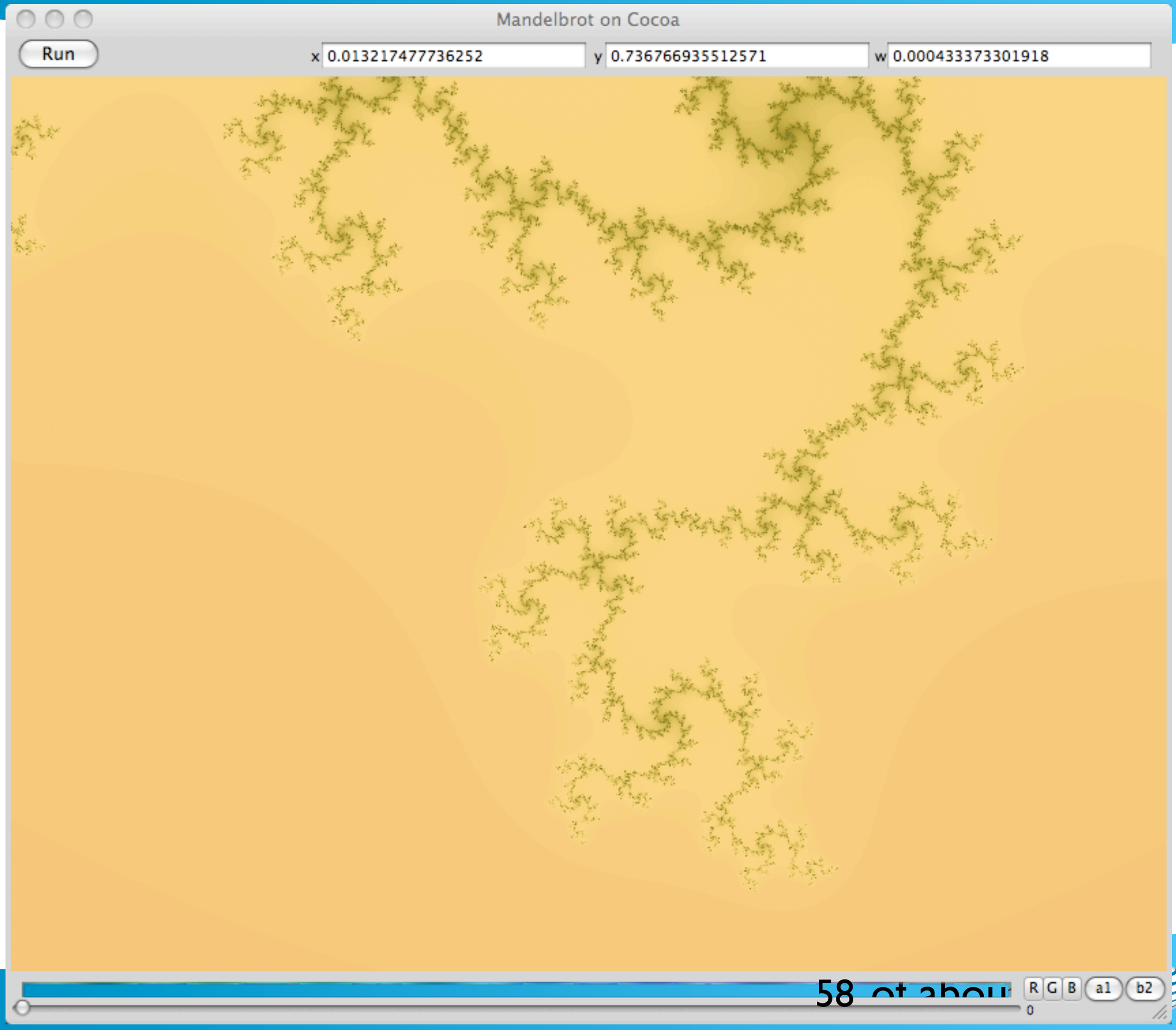

Mandelbrot on Cocoa
Run
x 0.0000000
y 0.0000000
w 2.0000000
R
G
B
a1
b2
0




Mandelbrot on Cocoa
Run
x -0.123698691255205
y 0.913816180844735
w 0.291400208209399
R
G
B
a1
b2
0


Mandelbrot on Cocoa
Run
x 0.016670921235908
y 0.761008754588587
w 0.035536610757244
R
G
B
a1
b2
0


Mandelbrot on Cocoa
Run
x 0.013420621471526
y 0.736956536332160
w 0.004442076344655
R
G
B
a1
b2
0


Mandelbrot on Cocoa
Run
x 0.013217477736252
y 0.736766935512571
w 0.000433373301918
R G B a1 b2
0


Mandelbrot on Cocoa
Run
x 0.013114419451040
y 0.736712763849831
w 0.000017176380869
R G B a1 b2
0

Passgraphs?

- Similar to passmaps, but Google is out of the equation
- Maps can have a personal meaning
  - Is this a good thing, or a bad thing?

Some Whacko Ches Ideas

Obfuscated human-computed challenge response

Problem

- One-time passwords solve a lot of password problems
- One-time passwords (usually challenge/response) require something you have
- Equipment can be expensive, and it may be necessary to authenticate when equipment is not available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Baseball players

- Under a lot of stress
- Information is often vital to the game
- Not always the sharpest knife in the drawer
  - Babe Ruth forgot the signs five steps out on the field

Key insight?

- Humans can't compute well, but perhaps they can obfuscate well enough

Proposed approach

- Use human-computed responses to computer challenges for authentication
- Though the computation is easy, much of the challenge and response is ignored
- Obfuscation and lack of samples complicate the attacker's job beyond utility

Challenge:	Response:	
ches 00319 Thu Dec 20 15:32:22 2001	23456bcd;f.k	
root 00294 Fri Dec 21 16:47:39 2001	nj3kdi2jh3yd6fh:/	
ches 00311 Fri Dec 21 16:48:50 2001	/ldh3g7fgl	
ches 00360 Thu Jan 3 12:52:29 2002	jdi38kfj934hdy;dkf7	
ches 00416 Fri Jan 4 09:02:02 2002	jf/l3kf.l2cxn. y	
ches 00301 Fri Jan 4 13:29:12 2002	j2mdjudurut2jdnch2hdtg3kdjf;s'/s	
ches 00301 Fri Jan 4 13:29:30 2002	j2mdgfj./m3hd'k4hfz	
ches 00308 Tue Jan 8 09:35:26 2002	/l6k3jdq,	
ches 84588 Thu Jan 10 09:24:18 2002	jf010fk;.j	
ches 84588 Thu Jan 10 09:24:35 2002	heu212jdg431j/	
ches 00306 Thu Jan 17 10:46:00 2002	jfg.bv,vj/,1	
ches 00309 Fri Jan 18 09:37:09 2002	no way 1 way is best!/1	
ches 00309 Fri Jan 18 09:37:36 2002	jzw	* no *
ches 00368 Tue Jan 22 09:51:41 2002	84137405jgf/	
ches 77074 Tue Feb 19 09:02:52 2002	d	* no *
ches 77074 Tue Feb 19 09:02:57 2002	hbcg3]'d/	
ches 00163 Mon Feb 25 09:24:30 2002	d	* no *
ches 00163 Mon Feb 25 09:24:35 2002	ozhdkf0ey2k/.,vk0l	
ches 00156 Tue Mar 12 12:41:12 2002	3+4=7 but not 10 or 4/2	
ches 00161 Fri Mar 15 09:41:20 2002	/.,kl9djfir	
ches 00161 Fri Mar 15 09:41:36 2002	3	* no *
ches 00160 Mon Mar 25 08:52:59 2002	222	
ches 00160 Mon Mar 25 08:53:09 2002	2272645	
ches 29709 Mon Apr 1 11:36:34 2002	4	
ches 41424 Mon Apr 8 09:49:09 2002	ab3kdhf	
ches 85039 Tue Apr 9 09:46:06 2002	04	
ches 00161 Thu Apr 18 10:49:14 2002	898for/dklf7d	

Pass-authentication

- Literature goes back to 1967
- A variety of names used: *reconstructed passwords, pass-algorithms, human-computer cryptography, HumanAut, secure human-computer identification, cognitive trapdoor games, human interactive proofs*

Possible uses

- emergency holographic logins ("passwords of last resort")
- use from insecure terminals, when single session eavesdropping is probably not a problem
- if a solution is found: daily logins
- home run: online transactions: banking

Problems

- Can Joe Sixpack do this?
- Math is hard
- Procedural *vs* informational knowledge

Two Kinds of P-A Solutions

- *ad hoc*
- information theoretic

Ad Hoc solutions

- familiar to the designer
- idiosyncratic
- hard to analyze

Information theoretic

- Strong proof of work factor to crack
- None seem usable to me, and certainly not useable to Joe Sixpack

Current Threats and Some Revised Advice

Disclaimer

- These are all guidelines, suggestions, thoughts for your own risk/benefits analysis
- Every security person I've discussed this with has a somewhat different take
- Rethink and reengineer these systems, when appropriate

Threats to casual targets

- Password capture by phishing
- Password capture by keystroke logging
- *Not* dictionary attacks
  - Most online systems limit password guessing
- Most attacks are wholesale, not targeted

Dictionary attacks still a concern

- For standard Unix logins
- For ssh password logins
- Against captured oracle streams, like PGP and ssh key files, cleartext challenge/ response fields in protocols
- These are not mainstream attacks these days. Stolen laptops/iPhones a concern

Mother's Maiden Name is a Bad Idea

- Secondary passwords are weaker, why would we use them?
- Mother's maiden name is available on ancestor.com
- *A hint about the primary password is much better!*

Recommendations for users

- Use three levels of passwords based on importance:
  - No importance: NY Times, etc.
  - Inconvenient if stolen: Amazon
  - Major problem if abused: bank access, medical records(?)
  - But these can change!

For users (cont.)

- Write down the rare ones if you must
- Don't write down the password, write a reminder of the password
- Use variations to meet "strong" password requirements.
- Note required variations (i.e. lower case, no spaces)

Save your passwords with Firefox?

- Little difference against keystroke logging
- Key-ring protection mechanisms subject to dictionary attacks
- If stolen, you have given away an authentication factor

Updated Advice

For Implementors

Out of the Dictionary Attack Game Game

- Count and manage authentication attempts with a server
- pam_tally
- slow or block accounts (block is better than loss of control of an account)
- blacklist inquisitive IP addresses

Locking an account

- Locking or slowing account authentication simplifies denial-of-service attacks
- A locked account is much better than a stolen account
- Slower authentication, or a timeout on lockout, mitigates user support costs

Use an authentication server

- Centralizes the security function
- Make it strong and robust
- Replication is dangerous, reliability is better
- Limit authentication attempts

If password is forgotten

- Use a user-supplied reminder of the primary password
- Do not a (usually weaker) secondary password
  - The net has ancestor, and personal data, and will have lots more soon
- blacklisting doesn't have to be forever

PIN != password

- A PIN is a sequence of digits only
- A password is a superset of PINs
- A passphrase is a series of words, but probably should not be called a *phrase*. *Passcode* is probably better

Identify the auth. server and pw rules

- Usually just an additional line to a web pages
- Yes, it leaks a little information
- It greatly eases the usability
  - name of server eliminates guessing and pw leakage
  - rules remind user of pw variation used

Don't make acct. names too easy to guess

- Thwarts single password, multi-account scans
- U.S. Social security numbers are a little too guessable. Credit cards seem to be okay.
- But secret rules (hyphens in social security number?) reduce usability without improving security

Near-public authentication servers

- OpenID
- Openauth
- The general idea is appealing

Biometrics?

- Generally around 90% accurate
- A variety of workarounds
- Users may be reluctant to give up data
- Not bad for an auxiliary factor in strong authentication

Getting out of the game: ssh

- disable password logins. Use DSA key from a trustable client, that key locked with a strong pass-phrase
- two-factor authentication
- dictionary attack is rare endgame: you have to steal or own the client first
- Reasonably secure clients are doable

Routine on seismo.arpa.net

```
seismo.arpa.net login failures:
Oct 21 00:12:56 seismo sshd[14326]: Invalid user foobar from 209.160.73.63
Oct 21 00:13:17 seismo sshd[14392]: Invalid user test from 209.160.73.63
Oct 21 00:13:18 seismo sshd[14394]: Invalid user test from 209.160.73.63
Oct 21 00:13:18 seismo sshd[14396]: Invalid user test from 209.160.73.63
Oct 21 00:13:19 seismo sshd[14398]: Invalid user test from 209.160.73.63
Oct 21 05:32:43 seismo sshd[33315]: Invalid user admin from 209.160.73.63
Oct 21 05:32:43 seismo sshd[33317]: Invalid user admin from 209.160.73.63
Oct 21 05:32:44 seismo sshd[33319]: Invalid user admin from 209.160.73.63
Oct 21 05:32:45 seismo sshd[33321]: Invalid user admin from 209.160.73.63
Oct 21 05:32:46 seismo sshd[33323]: Invalid user admin from 209.160.73.63
Oct 21 05:32:46 seismo sshd[33325]: Invalid user admin from 209.160.73.63
Oct 21 05:48:24 seismo sshd[33399]: Invalid user eric from 209.160.73.63
Oct 21 05:48:25 seismo sshd[33401]: Invalid user johny from 209.160.73.63
Oct 21 05:48:38 seismo sshd[33445]: Invalid user edward from 209.160.73.63
Oct 21 05:48:39 seismo sshd[33447]: Invalid user edward from 209.160.73.63
Oct 21 05:48:39 seismo sshd[33449]: Invalid user edward from 209.160.73.63
Oct 21 05:48:40 seismo sshd[33451]: Invalid user russ from 209.160.73.63
....
```

Strong Passwords, if you must

If you must, here are at least 60 random bits

- value part Peter sense some computer
- anxiety materials preparation sample experimental
- bliss rubbery uncial Irish
- 2e3059156c9e378

User choice is bad for entropy

- not user-chosen, but user can veto, waiting for a "good one"
- User-chosen phrases have *much* lower entropy
- they are going to write it down, for a while
- for daily use: who's going to remember this over a year?

Uncial

uncial |ˈən sh əl; -sēəl| *adjective*

1 of or written in a majuscule script with rounded unjoined letters that is found in European manuscripts of the 4th–8th centuries and from which modern capital letters are derived.

2 *rare* of or relating to an inch or an ounce.

noun
an uncial letter or script.

Words are better than eye-of-newt

- much easier to type
- spelling checking (iPhone) is your friend, not enemy

Entropy >41 bits

www.cheswick.com/pw

You grim-faced pipe of pleuritic snipe sweat
You dire chiffonier of foul miniature poodle squirt
You teratic theca of pathogenic moth dingleberry
You worrying pan broiler of bilious puff adder slobber
You vile wok of tumorigenic aphid leftovers
You baneful reliquary of pneumonic miller stumps
You atrocious terrine of harmful Virginia deer vomition
You excruciating pony of septic redstart eccrisis
You blotted kibble of unhygenic wild sheep spittle
You hard-featured fistula of podagric macaque flux

iPhone-friendly passwords?

- grade likes jokes guess
- goes joke gold gods rode fire rows
- votes mines bored alike yard
- what knit bomb unit star grow
- actor agent above angel abuse
- honey learn least lemon links

Bad iPhone words

19	goes	bird fled flew view core cows gods goes fire toes tide tied ties hide blew bore boss hire code
18	joke	mood joke mild mile mind mine none hold hole home nine bold kind bond bone blow bike bile
18	gold	food cold come cope file gold golf told good time tips hold hole home hope bold bike bile
18	gods	bird fled flew view core gods goes fire toes tide tied ties hide blew bore boss hire code
17	rose	fled flew toes does dose tide tied ties died dies road rode rose rows ride else rise
17	rode	fled flew fire toes does dose tide tied ties died dies rode rose rice ride else rise
17	fire	vote view core gods goes fire toes does tide tied ties died dies rode ride cuts code
17	dose	fled flew side cows does size dose died dies road rode rose rows ride else rise code
17	does	fled flew core side cows fire does dose died dies rode rose rows ride else rise code
16	time	fond guns tune file find fine gold gone told tone tons rule runs time role fund
16	file	food cold come cope duke file gold told good door rule time tips role rope cups
16	died	core side cows fire does dose died dies rode disc rose rows ride sure rise code
16	date	dare date days rage ears rare rate rats safe cage fate card care cars cats says
15	good	food cold cope file gold golf told good tips hold hole hope bold bike bile
15	fine	fond tube come guns tune duke find fine gone tone tons done runs time fund
15	find	fond tube come guns tune duke find fine gone tone tons done runs time fund
15	dies	core side cows fire does dose died dies rode rose rows ride sure rise code
15	bike	guns joke gold gone good none hold hole home nine bold bond bone bike bile
14	toes	fled flew gods goes fire toes tide tied ties rode rose rows ride rise
14	rows	fled flew toes does dose tied ties died dies road rose rows else rise

Easier words

a	inch	adapt	charm	fruit	media	relax	thick
m	iron	admit	chart	fully	meets	reply	think
v	isle	adopt	cheap	funny	mercy	rings	throw
at	item	adult	check	giant	minus	rival	toxic
by	keen	again	cheek	gifts	model	round	track
cm	keep	agent	choir	given	money	rural	trail
ft	kept	ahead	civil	grant	month	salad	trees
ii	knit	alarm	claim	graph	moral	scale	trial
la	know	album	clear	group	motor	scene	trips
my	lamb	alive	clerk	habit	mouth	scope	truly
act	lamp	alpha	clock	happy	movie	serve	twice
aha	left	angel	coach	harsh	mummy	seven	uncle
all	lend	anger	coast	heart	music	shall	under
arm	loch	angle	could	heels	nails	shape	union
ask	main	apart	crack	hello	nasty	sharp	units
bed	many	apply	crime	hence	naval	shelf	unity
cup	mark	argue	cruel	honey	nerve	shell	until
erm	meal	array	curve	hotel	never	shock	upset

www.cheswick.com/pw

Here is a list of ten random words chosen from a list of 1,020 *iPhone-friendly English words*. /dev/random is used to create the random numbers.

```
firmly
only
signal
merely
behave
proud
shield
pylori
rounds
harsh
```

More Advice

Use Client certificates to limit attack surface

- Limiting connections to those with known client certificates gets you mostly out of the game
- Many mail clients do not offer client cert. processing, and should

Yeahbuttal

Yeahbuttal

- These ideas will take time to deploy, if they do
- Huge installed base
- Corporate conglomerates have hundreds or thousands of these!

Yeahbuttal

- Who owns the ap?
- Who hosts it?
- Third party applications? (401k, health, etc.)
- Who developed it? (often long gone)
- What is the business function
- Buy-in is needed from all parties
- Development costs?

Fix it anyway

- This is one of those economies of scale you told the shareholders the merger was going to give you
- Authentication servers should be relatively simple to code and maintain
- If you don't understand who your users are, your security is shot from the start

Fix it anyway

- Annoyed users are uncooperative users
- There is a substantial cost when a large community has to deal with authentication foolishness on a routine basis

Strong Authentication, not strong passwords

- Use multi-factor authentication when it is really important
- Ubiquitous laptops and cell phones can be used for middle-level authentication

Selling weaker passwords

- ATM PINs of 4 digits work fine
- Cut user support costs
- Backup passwords are usually weaker
- Improve the users' experience
- Annoyed users are less cooperative
- Tell them I said it was probably a good idea

Summary

- Distribute and require client certificates
- Use ssh with pass-phrased locked digital key, never passwords
- Use crypto services, like IMAPS, SMTPS
- Limit password attempts

People, we have to do better than this

- The Bad Guys are getting much better
- Our computer systems are getting much more important to us
- Security has to be thought about, and reviewed

There is plenty new to worry about

- Dangerous browsing
- Dangerous patches
- Dangerous COTS CPUS?
- Hidden malware
- The bad guys are pros, not disaffected teenagers

Dangerous browsing

- *All Your IFRAMES Point to Us*, Provos and Mavrommatis (Google), Rajab and Monrose (JHU); Usenix Security 2008

Dangerous patches

- *Automatic Patch-Based Exploit Generation is Possible: Techniques and Implications*. Brumley and Poosankam (CMU), Song (Berkeley), Zheng (Pitt); Proceedings of the IEEE Security and Privacy Symposium, May 2008.

Provably-hidden malware

- *Analysis-Resistant Malware*. Bethencourt and Song (BSD/CMU), Waters (SRI). ISOC NDSS, Feb 2008.

COTS CPUs dangerous?

- *Designing and Implementing Malicious Hardware*. King, Tucek, Cozzie, Grier, Jiang, and Zhou (U Illinois at Urbana Champaign). Usenix LEET 2008, April, San Francisco.

Rethinking Passwords

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