```python
#!/usr/bin/env python3
# vim: ts=2 sw=2 sts=2 et :
```

```
"""
./sublime.py [OPTIONS]
(c)2022 Tim Menzies <timm@ieee.org> unlicense.org.
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](issues) âM-^@¢ [repo](github)

## Algorithm

Stochastic clustering to generate tiny models.  Uses random projections
then   unsupervised iterative dichotomization using ranges that
most distinguish sibling clusters.

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"""
```
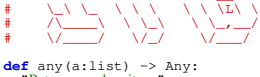

```python
import traceback, random, math, sys, re
from random import random as r
from typing import Any
```



```python
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 [atom(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+str(
      {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 second(a:list) -> Any:
  "Return second item."
  return a[1]

the = options(__doc__)
```

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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 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[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(), Num()
    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
    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 Num(Col):
  "Summarize numeric columns."
  def __init__(i,**kw):
    super().__init__(**kw)
    i._all, i.lo, i.hi, i.max, i.ok = [], 1E32, -1E32, the.Max, 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(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 spans(i,j, all):
    """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) / (6/the.xsmall)
    at  = lambda z: lo + int((z-lo)/gap)*gap
    tmp = {}
    for x in map(at, i._all):
      s = tmp[x] = tmp[x] if x in tmp else Span(i,x,x+gap)
      s.add(x,0)
    for x in map(at, j._all):
      s = tmp[x] = tmp[x] if x in tmp else Span(i,x,x+gap)
      s.add(x,1)
    tmp = merge([x for _,x in sorted(tmp.items(),key=first)])
    if len(tmp) > 1 : all + tmp

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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/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 k,n in i.has.items(): k.add(x,n)
    for k,n in j.has.items(): k.add(x,n)
    return k

  def mid(i):
    "Return central tendancy of this distribution (using mode)."
    return i.mode

  def spans(i,j, all):
    """For each symbol in ‘i‘ and ‘j‘, count the
  number of times we see it on either side."""
    tmp = {}
    for x,n in i.has.items():
      s = tmp[x] = (tmp[x] if x in tmp else Span(i,x,x))
      s.add(x,0,n)
    for x,n in j.has.items():
      s = tmp[x] = (tmp[x] if x in tmp else Span(i,x,x))
      s.add(x,1,n)
    tmp = [second(x) for x in sorted(tmp.items(), key=first)]
    if len(tmp) > 1 : all + tmp

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class Sample(o):
  "Load, then manage, a set of examples."
  def __init__(i,inits=[]):
    i.rows, i.cols, i.x, i.y = [], [], [], []
    if str ==type(inits): [i + row for row in file(inits)]
    if list==type(inits): [i + row for row in inits]

  def __add__(i,a):
    def col(at,txt):
      what  = Num if txt[0].isupper() else Sym
      now   = what(at=at, txt=txt)
      where = i.y if "+" in txt or "-" in txt or "!" in txt else i.x
      if txt[-1] != ":": where += [now]
      return now
    #-----------
    if i.cols: i.rows += [[col.add(a[col.at]) for col in i.cols]]
    else:      i.cols  = [col(at,txt) for at,txt in enumerate(a)]

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

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

  def half(i, top=None):
    top  = top or i
    some = random.choices(i.rows, k=the.Some)
    w    = some[0]
    _,x  = top.far(w, some)
    c,y  = top.far(x, some)
    left, right = i.clone(), i.clone()
    for n,(_,r) in enumerate(
                  sorted([top.proj(r,x,y,c) for r in i.rows],key=first)):
      (left if n <= len(i.rows)//2 else right).__add__(r)
    return left,right

  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) , row)

  def split(i,top=None):
    """Split the data using random projections. Find the span that most
  separates the data. Divide data on that span."""
    here = Tree(i)
    top = top or i
    if len(i.rows) >= 2*len(top.rows)**the.enough:
      left, right = i.half(top)
```

```
      spans = []
      [lcol.spans(rcol,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 span.selects(row) else no).add(row) for row in i.rows]
        if len(yes.rows) < len(i.rows): here.yes = yes.split(top)
        if len(no.rows ) < len(i.rows): here.no  = no.split(top)
    return here

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class Tree(o):
  """Binary tree that splits into 'yes','no' branches containing 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=""):
    "Print tree with indents."
    print(f"{pre}{i.span.ys.n}")
    if i.yes:
      print(f"{pre}  {i.span.show(True)}") ; i.yes.show(pre + "|.. ")
    if i.no:
      print(f"{pre}  {i.span.show(False)}"); i.no.show( pre + "|.. ")
```

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class Demos:
  "Possible start-up actions."
  fails=0
  def opt():
    "show the config."
    [print(f"{k:>10} = {v}") for k,v in the.__dict__.items()]

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

  def num():
    "check 'Num'."
    n = Num()
    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.data)
    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.data)
    assert .84 <= s.dist(s.rows[1], s.rows[-1]) <= .842

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

  def clone():
    "cloning"
    s=Sample(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.data); s1,s2 = s.half()
    print(s1.mid(s1.y))
    print(s2.mid(s2.y))

if __name__ == "__main__": demo(the.todo,Demos)
```