Refactoring Python: Why and how to restructure your code

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Agenda

- What, When, Why, How
- Strategies
  - Extract Variable & Function
  - Extract Class & Move Fields
  - Move Field gotchas
- Follow-up
- Bonus
  - Extract Closure

What is refactoring?

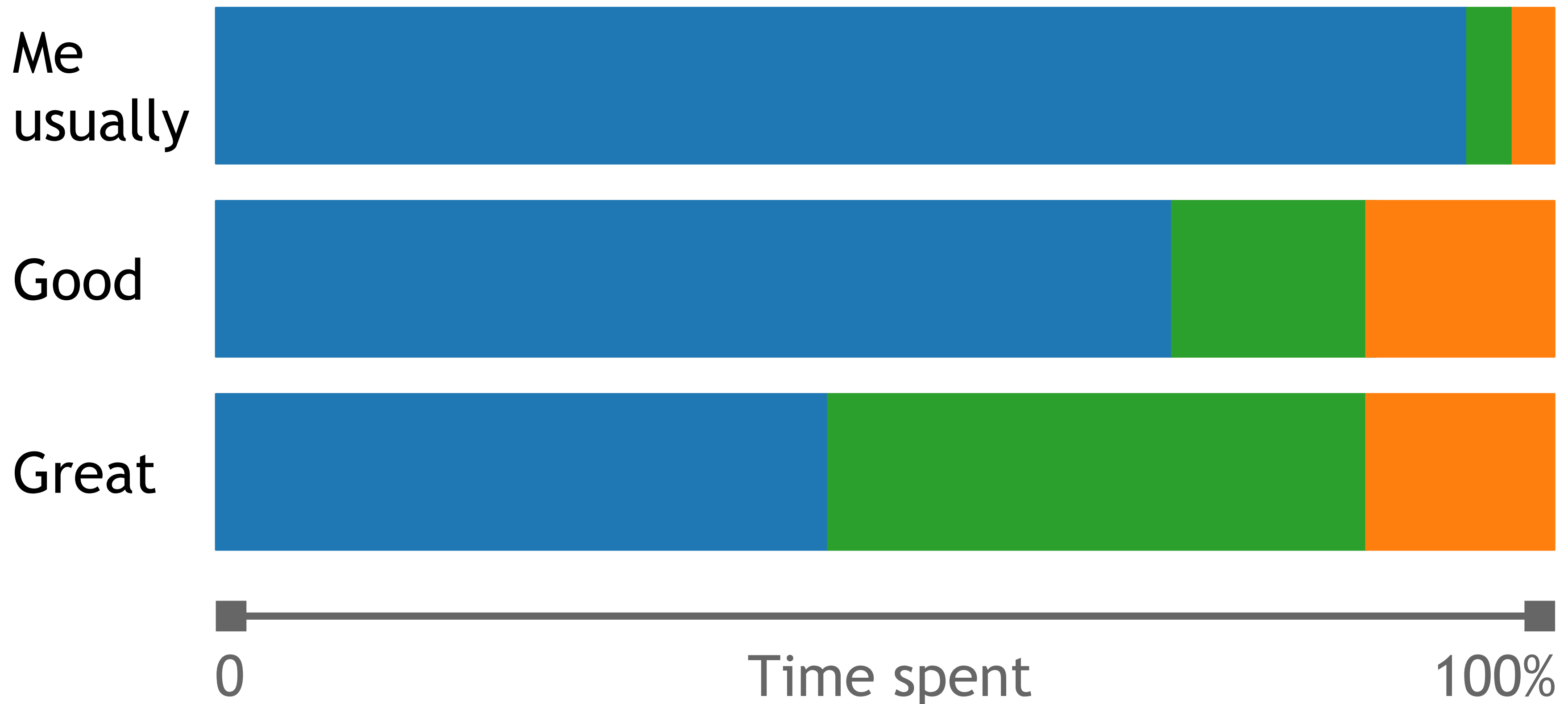
Repeatedly reorganizing and rewriting code until it's **obvious*** to a new reader.

* See Clean Code by Robert Martin

When do you refactor?

- In advance
- For testing
- "Don't repeat yourself"
- Brittleness
- Complexity

What's the difference between good and great programmers? (anecdotally)



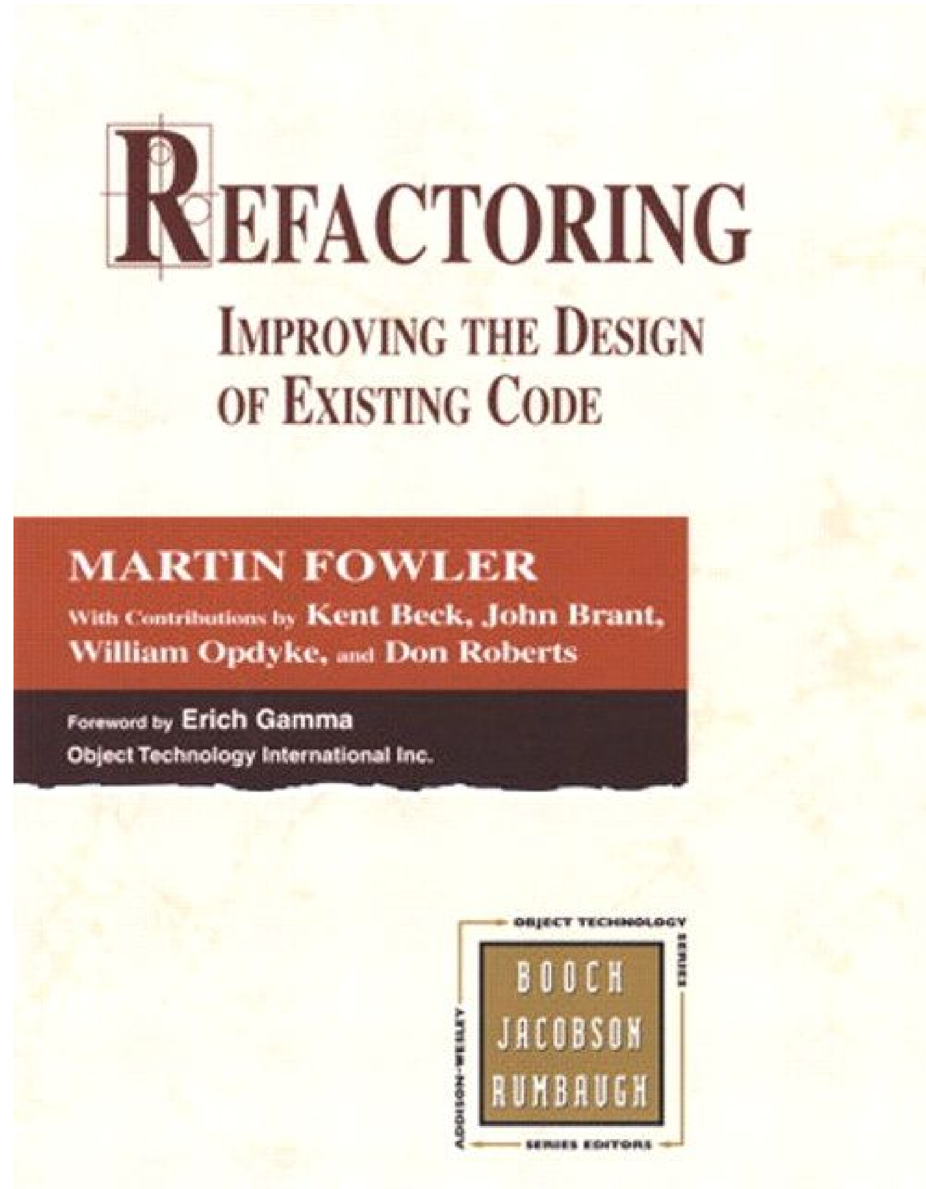
How do you refactor?

1. Identify bad code
2. Improve it
3. Run tests
4. Fix and improve tests
5. Repeat

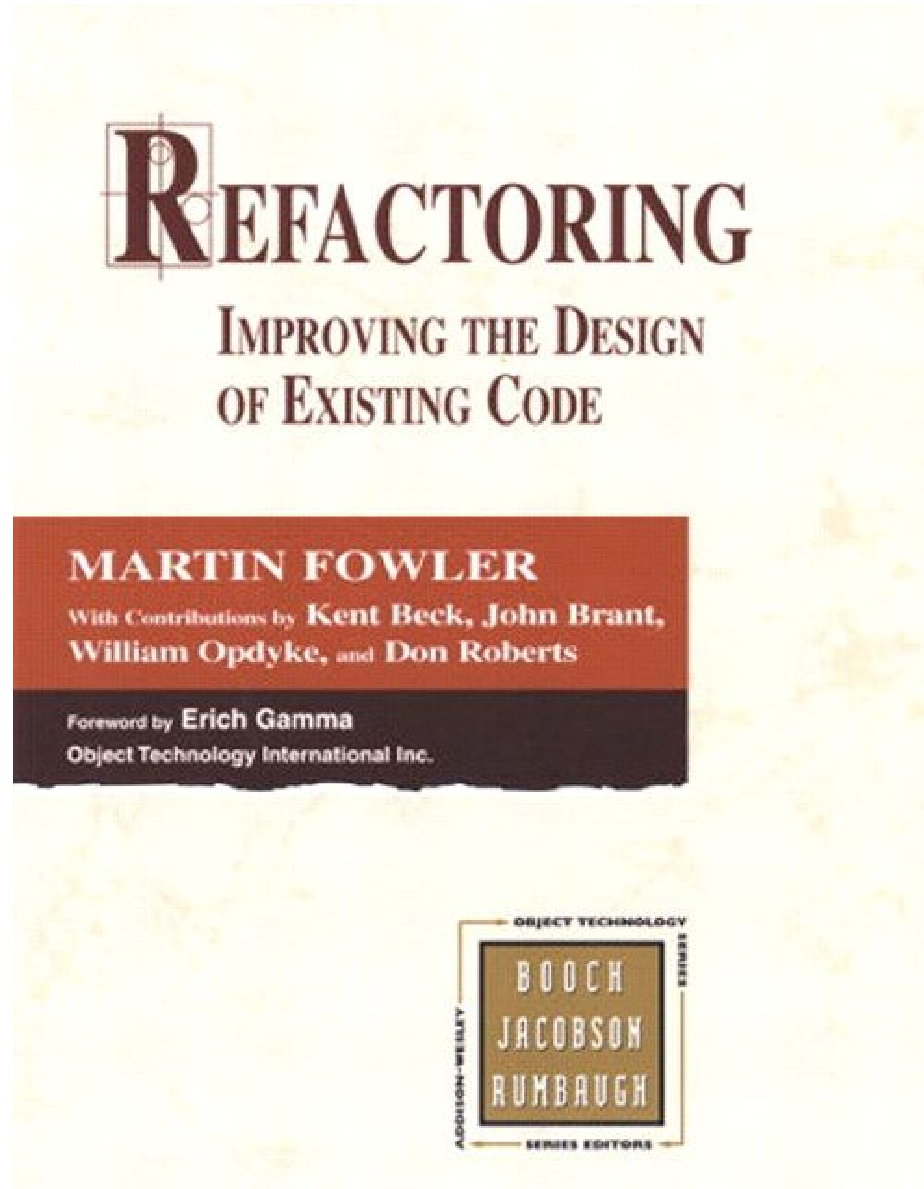
How do you refactor in practice?

- Rename, split, move
- Simplify
- Redraw boundaries

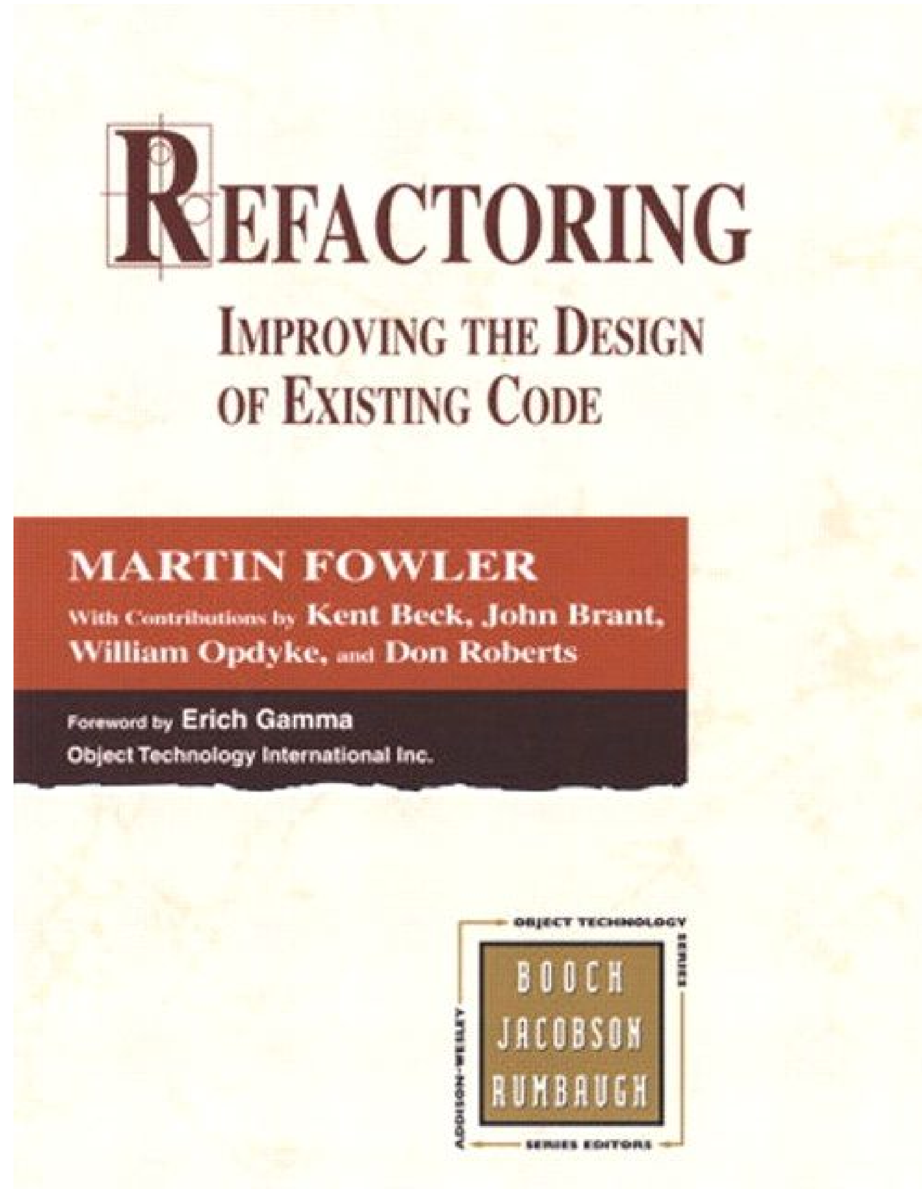
The canonical reference (1999)



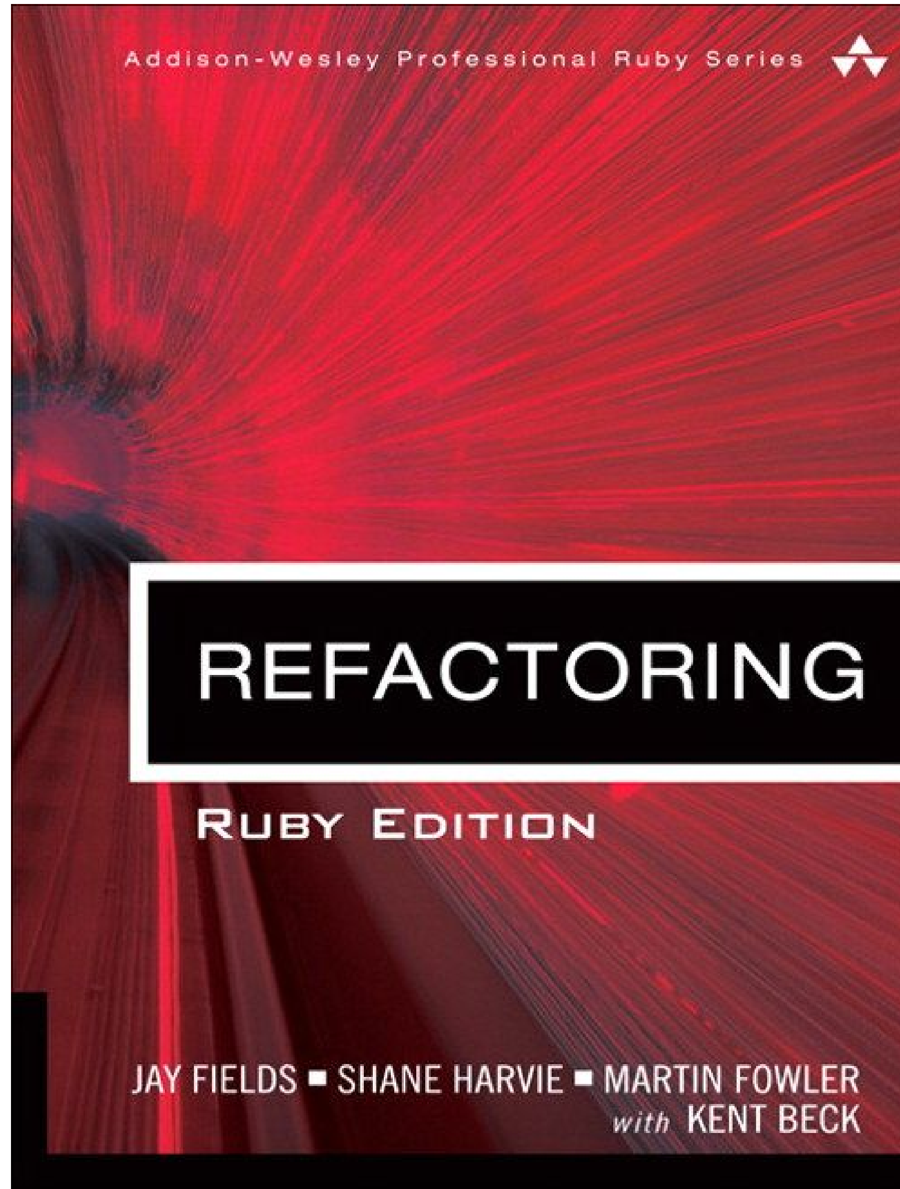
But...



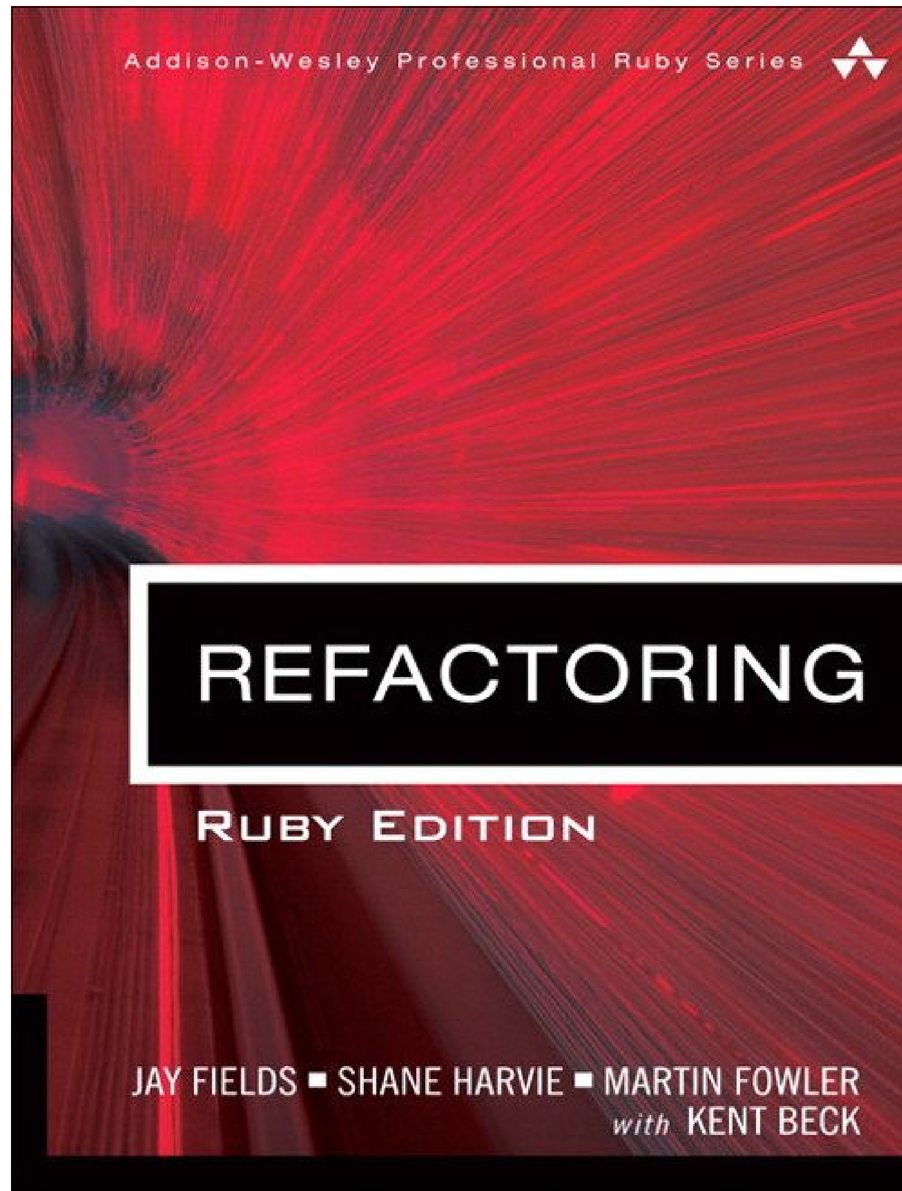
But... it's for Java programmers



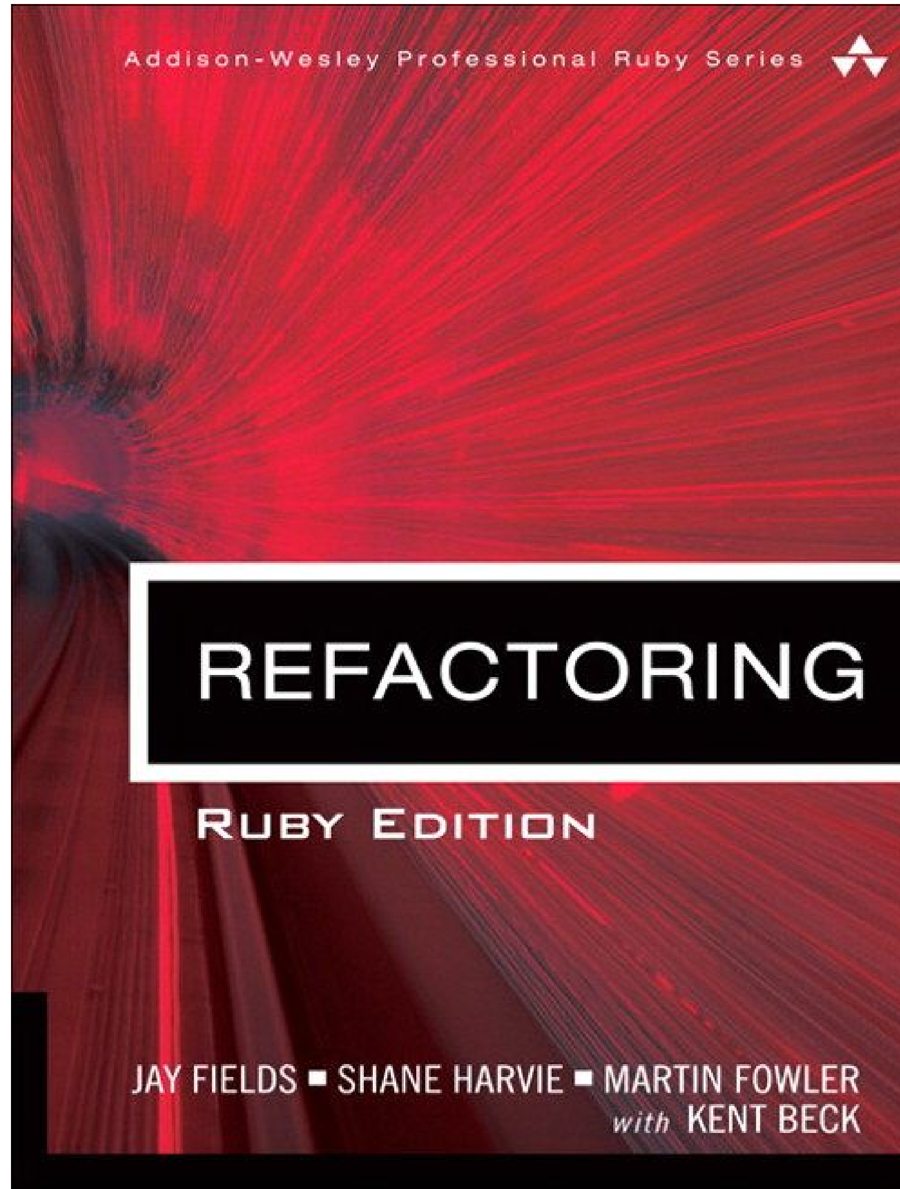
The more recent version (2009)



But...



But... it's for Ruby programmers



How do you refactor Python?

Effective Software Development Series
Scott Meyers, Consulting Editor

Effective Python

59 Specific Ways to Write Better Python

Brett Slatkin

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Strategies

Prerequisites

- Thorough tests
- Quick tests
- Source control
- Willing to make mistakes

Extract Variable & Extract Function

When should you eat certain foods?

```
MONTHS = ('January', 'February', ...)


def what_to_eat(month):
    if (month.lower().endswith('r') or
            month.lower().endswith('ary')):
        print('%s: oysters' % month)
    elif 8 > MONTHS.index(month) > 4:
        print('%s: tomatoes' % month)
    else:
        print('%s: asparagus' % month)
```

When should you eat certain foods?

```
what_to_eat('November')
what_to_eat('July')
what_to_eat('March')
```

```
>>>
November: oysters
July: tomatoes
March: asparagus
```

Before

```
if (month.lower().endswith('r') or
    month.lower().endswith('ary')):
  print('%s: oysters' % month)
elif 8 > MONTHS.index(month) > 4:
  print('%s: tomatoes' % month)
else:
  print('%s: asparagus' % month)
```

After: Extract variables

```
lowered = month.lower()
ends_in_r = lowered.endswith('r')
ends_in_ary = lowered.endswith('ary')
index = MONTHS.index(month)
summer = 8 > index > 4

if ends_in_r or ends_in_ary:
  print('%s: oysters' % month)
elif summer:
  print('%s: tomatoes' % month)
else:
  print('%s: asparagus' % month)
```

Extract variables into functions

```python
def oysters_good(month):
  lowered = month.lower()
  return (
      lowered.endswith('r') or
      lowered.endswith('ary'))


def tomatoes_good(month):
  index = MONTHS.index(month)
  return 8 > index > 4
```

Before

```
if (month.lower().endswith('r') or
    month.lower().endswith('ary')):
  print('%s: oysters' % month)
elif 8 > MONTHS.index(month) > 4:
  print('%s: tomatoes' % month)
else:
  print('%s: asparagus' % month)
```

After: Using functions

```
if oysters_good(month):
  print('%s: oysters' % month)
elif tomatoes_good(month):
  print('%s: tomatoes' % month)
else:
  print('%s: asparagus' % month)
```

After: Using functions with variables

```
time_for_oysters = oysters_good(month)
time_for_tomatoes = tomatoes_good(month)


if time_for_oysters:
  print('%s: oysters' % month)
elif time_for_tomatoes:
  print('%s: tomatoes' % month)
else:
  print('%s: asparagus' % month)
```

These functions will get complicated

```
def oysters_good(month):
  lowered = month.lower()
  return (
      lowered.endswith('r') or
      lowered.endswith('ary'))


def tomatoes_good(month):
  index = MONTHS.index(month)
  return 8 > index > 4
```

Extract variables into classes

```
class OystersGood:
  def __init__(self, month):
    lowered = month.lower()
    self.r = lowered.endswith('r')
    self.ary = lowered.endswith('ary')
    self._result = self.r or self.ary

  def __bool__(self):  # aka __nonzero__
    return self._result
```

Extract variables into classes

```
class TomatoesGood:
    def __init__(self, month):
        self.index = MONTHS.index(month)
        self._result = 8 > index > 4

    def __bool__(self):  # aka __nonzero__
        return self._result
```

Before: Using functions

```
time_for_oysters = oysters_good(month)
time_for_tomatoes = tomatoes_good(month)

if time_for_oysters:
  print('%s: oysters' % month)
elif time_for_tomatoes:
  print('%s: tomatoes' % month)
else:
  print('%s: asparagus' % month)
```

After: Using classes

```
time_for_oysters = OystersGood(month)
time_for_tomatoes = TomatoesGood(month)

if time_for_oysters:  # Calls __bool__
  print('%s: oysters' % month)
elif time_for_tomatoes:  # Calls __bool__
  print('%s: tomatoes' % month)
else:
  print('%s: asparagus' % month)
```

Extracting classes facilitates testing

```
test = OystersGood('November')
assert test
assert test.r
assert not test.ary

test = OystersGood('July')
assert not test
assert not test.r
assert not test.ary
```

Things to remember

- Extract variables and functions to improve readability
- Extract variables into classes to improve testability
- Use `__bool__` to indicate a class is a paper trail

Extract Class & Move Fields

Keeping track of your pets

```
class Pet:
  def __init__(self, name):
    self.name = name
```

Keeping track of your pets

```
pet = Pet('Gregory the Gila')
print(pet.name)
```

```
>>>
Gregory the Gila
```

Keeping track of your pet's age

```
class Pet:
  def __init__(self, name, age):
    self.name = name
    self.age = age
```

Keeping track of your pet's age

```
pet = Pet('Gregory the Gila', 3)

print('%s is %d years old' %
      (pet.name, pet.age))


>>>
Gregory the Gila is 3 years old
```

Keeping track of your pet's treats

```
class Pet:
  def __init__(self, name, age):
    self.name = name
    self.age = age
    self.treats_eaten = 0

  def give_treats(self, count):
    self.treats_eaten += count
```

Keeping track of your pet's treats

```
pet = Pet('Gregory the Gila', 3)

pet.give_treats(2)

print('%s ate %d treats' %
      (pet.name, pet.treats_eaten))
```

```
>>>
Gregory the Gila ate 2 treats
```

Keeping track of your pet's needs

```
class Pet:
  def __init__(self, name, age, *,
               has_scales=False,
               lays_eggs=False,
               drinks_milk=False):
    self.name = name
    self.age = age
    self.treats_eaten = 0
    self.has_scales = has_scales
    self.lays_eggs = lays_eggs
    self.drinks_milk = drinks_milk
```

Keeping track of your pet's needs

```
class Pet:
  def __init__(self, ...): ...

  def give_treats(self, count): ..

  @property
  def needs_heat_lamp(self):
    return (
      self.has_scales and
      self.lays_eggs and
      not self.drinks_milk)
```

Keeping track of your pet's needs

```
pet = Pet('Gregory the Gila', 3,
          has_scales=True,
          lays_eggs=True)

print('%s needs a heat lamp? %s' %
      (pet.name, pet.needs_heat_lamp))


>>>
Gregory the Gila needs a heat lamp? True
```

It's getting complicated

```
class Pet:
  def __init__(self, name, age, *,
               has_scales=False,
               lays_eggs=False,
               drinks_milk=False):
    self.name = name
    self.age = age
    self.treats_eaten = 0
    self.has_scales = has_scales
    self.lays_eggs = lays_eggs
    self.drinks_milk = drinks_milk
```

How do you redraw boundaries?

1. Add an improved interface
    - Maintain backwards compatibility
    - Issue `warnings` for old usage

2. Migrate old usage to new usage
    - Run tests to verify correctness
    - Fix and improve broken tests

3. Remove code for old interface

What are warnings?

```python
import warnings
warnings.warn('Helpful message')
```

- Default: Print messages to stderr
- Force warnings to become exceptions:

```
python -W error your_code.py
```

Before

```python
class Pet:
  def __init__(self, name, age, *,
                 has_scales=False,
                 lays_eggs=False,
                 drinks_milk=False):
    self.name = name
    self.age = age
    self.treats_eaten = 0
    self.has_scales = has_scales
    self.lays_eggs = lays_eggs
    self.drinks_milk = drinks_milk
```

After: Extract `Animal` from `Pet`

```
class Animal:
    def __init__(self, *,
                 has_scales=False,
                 lays_eggs=False,
                 drinks_milk=False):




        self.has_scales = has_scales
        self.lays_eggs = lays_eggs
        self.drinks_milk = drinks_milk
```

Before

```
class Pet:
  def __init__(self, name, age, *,
               has_scales=False,
               lays_eggs=False,
               drinks_milk=False):
    ...
```

After: Add / intro parameter object

```
class Pet:
  def __init__(self, name, age,
               animal=None, **kwargs):
    ...
```

After: Backwards compatible

```
class Pet:
  def __init__(self, name, age,
               animal=None, **kwargs):
    if kwargs and animal is not None:
      raise TypeError('Mixed usage')
    if animal is None:
      warnings.warn('Should use Animal')
      animal = Animal(**kwargs)
    self.animal = animal
    self.name = name
    self.age = age
    self.treats_eaten = 0
```

Mixed usage raises exception

```
animal = Animal(has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', 3,
          animal, has_scales=False)
```

```
>>>
Traceback ...
TypeError: Mixed usage
```

Old constructor works, but warns

```
pet = Pet('Gregory the Gila', 3,
          has_scales=True,
          lays_eggs=True)
```

```
>>>
UserWarning: Should use Animal
```

New constructor usage doesn't warn

```
animal = Animal(has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', 3, animal)

print('My pet is %s' % pet.name)
```

```
>>>
My pet is Gregory the Gila
```

Before: Fields on self

```
class Pet:
  def __init__(self, name, age, *,
               has_scales=False,
               lays_eggs=False,
               drinks_milk=False):
    ...
    self.has_scales = has_scales
    self.lays_eggs = lays_eggs
    self.drinks_milk = drinks_milk
```

After: Move fields to inner object

```
class Pet:
  ...
  @property
  def has_scales(self):
    warnings.warn('Use animal attribute')
    return self.animal.has_scales

  @property
  def lays_eggs(self): ...

  @property
  def drinks_milk(self): ...
```

Old attributes issue a warning

```
animal = Animal(has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', 3, animal)

print('%s has scales? %s' %
      (pet.name, pet.has_scales))


>>>
UserWarning: Use animal attribute
Gregory the Gila has scales? True
```

New attributes don't warn

```
animal = Animal(has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', 3, animal)

print('%s has scales? %s' %
      (pet.name, pet.animal.has_scales))


>>>
Gregory the Gila has scales? True
```

Before: Helpers access self

```
class Pet:
  def __init__(self, ...): ...

  def give_treats(self, count): ..

  @property
  def needs_heat_lamp(self):
    return (
        self.has_scales and
        self.lays_eggs and
        not self.drinks_milk)
```

After: Helpers access inner object

```
class Pet:
  def __init__(self, ...): ...

  def give_treats(self, count): ..

  @property
  def needs_heat_lamp(self):
    return (
      self.animal.has_scales and
      self.animal.lays_eggs and
      not self.animal.drinks_milk)
```

Existing helper usage doesn't warn

```
animal = Animal(has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', 3, animal)

print('%s needs a heat lamp? %s' %
      (pet.name, pet.needs_heat_lamp))

>>>
Gregory the Gila needs a heat lamp? True
```

Things to remember

- Split classes using optional arguments to __init__
- Use `@property` to move methods and fields between classes
- Issue `warnings` in old code paths to find their occurrences

Move Field gotchas

Before: Is this obvious?

```
class Animal:
  def __init__(self, *,
               has_scales=False,
               lays_eggs=False,
               drinks_milk=False):
    ...


class Pet:
  def __init__(self, name, age, animal):
    ...
```

After: Move age to Animal

```
class Animal:
  def __init__(self, age=None, *,
                has_scales=False,
                lays_eggs=False,
                drinks_milk=False):
    ...


class Pet:
  def __init__(self, name, animal):
    ...
```

After: Constructor with optional age

```
class Animal:
  def __init__(self, age=None, *,
               has_scales=False,
               lays_eggs=False,
               drinks_milk=False):
    if age is None:
      warnings.warn('age not specified')
    self.age = age
    self.has_scales = has_scales
    self.lays_eggs = lays_eggs
    self.drinks_milk = drinks_milk
```

Before: Pet constructor with age

```
class Pet:
  def __init__(self, name, age, animal):
    ...
```

After: Pet constructor with optional age

```
class Pet:
  def __init__(self, name, maybe_age,
                    maybe_animal=None):
    ...
```

After: Pet constructor with optional age

```
class Pet:
  def __init__(self, name, maybe_age,
               maybe_animal=None):
    if maybe_animal is not None:
      warnings.warn('Put age on animal')
      self.animal = maybe_animal
      self.animal.age = maybe_age
    else:
      self.animal = maybe_age

   ...
```

After: Compatibility property age

```
class Pet:
  def __init__(self, name, maybe_age,
               maybe_animal=None): ...

  def give_treats(self, count): ...

  @property
  def age(self):
    warnings.warn('Use animal.age')
    return self.animal.age
```

After: Old usage has a lot of warnings

```
animal = Animal(has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', 3, animal)

print('%s is %d years old' %
      (pet.name, pet.age))


>>>
UserWarning: age not specified
UserWarning: Put age on animal
UserWarning: Use animal.age
Gregory the Gila is 3 years old
```

After: New usage has no warnings

```
animal = Animal(3, has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', animal)

print('%s is %d years old' %
      (pet.name, pet.animal.age))
```

```
>>>
Gregory the Gila is 3 years old
```

Gregory is older than I thought

```
animal = Animal(3, has_scales=True,
                   lays_eggs=True)
pet = Pet('Gregory the Gila', animal)
pet.age = 5
```

Assigning to age breaks!

```
animal = Animal(3, has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', animal)
pet.age = 5  # Error
```

```
>>>
AttributeError: can't set attribute
```

Need a compatibility property setter

```
class Pet:
  ...

  @property
  def age(self):
    warnings.warn('Use animal.age')
    return self.animal.age

  @age.setter
  def age(self, new_age):
    warnings.warn('Assign animal.age')
    self.animal.age = new_age
```

Old assignment now issues a warning

```
animal = Animal(3, has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', animal)
pet.age = 5
```

```
>>>
UserWarning: Assign animal.age
```

New assignment doesn't warn

```
animal = Animal(3, has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', animal)
pet.animal.age = 5

print('%s is %d years old' %
      (pet.name, pet.animal.age))
>>>
Gregory the Gila is 5 years old
```

Finally: age is part of `Animal`

```
class Animal:
  def __init__(self, age, *,
                     has_scales=False,
                     lays_eggs=False,
                     drinks_milk=False):
    self.age = age
    self.has_scales = has_scales
    self.lays_eggs = lays_eggs
    self.drinks_milk = drinks_milk

  ...
```

Finally: Pet has no concept of age

```
class Pet:
    def __init__(self, name, animal):
        self.animal = animal
        self.name = name
        self.treats_eaten = 0

    ...
```

Again: Gregory is older than I thought

```
animal = Animal(3, has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', animal)
pet.age = 5

print('%s is %d years old' %
      (pet.name, pet.animal.age))
```

Surprise! Old usage is doubly broken

```
animal = Animal(3, has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', animal)
pet.age = 5

print('%s is %d years old' %
      (pet.name, pet.animal.age))
>>>
Gregory the Gila is 3 years old
```

Surprise! Old usage is doubly broken

```
animal = Animal(3, has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', animal)
pet.age = 5  # No error!

print('%s is %d years old' %
      (pet.name, pet.animal.age))

>>>
Gregory the Gila is 3 years old
```

Need defensive property tombstones

```
class Pet:
  ...

  @property
  def age(self):
    raise AttributeError('Use animal')

  @age.setter
  def age(self, new_age):
    raise AttributeError('Use animal')
```

Now accidental old usage will break

```python
animal = Animal(3, has_scales=True,
                lays_eggs=True)
pet = Pet('Gregory the Gila', animal)
pet.age = 5  # Error
```

```
>>>
Traceback ...
AttributeError: Use animal
```

Things to remember

- Use `@property.setter` to move fields that can be assigned

- Defend against muscle memory with tombstone `@property`s

Follow-up

Links

- PMOTW: Warnings - Doug Hellmann
- Stop Writing Classes - Jack Diederich
- Beyond PEP 8 - Raymond Hettinger

Links

- This talk's code & slides:
  - github.com/bslatkin/pycon2016
- My book: EffectivePython.com
  - Discount today: informit.com/deals
- Me: @haxor and onebigfluke.com

Appendix

Bonus: Extract Closure

Calculating stats for students

```
class Grade:
  def __init__(self, student, score):
    self.student = student
    self.score = score

grades = [
  Grade('Jim', 92), Grade('Jen', 89),
  Grade('Ali', 73), Grade('Bob', 96),
]
```

Calculating stats for students

```
def print_stats(grades):
  total, count, lo, hi = 0, 0, 100, 0
  for grade in grades:
    total += grade.score
    count += 1
    if grade.score < lo:
      lo = grade.score
    elif grade.score > hi:
      hi = grade.score
  print('Avg: %f, Lo: %f Hi: %f' %
        (total / count, lo, hi))
```

Calculating stats for students

```
print_stats(grades)
```

```
>>>
Avg: 87.5, Lo: 73.0, Hi: 96.0
```

Before

```
def print_stats(grades):
  total, count, lo, hi = 0, 0, 100, 0
  for grade in grades:
    total += grade.score
    count += 1
    if grade.score < lo:
      lo = grade.score
    elif grade.score > hi:
      hi = grade.score
  print('Avg: %f, Lo: %f Hi: %f' %
        (total / count, lo, hi))
```

After: Extract a stateful closure

```
def print_stats(grades):
  total, count, lo, hi = 0, 0, 100, 0

  def adjust_stats(grade):  # Closure
    ...

  for grade in grades:
    adjust_stats(grade)

  print('Avg: %f, Lo: %f Hi: %f' %
        (total / count, lo, hi))
```

Stateful closure functions are messy

```
def print_stats(grades):
  total, count, lo, hi = 0, 0, 100, 0

  def adjust_stats(grade):
    nonlocal total, count, lo, hi
    total += grade.score
    count += 1
    if grade.score < lo:
      lo = grade.score
    elif grade.score > hi:
      hi = grade.score
  ...
```

Instead: Stateful closure class

```
class CalculateStats:
    def __init__(self):
        self.total = 0
        self.count = 0
        self.lo = 100
        self.hi = 0

    def __call__(self, grade): ...

    @property
    def avg(self): ...
```

Instead: Stateful closure class

```
class CalculateStats:
  def __init__(self): ...

  def __call__(self, grade):
    self.total += grade.score
    self.count += 1
    if grade.score < self.lo:
      self.lo = grade.score
    elif grade.score > self.hi:
      self.hi = grade.score
```

Instead: Stateful closure class

```
class CalculateStats:
  def __init__(self): ...

  def __call__(self, grade): ...

  @property
  def avg(self):
    return self.total / self.count
```

Before

```
def print_stats(grades):
  total, count, lo, hi = 0, 0, 100, 0
  for grade in grades:
    total += grade.score
    count += 1
    if grade.score < lo:
      lo = grade.score
    elif grade.score > hi:
      hi = grade.score
  print('Avg: %f, Lo: %f Hi: %f' %
        (total / count, lo, hi))
```

Before: Closure function

```
def print_stats(grades):
  total, count, lo, hi = 0, 0, 100, 0

  def adjust_stats(grade):  # Closure
    ...

  for grade in grades:
    adjust_stats(grade)

  print('Avg: %f, Lo: %f Hi: %f' %
        (total / count, lo, hi))
```

After: Using stateful closure class

```
def print_stats(grades):
  stats = CalculateStats()




  for grade in grades:
    stats(grade)

  print('Avg: %f, Lo: %f Hi: %f' %
        (stats.avg, stats.lo, stats.hi))
```

Things to remember

- Extracting a closure function can make code less clear
- Use `__call__` to indicate that a class is just a stateful closure
- Closure classes can be tested independently