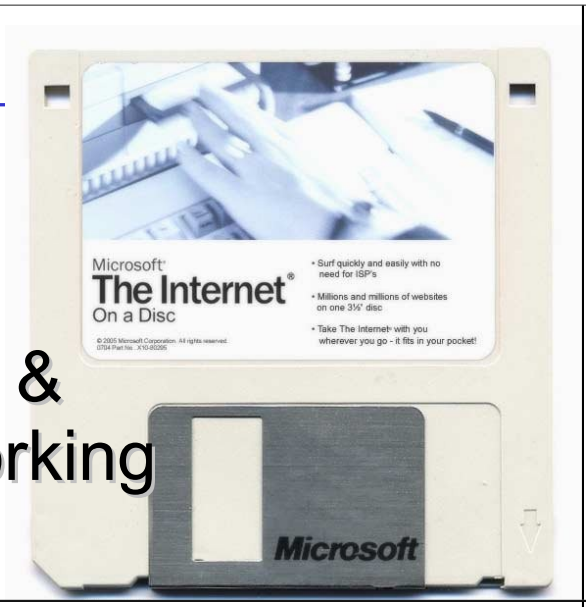
Types & Networking



One-Slide Summary

- A **type** is a (possibly infinite) set of values. Each type supports a set of **valid operations**. Types can be latent or manifest, static or dynamic, strong or weak.
- We can change the Charme interpreter to support manifest (program visible) types.
- A **network** is a group of three or more communicating entities.
- **Bandwidth** is the throughput of a communication resource, measured in bits per second. **Latency** is the time delay between the moment when communication is initiated and the moment the first bit arrives, measured in seconds.
- In **circuit switching**, a path through a network is reserved (high quality-of-service, used in telephones). In **packet switching**, each packet is routed individually (internet, postal service).

Outline

- Administration
- StaticCharme Typechecking
- Networking History
- Latency, Bandwidth, Switching
- The Internet
- Dynamic Web Sites

Administrivia

- **Start PS8 and PS9 Now**
  - PS9 Team Requests due Friday April 16
  - PS9 Project Descriptions due Wednesday April 21
  - PS9 Design Review Signup Wednesday April 21 (Class)
  - PS9 Presentation Requests Due Monday May 3
- PS9 Final Project **Presentation** Due Wednesday May 6
  - *or*
- PS9 Final Project **Report** Due Wednesday May 12

Displeased

11 - "takes a lot of time"
7 - nothing
6 - course is too difficult (100-level)
5 - learning Scheme
3 - learning Python (all that effort in Scheme)
2 - tests are hard
2 - problem set clarity (what is being asked? Ps5-7)
2 - many people in class have programming experience
2 - I'm in over my head / not getting all of it
2 - classroom is windowless / 3:30-5:00 timeslot obnoxious
2 - cannot complete problem set without TA help
11 - other

Pleased

13 - quality of lectures / engaging professor
9 - Python
7 - learning languages
7 - learned many things
5 - TAs (esp. Zak+Patrick) and Wes are helpful / prompt
5 - random trivia
5 - problem sets are applicable/interesting
4 - the challenge
3 - grading is fair (knowledge >> details)
2 - PS take a long time (appreciate my work more)
2 - learn important concepts/theories, not just one language
2 - candy
8 - other

Student Comments

- I'm super upset that we have to learn Python!!! It took me forever to actually start understanding Scheme and now I have to scrap that way of thinking for a new way that is actually more confusing for me. I don't understand why people prefer Python. Not only does it look super ugly, but I got really used to Scheme grammar. :(

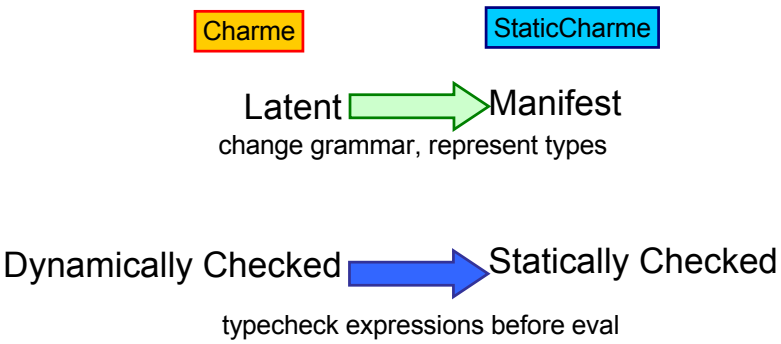
Student Comments #2

- Though the problem sets take a long time they are interesting. I was impressed that the first problem set had us producing a collage. Most of the time instructors go with boring the 'Hello World' approach. We built something interesting every time. Since the majority of the difficult bits were provided for us it allowed us to see what the language was capable of.

Student Comments #3 and #4

- I didn't like the actual classroom. It's windowless and rather sad. No doubt designed by a bitter and hateful little man, fighting delirium tremens to keep his hand steady just long enough to spite generations of students.
- There are a ton more girls in the class than I was led to expect from my experience in other CS courses.
  - CS involves math, science, art, and design under constraint. It is an inherently creative discipline that benefits from multiple viewpoints. We always seek to recruit and retain the best people into CS.

Types of Types



Recall the Goal

- Given a Charme program somewhat like this:

```
(define square : number -> number
  (lambda (x : number) (* x x)))
(square 3)
(square "hello")
```

- The **static type annotations** are in **red**.
- The second application (square "hello") has a type error.
  - You can't multiply hello by hello, unless you're the Beatles.

Adding Type Checking

```
def evalLoop():
    initializeGlobalEnvironment()
    while True:
        ...
            for expr in exprs:
                typ = typecheck(expr, globalEnvironment)
                if typ and typ.isError():
                    print "Type error:" + typ.getMessage()
                else:
                    res = meval(expr, globalEnvironment)
                    if res != None:
                        print str(res)
```

Static Type Checking

```
def typecheck(expr, env):
  if isPrimitive(expr):
    return typePrimitive(expr)
  elif isConditional(expr):
    return typeConditional(expr, env)
  elif isLambda(expr):
    return typeLambda(expr, env)
  elif isDefinition(expr):
    typeDefinition(expr, env)
  elif isName(expr):
    return typeName(expr, env)
  elif isApplication(expr):
    return typeApplication(expr, env)
  else: evalError ("Unknown expression: " + str(expr))
```



```
class Environment:
  # Store a [type, value] pair for each variable.
  ...
  def addVariable(self, name, typ, value):
    self._frame[name] = (typ, value)
  def lookupPlace(self, name):
    if self._frame.has_key(name): return self._frame[name]
    elif (self._parent): return self._parent.lookupPlace(name)
    else: return None
  def lookupVariableType(self, name):
    place = self.lookupPlace(name)
    if place: return place[0]
    else: return CErrorType("Name not found")
  def lookupVariable(self, name):
    return self.lookupPlace(name)[1]
  ...
```


Typechecking Names

```
def typeName(expr, env):
  return env.lookupVariableType(expr)
```

```
def evalDefinition(expr, env):
  name = expr[1]
  value = meval(expr[4], env)
  typ = CType.fromParsed(expr[3])
  env.addVariable(name, typ, value)
```


Static Type Checking

```
def typecheck(expr, env):
  if isPrimitive(expr):
    return typePrimitive(expr)
  elif isConditional(expr):
    return typeConditional(expr, env)
  elif isLambda(expr):
    return typeLambda(expr, env)
  elif isDefinition(expr):
    typeDefinition(expr, env)
  elif isName(expr):
    return typeName(expr, env)
  elif isApplication(expr):
    return typeApplication(expr, env)
  else: evalError ("Unknown expression: " + str(expr))
```



```
def typeDefinition(expr, env):
  assert isDefinition(expr)
  if len(expr) != 5:
    evalError ("Bad definition: %s" % str(expr))
  name = expr[1]
  if isinstance(name, str):
    if expr[2] != ':':
      evalError ("Definition missing type: %s" % str(expr))
    typ = CType.fromParsed(expr[3])
    etyp = typecheck(expr[4], env)
    if not typ.matches(etyp):
      evalError("Mistyped definition: ..." % (name, typ, etyp))
  elif isinstance(name, list):
    evalError ("Procedure definition syntax not implemented")
  else: evalError ("Bad definition: %s" % str(expr))
```

Example: (define x : Number “hello”)
Example: (define y : Number (+ 2 3))

Static Type Checking

```
def typecheck(expr, env):
  if isPrimitive(expr):
    return typePrimitive(expr)
  elif isConditional(expr):
    return typeConditional(expr, env)
  elif isLambda(expr):
    return typeLambda(expr, env)
  elif isDefinition(expr):
    typeDefinition(expr, env)
  elif isName(expr):
    return typeName(expr, env)
  elif isApplication(expr):
    return typeApplication(expr, env)
  else: evalError ("Unknown expression: " + str(expr))
```

```
(define square : (Number -> Number)
  (lambda (x : Number) (* x x)))
```

```
class Procedure:
    def __init__(self, params, typ, body, env):
        self._params = params
        self._body = body
        self._typ = typ
        self._env = env
    def getParams(self):
        return self._params
    def getParamTypes(self):
        return self._typ
    def getBody(self): return self._body
    def getEnvironment(self): return self._env
    def __str__(self):
        return "<Procedure %s / %s>" \
          % (str(self._params), str(self._body))
```

Add type to Procedure


```
def evalLambda(expr, env):
    assert isLambda(expr)
    if len(expr) != 3:
        evalError ("Bad lambda expression: %s" % (str(expr)))
    params = expr[1]
    paramtypes = []
    paramnames = []
    assert len(params) % 3 == 0
    for i in range(0, len(params) / 3):
        name = params[i*3]
        assert params[(i*3)+1] == ':'
        paramnames.append(name)
        typ = CType.fromParsed(params[(i*3)+2])
        paramtypes.append(typ)
    return Procedure(paramnames, paramtypes, expr[2], env)
```

```
(lambda (x : Number
         y : Number)
        (* x y))
```



```
def typeLambda(expr, env):
    assert isLambda(expr)
    if len(expr) != 3: evalError ("Bad lambda expression: %s" % str(expr))
    # this is a bit tricky - we need to "partially" apply it
    # to find the type of the body
    newenv = Environment(env)
    params = expr[1]
    paramnames = []
    paramtypes = []
    assert len(params) % 3 == 0
    for i in range(0, len(params) / 3):
        name = params[i*3]
        assert params[(i*3)+1] == ':'
        typ = CType.fromParsed(params[(i*3)+2])
        paramnames.append(name)
        paramtypes.append(typ)
        newenv.addVariable(name, typ, None)
    resulttype = typecheck(expr[2], newenv)
    return CProcedureType(CProductType(paramtypes), resulttype)
```

Study me for Exam 2!

Liberal Arts Trivia: Dance

- This closed position, ¾ time standard ballroom dance featuring gliding steps and rotations. It became fashionable in Vienna in the 1780s and shocked many when it was first introduced: unlike the popular folk dances of the time, it was a couples dance that involved the leader clasping the follower about the waist. This gave it a dubious moral status in the eyes of the gentry.
- Bonus: My uncle Walter goes ...

Liberal Arts Trivia: Linguistics

- This Chinese language dialect (Yuet Yu or Yue Yu) is popular in Hong Kong, Macau and southern mainland China. It retains more tones and consonant endings from older varieties of Chinese that have been lost to other modern Chinese dialects. Its rarely-used written form contains many characters not used in standard written Chinese. See 2nd here:

Static Type Checking

```
def typecheck(expr, env):
  if isPrimitive(expr):
    return typePrimitive(expr)
  elif isConditional(expr):
    return typeConditional(expr, env)
  elif isLambda(expr):
    return typeLambda(expr, env)
  elif isDefinition(expr):
    typeDefinition(expr, env)
  elif isName(expr):
    return typeName(expr, env)
  elif isApplication(expr):
    return typeApplication(expr, env)
  else: evalError ("Unknown expression: " + str(expr))
```

Typechecking an Application

```
def typeApplication(expr, env):
    proctype = typecheck(expr[0], env)
    if not proctype.isProcedureType():
        evalError("Application of non-procedure: " + str(expr[0]))
    optypes = map (lambda op: typecheck(op, env), expr[1:])
    optype = CProductType(optypes)
    if not optype.matches(proctype.getParameters()):
        evalError("Parameter type mismatch: ..." \
                % (proctype.getParameters(), optype))
    return proctype.getReturnType()
```

```
square : Number -> Number
Example: (+ 1 (square 5))
Example: (+ 2 (square “hello”))
```


Static Type Checking

```
def typecheck(expr, env):
  if isPrimitive(expr):
    return typePrimitive(expr)
  elif isConditional(expr):
    return typeConditional(expr, env)
  elif isLambda(expr):
    return typeLambda(expr, env)
  elif isDefinition(expr):
    typeDefinition(expr, env)
  elif isName(expr):
    return typeName(expr, env)
  elif isApplication(expr):
    return typeApplication(expr, env)
  else: evalError ("Unknown expression: " + str(expr))
```


Typechecking Primitives

```
def typePrimitive(expr):
    if isNumber(expr):
        return CPrimitiveType('Number')
    elif isinstance(expr, bool):
        return CPrimitiveType('Boolean')
    elif callable(expr):
        return findPrimitiveProcedureType(expr)
    else:
        assert False
```

This is a kludgey procedure that looks through the global environment to find the matching procedure, and returns its type

Static Type Checking

```
def typecheck(expr, env):
  if isPrimitive(expr):
    return typePrimitive(expr)
  elif isConditional(expr):
    return typeConditional(expr, env)
  elif isLambda(expr):
    return typeLambda(expr, env)
  elif isDefinition(expr):
    typeDefinition(expr, env)
  elif isName(expr):
    return typeName(expr, env)
  elif isApplication(expr):
    return typeApplication(expr, env)
  else: evalError ("Unknown expression: " + str(expr))
```

Left as possible Exam 2 question!

StaticCharme

```
StaticCharme> (+ 1 #t)
Error: Parameter type mismatch:
expected (Number Number), given (Number Boolean)
StaticCharme> (define square:((Number) -> Number)
   (lambda (x:Number) (* x x)))
StaticCharme> (square #t)
Type error: Parameter type mismatch:
expected (Number), given (Boolean)
StaticCharme> (define badret:((Number) -> Number)
                (lambda (x: Number) (> x 3)))
Error: Mistyped definition:
badret declared type ((Number) -> Number),
actual type ((Number) -> Boolean)
```


Who Invented the Internet?

Who Invented Networking?

What is a Network?

A **network** is a group of three or more connected communicating entities.

Beacon Chain Networking

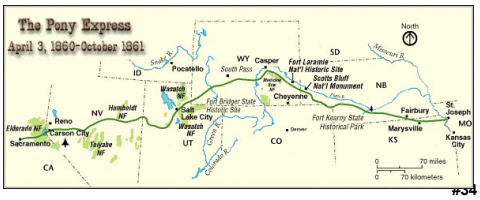
Thus, from some far-away beleaguered island, where all day long the men have fought a desperate battle from their city walls, the smoke goes up to heaven; but no sooner has the sun gone down than the light from the line of beacons blazes up and shoots into the sky to warn the neighboring islanders and bring them to the rescue in their ships.

Iliad, Homer, 700 BC

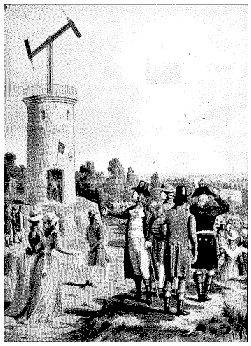
Chain of beacon's signaled Agammemnon's return (~1200BC), spread on Greek peaks over 600km.

Pony Express

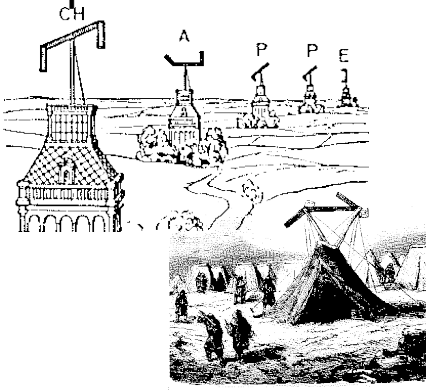
- April 1860 – October 1861
- Missouri to California
  - 10 days
  - 10-15 miles per horse, ~100 miles per rider
    - Ask me about the "human endurance runner" theory (cf. Dennis Proffitt)
- 400 horses total



Chappe's Semaphore Network



First Line (Paris to Lille), 1794



Mobile Semaphore Telegraph
Used in the Crimean War 1853-1856

Government and Networking

Chappe wanted a commercial network

The use of novel methods that modify established habits, often hurts the interests of those who profit the most from the older methods. Few people, with the exception of the inventors, are truly interested in helping projects succeed while their ultimate impact is still uncertain. . . . **Those in power will normally make no effort to support a new invention, unless it can help them to augment their power;** and even when they do support it, their efforts are usually insufficient to allow the new ideas to be fully exploited. (Claude Chappe, 1824)

Anyone performing unauthorized transmissions of signals from one place to another, with the aid of telegraphic machines or by any other means, will be punished with an imprisonment of one month to one year, and a fine of 1,000 to 10,000 Francs.

French Law passed in 1837 made private networking illegal

Liberal Arts Trivia: Mathematics

- The *this* of a function at a chosen input value describes the best linear approximation of the function near that input point. If *this* can be applied to a function infinitely many times, the function is called smooth. The *this* is also given by the limit, as the difference in input approaches zero, of the ratio of the difference between the function values of two nearby inputs to the difference between those two nearby inputs.

Liberal Arts Trivia: Astronomy

- This is a small, dense type of star composed of electron-degenerate matter. Such a star's mass is comparable to that of the Sun but with a volume comparable to that of the Earth. These starts are only faintly luminous and were strongly studied from 1910-1922. They are produced from red giants when the hydrogen-fusing lifetime of a main sequence start ends.
  - Not to be confused with the British comedy show.

Liberal Arts Trivia: Religious Studies

- Among the truths said to have been realized by Siddhartha Gautama Buddha during his experience of enlightenment are these:
  1) The Nature of Suffering (hint: almost everything)
  2) Suffering's Origin (hint: desire)
  3) Suffering's Cessation (hint: freedom from craving)
  4) The Way Leading to the Cessation of Suffering (hint: Noble Eightfold Path)

  What are these things collectively know as?

Measuring Networks

- **Latency**

  Time from sending a bit until it arrives

  seconds (or *seconds per geographic distance*)

- **Bandwidth**

  How much information can you transmit per time unit

  bits per second

Latency and Bandwidth

- Napoleon's Network: Paris to Toulon, 475 mi
- Latency: 13 minutes (1.6s per mile)
  - What is the delay at each signaling station, how many stations to reach destination
  - At this rate, it would take ~1 hour to get a bit from California
- Bandwidth: 2 symbols per minute (98 possible symbols, so that is ~13 bits per minute)
  - How fast can signalers make symbols
  - At this rate, it would take you about 9 days to get *ps8.zip*

Improving Latency

- Fewer transfer points
  - Longer distances between transfer points
  - Semaphores: how far can you see clearly
    - Curvature of Earth is hard to overcome
  - Use wires (electrical telegraphs, 1837)
- Faster transfers
  - Replace humans with machines
- Faster travel between transfers
  - Hard to beat speed of light (semaphore network)
  - Electrons in copper: about 1/3rd speed of light

How many transfer points between here and California?

tracert

```
K:\>tracert www.cs.berkeley.edu

Tracing route to hyperion.cs.berkeley.edu [169.229.60.105]
over a maximum of 30 hops:

  1     3 ms     3 ms     4 ms  128.143.69.1
  2    <1 ms    <1 ms    <1 ms  carruthers-6509a-x.misc.Virginia.EDU [....]
  3    <1 ms    <1 ms    <1 ms  new-internet-x.misc.Virginia.EDU [128.....]
  4     4 ms     4 ms     4 ms  nwv-nlrl3.misc.Virginia.EDU [192.35.48.30]
  5     5 ms     5 ms     5 ms  nlrl3-router.networkvirginia.net [192.7...]
  6    18 ms    18 ms    18 ms  atla-wash-64.layer3.nlr.net [216.24.186.20]
  7    43 ms    43 ms    42 ms  hous-atla-70 [...]
  8    73 ms    73 ms    73 ms  losa-hous-87 [...]
  9    72 ms    72 ms    72 ms  hpr-lax-hpr-[...]
 10    80 ms    81 ms    81 ms  svl-hpr--lax-hpr-10ge.cenic.net [137.16...]
 11   145 ms    81 ms    81 ms  hpr-ucb-ge--svl-hpr.cenic.net [137.164....]
 12    81 ms    81 ms    81 ms  g3-12.inr-201-eva.Berkeley.EDU [128.32....]
 13    81 ms    82 ms    83 ms  evans-soda-br-5-4.EECS.Berkeley.EDU [...]
 14    83 ms    84 ms    83 ms  sbd2a.EECS.Berkeley.EDU [169.229.59.226]
 15    83 ms    84 ms    83 ms  hyperion.CS.Berkeley.EDU [169.229.60.105]

Trace complete.
```

UVa

Atlanta → Houston → LA?

UCB


```
>>> cvilleberkeley = 3813 # kilometers
>>> seconds = 84.0/1000
>>> speed = cvilleberkeley / seconds
>>> speed
45392.857142857138
>>> light = 299792.458 # km/s
>>> speed / light
0.15141427321316114
```

Packets are traveling average at 15% of the speed of light (includes transfer time through 15 routers)

Bandwidth

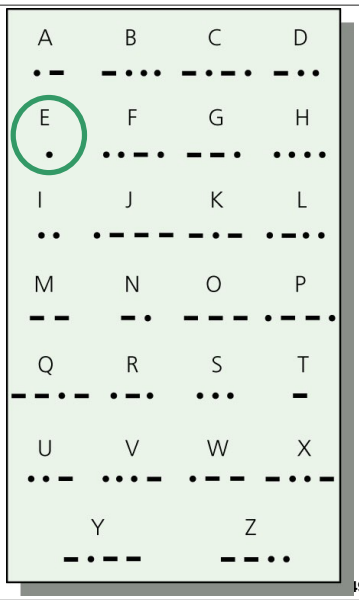
How much data can you transfer in a given amount of time?

Improving Bandwidth

- Faster transmission
  - Train signalers to move semaphore flags faster
  - Use something less physically demanding to transmit
- Bigger pipes
  - Have multiple signalers transmit every other letter at the same time
- Better encoding
  - Figure out how to code more than 98 symbols with semaphore signal
  - Morse code (1840s)

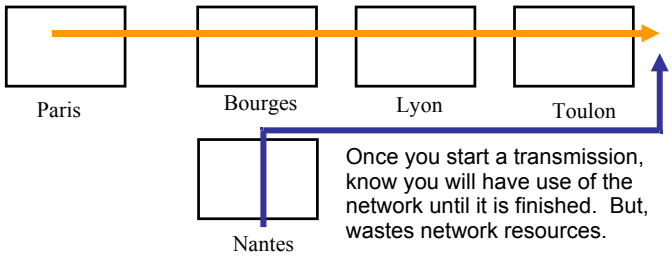
Morse Code

Represent letters with series of short and long electrical pulses



Circuit Switching

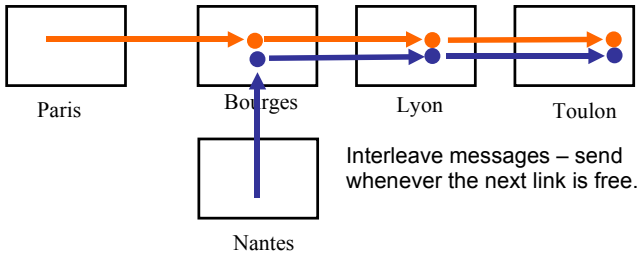
- Reserve a whole path through the network for the whole message transmission



Once you start a transmission, know you will have use of the network until it is finished. But, wastes network resources.

Packet Switching

- Use one link at a time



Interleave messages – send whenever the next link is free.

Circuit and Packet Switching

- (Land) Telephone Network (back in the old days)
  - Circuit: when you dial a number, you have a reservation on a path through the network until you hang up
- The Internet
  - Packet: messages are broken into small packets, that find their way through the network link by link

internetwork

An **internetwork** is a collection of multiple networks connected together, so messages can be transmitted between nodes on different networks.

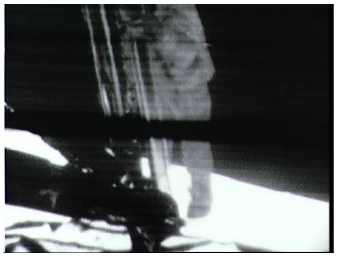
The First internet

- 1800: Sweden and Denmark worried about Britain invading
- Edelcrantz proposes link across strait separating Sweden and Denmark to connect their (signaling) telegraph networks
- 1801: British attack Copenhagen, network transmit message to Sweden, but they don't help.
- Denmark signs treaty with Britain, and stops communications with Sweden

First Use of Internet

- October 1969: First packets on the ARPANet from UCLA to Stanford. Starts to send "LOGIN", but it crashes on the G.
- 20 July 1969:

  Live video (b/w) and audio transmitted from moon to Earth, and to millions of televisions worldwide.



Okay, so *who* invented the Internet?

The Modern Internet

- Packet Switching: Leonard Kleinrock (UCLA) thinks he did, Donald Davies and Paul Baran, Edelcrantz's signalling network (1809)
- Internet Protocol: Vint Cerf, Bob Kahn
- Vision, Funding: J.C.R. Licklider, Bob Taylor
- Government: Al Gore (first politician to promote Internet, 1986; act to connect government networks to form "Interagency Network")

The World Wide Web

Available within the network will be functions and services to which you subscribe on a regular basis and others that you call for when you need them. In the former group will be investment guidance, tax counseling, selective dissemination of information in your field of specialization, announcement of cultural, sport, and entertainment events that fit your interests, etc. In the latter group will be dictionaries, encyclopedias, indexes, catalogues, editing programs, teaching programs, testing programs, programming systems, data bases, and – most important – communication, display, and modeling programs. **All these will be – at some late date in the history of networking - systematized and coherent; you will be able to get along in one basic language up to the point at which you choose a specialized language for its power or terseness.**

J. C. R. Licklider and Robert W. Taylor, *The Computer as a Communication Device*, April **1968**

The World Wide Web

- Tim Berners-Lee, CERN (Switzerland)
- First web server and client, 1990

- Established a *common language* for sharing information on computers
- Lots of previous attempts (Gopher, WAIS, Archie, Xanadu, etc.)

World Wide Web Success

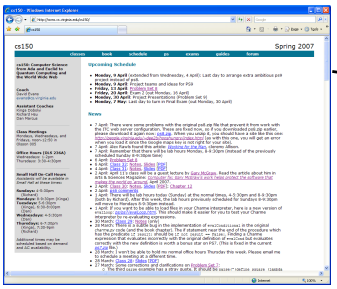
- World Wide Web succeeded because it was **simple**!
  - Didn't attempt to maintain links, just a common way to name things
  - Uniform Resource Locators (URL)

http://www.cs.virginia.edu/cs1120/index.html

Service — Hostname — File Path

HyperText Transfer Protocol

HyperText Transfer Protocol



Client (Browser)

Server

GET /cs1120/index.html HTTP/1.0

<html>
<head>
…

Contents of file

HTML
HyperText Markup Language

HTML: HyperText Markup Language

- Language for controlling presentation of web pages
- Uses formatting tags
  - Enclosed between < and >
- Not a universal programming language

Proof: no way to make an infinite loop

HTML Grammar Excerpt

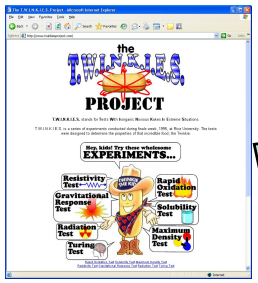
Document ::= **<html>** *Header Body* **</html>**
Header ::= **<head>** *HeadElements* **</head>**
HeadElements ::= *HeadElement HeadElements*
HeadElements ::=
HeadElement ::= **<title>** *Element* **</title>**

Body ::= **<body>** *Elements* **</body>**
Elements ::= *Element Elements*
Elements ::=
Element ::= ** ** *Element* ** **
Make *Element* a paragraph.
Element ::= ** ** *Element* ** **
Center *Element* horizontally on the page.
Element ::= **** *Element* ****
Display *Element* in **bold**.
Element ::= Text

What is a HTML interpreter?

Popular Web Site: Strategy 1 Static, Authored Web Site

Web Programmer, Content Producer



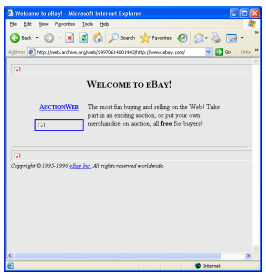
http://www.twinkiesproject.com/

Drawbacks:
- Have to do all the work yourself
- The world may already have enough Twinkie-experiment websites

Popular Web Site: Strategy 2 Dynamic Web Applications

Web Programmer, Content Producer

Seed content and function



eBay in 1997
http://web.archive.org/web/19970614001443/http://www.ebay.com/

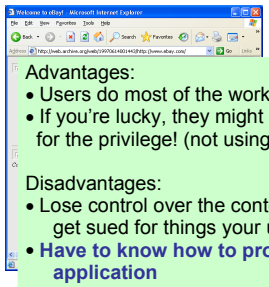
Attracts users

Produce more content

Popular Web Site: Strategy 2 Dynamic Web Applications

Seed content and function

Attracts users



Advantages:
- Users do most of the work
- If you're lucky, they might even pay you for the privilege! (not using UVa's servers)

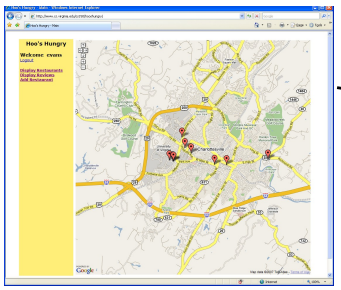
Disadvantages:
- Lose control over the content (you might get sued for things your users do)
- **Have to know how to program a web application**

eBay in 2007

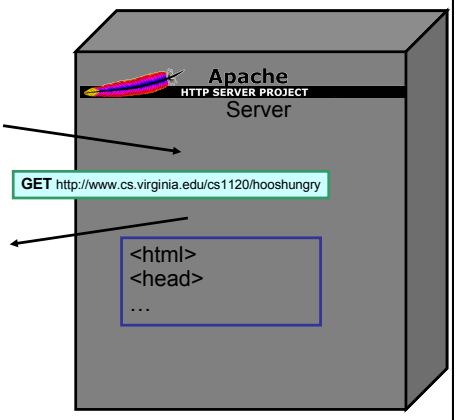
Dynamic Web Sites

- Programs that run on the client's machine
  - Java, JavaScript, Flash, etc.: language must be supported by the client's browser (so they are usually flaky and don't work for most visitors)
  - Used mostly to make annoying animations to make advertisements more noticeable
  - Occasionally good reasons for this: need a fancy interface on client side (like Google Maps)
- Programs that run on the web server
  - Can be written in any language, just need a way to connect the web server to the program
  - Program generates regular HTML – works for everyone
  - (Almost) Every useful web site does this

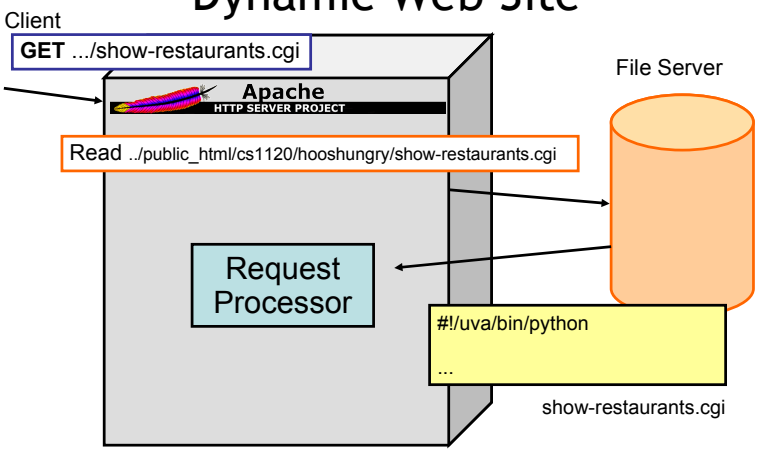
Dynamic Web Site



Client (Web Browser)
"HTML Interpreter"



Dynamic Web Site



Processing a GET Request

```
#!/usr/bin/python

import cgi
import headers
import restaurants
import restaurant
import reviews

headers.printHeader ("Restaurants")
headers.endHeader ()

print "<h1>Restaurants</h1>"
...
```

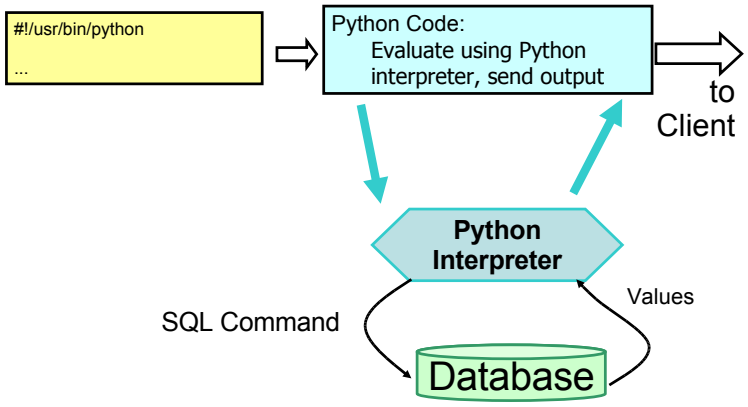
Python Code: Evaluate using Python interpreter, send output to client

to Client

Python Interpreter

Using a Database

- HTTP is **stateless**
  - No history of information from previous requests
- We probably need some state that changes as people visit the site
- That's what databases are for – store, manipulate, and retrieve data



SQL

- Structured Query Language (SQL)
  - (Almost) all databases use it
- Database is tables of fields containing values
- All fields have a type (and may have other attributes like UNIQUE)
- Similar to procedures from PS5

Homework

- Problem Set 9 Team Requests
- Problem Set 8

Student Comments 2009

- I am displeased with the course in general. I was expecting a course that showed how computing concepts relate to the liberal arts. While that is true to some extend, this class feels more like a straight programming class. DrScheme is not intuitive, and makes this course much harder than 101 and 201 without really giving more information.
  - *Managing expectations is the key to happiness!*

More Student Comments 2009

- I am displeased that the answer to question eight in this problem set require a lot of thinking and writing code for only one point of the assignment.
  - *Irony! The goal was to make it reasonable to not do all of the problem set.*
- I am displeased that I have to make a dynamic website, which will take a lot of time and likely be our hardest assignment.
  - *Yes, the final project will be hard.*

Even More Student Comments, 2009

- I am displeased that some people are opting not to do the problem sets. I am not a computer science major and this is the first cs class I have ever taken, but I still think it is important for everyone to branch out and learn new things. Although some people may say that they will never use this stuff again, you never know.
  - *Currently **zero** students have opted out of the problem sets.*

Displeased, 2009

- 21 Course and problem sets are hard/long/frustrating
- 6 Reading quizzes
- 5 Two exams + final = too much work at end
- 5 Switch languages (learning on our own)
- 4 Book remains dry, confusing, and without answers
- 3 Don't know what to do for PS9
- 2 It still takes too long to get help in office hours
- 2 Cannot drop lowest PS grade
- 2 IDLE sucks
- 8 Other