```
#!/usr/bin/env python3
# vim: ts=2 sw=2 sts=2 et :
"""
./sublime.py [OPTIONS]
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S.U.B.L.I.M.E. =
Sublime's unsupervised bifurcation: let's infer minimal explanations.

OPTIONS:

  -Max      max numbers to keep          : 512
  -Some     find 'far' in this many egs  : 512
  -cautious  On any crash, stop+show stack : False
  -data     data file                    : data/auto93.csv
  -enough   min leaf size                : .5
  -help     show help                    : False
  -far      how far to look in 'Some'    : .9
  -p        distance coefficient         : 2
  -seed     random number seed           : 10019
  -todo     start up task                : nothing
  -xsmall   Cohen's small effect         : .35

## See Also

[issues](https://github.com/timm/sublime/issues)
:: [repo)(https://github.com/timm/sublime)
:: [view source](https://github.com/timm/sublime/blob/main/docs/pdf)

![](https://img.shields.io/badge/purpose-se--ai-blueviolet)
![](https://img.shields.io/badge/language-python3-orange)
![](https://img.shields.io/badge/platform-osx,linux-pink)
<a href=https://github.com/timm/sublime/actions/workflows/main.yml><img
src=https://github.com/timm/sublime/actions/workflows/main.yml/badge.svg></a>
[![DOI](https://zenodo.org/badge/DOI/10.5281/zenodo.5912461.svg)](https://doi.org/10.5281/zenodo.5912461)

## Algorithm

Stochastic clustering to generate tiny models.  Uses random projections
to divide the space. Then, optionally, explain the clusters by
unsupervised iterative dichotomization using ranges that most
distinguish sibling clusters.

### Example1: just bi-cluster on two distant points

```
/sublime.py -c -s $RANDOM -t cluster
                                :  398
|..                             :  199
|.. |..                         :  99
|.. |.. |..                     :  49   Lbs-   Acc+  Mpg+
|.. |.. |.. |..                 :  24  : [2255, 15.5, 30]
|.. |.. |.. |..                 :  25  : [2575, 16.4, 30]
|.. |.. |..                     :  50
|.. |.. |.. |..                 :  25  : [2110, 16.4, 30] <== best
|.. |.. |.. |..                 :  25  : [2205, 16, 30]
|.. |..                         :  100
|.. |.. |..                     :  50
|.. |.. |.. |..                 :  25  : [2234, 15.5, 30]
|.. |.. |.. |..                 :  25  : [2278, 16.5, 30]
|.. |.. |..                     :  50
|.. |.. |.. |..                 :  25  : [2220, 15.5, 30]
|.. |.. |.. |..                 :  25  : [2320, 15.8, 30]
|..                             :  199
|.. |..                         :  99
|.. |.. |..                     :  49
|.. |.. |.. |..                 :  24  : [2451, 16.5, 20]
|.. |.. |.. |..                 :  25  : [3021, 15.5, 20]
|.. |.. |..                     :  50
|.. |.. |.. |..                 :  25  : [3425, 17.6, 20]
|.. |.. |.. |..                 :  25  : [3155, 16.7, 20]
|.. |..                         :  100
|.. |.. |..                     :  50
|.. |.. |.. |..                 :  25  : [4141, 13.5, 10]
|.. |.. |.. |..                 :  25  : [4054, 13.2, 20]
|.. |.. |..                     :  50
|.. |.. |.. |..                 :  25  : [4425, 11, 10]
|.. |.. |.. |..                 :  25  : [4129, 13, 10]
```

Example2: as above but split on range that most divides data

```
./sublime.py -c -s $RANDOM -t xplain
                                    Lbs-  Acc+  Mgg+
                                :  398 : [2807, 15.5, 20]
198 <= Lbs < 454                :  167 : [3725, 14.5, 20]
|.. Modl < 72                   :   34 : [3609, 13,   20]
|.. Modl >= 72                  :  133 : [3735, 14.9, 20]
|.. |.. Cylr < 8               :   56 : [3336, 17,   20]
|.. |.. |.. 77 <= Modl < 82     :   22 : [3410, 17.1, 20]
|.. |.. |.. Modl < 77 or Modl >= 82  :   34 : [3233, 17,   20]
|.. |.. Cylr >= 8              :   77 : [4129, 13.2, 20]
|.. |.. |.. Modl < 75          :   37 : [4274, 13,   10]
|.. |.. |.. Modl >= 75         :   40 : [3962, 13.5, 20]
|.. |.. |.. |.. Lbs >= 302     :   35 : [4054, 13.2, 20]
Lbs < 198 or Lbs >= 454         :  231 : [2290, 16,   30] <== best
```

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SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
"""

import traceback, random, copy, math, sys, re
from random import random as r
from typing import Any
```

```python
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def any(a:list) -> Any:
  "Return a random item."
  return a[anywhere(a)]

def anywhere(a:list) -> int:
  "Return a random index of list ‘a‘."
  return random.randint(0, len(a)-1)

big = sys.maxsize

def atom(x):
  "Return a number or trimmed string."
  x=x.strip()
  if   x=="True" : return True
  elif x=="False": return False
  else:
    try: return int(x)
    except:
      try: return float(x)
      except: return x.strip()

def demo(do,all):
  "Maybe run a demo, if we want it, resetting random seed first."
  todo = dir(all)
  if do and do != "all":
    todo = [x for x in dir(all) if x.startswith(do)]
  for one in todo:
    fun = all.__dict__.get(one,"")
    if type(fun)==type(demo):
      random.seed(the.seed)
      doc = re.sub(r"\n\s+", "\n", fun.__doc__ or "")
      try:
        fun()
        print("PASS:", doc)
      except Exception as e:
        all.fails += 0
        if the.cautious : traceback.print_exc(); exit(1)
        else            : print("FAIL:", doc, e)
  exit(all.fails)

def file(f):
  "Iterator. Returns one row at a time, as cells."
  with open(f) as fp:
    for line in fp:
      line = re.sub(r'([\n\t\r"\' ]|#.*)', '', line)
      if line:
        yield [cell.strip() for cell in line.split(",")]

def first(a:list) -> Any:
  "Return first item."
  return a[0]

def merge(b4:list) -> list:
  "While we can find similar adjacent things, merge them."
  j,n,now = -1,len(b4),[]
  while j < n-1:
    j += 1
    a  = b4[j]
    if j < n-2:
      if merged := a.merge(b4[j+1]):
        a  = merged
        j += 1 # we will continue, after missing one
    now += [a]
  # if `now` is same size as `b4`, look for any other merges.
  return b4 if len(now)==len(b4) else merge(now)

class o(object):
  "Class that can pretty print its slots, with fast inits."
  def __init__(i, **d): i.__dict__.update(**d)
  def __repr__(i):
    pre = i.__class__.__name__ if isinstance(i,o) else ""
    return pre+'{'+(' '.join([f":{k} {v}" for k, v in
                   sorted(i.__dict__.items()) if str(k)[0] != "_"]))+'}'

def options(doc:str) ->o:
  """Convert ‘doc‘ to options dictionary using command line args.
  Args canuse two ’shorthands’: (1) boolean flags have no arguments (and mentioning
  those on the command line means ’flip the default value’; (2) args need only
  mention the first few of a key (e.g. –s is enough to select for –seed)."""
  d={}
  for line in doc.splitlines():
    if line and line.startswith("  -"):
       key, *_, x = line.strip()[1:].split(" ") # get 1st,last word on each line
       for j,flag in enumerate(sys.argv):
         if flag and flag[0]=="-" and key.startswith(flag[1:]):
           x= "True" if x=="False" else("False" if x=="True" else sys.argv[j+1])
       d[key] = atom(x)
  if d["help"]: exit(print(re.sub(r'\n#.*',"",doc,flags=re.S)))
  return o(**d)

def r() -> float:
  "Return random number 0..1"
  return random.random()

def rn(x:float, n=3) -> float:
  "Round a number to three decimals."
  return round(x,n)

def rN(a:list, n=3) -> list:
  "Round a list of numbers to three decimals."
  return [rn(x,n=n) for x in a]

def second(a:list) -> Any:
  "Return second item."
  return a[1]
#          ___
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#    ___  \//\ \      __      ____    ____     __    ____
#   /'___\  \ \ \   /'__`\   /',__\  /',__\  /'__`\ /',__\
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class Span(o):
  """Given two ‘Sample‘s and some ‘x‘ range ‘lo..hi‘,
  a ‘Span‘ holds often that range appears in each ‘Sample‘."""
  def __init__(i,col, lo, hi, ys=None,):
    i.col, i.lo, i.hi, i.ys = col, lo, hi,  ys or Sym()

  def add(i, x:float, y:Any, inc=1) -> None:
    "‘y‘ is a label identifying, one ‘Sample‘ or another."
    i.lo = min(x, i.lo)
    i.hi = max(x, i.hi)
    i.ys.add(y,inc)

  def merge(i, j): # -> Span|None
    "If the merged span is simpler, return that merge."
    a, b, c = i.ys, j.ys, i.ys.merge(j.ys)
    if (i.ys.n==0 or j.ys.n==0 or
        c.div()*.99 <= (a.n*a.div() + b.n*b.div())/(a.n + b.n)):
      return Span(i.col, min(i.lo,j.lo),max(i.hi,j.hi), ys=c)

  def selects(i,row:list) -> bool:
    "True if the range accepts the row."
    x = row[i.col.at]; return x=="?" or i.lo<=x and x<i.hi

  def show(i, positive=True) -> None:
    "Show the range."
    txt = i.col.txt
    if positive:
      if   i.lo == i.hi: return f"{txt} == {i.lo}"
      elif i.lo == -big: return f"{txt} < {i.hi}"
      elif i.hi ==  big: return f"{txt} >= {i.lo}"
      else             : return f"{i.lo} <= {txt} < {i.hi}"
    else:
      if   i.lo == i.hi: return f"{txt} != {i.lo}"
      elif i.lo == -big: return f"{txt} >= {i.hi}"
      elif i.hi ==  big: return f"{txt} < {i.lo}"
      else             : return f"{txt} < {i.lo} or {txt} >= {i.hi}"

  def support(i) -> float:
    "Returns 0..1."
    return i.ys.n / i.col.n

  @staticmethod
  def sort(spans : list) -> list:
    "Good spans have large support and low diversity."
    divs, supports = Num(512), Num(512)
    sn = lambda s: supports.norm( s.support())
    dn = lambda s: divs.norm(     s.ys.div())
    f  = lambda s: ((1 - sn(s))**2 + dn(s)**2)**.5/2**.5
    for s in spans:
      divs.add(    s.ys.div())
      supports.add(s.support())
    return sorted(spans, key=f)

#            _
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class Col(o):
  "Summarize columns."
  def __init__(i,at=0,txt=""):
    i.n,i.at,i.txt,i.w=0,at,txt,(-1 if "-" in txt else 1)

  def dist(i,x:Any, y:Any) -> float:
    return 1 if x=="?" and y=="?" else i.dist1(x,y)

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class Sym(Col):
  "Summarize symbolic columns."
  def __init__(i,**kw):
    super().__init__(**kw)
    i.has, i.mode, i.most = {}, None, 0

  def add(i, x:str, inc:int=1) -> str:
    "Update symbol counts in ‘has‘, updating ‘mode‘ as we go."
    if x != "?":
      i.n += inc
      tmp = i.has[x] = inc + i.has.get(x,0)
      if tmp > i.most: i.most, i.mode = tmp, x
    return x

  def dist(i,x:str, y:str) ->float:
    "Distance between two symbols."
    return 0 if x==y else 1

  def div(i):
    "Return diversity of this distribution (using entropy)."
    p = lambda x: x / (1E-31 + i.n)
    return sum( -p(x)*math.log(p(x),2) for x in i.has.values() )

  def merge(i,j):
    "Merge two ‘Sym‘s."
    k = Sym(at=i.at, txt=i.txt)
    for x,n in i.has.items(): k.add(x,n)
    for x,n in j.has.items(): k.add(x,n)
    return k

  def mid(i) -> Any:
    "Return central tendency of this distribution (using mode)."
    return i.mode

  def prep(i,x) -> Any:
    "Return ‘x‘ as anything at all."
    return x

  def spans(i,j, _bins, out):
    """For each symbol in ‘i‘ and ‘j‘, count the
  number of times we see it on either side."""
    xys = [(x,"this",n) for x,n in i.has.items()] + [
           (x,"that",n) for x,n in j.has.items()]
    one, last = None,None
    all  = []
    for x,y,n in sorted(xys, key=first):
      if x != last:
        last = x
        one  = Span(i, x,x)
        all += [one]
      one.add(x,y,n)
    if len(all) > 1 : out += all
```

```python
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class Num(Col):
  "Summarize numeric columns."
  def __init__(i,size,**kw):
    super().__init__(**kw)
    i._all, i.lo, i.hi, i.max, i.ok = [], 1E32, -1E32, size, False

  def add(i,x: float ,inc=1):
    "Reservoir sampler. If ‘_all‘ is full, sometimes replace an item at random."
    if x != "?":
      i.n += inc
      i.lo = min(x,i.lo)
      i.hi = max(x,i.hi)
      if len(i._all) < i.max    : i.ok=False; i._all += [x]
      elif r()       < i.max/i.n: i.ok=False; i._all[anywhere(i._all)] = x
    return x

  def all(i):
    "Return ‘_all‘, sorted."
    if not i.ok: i.ok=True; i._all.sort()
    return i._all

  def dist1(i,x,y):
    if   x=="?": y=i.norm(y); x=(1 if y<.5 else 0)
    elif y=="?": x=i.norm(x); y=(1 if x<.5 else 0)
    else       : x,y = i.norm(x), i.norm(y)
    return abs(x-y)

  def div(i):
    """Report the diversity of this distribution (using standard deviation).
  &pm;2, 2.56, 3 &sigma; is 66,90,95%, of the mass.  28&sigma;. So one
  standard deviation is (90-10)th divide by  2.4 times &sigma;."""
    return (i.per(.9) - i.per(.1)) / 2.56

  def merge(i,j):
    "Return two ‘Num‘s."
    k = Num(i.max, at=i.at, txt=i.txt)
    for x in i._all: k.add(x)
    for x in j._all: k.add(x)
    return k

  def mid(i):
    "Return central tendency of this distribution (using median)."
    return i.per(.5)

  def norm(i,x):
    "Normalize ‘x‘ to the range 0..1."
    return 0 if i.hi-i.lo < 1E-9 else (x-i.lo)/(i.hi-i.lo)

  def per(i,p:float=.5) -> float:
    "Return the p-th ranked item."
    a = i.all(); return a[ int(p*len(a)) ]

  def prep(i,x):
    "Return ‘x‘ as a float."
    return x if x=="?" else float(x)

  def spans(i,j, bins, out):
    """Divide the whole space ‘lo‘ to ‘hi‘ into, say, ‘xsmall‘=16 bin,
  then count the number of times we the bin on other side.
  Then merge similar adjacent bins."""
    lo  = min(i.lo, j.lo)
    hi  = max(i.hi, j.hi)
    gap = (hi-lo) / bins
    xys = [(x,"this",1) for x in i._all] + [
           (x,"that",1) for x in j._all]
    one = Span(i,lo,lo)
    all = [one]
    for x,y,n in sorted(xys, key=first):
      if one.hi - one.lo > gap:
        one  = Span(i, one.hi,x)
        all += [one]
      one.add(x,y,n)
    all = merge(all)
    all[ 0].lo = -big
    all[-1].hi =  big
    if len(all) > 1: out += all
#                _      _
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class Explain(o):
  "Tree with ‘yes‘,‘no‘ branches for samples that do/do not match a ‘span‘."
  def __init__(i,here):
    i.here, i.span, i.yes, i.no = here, None, None, None

  def show(i,pre=""):
    if not pre:
      tmp= i.here.mid(i.here.y)
      print(f"{'':40} : {len(i.here.rows):5} : {tmp}")
    if i.yes:
      s=f"{pre}{i.span.show(True)}"
      tmp= i.yes.here.mid(i.yes.here.y)
      print(f"{s:40} : {len(i.yes.here.rows):5} : {tmp}")
      i.yes.show(pre + "|.. ")
    if i.no:
      s=f"{pre}{i.span.show(False)}"
      tmp= i.no.here.mid(i.no.here.y)
      print(f"{s:40} : {len(i.no.here.rows):5} : {tmp}")
      i.no.show(pre + "|.. ")

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#
class Cluster(o):
  "Tree with ‘left‘,‘right‘ samples, broken at median between far points."
  def __init__(i,here,x=None,y=None,c=None,mid=None):
    i.here,i.x,i.y,i.c,i.mid,i.left,i.right = here,x,y,c,mid,None,None

  def show(i,pre=""):
    s= f"{pre:40} : {len(i.here.rows):5}"
    print(f"{s}" if i.left  else f"{s} : {i.here.mid(i.here.y)}")
    for kid in [i.left,i.right]:
      if kid: kid.show(pre + "|.. ")
#                       _
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#                |_|

class Sample(o):
  "Load, then manage, a set of examples."

  def __init__(i, the, inits=[]):
    i.the = the
    i.rows, i.cols, i.x, i.y, i.klass = [], [], [], [],None
    if str ==type(inits): [i.add(row, True) for row in file(inits)]
    if list==type(inits): [i.add(row) for row in inits]

  def add(i, a, raw=False):
    pre    = lambda a,c: c.prep(a[c.at]) if raw else a[c.at]
    nump   = lambda x  : x[0].isupper()
    skipp  = lambda x  : x[-1]==":"
    klassp = lambda x  : "!" in x
    goalp  = lambda x  : "+" in x or "-" in x or klassp(x)
    #----------------
    def col(at,txt):
      now  = Num(i.the.Max,at=at,txt=txt) if nump(txt) else Sym(at=at,txt=txt)
      where= i.y if goalp(txt) else i.x
      if not skipp(txt):
        where += [now]
        if klassp(txt): i.klass = now
      return now
    #-----------
    if i.cols: i.rows += [[col.add(pre(a,col)) for col in i.cols]]
    else:      i.cols  = [col(at,txt) for at,txt in enumerate(a)]

  def clone(i,inits=[]):
    out = Sample(i.the)
    out.add([col.txt for col in i.cols])
    [out.add(x) for x in inits]
    return out

  def cluster(i,top=None):
    """Split the data using random projections. Find the span that most
  separates the data. Divide data on that span."""
    here = Cluster(i)
    top = top or i
    if len(i.rows) >= 2*(len(top.rows)**i.the.enough):
      left,right,x,y,c,mid = i.half(top)
      if len(left.rows) < len(i.rows):
        here       = Cluster(i,x,y,c,mid)
        here.left  = left.cluster(top)
        here.right = right.cluster(top)
    return here

  def dist(i,x,y):
    d = sum( col.dist(x[col.at], y[col.at])**i.the.p for col in i.x )
    return (d/len(i.x)) ** (1/i.the.p)

  def div(i,cols=None):
    return [col.div() for col in (cols or i.all)]

  def far(i, x, rows=None):
    tmp= sorted([(i.dist(x,y),y) for y in (rows or i.rows)],key=first)
    return tmp[ int(len(tmp)*i.the.far) ]

  def half(i, top=None):
    "Using two faraway points ‘x,y‘ break data at median distance."
    some= i.rows if len(i.rows)<i.the.Some else random.choices(i.rows, k=the.Som
e)
    top= top or i
    w  = any(some)
    _,x= top.far(w, some)
    c,y= top.far(x, some)
    tmp= [r for _,r in sorted([(top.proj(r,x,y,c),r)
                              for r in i.rows],key=first)]
    mid= len(tmp)//2
    return i.clone(tmp[:mid]), i.clone(tmp[mid:]), x, y, c, tmp[mid]

  def mid(i,cols=None):
    return [col.mid() for col in (cols or i.all)]

  def proj(i,row,x,y,c):
    "Find the distance of a ‘row‘ on a line between ‘x‘ and ‘y‘."
    a = i.dist(row,x)
    b = i.dist(row,y)
    return (a**2 + c**2 - b**2) / (2*c)

  def xplain(i,top=None):
    """Split the data using random projections. Find the span that most
  separates the data. Divide data on that span."""
    here = Explain(i)
    top = top or i
    tiny = len(top.rows)**i.the.enough
    if len(i.rows) >= 2*tiny:
      left, right,*_ = i.half(top)
      spans = []
      [lcol.spans(rcol,6/i.the.xsmall,spans) for lcol,rcol
                                          in zip(left.x, right.x)]
      if len(spans) > 0:
        here.span = Span.sort(spans)[0]
        yes, no = i.clone(), i.clone()
        [(yes if here.span.selects(row) else no).add(row) for row in i.rows]
        if tiny <= len(yes.rows) < len(i.rows): here.yes = yes.xplain(top=top)
        if tiny <= len(no.rows ) < len(i.rows): here.no  = no.xplain(top=top)
    return here
```

```
#    _
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#  \_\ \       __     ___ ___      ___     ____
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# /\ \L\ \ /\  __/ /\ \/\ \/\ \ /\ \L\ \/\__, `\
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class Demos:
  "Possible start-up actions."
  fails=0
  def opt():
    "show the config."
    print(the)

  def seed():
    "seed"
    assert .494 <= r() <= .495

  def num():
    "check `Num`."
    n = Num(512)
    for _ in range(100): n.add(r())
    assert .30 <= n.div() <= .31, "in range"

  def sym():
    "check `Sym`."
    s = Sym()
    for x in "aaaabbc": s.add(x)
    assert 1.37 <= s.div() <= 1.38, "entropy"
    assert 'a'  == s.mid(), "mode"

  def rows():
    "count rows in a file."
    assert 399 == len([row for row in file(the.data)])

  def sample():
    "sampling."
    s = Sample(the, the.data)
    print(the.data, len(s.rows))
    assert 398 == len(s.rows),     "length of rows"
    assert 249 == s.x[-1].has['1'], "symbol counts"

  def dist():
    "distance between rows"
    s = Sample(the, the.data)
    assert .84 <= s.dist(s.rows[1], s.rows[-1]) <= .842

  def far():
    "distant items"
    s = Sample(the, the.data)
    for _ in range(32):
      a,_ = s.far(any(s.rows))
      assert a>.5, "large?"

  def clone():
    "cloning"
    s = Sample(the, the.data)
    s1 = s.clone(s.rows)
    d1,d2 = s.x[0].__dict__, s1.x[0].__dict__
    for k,v in d1.items():
      assert d2[k] == v, "clone test"

  def half():
    "divide data in two"
    s = Sample(the, the.data)
    s1,s2,*_ = s.half()
    print(s1.mid(s1.y))
    print(s2.mid(s2.y))

  def cluster():
    "divide data in two"
    s = Sample(the, the.data)
    s.cluster().show(); print("")

  def xplain():
    "divide data in two"
    s = Sample(the, the.data)
    s.xplain().show(); print("")

#--------------------------------------------------
the=options(__doc__)
if __name__ == "__main__": demo(the.todo,Demos)

"""
Example class
"""
```