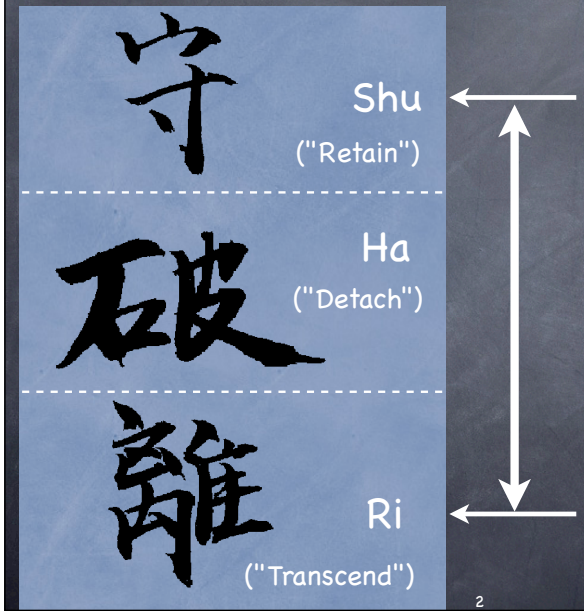
Don't call us, we'll call you:
callback patterns and idioms in Python

http://www.aleax.it/cback_sfp12.pdf

Audience levels for this talk



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The "Callback" concept

- it's about library/framework code that "calls back" into YOUR code
  - rather than the "traditional" (procedural) approach where YOU call code supplied as entry points by libraries &c
- AKA "the Hollywood principle": "don't call us, we'll call you"
  - coinage: Richard E. Sweet, in "The Mesa Programming Environment", SigPLAN Notices, July 1985
- for: customization (flexibility) and "event-driven" architectures ("actual" events OR "structuring of control-flow" ["pseudo" events])

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"Callback" implementation

- hand a callable over to "somebody"
- the "somebody" will store it "somewhere"
  - a container, an attribute, whatever
  - or even just keep it as a local variable
- and calls it "when appropriate"
  - when it needs some specific functionality (i.e., for customization)
  - or, when appropriate events "occur" (state changes, user actions, network or other I/O, timeouts, system events, ...) or "are made up" (structuring of control-flow)

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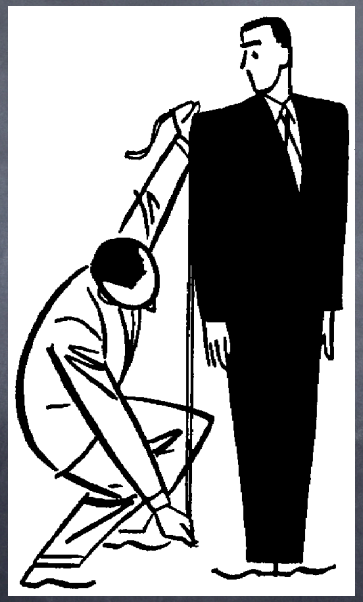
Customization



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Customizing sort (by key)

```
mylist.sort(key=str.toupper)
```

handily, speedily embodies the DSU pattern:

```
def DSU_sort(mylist, key):
  aux = [ (key(v), j, v)
          for j, v in enumerate(mylist)]
  aux.sort()
  mylist[:] = [v for k, j, v in aux]
```

Note that a little "workaround" is needed wrt the usual "call a method on each object" OO idiom...!

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More-OO-ish callbacks

```
import operator

mylist.sort(key=operator.attrgetter('k'))

mylist.sort(key=cls.argless_method)

mylist.sort(key=operator.methodcaller(
  'methodname', 'maybe', 'some', 'args'))
```

Key point: don't lambda needlessly!

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OO customizing: the TM DP

- "Template Method" Design Pattern: perform the callbacks by "self delegation":

```
class TMparent(object):
...self.somehook()...
```

- and customize by inheriting & overriding:

```
class TMchild(TMparent):
...def somehook(self):...
```

- handy, compact, sometimes a bit rigid
- http://video.google.com/videoplay?docid=-5434189201555650834 and http://www.aleax.it/goo_pydp.pdf (49ff) for more

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Customizing scheduling

- sched needs TWO callback functionalities:
  - what time is it right now?
  - wait (sleep) until time T
- the OO way (more structured) would be:

```
import time
s=sched(time)
```

- the FP way (more flexible) is instead:

```
s=sched(time.time, time.sleep)
```

- you might supply default callbacks, or not
- (Dependency Injection DP & variants)

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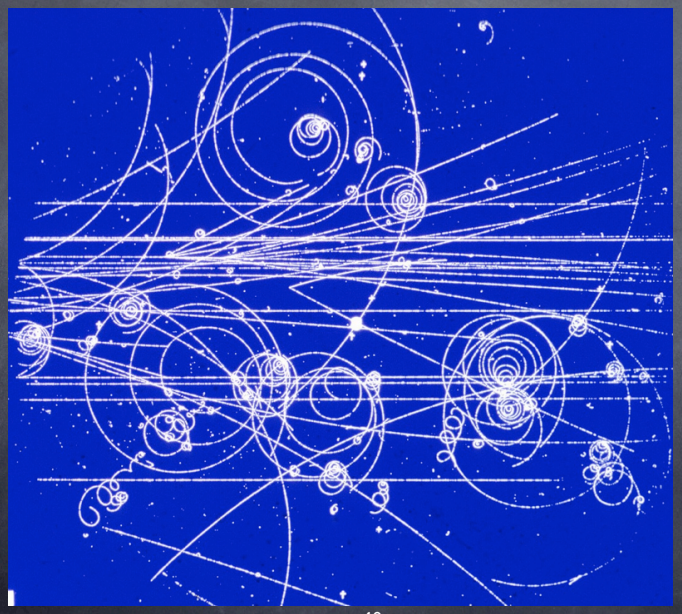
Events



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Kinds of "Event" callbacks

- Events "proper"...:
  - GUI frameworks (mouse, keyboard, ...)
  - Observer/Observable design pattern
  - asynchronous (event-driven) I/O (net &c)
  - "system-event" callbacks
- Pseudo-events for "structuring" execution:
  - "event-driven" parsing (SAX &c)
  - "scheduled" callbacks (sched)
  - "concurrent" callbacks (threads &c)
  - timing and debugging (timeit, pdb, ...)

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Events in GUI frameworks

- the most classic of event-driven fields
- e.g, consider Tkinter:
- elementary callbacks e.g. for buttons:
  - b=Button(parent, text='boo!', command=...)
- flexible, advanced callbacks and events:
  - somewidget.bind(event, handler)
    - event: string describing the event (e.g. '<Enter>', '<Leave>', '<Key>', ...)
    - handler: callable taking Event argument (w. attributes .widget, .x, .y, .type, ...)
  - can also bind by class, all, root window...

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The Observer DP

- a "target object" lets you add "observers"
  - could be simple callables, or objects
- when the target's state changes, it calls back to "let the observers know"
- design choices: "general" observers (callbacks on ANY state change), "specific" observers (callbacks on SPECIFIC state changes; level of specificity may vary), "grouped" observers (objects with >1 methods for kinds of state-change), ...

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Callback issues

- what arguments are to be used on the call?
  - no arguments: simplest, a bit "rough"
  - in Observer: pass as argument the target object whose state just changed
    - lets 1 callable observe several targets
  - or: a "description" of the state changes
    - saves "round-trips" to obtain them
  - other: identifier or description of event
- but -- what about other arguments (related to the callable, not to the target/event)...?

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Fixed args in callbacks

- functools.partial(callable, *a, **kw)
  - pre-bind any or all arguments
- however, note the difference...:
  - x.setCbk(functools.partial(f, *a, **kw))
    - vs
  - x.setCbk(f, *a, **kw)
- ...having the set-callback itself accept (and pre-bind) arguments is far neater/handier
- sombunall[1] Python callback systems do that

[1]: Robert Anton Wilson

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Callback "dispatching"

- what if more than one callback is set for a single event (or, Observable target)?
  - remember and call the latest one only
    - simplest, roughest
  - or, remember and call them all
    - LIFO? FIFO? or...?
    - how do you _remove_ a callback?
    - can one callback "preempt" others?
- can events (or state changes) be "grouped"?
  - use object w/methods instead of callable

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Callbacks and Errors

- are "errors" events like any others?
- or are they best singled-out?
  http://www.python.org/pycon/papers/deferex/
- Twisted Matrix's "Deferred" pattern: one Deferred object holds...
  - N "chained" callbacks for "successes" +
  - M "chained" callbacks for "errors"
  - each callback is held WITH opt *a, **kw
  - plus, argument for "event / error identification" (or, result of previous callback along the appropriate "chain")

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System-events callbacks

- for various Python "system-events":
  - atexit.register(callable, *a, **k)
  - oldhandler = signal.signal(signum, callable)
  - sys.displayhook, sys.excepthook, sys.settrace(callable), sys.setprofile(callable)
- some extension modules do that, too...:
  - readline.set_startup_hook, set_pre_input_hook, set_completer

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"Pseudo" events

- "events" can be a nice way to structure execution (control) flow
  - so in some cases "we make them up" (!) just to allow even-driven callbacks in otherwise non-obvious situations;-)
- parsing, scheduling, concurrency, timing, debugging, ...

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Event-driven parsing

- e.g. SAX for XML
  - "events" are start and end of tags
  - handlers are responsible for keeping stack or other structure as needed
    - often not necessary to keep all...!
- at the other extreme: XML's DOM
- somewhere in-between: "pull DOM"...
  - events as "stream" rather than callback
  - can "expand node" for DOMy subtrees

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Scheduled callbacks

- standard library module sched
- s = sched.Sched(timefunc, delayfunc)
  - e.g, Sched(time.time, time.sleep)
- evt = s.enter(delay, priority, callable, arg)
  - or s.enterabs(time, priority, callable, arg)
  - may s.cancel(evt) later
- s.run() runs events until queue is empty (or an exception is raised in callable or delayfunc: it propagates but leaves s in stable state, s.run can be called again later)

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"Concurrent" callbacks

- threading.Thread(target=..,args=..,kwargs=..)
  - call backs to target(*args,**kwargs)
  - at the t.start() event [or later...]
  - *in a separate thread* (the key point!-)
- stacklet.tasklet(callable)
  - calls back according to setup
  - when tasklet active and front-of-queue
  - channels, reactivation, rescheduling
- processing.Process(...like threading.Thread...)
- NWS' sleigh: eachElem, eachWorker

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Timing and debugging

- timeit.Timer(stmt, setup)
  - *string* arguments to compile & execute
  - a dynamic-language twist on callback!-)
  - "event" for callback:
    - setup: once, before anything else
    - stmt: many times, for timing
- the pdb debugger module lets you use either strings or callables...:
  - pdb.run and .runeval: strings
  - pdb.runcall: callable, arguments

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Q & A

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