

Programming the Crowd

**Crowdsourcing and Human Computation
Lecture 5**

**Instructor: Chris Callison-Burch
TA: Ellie Pavlick**

Website: crowdsourcing-class.org

Algorithms for Human Computation

- MTurk provides an on-demand source for human computation
- Potential opportunities for exploring algorithms that use people as a fn call
- However, MTurk isn't set up to support algorithms

MTurk limitations

- MTurk requesters can post batches of independent jobs
- Perfect for tasks that can be done in parallel like labeling 1000 images
- But poorly suited for tasks that build on each other
- **What is MTurk missing that is essential in algorithms or programming languages?**

TurKit: A programming language for the crowd

```
ideas = []
for (var i = 0; i < 5; i++) {
  idea = mturk.prompt(
    "What's fun to see in New York City? Ideas so
    far: " + ideas.join(", "))
  ideas.push(idea)
}
ideas.sort(function (a, b) {
  v = mturk.vote("Which is better?", [a, b])
  return v == a ? -1 : 1
})
```

What new concerns exist
for crowd programming?

What new concerns exist for crowd programming?

- When posting a HIT to MTurk it can take hours before Turkers complete it, so latency could cause algorithms to take days
- What is the behavior if your program crashes?
- What if this happens after you have already spend money on a bunch of HITs?

Crash and re-run

- TurKit introduces a new programming paradigm called crash and rerun
- Designed for long running processes where local computation is cheap, and remote work is costly
- ~~Crash~~ Cache and re-run

Quicksort

```
quicksort(A)
```

```
    if A.length > 0
```

```
        pivot ← A.remove(A.randomIndex())
```

```
        left ← new array; right ← new array
```

```
        for x in A
```

```
            if compare(x, pivot)
```

```
                left.add(x)
```

```
            else
```

```
                right.add(x)
```

```
        quicksort(left)
```

```
        quicksort(right)
```

```
        A.set(left + pivot + right)
```


81

39

68

9

3

28

62

42

25

97

81	39	68	9	3	28	62	42	25	97
----	----	----	---	---	----	----	----	----	----

39	68	9	3	28	62
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25	97
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81

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42

39	68	9	3	28	62
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68	9	3	28	62
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68	9	3	28	62
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39	9	3	28	25
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39	9	3	28	25	42	81	68	62	97
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39	9	3	28	25	42	81	68	62	97
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9	3	25	28	39	42	62	68	81	97
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9	3	25	28	39	42	62	68	81	97
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9	3	25	28	39	42	62	68	81	97
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3	9	25	28	39	42	62	68	81	97
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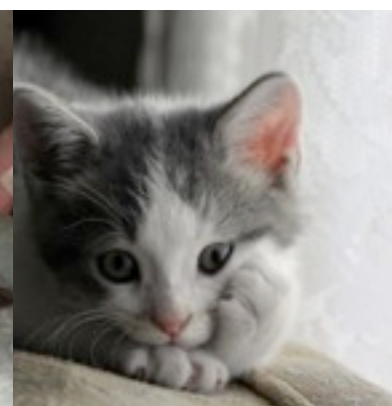
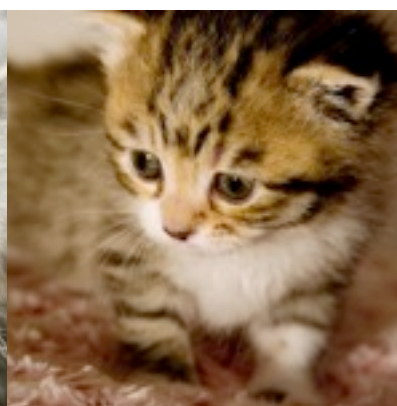
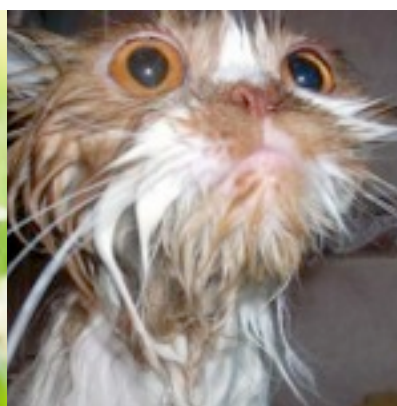
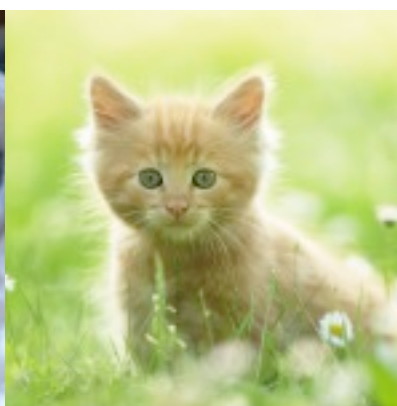
Quicksort on MTurk

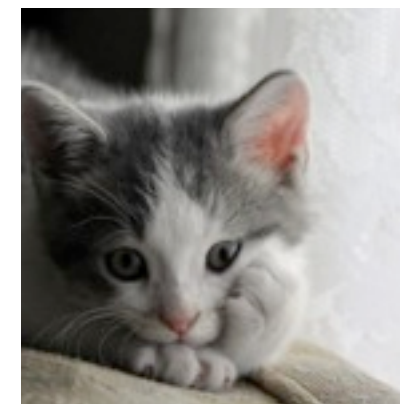
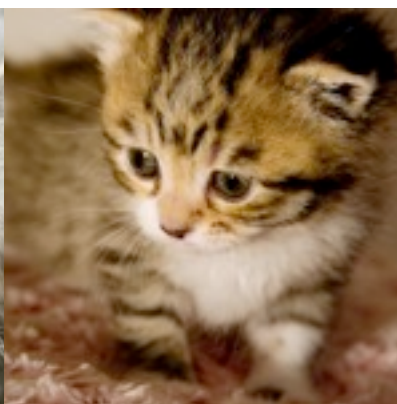
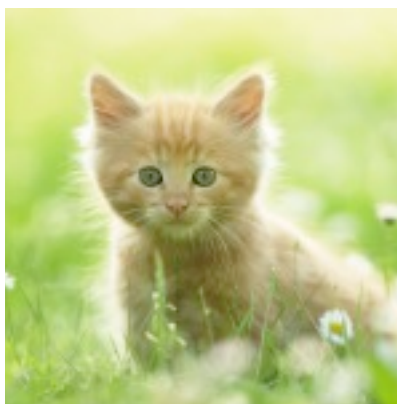
compare(a, b)

hitId \leftarrow **createHIT**(...a...b...)

result \leftarrow **getHITResult**(hitId)

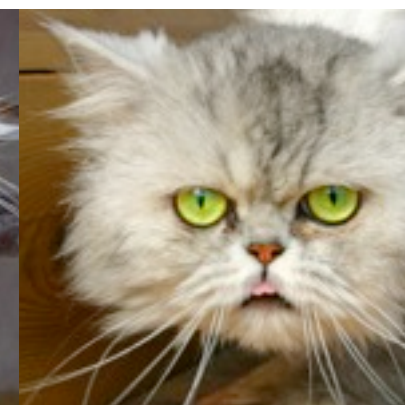
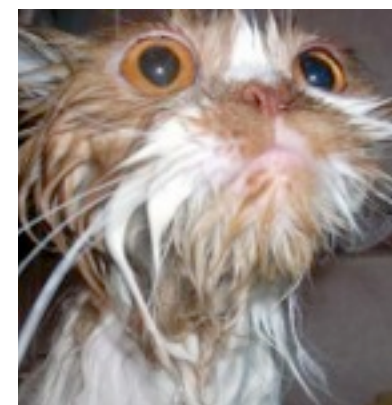
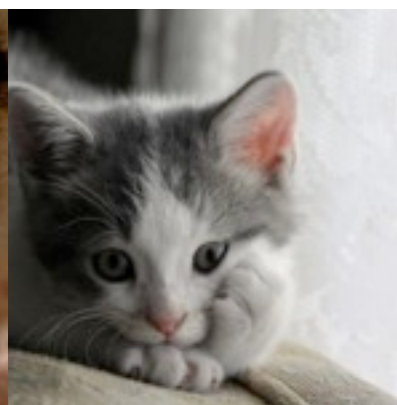
return (result says $a < b$)



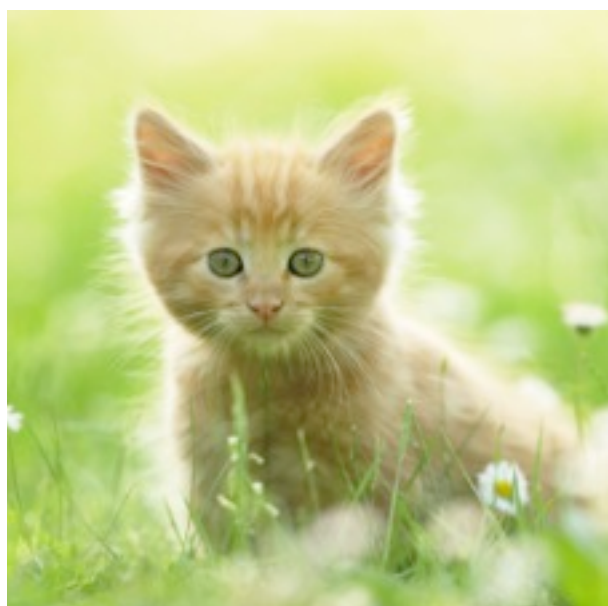
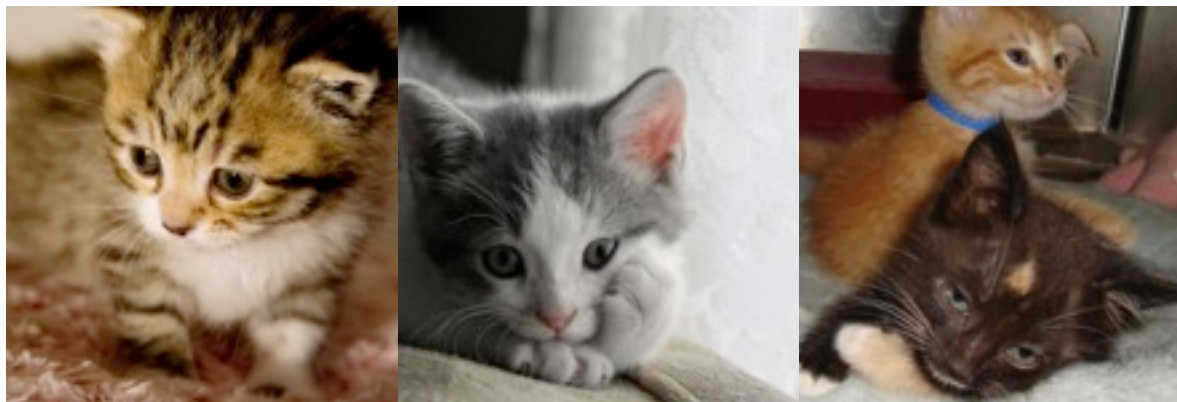


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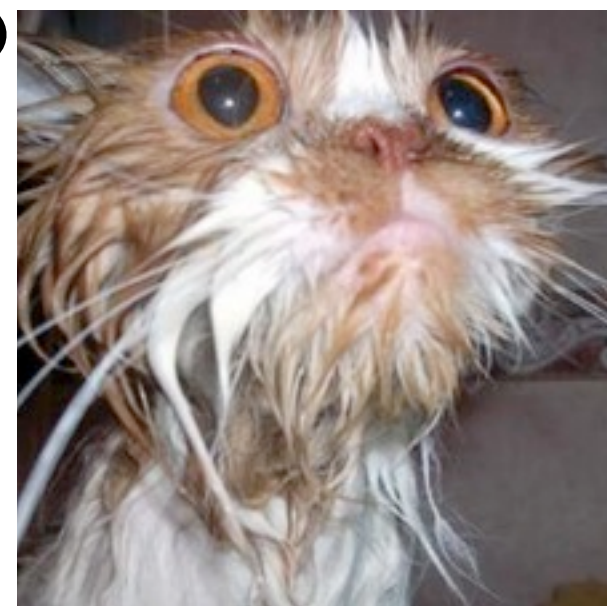






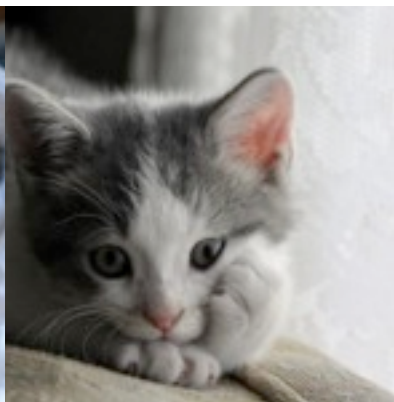


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Quicksort as a Long-running process

- With this implementation we must wait for people to complete their judgments
- The algorithm may need to run for a very long time while waiting
- Challenge: how to maintain state

Quicksort as a Long-running process

- Normally quicksort maintains its state in the heap or the stack
- These are normally dynamically allocated in memory, and used by all of the programs running on a computer
- Memory isn't typically used for hours or days
- If the computer reboots, then our program's state would be lost and we would lose \$\$\$

Store results in DB

- Insight of crash-and-rerun paradigm is that if the program crashes, it should be cheap to re-run
- Use a database to store all of the results up to the place that it crashed
- Since local computation is cheap, calling DB and re-executing code with store results is cheap

New keyword **once**

- Costly operations can be marked in a TurKit program with keyword **once**
- **once** denotes that an operation should only be executed once across all runs of a program

Quicksort on MTurk

```
compare(a, b)
```

```
  hitId ← once createHIT(...a...b...)
```

```
  result ← once getHITResult(hitId)
```

```
  return (result says  $a < b$ )
```

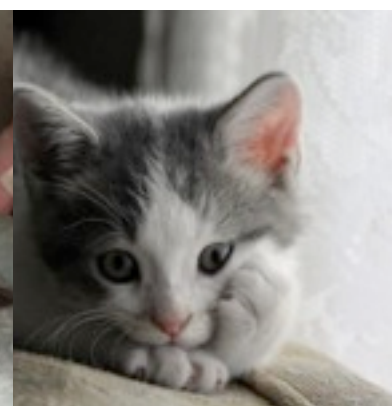
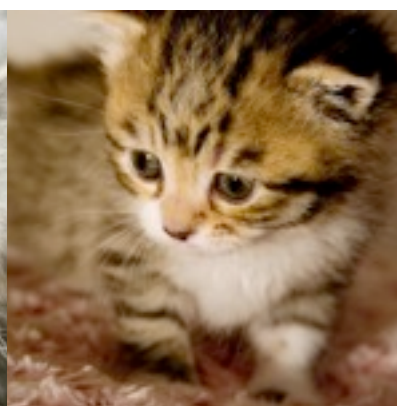
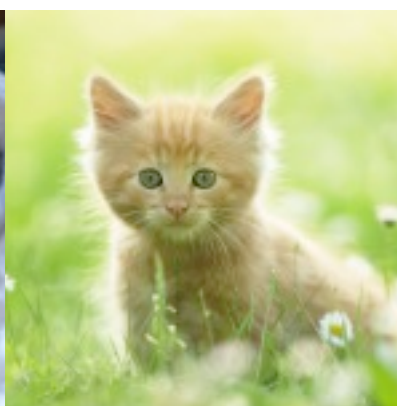
- Subsequent runs of the program will check the database before performing these operations

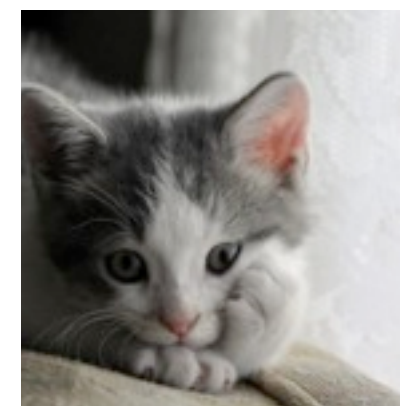
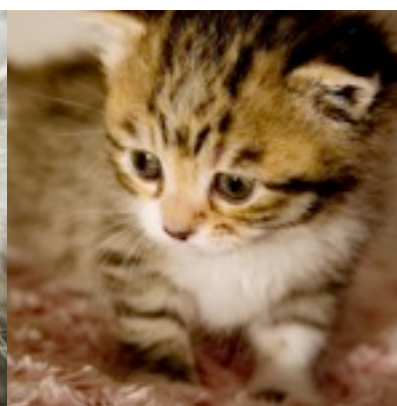
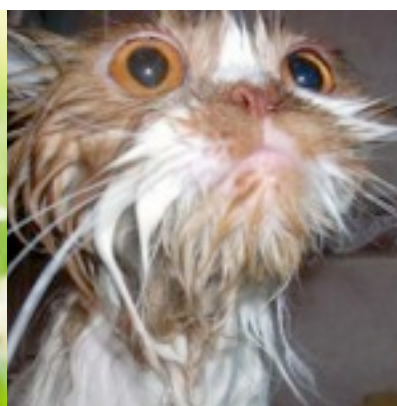
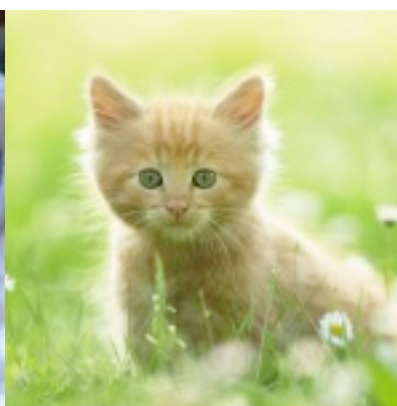
When should you mark a function with **once**?

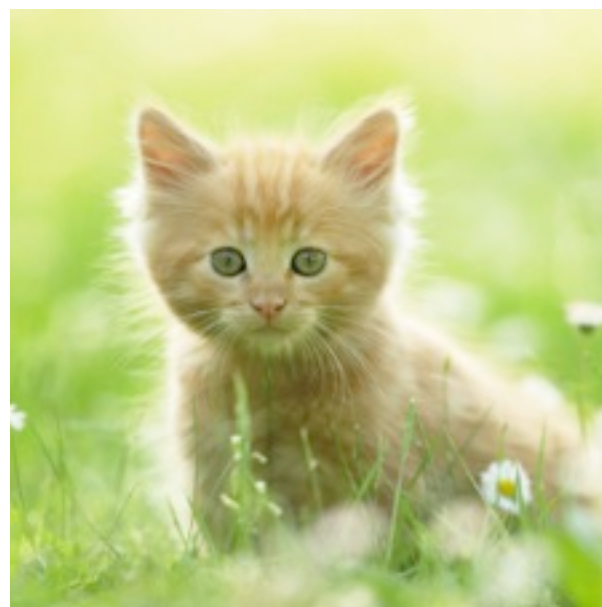
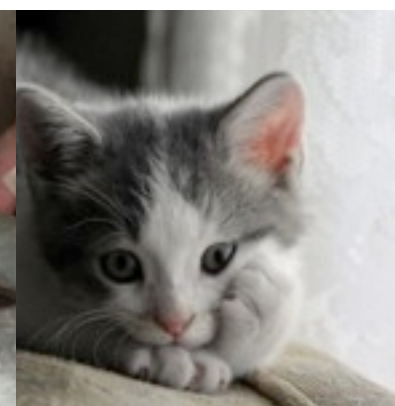
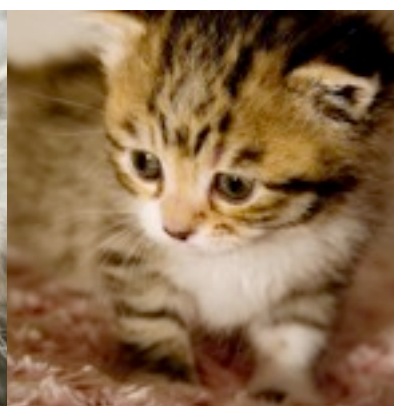
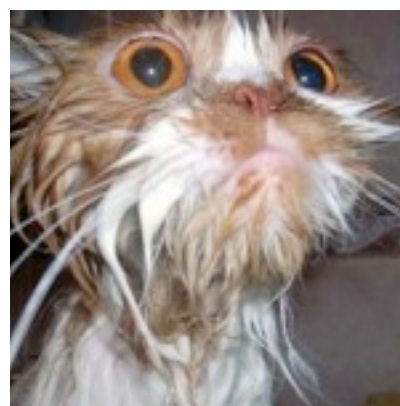
- **High cost** - This is its main usage.
Whenever a fn is high-cost in terms of money or time, **once** saves the day

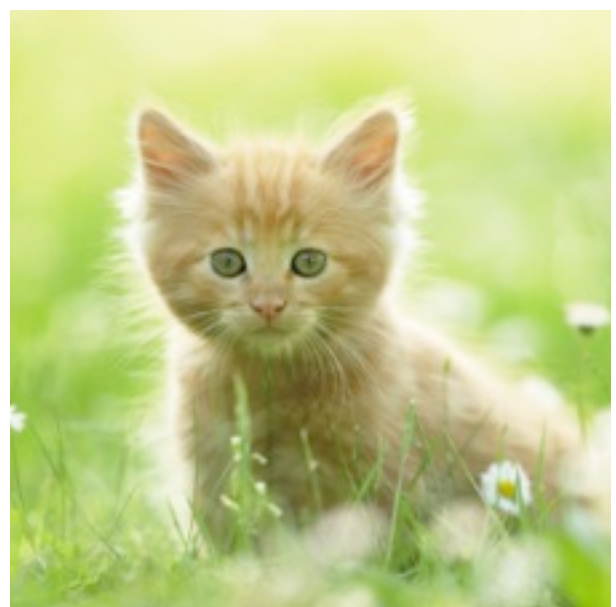
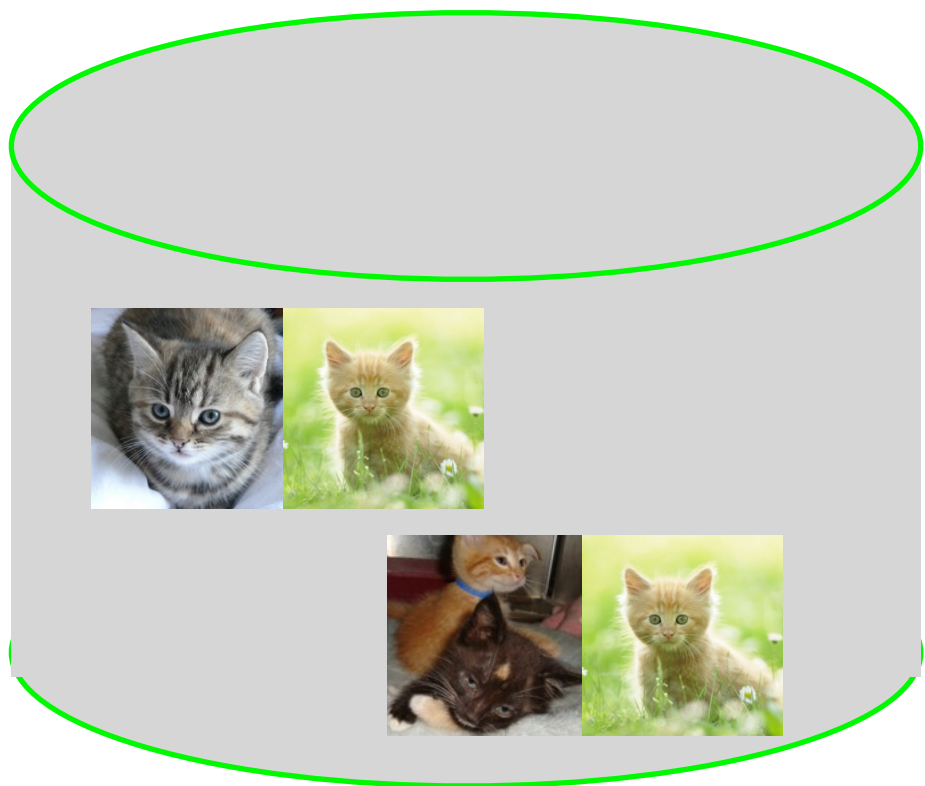
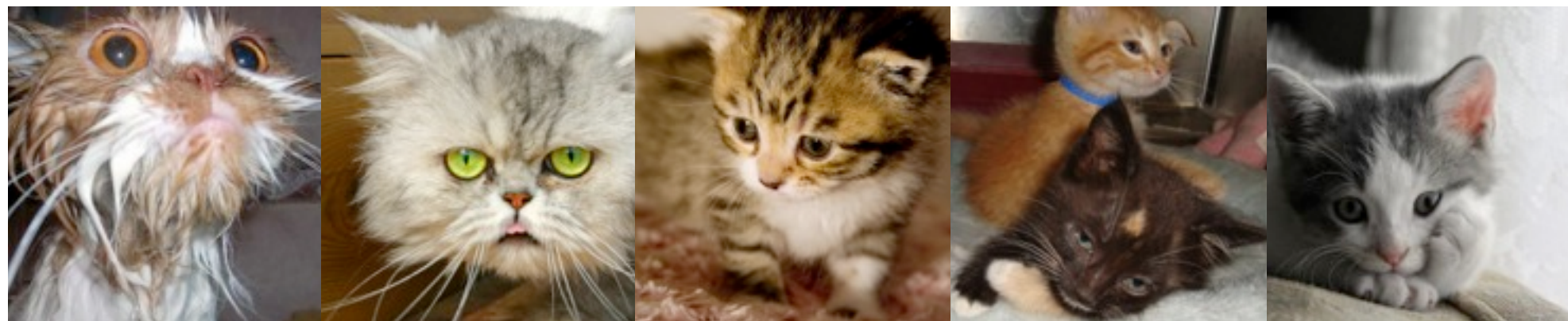
When should you mark a function with **once**?

- **Non-determinism** - storing results in DB assumes that the program executes in a deterministic way











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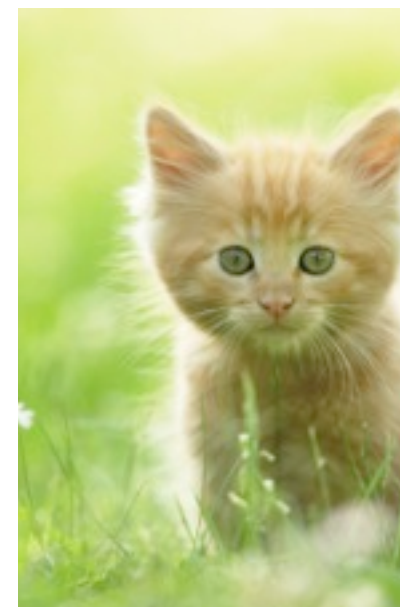
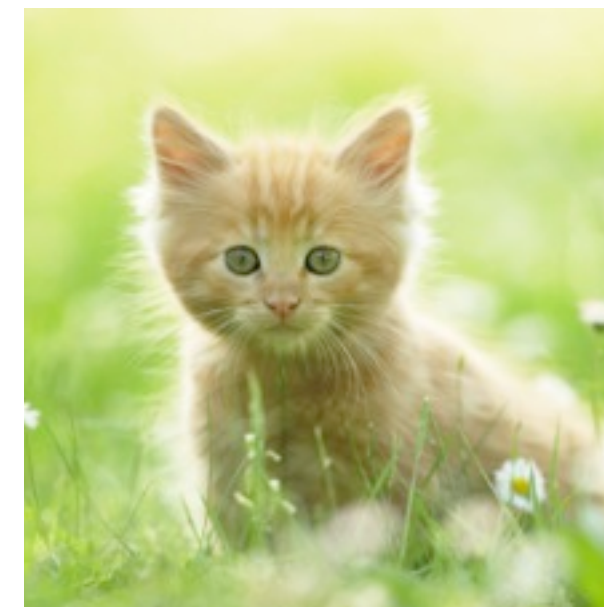
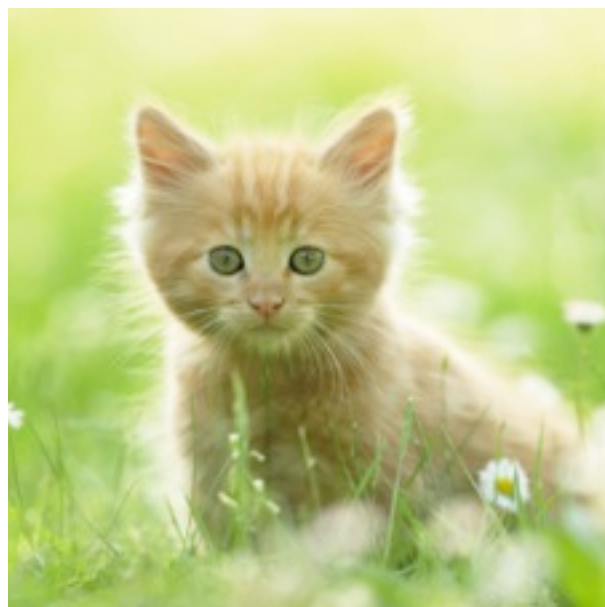
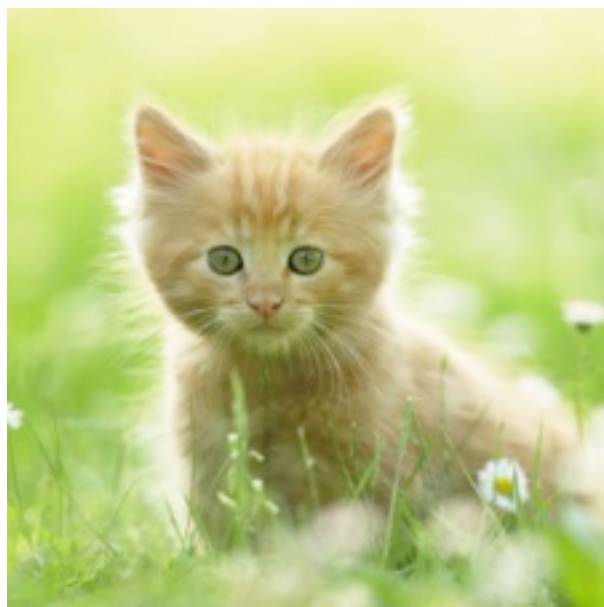
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X



Quicksort

```
quicksort(A)
```

```
    if A.length > 0
```

```
        pivot ← A.remove(once A.randomIndex())
```

```
        left ← new array; right ← new array
```

```
        for x in A
```

```
            if compare(x, pivot)
```

```
                left.add(x)
```

```
            else
```

```
                right.add(x)
```

```
        quicksort(left)
```

```
        quicksort(right)
```

```
        A.set(left + pivot + right)
```

When should you mark a function with **once**?

- **Side-effects** - if a function has side effects during repeated calls, then wrap it in **once**.

Other benefits of **once**

- **Incremental programming** - you can write part of an algorithm, test it, view the results, modify it, and rerun.

Other benefits of **once**

- **Retroactive print-line debugging** - if your program behaves in an unexpected fashion, you can put in debugging print statements after the fact
- This also lets you print data to a file if you decide that you want to analyze it

TurKit Script

- TurKit is built on top of JavaScript
- Users have full access to JavaScript
- Plus a set of APIs built around MTurk and the crash-and-rerun programming paradigm

TurKit keywords

- once
- crash
- fork / join

The **crash** keyword

- Why in the hell would you want to tell your program to crash?
- Since we cache results in a DB, **crash** is an alternate to **wait**
- Most common use for **crash** is waiting for results to be returned from MTurk
- TurKit automatically re-runs program after a set interval

fork allows for parallel execution

- TurKit allows multiple branches to be run in parallel via **fork**
- Calling **crash** from within a **forked** branch resumes the execution of the former branch
- This allows you to post multiple jobs on MTurk simultaneously
- The script can make progress on whatever path gets a result first

One HIT at a time

```
a = createHITAndWait()           // HIT A
b = createHITAndWait(...a...)    // HIT B
c = createHITAndWait()           // HIT C
d = createHITAndWait(...c...)    // HIT D
```

- B depends on A
- D depends on C
- They don't depend on each other. Why wait?

Multiple HITs at a time

```
fork(function() {  
    a = createHITAndWait()           // HIT A  
    b = createHITAndWait(...a...)   // HIT B  
})  
  
fork(function() {  
    c = createHITAndWait()           // HIT C  
    d = createHITAndWait(...c...)   // HIT D  
})
```

The **join** keyword

```
fork(...b = ...)
```

```
fork(...d = ...)
```

```
join()
```

```
e = createHITAndWait(...b...d...)
```

- **join** waits for all previous forks for finish

Calling Mechanical Turk

- TurKit adds several simple commands for interacting with MTurk
- **prompt**
- **vote**
- **sort**

Calling MTurk: **prompt**

```
print(mturk.prompt("When did Colorado become a  
state?"))
```

- **prompt** optionally allows a second argument with the number of responses

```
a = mturk.prompt("What is your favorite  
color?"), 100)
```

Calling MTurk: **vote**

```
v = mturk.vote("Which is better?", [a, b])  
// returns the list item with the most votes
```

- Optional 3rd argument to specify many votes to collect

Calling MTurk: **vote**

```
function vote(message, options) {  
    // create comparison HIT  
    var h = mturk.createHITAndWait({  
        ...message...options...  
        assignments : 3})  
    // get enough votes  
    while (...votes for best option < 3...) {  
        mturk.extendHIT(...add assignment...)  
        h = mturk.waitForHIT(h)  
    }  
    return ...best option...  
}
```

Calling MTurk: **sort**

```
ideas.sort(function (a, b) {  
    v = mturk.vote("Which is better?", [a, b])  
    return v == a ? -1 : 1  
})
```

- This version just uses JavaScripts built-in sorting function
- Defines a comparator using `mturk.vote`
- Negative: comparisons are done serially

Calling MTurk: **sort**

```
ideas.sort(function (a, b) {  
    v = mturk.vote("Which is better?", [a, b])  
    return v == a ? -1 : 1  
})
```

- This version just uses JavaScripts built-in sorting function
- Defines a comparator using `mturk.vote`
- Negative: comparisons are done serially

Under the hood

- TurKit is handles the MTurk API
- It generates web pages and CSS and hosts them on its server
- Nice additional features, like disabling of form elements while in preview mode
- Uses Java Rhino to interpret JavaScript
- DB is serialized using JSON

TurKit online

- IDE for writing TurKit scripts, running them, and automatically rerunning them
- TurKit “crashes” after publishing a HIT; re-running polls MTurk to check for result
- Provides controls for switching from sandbox into normal MTurk, clearing DB

Amazon Web Service Credentials

Turkit

aws access key id:
AKIAJWIROTA3QHKOG

aws secret access key:
●●●●●●●●●●●●●●●●

User

user@gmail.com
[logout](#)

[new project](#)

HelloWorld

props

main.js

output

db

[new file](#)

hit.html



[reset](#)

OtherProject

main.js

```
print("Hello World")
print("Your balance is: " + mturkBase.getAccountBalance())

var w = webpage.create(read("hit.html"))

for (var i = 0; i < 2; i++) {
  fork(function () {
    var hitId = mturk.createHIT({
      title : "Simple question",
      desc : "Answer a simple question.",
      reward : 0.01,
      url : w
    })
    var hit = mturk.waitForHIT(hitId)

    print("Answer = " + hit.assignments[0].answer.choice)

    mturk.approveAssignment(hit.assignments[0])
    mturk.deleteHIT(hit)
  })
}
join()

webpage.remove(w)
```

output

```
Hello World
Your balance is: 10000
Answer = 42
```

```
crashed - waiting on hit:
1QQJRV9TXEVEZQM7K62JHJREVJXTHA

crashed - ready to rerun
```

execution trace

```
└─ create webpage
  └─ fork
    └─ createHIT
    └─ waitForHIT
    └─ approveAssignment
    └─ deleteHIT
  └─ fork
    └─ createHIT
    └─ waitForHIT
```

Editor

[API reference](#)

example projects

hello world

iterative writing

brainstorming

sorting

[clone](#)

[clone](#)

[clone](#)

[clone](#)

Output

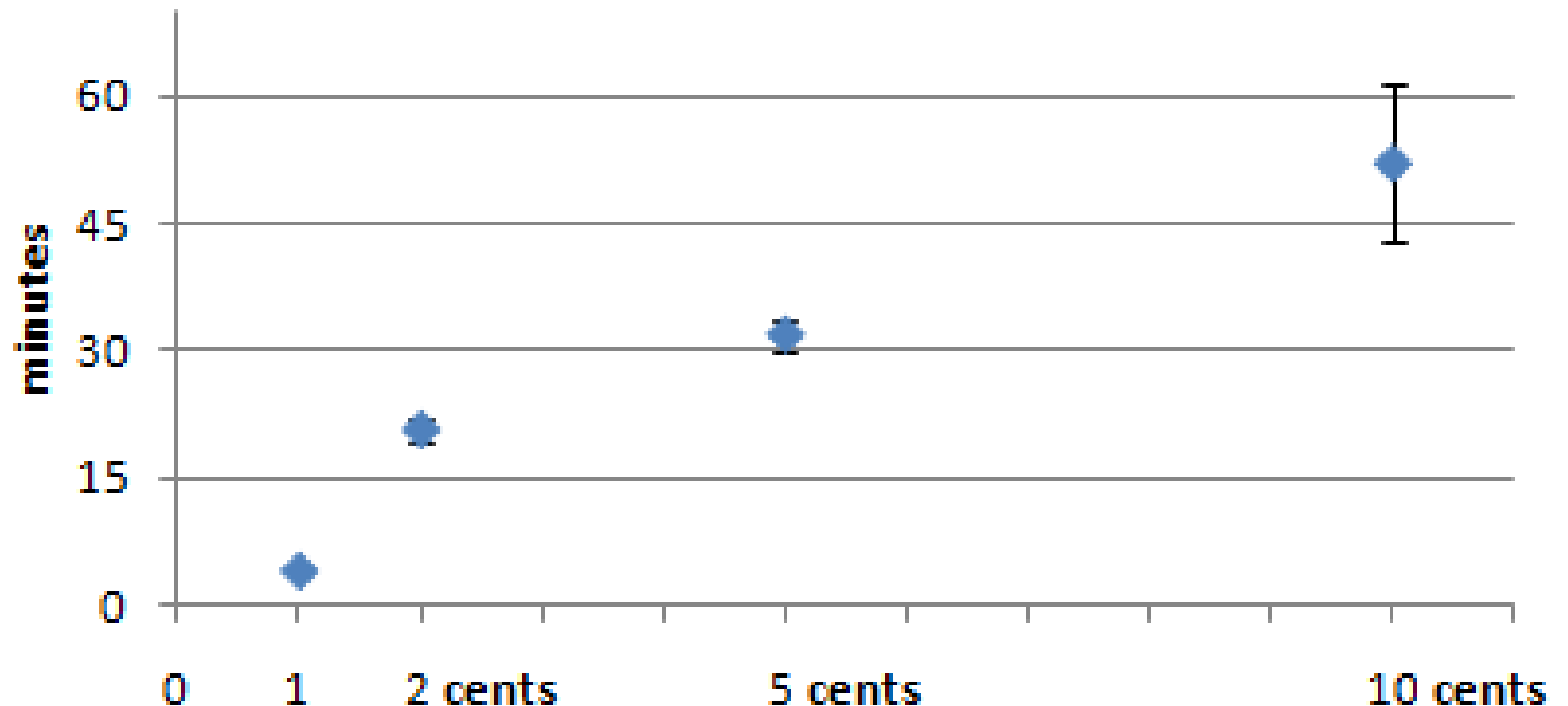
Execution Trace

Projects

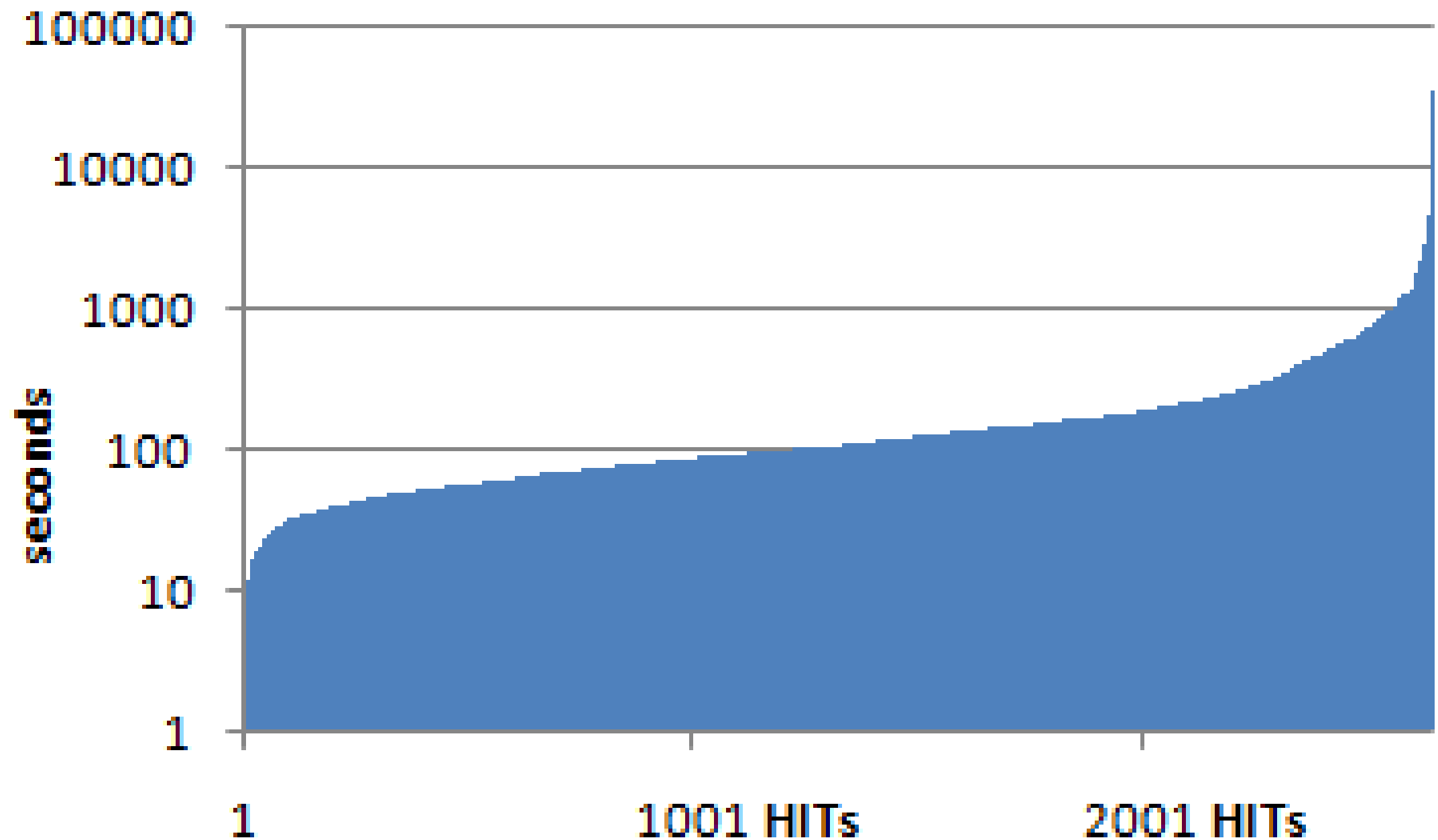
Run Controls

Getting Started

Time for results to come back, by reward amount



Time for first \$0.01 assignment to complete



Dealing with Latency

- Build the programming language to deal with high-latency operations
- Do something to optimize throughput on MTurk
- One (nefarious) example: artificially inflate number of assignments in your HIT to get front-page placement

All HITs

1-10 of 3390 Results

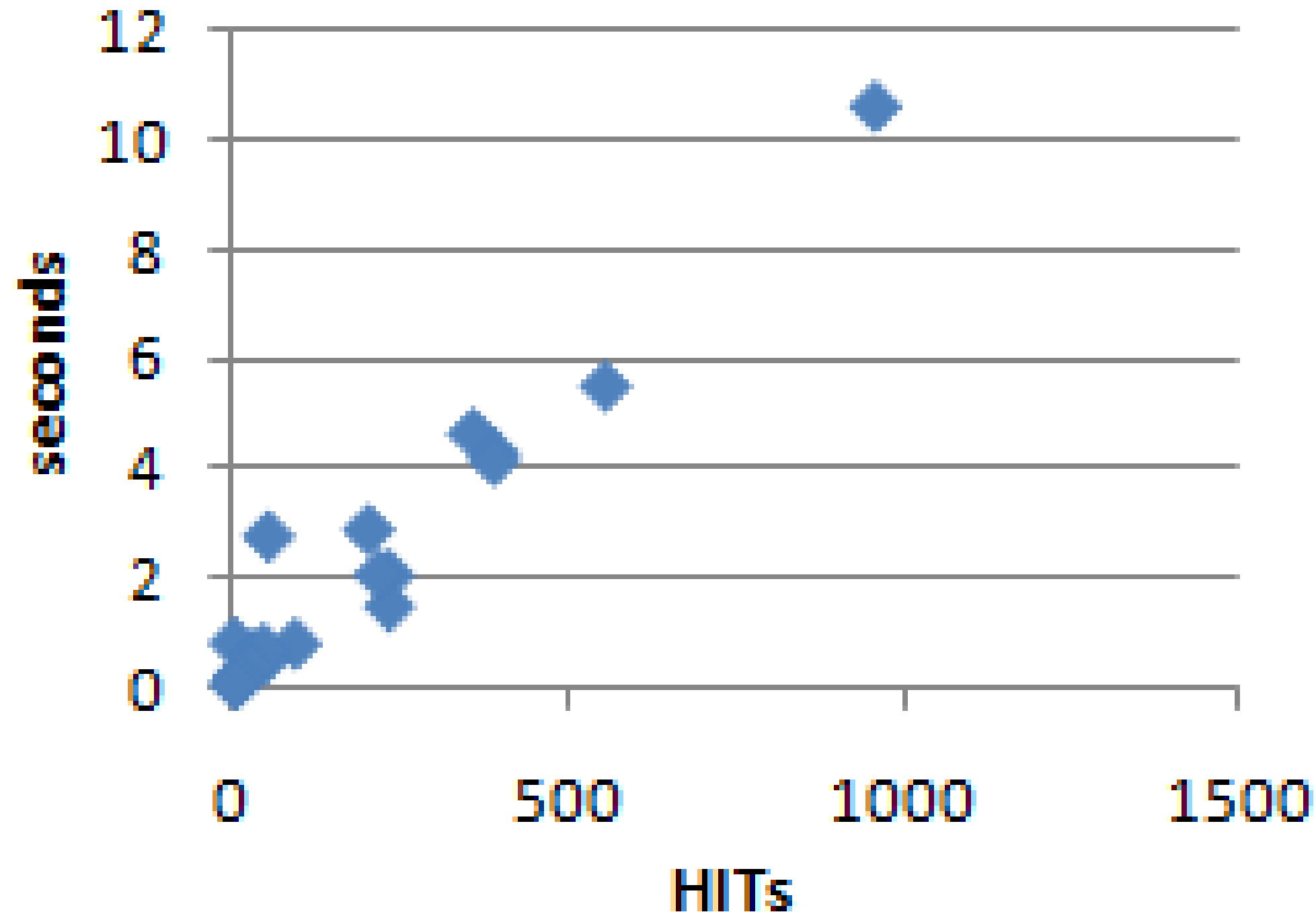
Sort by:

HITs Available (most first)



GO!

Time to execute once all HITs have been cached



Pros and Cons of TurKit?

Pros and Cons of TurKit

- Scalability - assumes local computation is minimal. Rerunning after each HIT might be tedious if task is large
- Parallel programming - not completely general in TurKit. **once**, **fork** and **join** do not give enough state.
- Experimental replicability - usually one downside of human computation is that results with differ each time. Not so with TurKit!

What experiments
would you run?

For Wednesday:
Finish programming
assignment #2,
sign up for a company
to profile and present

<http://crowdsourcing-class.org/assignments.html>