Python Threads

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title: Title

Meta Tutorial

- I'm hearing-impaired
  - Please write questions if at all possible
- Take notes - or not
- Pop Quiz
- Slideshow on web

Contents

- Goal: Use Threads!
- Thread Overview
- Python's Thread Library
- Two Applications
  - Web Spider
  - GUI Background Thread

Part 1

- What are threads?
- GIL
- Python threads

Generic Threads

- Similar to processes
- Shared memory
- Light-weight
- Difficult to set up
  - Especially cross-platform

Why Use Threads?

- Efficiency/speed
- Responsiveness
- Algorithmic simplicity

Python Threads

- Class-based
  - Use `threading`, not `thread`
- Cross-platform
- Thread Library

Python 1.5.2 vs. 2.0

- Compile `--with-thread`
  - Except on MS Windows and some Linux distributions
- Multi-CPU bug
  - Creating/destroying large numbers of threads

GIL

- Global Interpreter Lock (GIL)
- Full Documentation:

`http://www.python.org/doc/current/api/threads.html`

- Only one Python thread can run
- GIL is your friend (really!)

GIL in Action

- Which is faster?

One Thread

```
total = 1
for i in range(10000):
    total += 1
total = 1
for i in range(10000):
    total += 1
```

Two Threads

```
total = 1
for i in range(10000):
    total += 1
```

```
total = 1
for i in range(10000):
    total += 1
```

Dealing with GIL

- `sys.setcheckinterval()` (default 10)
- C extensions can release GIL
- Blocking I/O releases GIL
  - So does `time.sleep(!=0)`
- Multiple Processes

Performance Tip

- `python -O`
  - Also set `PYTHONOPTIMIZE`
  - 15% performance boost
  - Removes bytecodes (`SET_LINENO`)
  - Fewer context switches!

GIL and C Extensions

- Look for macros:

  ```
  Py_BEGIN_ALLOW_THREADS
  Py_END_ALLOW_THREADS
  ```

- Some common extensions:

  mxODBC - yes

  NumPy - no

Share External Objects

- Files, GUI, DB connections

Share External Objects

- Files, GUI, DB connections

Don't

Share External Objects

- Files, GUI, DB connections

Don't

- Partial exception: `print`
- Still need to share?
  - Use worker thread

Create Python Threads

- Subclass `threading.Thread`
- Override `__init__()` and `run()`
- Do *not* override `start()`
- In `__init__()`, call `Thread.__init__()`

Using Python Threads

- Instantiate thread object

```
t = MyThread()
```

- Start the thread

```
t.start()
```

- Methods/attribs from outside thread

```
t.put('foo')
if t.done:
```

Non-threaded Example

```
class Retriever:
    def __init__(self, URL):
        self.URL = URL
        self.page = self.getPage()

retriever = Retriever('http://www.foo.com/')
URLs = retriever.getLinks()
```

Threaded Example

```
from threading import Thread

class Retriever(Thread):
    def __init__(self, URL):
        Thread.__init__(self)
        self.URL = URL
    def run(self):
        self.page = self.getPage()

retriever = Retriever('http://www.foo.com/')
retriever.start()
while retriever.isAlive():
    time.sleep(1)
URLs = retriever.getLinks()
```

Multiple Threads

```
seeds = ['http://www.foo.com/',
    'http://www.bar.com/',
    'http://www.baz.com/']
threadList = []
URLs = []

for seed in Seed:
    retriever = Retriever(seed)
    retriever.start()
    threadList.append(retriever)

for retriever in threadList:
    # join() is more efficient than sleep()
    retriever.join()
    URLs += retriever.getLinks()
```

`import` Editorial

- How to import

  ```
  from threading import Thread, Semaphore
  ```

  or

  ```
  import threading
  ```

- Don't use

  ```
  from threading import *
  ```

Thread Methods

- Module functions:
  - `activeCount()` (not useful)
  - `enumerate()` (not useful)
- Thread object methods:
  - `start()`
  - `join()` (somewhat useful)
  - `isAlive()` (not useful)
  - `isDaemon()`
  - `setDaemon()`

Unthreaded Spider

- `SingleThreadSpider.py`
- Compare `Tools/webchecker/`

Brute Thread Spider

- `BruteThreadSpider.py`
- Few changes from `SingleThreadSpider.py`
- Spawn one thread per retrieval
- Inefficient polling in main loop

Part 2

- Recap
- Thread Theory
- Python Thread Library

Recap Part 1

- GIL
- Creating threads
- Brute force threads

Thread Order

- Non-determinate

Thread 1

```
print "a,",
print "b,",
print "c,",
```

Thread 2

```
print "1,",
print "2,",
print "3,",
```

- Sample output

```
1, a, b, 2, c, 3,
a, b, c, 1, 2, 3,
1, 2, 3, a, b, c,
a, b, 1, 2, 3, c,
```

Thread Communication

- Critical Section Lock
  - Protects shared memory
  - Only one thread accesses chunk of code
  - aka "mutex", or "atomic operation"
- Wait/Notify
  - Synchronizes actions between threads
  - Threads wait for each other to finish a task
  - More efficient than polling

Thread Library

- `Lock()`
- `RLock()`
- `Semaphore()`
- `Condition()`
- `Event()`
- `Queue.Queue()`

Lock()

- Basic building block
- Methods

  `acquire(`*`blocking`*`)`

  `release()`

Critical Section Lock

Thread 1

```
mutex.acquire()
if myList:
    work = myList.pop()
mutex.release()
...
...
...
...
```

Thread 2

```
...
...
...
...
mutex.acquire()
if len(myList)<10:
    myList.append(work)
mutex.release()
```

GIL and Shared Vars

- Safe: one bytecode

  Single operations against Python basic types (e.g. appending to a list)

- Unsafe

  Multiple operations against Python variables (e.g. checking the length of a list before appending) or any operation that involves a callback to a class (e.g. the `__getattr__` hook)

GIL example

- Mutex only one thread

Thread 1

```
myList.append(work)
...
...
...
```

Thread 2

```
mutex.acquire()
if myList:
    work = myList.pop()
mutex.release()
```

`dis` this

- `dis`assemble source to byte codes
- Thread-unsafe statement
  - If a single Python statement uses the same shared variable across multiple byte codes, or if there are multiple mutually-dependent shared variables, that statement is not thread-safe

Misusing Lock()

- `Lock()` steps on itself

```
mutex = Lock()
mutex.acquire()
  ...
mutex.acquire()   # OOPS!
```

Synch Two Threads

```
class Synchronize:
    def __init__(self):
        self.lock = Lock()
    def wait(self):
        self.lock.acquire()
        self.lock.acquire()
        self.lock.release()
    def notify(self):
        self.lock.release()
```

Thread 1

```
self.synch.wait()
...
...
self.synch.notify()
```

Thread 2

```
...
self.synch.notify()
self.synch.wait()
...
```

RLock()

- Mutex only
  - Other threads cannot release RLock()
- Recursive
- Methods
  - `acquire(`*`blocking`*`)`
  - `release()`

Using RLock()

```
mutex = RLock()
mutex.acquire()
   ...
mutex.acquire()   # Safe
   ...
mutex.release()
mutex.release()
```

Thread 1

```
mutex.acquire()
self.update()
mutex.release()
...
...
...
```

Thread 2

```
...
...
...
mutex.acquire()
self.update()
mutex.release()
```

Semaphore()

- Restricts number of running threads
  - In Python, primarily useful for simulations (but consider using microthreads)
- Methods
  - `Semaphore(`*`value`*`)`
  - `acquire(`*`blocking`*`)`
  - `release()`

Condition()

- Methods
  - `Condition(`*`lock`*`)`
  - `acquire(`*`blocking`*`)`
  - `release()`
  - `wait(`*`timeout`*`)`
  - `notify()`
  - `notifyAll()`

Using Condition()

- Must use lock

```
cond = Condition()
cond.acquire()
cond.wait()          # or notify()/notifyAll()
cond.release()
```

- Avoid *`timeout`*

  Creates polling loop, so inefficient

Event()

- Thin wrapper for `Condition()`
  - Don't have to mess with lock
  - Only uses `notifyAll()`, so can be inefficient
- Methods
  - `set()`
  - `clear()`
  - `isSet()`
  - `wait(`*`timeout`*`)`

TMTOWTDI

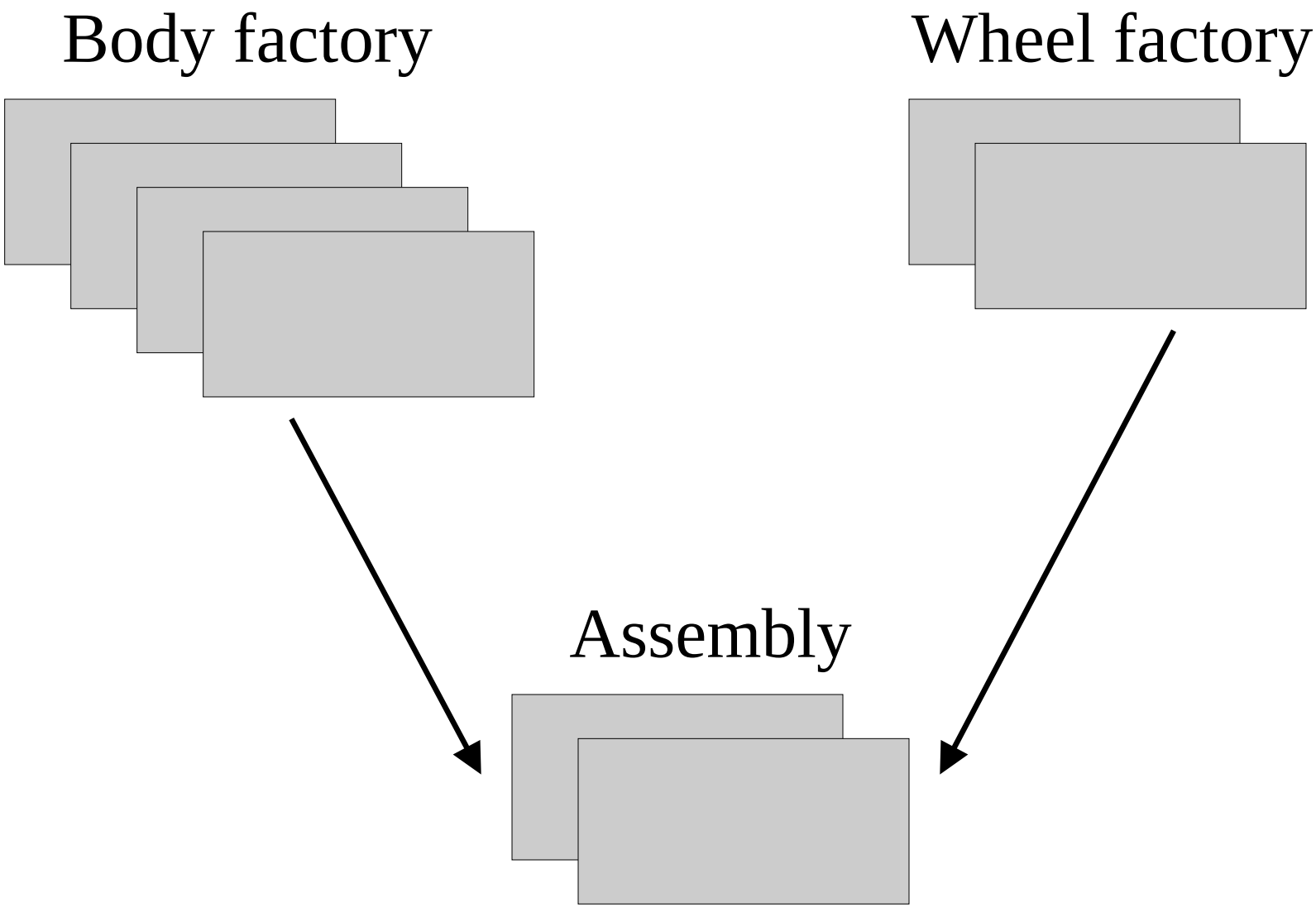
- Perl:

  There's More Than One Way To Do It

- Python:

  There should be one - and preferably only one - obvious way to do it

- Threads more like Perl



title: Factory 1

Factory Objects 1

Body

```
body.list
body.rlock
body.event
assembly.event
```

Wheels

```
wheels.list
wheels.rlock
wheels.event
assembly.event
```

Assembly

```
body.list
body.rlock
body.event
wheels.list
wheels.rlock
wheels.event
assembly.rlock
assembly.event
```

Queue()

- Does not use `threading`
  - Can be used with `thread`
- Designed for subclassing
  - Can implement stack, priority queue, etc.
- Simple!
  - Handles *both* data protection and synchronization

Queue() Objects

- Methods

  `Queue(`*`maxsize`*`)`
  `put(item,`*`block`*`)`
  `get(`*`block`*`)`
  `qsize()`
  `empty()`
  `full()`

- Raises exception when non-blocking

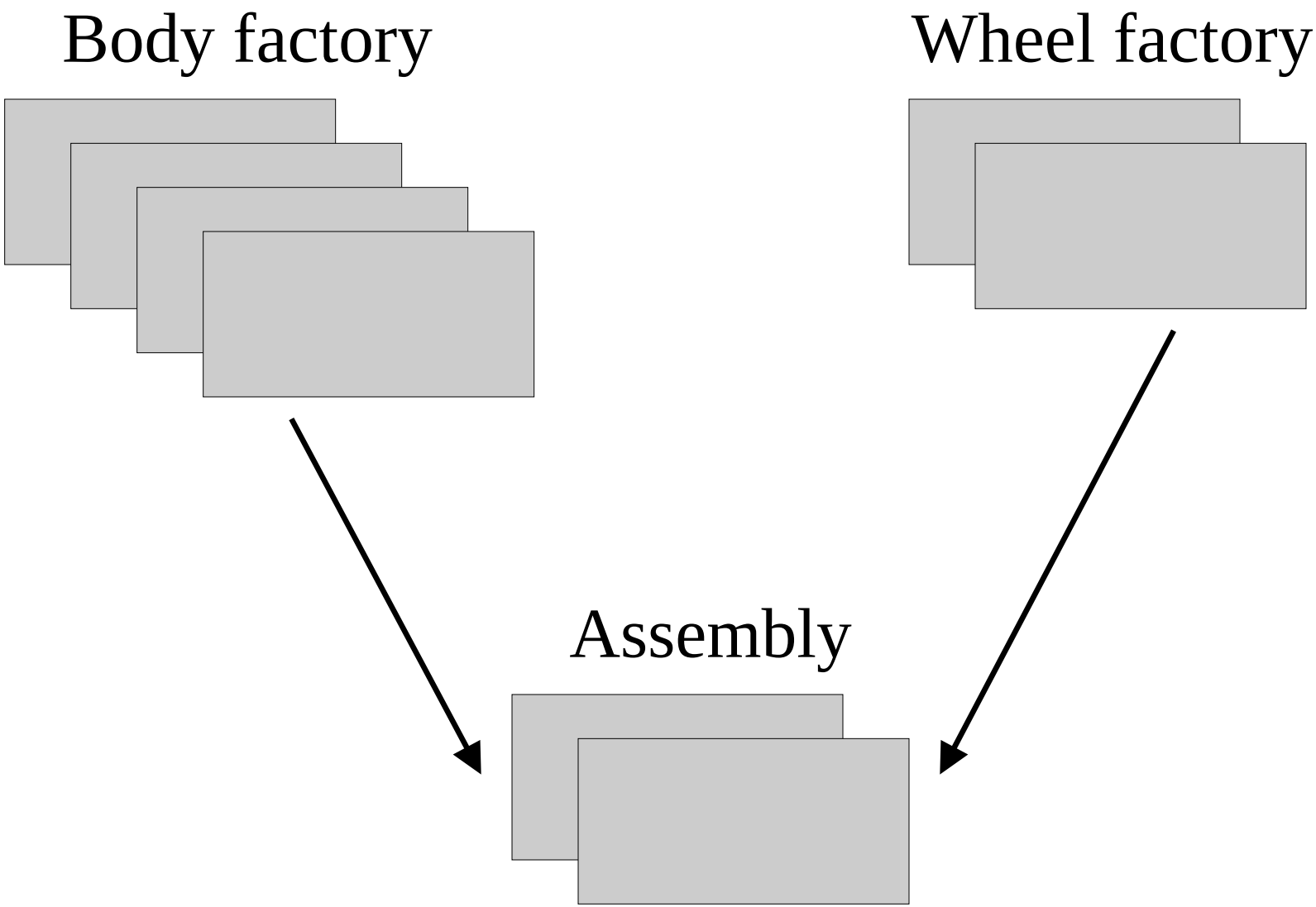
Using Queue()

Thread 1

```
output = self.doWork()
queue.put(output)
...
...
...
self.input = queue.get()
```

Thread 2

```
...
...
self.input = queue.get()
output = self.doWork()
queue.put(output)
...
```



title: Factory 2

Factory Objects 2

Body

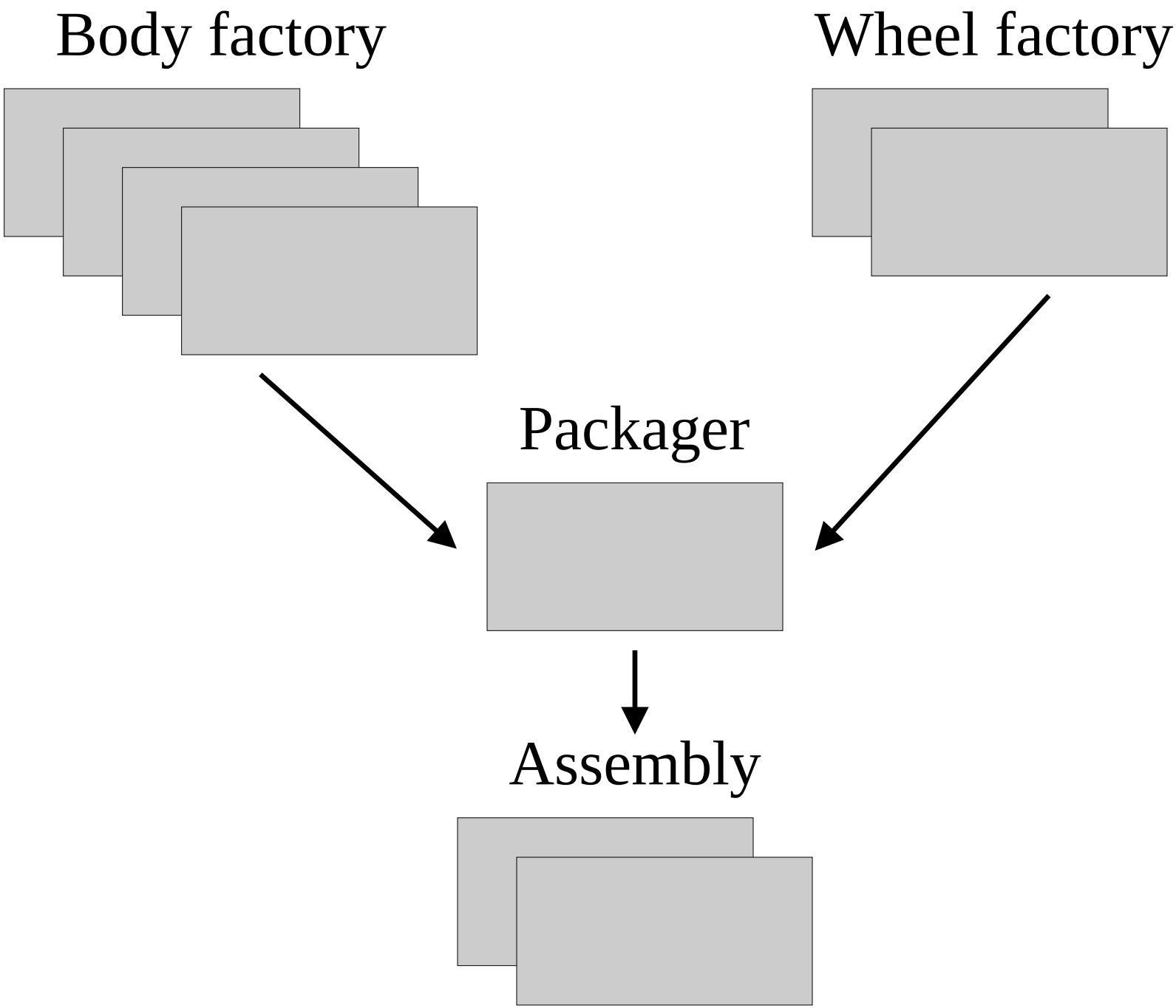
`body.queue`

Wheels

`wheels.queue`

Assembly

`body.queue`
`wheels.queue`
`assembly.rlock`



title: Factory 3

Factory Objects 3

Body

`body.queue`

Wheels

`wheels.queue`

Packager

```
while 1:
    body = self.body.queue.get()
    wheels = self.wheels.queue.get()
    self.assembly.put( (body,wheels) )
```

Assembly

`assembly.queue`

Part 3

- Recap
- Using Queues
  - spider
  - GUI (Tkinter)

Recap Part 2

- Data protection and synchronization
- Python Thread Library
- Queues are good

Spider w/Queue

- `ThreadPoolSpider.py`
- Two queues
  - Pass work to thread pool
  - Get links back from thread pool
- Queue for both data and events

Tkinter Intro

This space intentionally left blank

GUI building blocks

- Widgets

  Windows, buttons, checkboxes, text entry, listboxes

- Events

  Widget activation, keypress, mouse movement, mouse click, timers

Widgets

- Geometry manager
- Register callbacks

Events

- Event loop
- Trigger callbacks

Tkinter resources

- Web

  `http://www.python.org/topics/tkinter/doc.html`

- Books

  Python and Tkinter Programming, John E. Grayson

Fibonacci

- `Fibonacci.py`
- UI freezes during calc
- Frequent screen updates slow calc

Threaded Fibonacci

- `FibThreaded.py`
- Tkinter needs to poll
  - Use `after` event
- Single-element queue
  - Use in non-blocking mode to minimize updates
- Must use "Quit" button

Pop Quiz 1

How are threads and processes similar and different?

What is the GIL?

In what ways does the GIL make thread programming easier and harder?

How do you create a thread in Python?

What should not be shared between threads?

What are "brute force" threads?

Pop Quiz 2

Explain what each of the following is used for:

- Lock()
- RLock()
- Semaphore()
- Condition()
- Event()
- Queue.Queue()

Why are queues great?