```
#!/usr/bin/env python3
"""
bing1.py: tiny AI. multi objective, explainable, AI
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Options, with (defaults):

  -f  file      data name (../moot/optimize/misc/auto93.csv)
  -r  rseed     set random number rseed (123456781)
  -F  Few       a few rows to explore (64)
  -l  leaf      tree learning: min leaf size (2)
  -p  p         distance calcs: set Minkowski coefficient (2)

Bayes:
  -k  k         bayes hack for rare classes (1)
  -m  m         bayes hack for rare attributes (2)

Active learning:
  -A  Acq       xploit or xplore or adapt (xploit)
  -s  start     guesses, initial (4)
  -S  Stop      guesses, max (20)
  -G  Guess     division best and rest (0.5)

Stats:
  -B  Boots     significance threshold (0.95)
  -b  bootstrap  num. bootstrap samples (512)
  -C  Cliffs    effect size threshold (0.197)
  """
import traceback,random,math,sys,re
sys.dont_write_bytecode = True

### Sample data ------------------------------------------------------------
EXAMPLE="""
Max_spout, hashing, Spliters, Counters, Throughput+, Latency-
1     ,off  ,1  ,1  ,4255.3  ,2.5621
1     ,on   ,1  ,3  ,4160.1  ,2.6057
1     ,off  ,1  ,6  ,4089.5  ,2.55
1     ,on   ,1  ,9  ,4156.9  ,2.5688
1     ,on   ,1  ,12  ,4013.8  ,2.5474
1     ,off  ,1  ,15  ,4194.1  ,2.5676
1     ,on   ,1  ,18  ,3964.2  ,2.5503
1     ,off  ,2  ,1  ,4294.7  ,4.7793
1     ,on   ,2  ,3  ,4343.6  ,2.381
1     ,off  ,2  ,6  ,4423.6  ,2.3538
1     ,on   ,2  ,9  ,4369.6  ,2.4306
1     ,off  ,2  ,12  ,4288.1  ,2.3965
1     ,on   ,2  ,15  ,4291.2  ,2.4462
1     ,off  ,2  ,18  ,4236.2  ,2.4647
1     ,on   ,3  ,1  ,4980.3  ,2.1598
1     ,off  ,3  ,3  ,5058.6  ,3.5506
1     ,on   ,3  ,6  ,4836.7  ,2.1283
1     ,off  ,3  ,9  ,4786.9  ,2.1468
1     ,on   ,3  ,12  ,4528.8  ,3.0358
1     ,off  ,3  ,15  ,4767.6  ,2.2173
1     ,on   ,3  ,18  ,4949.1  ,2.1277
1     ,off  ,6  ,1  ,4904.2  ,2.1626
1     ,on   ,6  ,3  ,5151  ,2.0815
1     ,off  ,6  ,6  ,4847.1  ,2.1376
1     ,on   ,6  ,9  ,4891.9  ,2.1503
1     ,off  ,6  ,12  ,4871  ,2.2277
1     ,on   ,6  ,15  ,4645.8  ,2.1468
1     ,off  ,6  ,18  ,4688.1  ,2.2277
10    ,on   ,1  ,1  ,8226.1  ,13.733
10    ,off  ,1  ,3  ,12697  ,9.2121
10    ,on   ,1  ,6  ,14870  ,8.1247
10    ,off  ,1  ,9  ,14807  ,7.5491
10    ,on   ,1  ,12  ,15374  ,7.1335
10    ,off  ,1  ,15  ,16019  ,7.3717
10    ,on   ,1  ,18  ,15103  ,7.3965
10    ,off  ,2  ,1  ,7006.2  ,15.859
10    ,on   ,2  ,3  ,14169  ,8.1471
10    ,off  ,2  ,6  ,18462  ,6.481
10    ,on   ,2  ,9  ,18652  ,6.2867
10    ,off  ,2  ,12  ,20233  ,5.7734
10    ,on   ,2  ,15  ,19505  ,5.6023
10    ,off  ,2  ,18  ,19335  ,5.641
10    ,on   ,3  ,1  ,8219.4  ,13.865
10    ,off  ,3  ,3  ,14591  ,7.6695
10    ,on   ,3  ,6  ,15736  ,7.2908
10    ,off  ,3  ,9  ,17161  ,6.5827
10    ,on   ,3  ,12  ,17130  ,6.2694
10    ,off  ,3  ,15  ,17209  ,6.2798
10    ,on   ,3  ,18  ,16140  ,7.2948
10    ,off  ,6  ,1  ,7524.2  ,13.959
10    ,on   ,6  ,3  ,16238  ,7.0838
10    ,off  ,6  ,6  ,20089  ,5.2988
10    ,on   ,6  ,9  ,20066  ,5.0202
10    ,off  ,6  ,12  ,19528  ,4.9185
10    ,on   ,6  ,15  ,19157  ,5.0006
10    ,off  ,6  ,18  ,18380  ,5.0711
100   ,on   ,1  ,1  ,8511.2  ,135.2
100   ,off  ,1  ,3  ,15515  ,75.825
100   ,on   ,1  ,6  ,18264  ,61.409
100   ,off  ,1  ,9  ,18652  ,62.08
100   ,on   ,1  ,12  ,20872  ,55.886
100   ,off  ,1  ,15  ,19875  ,53.539
100   ,on   ,1  ,18  ,20121  ,56.687
100   ,off  ,2  ,1  ,8746  ,117.57
100   ,on   ,2  ,3  ,18568  ,65.437
100   ,off  ,2  ,6  ,20814  ,53.103
100   ,on   ,2  ,9  ,24962  ,43.247
100   ,off  ,2  ,12  ,26373  ,40.169
100   ,on   ,2  ,15  ,25948  ,46.001
100   ,off  ,2  ,18  ,25565  ,39.447
100   ,on   ,3  ,1  ,8465.1  ,132.78
100   ,off  ,3  ,3  ,16941  ,65.185
100   ,on   ,3  ,6  ,20045  ,58
100   ,off  ,3  ,9  ,21448  ,54.396
100   ,on   ,3  ,12  ,20821  ,56.731
100   ,off  ,3  ,15  ,23240  ,51.463
100   ,on   ,3  ,18  ,21234  ,53.927
100   ,off  ,6  ,1  ,9214.4  ,116.13
100   ,on   ,6  ,3  ,20359  ,55.501
100   ,off  ,6  ,6  ,21587  ,48.702
100   ,on   ,6  ,9  ,23142  ,37.915
100   ,off  ,6  ,12  ,24892  ,41.478
100   ,on   ,6  ,15  ,23675  ,32.286
100   ,off  ,6  ,18  ,22884  ,33.092
1000  ,on   ,1  ,1  ,10038  ,1063.6
1000  ,off  ,1  ,3  ,20050  ,553.74
1000  ,on   ,1  ,6  ,22015  ,511.62
1000  ,off  ,1  ,9  ,24910  ,467.36
1000  ,on   ,1  ,12  ,21808  ,470.82
1000  ,off  ,1  ,15  ,23497  ,439.35
1000  ,on   ,1  ,18  ,24392  ,419.91
1000  ,off  ,2  ,1  ,8666.8  ,1239.5
1000  ,on   ,2  ,3  ,22289  ,518.71
1000  ,off  ,2  ,6  ,25805  ,463.33
1000  ,on   ,2  ,9  ,28129  ,398.1
1000  ,off  ,2  ,12  ,32399  ,332.68
1000  ,on   ,2  ,15  ,33549  ,321.53
1000  ,off  ,2  ,18  ,32815  ,341.28
1000  ,on   ,3  ,1  ,9973.9  ,1105.8
1000  ,off  ,3  ,3  ,19036  ,595.91
"""


### Utils ------------------------------------------------------------------
#### Shortcuts
big = 1E32
pick = random.choice
picks = random.choices

#### Shuffle
def shuffle(lst):
  random.shuffle(lst)
  return lst

#### Bulk inits
def adds(i, src):
  [add(i,x) for x in src]; return i

#### Read iterators.

# Iterate over lines in a file.
def doc(file):
  with open(file, 'r', newline='', encoding='utf-8') as f:
    for line in f: yield line

# Iterate over lines in a string.
def lines(s):
 for line in s.splitlines(): yield line

# Interate over rows read from lines.
def csv(src):
  for line in src:
    if line: yield [atom(s) for s in line.strip().split(',')]

#### Coerce

# String to thing
def atom(x):
  for what in (int, float):
    try: return what(x)
    except Exception: pass
  x = x.strip()
  y = x.lower()
  return (y == "true") if y in ("true", "false") else x

# Thing to string.
def cat(v):
  it = type(v)
  inf = float('inf')
  if it is list:  return "[" + ",".join(map(cat, v)) + "]"
  if it is float: return str(int(v)) if -inf<v<inf and v==int(v) else f"{v:.3g}"
  if it is dict:  return cat([f":{k} {cat(w)}" for k, w in v.items()])
  if it in [type(abs), type(cat)]: return v.__name__ + '()'
  return str(v)

#### Simple Classes

# Easy inits. Can print itself.
class o:
  __init__ = lambda i, **d: i.__dict__.update(**d)
  __repr__ = lambda i: cat(i.__dict__)


### Create -----------------------------------------------------------------

# Summary of numeric columns.
def Num(inits=[],at=0, txt=" ", rank=0):
  return adds(o(it=Num,
                n=0,        ## items seen
                at=at,      ## column position
                txt=txt,    ## column name
                mu=0,       ## mean
                sd=0,       ## standard deviation
                m2=0,       ## second moment
                hi= -big,   ## biggest seen
                lo= big,    ## smallest seen
                heaven= (0 if txt[-1] == "-" else 1), ## 0,1 = minimize,maximize
                rank= rank ## used by stats, ignored otherwise
                ), inits)

# Summary of symbolic columns.
def Sym( inits=[], at=0, txt=" "):
  return adds(o(it=Sym,
                n=0,        ## items see
                at=at,      ## column position
                txt=txt,    ## column name
                has={}      ## counts of symbols seen
                ), inits)

# Factory. <br> List[str] -> Dict[str, List[ Sym | Num ]]
def Cols(names):
  all,x,y = [],[],[]
  for c,s in enumerate(names):
    all += [(Num if s[0].isupper() else Sym)(at=c, txt=s)]
    if s[-1] != "X":
      (y if s[-1] in "+-" else x).append(all[-1])
  return o(it=Cols,
           names=names,   ## all the column names
           all=all,       ## all the columns
           x=x,           ## also, independent columns stored here
           y=y)           ## also, dependent columns stored here

# Data stores rows and columns.
def Data(inits):
  inits = iter(inits)
  return adds( o(it=Data,
                 n=0,                  ## items seen
                 _rows=[],             ## rows
                 cols=Cols(next(inits))  ## columns (which summarize the rows)
                 ), inits)

def clone(data, rows=[]):
  return Data([data.cols.names]+rows)

### Update -----------------------------------------------------------------
# Subtraction means add, with a negative increment
def sub(i,v,purge=False):
  return add(i, v, inc= -1, purge=purge)

# Add 'v' to 'i'. Skip unknowns ("?"), return v.
def add(i,v, inc=1, purge=False): # -> v
  def _sym(sym,s): sym.has[s] = inc + sym.has.get(s,0)

  def _data(data,row):
    if inc < 0:
      if purge: data._rows.remove(v)
      [sub(col, row[col.at], inc) for col in data.cols.all]
    else:
      data._rows += [row] # update rows
      [add(col, row[col.at],inc) for col in data.cols.all] # update columns

  def _num(num,n):
    num.lo = min(n, num.lo)
    num.hi = max(n, num.hi)
    if inc < 0 and num.n < 2:
      num.sd = num.m2 = num.mu = num.n = 0
    else:
      d      = n - num.mu
      num.mu += inc * (d / num.n)
      num.m2 += inc * (d * (n - num.mu))
      num.sd  = 0 if num.n <=2 else (num.m2/(num.n - 1)) ** .5

  if v != "?":
    i.n += inc
    (_num if i.it is Num else (_sym if i.it is Sym else _data))(i,v)
  return v

### Query ------------------------------------------------------------------
# Middle tendency.
def mid(i):
  _mode = lambda: max(i.has,key=i.has.get)
  return i.mu    if i.it is Num else (
         _mode() if i.it is Sym else ([mid(col) for col in i.cols.all]))

# Spread around middle tendency.
def spread(i):
  _ent = lambda: -sum(p*math.log(p,2) for n in i.has.values() if (p:=n/i.n) > 0)
  return i.sd    if i.it is Num else (
         _ent() if i.it is Sym else ([spread(col) for col in i.cols.all]))

# Map v --> (0..1) for lo..hi.
def norm(num,v):
  return v if v=="?" else (v-num.lo) / (num.hi-num.lo + 1/big)
```

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### Bayes -------------------------------------------------------------------
# Return the `data` in `datas` that likes `row` the most.
def likes(datas, row):
  n = sum(data.n for data in datas)
  return max(datas, key=lambda data: like(data, row, n, len(datas)))

# Report how much `data` like `row`.
def like(data, row, nall=2, nh=100):
  prior = (data.n + the.k) / (nall + the.k*nh)
  tmp = [pdf(c,row[c.at],prior)
         for c in data.cols.x if row[c.at] != "?"]
  return sum(math.log(n) for n in tmp + [prior] if n>0)

# How probable is it that  `v` belongs to a column?
def pdf(col,v, prior=0):
  if col.it is Sym:
    return (col.has.get(s,0) + the.m*prior) / (col.n + the.m + 1/big)
  sd = col.sd or 1 / big
  var = 2 * sd * sd
  z = (v - col.mu) ** 2 / var
  return min(1, max(0, math.exp(-z) / (2 * math.pi * var) ** 0.5))

# Split rows to best,rest. Label row that's e.g. max best/rest. Repeat.
def acquires(data):
  def _acquire(b, r, acq="xploit", p=1):
    b,r = math.e**b, math.e**r
    q   = 0 if acq=="xploit" else (1 if acq=="xplor" else 1-p)
    return (b + r*q) / abs(b*q - r + 1/big)
  def _guess(row):
    return _acquire(like(best,row,n,2), like(rest,row,n,2), the.Acq, n/the.Stop)

  random.shuffle(data._rows)
  n          = the.start
  todo       = data._rows[n:]
  bestrest   = clone(data, data._rows[:n])
  done       = ysort(bestrest)
  cut        = round(n**the.Guess)
  best       = clone(data, done[:cut])
  rest       = clone(data, done[cut:])
  while len(todo) > 2 and n < the.Stop:
    n     += 1
    hi, *lo = sorted(todo[:the.Few*2], # runs 100 times faster if only sort a Few
                     key=_guess, reverse=True)
    todo    = lo[:the.Few] + todo[the.Few*2:] + lo[the.Few:]
    add(bestrest, add(best, hi))
    best._rows = ysort(bestrest)
    if len(best._rows) >= round(n**the.Guess):
       add(rest, # runs 100 times faster if incremental update
           sub(best, best._rows.pop(-1)))
  return o(best=best, rest=rest, test=todo)


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### Distance ----------------------------------------------------------------
# Return pth root of the sum of the distances raises to p.
def minkowski(src):
  d, n = 0, 1/big
  for x in src:
    n += 1
    d += x**the.p
  return (d / n)**(1 / the.p)

# Distance to heaven.
def ydist(data, row):
  return minkowski(abs(norm(c, row[c.at]) - c.heaven) for c in data.cols.y)

# Sort rows by distance to heaven.
def ysort(data,rows=None):
  return sorted(rows or data._rows, key=lambda row: ydist(data,row))

# Distance between independent attributes.
def xdist(data, row1, row2):
  def _aha(col,u,v):
    if u=="?" and v=="?": return 1
    if col.it is Sym: return u!=v
    u = norm(col,u)
    v = norm(col,v)
    u = u if u != "?" else (0 if v > .5 else 1)
    v = v if v != "?" else (0 if u > .5 else 1)
    return abs(u - v)

  return minkowski(_aha(c, row1[c.at], row2[c.at]) for c in data.cols.x)

# K-means plus plus: k points, usually D^2 distance from each other.
def kpp(data, k=None, rows=None):
  k = k or the.Stop
  row, *rows = shuffle(rows or data._rows)
  some = rows[:the.Few]
  centroids  = [row]
  for _ in range(1, k):
    dists = [min(xdist(data,x,y)**2 for y in centroids) for x in some]
    r     = random.random() * sum(dists)
    for j, d in enumerate(dists):
      r -= d
      if r <= 0:
        centroids.append(some.pop(j))
        break
  return centroids


```

```
### Tree --------------------------------------------------------------------
# eq, eq, gt
ops = {'<=' : lambda x,y: x <= y,
       "==" : lambda x,y: x == y,
       '>'  : lambda x,y: x >  y}

# select a row
def selects(row, op, at, y): x=row[at]; return  x=="?" or ops[op](x,y)

# what cuts most reduces spread?
def cuts(col,rows,Y,Klass):
  def _sym(sym):
    n,d = 0,{}
    for row in rows:
      if (x := row[sym.at]) != "?":
        n = n + 1
        d[x] = d[x] if x in d else Klass()
        add(d[x], Y(row))
    return o(div = sum(c.n/n * spread(c) for c in d.values()),
             hows = [("==",sym.at, k) for k,_ in d.items()])

  def _num(num):
    out, b4, lhs, rhs = None, None, Klass(), Klass()
    xys = [(r[num.at], add(rhs, Y(r))) for r in rows if r[num.at] != "?"]
    xpect = rhs.sd
    for x, y in sorted(xys, key=lambda xy: xy[0]):
      if x != b4:
        if the.leaf <= lhs.n <= len(xys) - the.leaf:
          tmp = (lhs.n * lhs.sd + rhs.n * rhs.sd) / len(xys)
          if tmp < xpect:
            xpect, out = tmp, [("<=", num.at, b4), (">", num.at, b4)]
      add(lhs, sub(rhs,y))
      b4 = x
    if out:
      return o(div=xpect, hows=out)

  return (_sym if col.it is Sym else _num)(col)

# Split data on best cut. Recurse on each split.
def tree(data, Klass=Num, Y=None, how=None):
  Y          = Y or (lambda row: ydist(data,row))
  data.kids = []
  data.how   = how
  data.ys    = Num(Y(row) for row in data._rows)
  if data.n >= the.leaf:
    tmp = [x for c in data.cols.x if (x := cuts(c,data._rows,Y,Klass=Klass))]
    if tmp:
      for how1 in sorted(tmp, key=lambda cut: cut.div)[0].hows:
        rows1 = [row for row in data._rows if selects(row, *how1)]
        if the.leaf <= len(rows1) < data.n:
          data.kids += [tree(clone(data,rows1), Klass, Y, how1)]
  return data

# Iterate over all nodes.
def nodes(data1, lvl=0, key=None):
  yield lvl, data1
  for data2 in (sorted(data1.kids, key=key) if key else data1.kids):
    yield from nodes(data2, lvl + 1, key=key)

# Return leaf selected by row.
def leaf(data1,row):
  for data2 in data1.kids or []:
    if selects(row, *data2.how):
      return leaf(data2, row)
  return data1

# Pretty print a tree
def show(data, key=lambda z:z.ys.mu):
  stats = data.ys
  win = lambda x: 100-int(100*(x-stats.lo)/(stats.mu - stats.lo))
  print(f"{'d2h':>4} {'win':>4} {'n':>4}  ")
  print(f"{'----':>4} {'----':>4} {'----':>4}  ")
  for lvl, node in nodes(data, key=key):
    leafp = len(node.kids)==0
    post = "." if leafp else ""
    xplain = ""
    if lvl > 0:
      op,at,y = node.how
      xplain = f"{data.cols.all[at].txt} {op} {y}"
    indent = (lvl - 1) * "| "
    print(f"{node.ys.mu:4.2f} {win(node.ys.mu):4} {node.n:4}  "
          f"{indent}{xplain}{post}")


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```
### Stats -----------------------------------------------------------------
# Table pretty print (aligns columns).
def report(rows, head, decs=2):
  w=[0] * len(head)
  Str  = lambda x   : f"{x:.{decs}f}"      if type(x) is float else str(x)
  say  = lambda w,x : f"{x:>{w}.{decs}f}" if type(x) is float else f"{x:>{w}}"
  says = lambda row : ' | '.join([say(w1, x) for w1, x in zip(w, row)])
  for row in [head]+rows:
    w = [max(b4, len(Str(x))) for b4,x in zip(w,row)]
  print(says(head))
  print('-'*(w1) for w1 in w))
  for row in rows: print(says(row))

# Non-parametric significance test from Chpt20, doi.org/10.1201/9780429246593
# 2 distributions are the same if, often, we `see` differences just by chance.
# We center both samples around the combined mean to simulate
# what data might look like if vals1 and vals2 came from the same population.
def bootstrap(vals1, vals2):
  _see = lambda i,j: abs(i.mu - j.mu) / ((i.sd**2/i.n + j.sd**2/j.n)**.5 +1/big)
  x,y,z = Num(vals1+vals2), Num(vals1), Num(vals2)
  yhat  = [y1 - mid(y) + mid(x) for y1 in vals1]
  zhat  = [z1 - mid(z) + mid(x) for z1 in vals2]
  n     = 0
  for _ in range(the.bootstrap):
    n += _see(Num(picks(yhat, k=len(yhat))),
              Num(picks(zhat, k=len(zhat)))) > _see(y,z)
  return n / the.bootstrap >= (1- the.Boots)

# Non-parametric effect size from Tbl of  doi.org/10.3102/10769986025002101
def cliffs(vals1,vals2):
  n,lt,gt = 0,0,0
  for x in vals1:
    for y in vals2:
      n += 1
      if x > y: gt += 1
      if x < y: lt += 1
  return abs(lt - gt)/n  < the.Cliffs # 0.197)  #med=.28, small=.11

# Recurive bi-cluster of treatments. Stops when splits are the same.
def scottKnott(rxs, eps=0, reverse=False):
  def _same(a,b): return cliffs(a,b) and bootstrap(a,b)
  def _flat(rxs): return  [x for _,_,_,lst in rxs for x in lst]

  def _cut(rxs):
    out, most = None,0
    n1 = s1 = 0
    s0 = s2 = sum(s for _,_,s,_ in rxs)
    n0 = n2 = sum(n for _,n,_,_ in rxs)
    for i, (_,n,s,_) in enumerate(rxs):
      if i > 0:
        m0, m1, m2 = s0/n0, s1/n1, s2/n2
        if abs(m1 - m2) > eps:
          if (tmp := (n1*abs(m1 - m0) + n2*abs(m2 - m0)) / (n1 + n2)) > most:
            most, out = tmp, i
      n1, s1, n2, s2 = n1+n, s1+s, n2-n, s2-s
    return out

  def _div(rxs, rank=0):
    if len(rxs) > 1:
      if (cut := _cut(rxs)):
        left, right = rxs[:cut], rxs[cut:]
        if not _same(_flat(left), _flat(right)):
          return _div(right, _div(left, rank) + 1)
    for row,_,_,_ in rxs: row.rank = rank
    return rank

  rxs = [(Num(a,txt=k, rank=0), len(a), sum(a), a) for k,a in rxs.items()]
  rxs.sort(key=lambda x: x[0].mu, reverse=reverse)
  _div(rxs)
  return {num.txt:num for num,_,_,_ in rxs}


```

```
### Demos -----------------------------------------------------------------
#### Utils
def eg__the(_):
  "   show config"
  print(the)

def eg__str(_):
  "   show string --> csv"
  s,n = 0,0
  for row in csv(lines(EXAMPLE)):
    assert len(row)==6
    if type(row[0]) is str: s += 1
    if type(row[0]) in [int,float]: n += 1
  assert s==1 and n==100

#### Create and Update
def eg__nums(_):
  "   nums --> summary"
  num=Num([random.gauss(10,2) for _ in range(1000)])
  assert 10 < mid(num) < 10.2 and 2 < spread(num) < 2.1

def eg__sym(_) :
  "   chars --> summary"
  sym = Sym("aaaabbc")
  assert "a"==mid(sym) and 1.3 < spread(sym) < 1.4

def eg__cols(_):
  "   List[str] --> columns"
  cols = Cols(["name","Age","Salary+"])
  for what,lst in (("x", cols.x), ("y",cols.y)):
    print("\n"+what)
    [print("\t"+cat(one)) for one in lst]

def eg__data(file):
  "   csv data --> data"
  data = Data(csv(doc(file) if file else lines(EXAMPLE)))
  print(data.n)
  print("X"); [print(" ",col) for col in data.cols.x]
  print("Y"); [print(" ",col) for col in data.cols.y]

#### Query
def eg__addSub(file):
  "   demo row addition / deletion"
  data1 = Data(csv(doc(file) if file else lines(EXAMPLE)))
  data2 = clone(data1)
  for row in data1._rows:
    add(data2,row)
    if len(data2._rows)==100:
      mids    = mid(data2)
      spreads = spread(data2)
  for row in data1._rows[::-1]:
    if len(data2._rows)==100:
      assert mids    == mid(data2)
      assert spreads == spread(data2)
      return
    sub(data2, row)

#### Distance
def eg__dist(file):
  "   demo data distances"
  data = Data(csv(doc(file) if file else lines(EXAMPLE)))
  row1 = data._rows[0]
  assert all(0 <= xdist(data,row1,row2) <= 1 for row2 in data._rows)
  assert all(0 <= ydist(data,row2) <= 1      for row2 in data._rows)
  lst = ysort(data)
  [print(round(ydist(data,row),2), row) for row in lst[:3] + lst[-3:]]

def eg__line(file):
  "   demo data distances"
  data = Data(csv(doc(file) if file else lines(EXAMPLE)))
  one = lambda: sorted([ydist(data,row) for row in kpp(data)])[0]
  print(cat(sorted([one() for _ in range(20)])))

#### Bayes
def eg__bayes(file):
  "   demo bayes"
  data = Data(csv(doc(file) if file else lines(EXAMPLE)))
  print(cat(sorted([like(data,row,2,1000) for row in data._rows[::10]])))

def eg__lite(file):
  "   demo active learning"
  data = Data(csv(doc(file) if file else lines(EXAMPLE)))
  b4   = [ydist(data, row) for row in data._rows][::8]
  now  = [ydist(data, acquires(data).best._rows[0]) for _ in range(12)]
  print(o(b4=sorted(b4)))
  print(o(now=sorted(now)))

#### Tree
def eg__tree(file):
  "   demo active learning"
  data = Data(csv(doc(file) if file else lines(EXAMPLE)))
  show(tree(data))

#### Stats
def eg__stats(_):
  def c(b): return 1 if b else 0
  b4 = [random.gauss(1,1)+ random.gauss(10,1)**0.5 for _ in range(59)]
  d=0.5
  while d < 1.5:
    now = [x+d*random.random() for x in b4]
    b1  = cliffs(b4,now)
    b2  = bootstrap(b4,now)
    print(o(agree=c(b1==b2), cliffs=c(b1), boot=c(b2),d=d))
    d += 0.05

def eg__rank(_):
  n=100
  d=dict(asIs  = [random.gauss(10,1) for _ in range(n)],
         copy1 = [random.gauss(20,1) for _ in range(n)],
         now1  = [random.gauss(20,1) for _ in range(n)],
         copy2 = [random.gauss(40,1) for _ in range(n)],
         now2  = [random.gauss(40,1) for _ in range(n)])
  [print(o(rank=num.rank, mu=num.mu)) for num in scottKnott(d).values()]

def eg__rank2(_):
  n=100
  d=dict(asIs  = [random.gauss(10,1) for _ in range(n)],
         copy1 = [random.gauss(20,1) for _ in range(n)])
  [print(o(rank=num.rank, mu=num.mu)) for num in scottKnott(d).values()]

#### Control
def eg__all(_):
  "   run all demos"
  for s,fn in globals().items():
    if s.startswith("eg_") and s!="eg__all":
      print(f"\n{'-'*78}\n## {s}\n")
      print("\n```")
      run(fn)
      print("```\n")

def eg_h(_):
  "   show help"
  print("\n"+__doc__);
  for s,fn in globals().items():
    if s.startswith("eg_"):
      print(f"  {s[2:].replace("_","-"):6s} {(fn.__doc__ or "  ")[1:]}")


```

```
### Start-up -----------------------------------------------------------------
# Update slot `k` in dictionary `d` from CLI flags matching `k`.
def cli(d):
  for k, v in d.items():
    for c, arg in enumerate(sys.argv):
      if arg == "-" + k[0]:
        d[k] = atom("False" if str(v) == "True" else (
                    "True" if str(v) == "False" else (
                    sys.argv[c + 1] if c < len(sys.argv) - 1 else str(v))))

# Reset seed before running. Crashes print stack, but keep going.
def run(fn,x=None):
  try:
    random.seed(the.rseed)
    fn(x)
  except Exception as e:
    tb = traceback.format_exc().splitlines()[4:]
    return sys.stdout.write("\n".join(tb) + "\n")

# Geneate options struct from top-of-file string.
the = o(**{m[1]: atom(m[2])
       for m in re.finditer(r"-\w+\s+(\w+)[^\(]*\(\s*([^)]+)\s*\)", __doc__)})

# Maybe run command-line options.
if __name__ == "__main__":
  cli(the.__dict__)
  for i,s in enumerate(sys.argv):
    if fn := globals().get("eg" + s.replace("-", "_")):
      run(fn, None if i == len(sys.argv) - 1 else atom(sys.argv[i+1]))
```