```lua
#!/usr/bin/env lua
-- vi: filetype=lua :
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local b4={}; for k,_ in pairs(_ENV) do b4[k]=k end
local help=[[
brknbad.lua: explore the world better, explore the world for good.
(c) 2022, Tim Menzies

      .-------.
      | Ba    | Bad <----.  planning= (better - bad)
      |    56 |          |  monitor = (bad - better)
      .-------.------.   |
              | Be   |   v
              |    4 | Better
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USAGE:
  ./bnb [OPTIONS]

OPTIONS:
  -bins  -b   max. number of bins             = 16
  -best  -B   best set                        = .5
  -rest  -R   rest is -R*best                 = 4
  -cohen -c   cohen                           = .35
  -goal  -g   goal                            = recurrence-events
  -K     -K   manage low class counts         = 1
  -M     -M   manage low evidence counts      = 2
  -seed  -S   seed                            = 10019
  -wait  -w   wait                            = 10

OPTIONS (other):
  -dump  -d   dump stack on error, then exit = false
  -file  -f   file name                       = ../etc/data/breastcancer.csv
  -help  -h   show help                       = false
  -todo  -t   start up action                 = nothing
]]

local ent,per,norm
local slice,many,any,push,map,collect,copy,powerset
local sort,up1,upx,down1,slots,up1,down1
local words,thing, things, items
local cli
local rnd,rnds,fmt,o,oo
local inc,inc2,inc3,has,has2,has3
local ok,ish, rogues
local cols,update,classify,test,train,score,header,nb1,nb2,abcd
local bins,nb3
local sorted,mid,div,dist,clone,create,better,xplain
local the={}

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local ako={}
ako.num    = function(x) return x:find"^[A-Z]" end
ako.goal   = function(x) return x:find"[-+!]"  end
ako.klass  = function(x) return x:find"!$"     end
ako.ignore = function(x) return x:find":$"     end
ako.weight = function(x) return x:find"-$" and -1 or 1 end
ako.xnum   = function(x) return ako.num(x) and not ako.goal(x) end

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local big = 1E32
local it={}
function it.num()
  return {nump=true,indep=false,n=0,at=0,name="",
          lo=big,hi=-big,mu=0,m2=0,sd=0,bins={}} end

function it.sym()
  return {nump=false,indep=false, n=0, at=0,name="",
          has={}, most=0, mode=nil} end

function it.cols()
  return {names={}, klass=nil,xy= {}, x= {}, y={}} end

function it.egs()
  return {h={}, nh=0, e={}, n=0, bests=0, rests=0,
         best={}, rest={}, log={}, cols=nil} end
```

```lua
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function classify(i,t,use)
  local hi,out = -1
  for h,_ in pairs(i.h) do
    local prior = ((i.h[h] or 0) + the.K)/(i.n + the.K*i.nh)
    local l = prior
    for col,x in pairs(t) do
      if x ~= "?" and i.cols[col].indep then
        l=l*(has3(i.e,col,x,h) + the.M*prior)/((i.h[h] or 0) + the.M) end end
    if l>hi then hi,out=l,h end end
  return out end

function test(i,t)
  if i.n > the.wait then push(i.log,{want=t[#t], got=classify(i,t)}) end  end

function train(i,t)
  local more, kl = false, t[#t]
  for col,x in pairs(t) do
    if x ~="?" then
      more = true
      inc3(i.e, col, x, kl)
      if col ~= #t then
        inc2(kl==the.goal and i.best or i.rest, col,x) end end end
  if more then
    i.n = i.n + 1
    if not i.h[kl] then i.nh = i.nh + 1 end
    inc(i.h, kl)
    if kl==the.goal then i.bests=i.bests+1 else i.rests=i.rests+1 end end end

function score(i)
  local acc,out=0,{}
  for _,x in pairs(i.log) do if x.want==x.got then acc=acc+1/#i.log end end
  for col,xns in pairs(i.best) do
    for x,b in pairs(xns) do
      local r  = has2(i.rest,col,x)
      local r1 = r/i.rests
      local b1 = b/i.bests
      push(out, {100*(b1^2/(b1+r1))//1, col,x,b,i.bests,r,i.rests}) end end
  return acc, sort(out,down1) end

function nb1(data, log)
  local i = {h={}, nh=0,e={}, n=0, wait=the.wait,
             bests=0,rests=0,best={}, rest={},log=log or {}, cols=nil}
  for row in items(data) do
    if   not i.cols
    then i.cols = collect(row,function(j,s) return {name=s, indep=j~=#row} end)
    else test(i,row); train(i,row) end end
  return i end


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function nb2(data,  log)
  local tmp,xnums = {}
  local function discretize(c,x,    col)
    if x ~= "?" then
      col = xnums[c]
      if col then x=(x - col.lo) // ((col.hi - col.lo+1E-32) / the.bins)  end end
    return x end
  local function xnum(c,name)
    if ako.xnum(name) then return {lo=1E32, hi=-1E32} end end
  local function train(c,x,    col)
    col = xnums[c]
    if col and x ~= "?" then
      col.hi = math.max(x, col.hi)
      col.lo = math.min(x, col.lo) end
    return x end
  -- start
  for row in items(data) do
    push(tmp, row)
    if   xnums then collect(row, train)
    else xnums = collect(row,xnum)  end end
  for j=2,#tmp do tmp[j] = collect(tmp[j], discretize) end
  return nb1(tmp) end
---------------------------------------------------------------------------
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function abcd(gotwants, show)
  local i, exists, add, report, pretty
  i={data=data or "data",rx= rx or "rx",known={},a={},b={},c={},d={},yes=0,no=0}

  function exists(x,   new)
    new = not i.known[x]
    inc(i.known,x)
    if new then
      i.a[x]=i.yes + i.no; i.b[x]=0; i.c[x]=0; i.d[x]=0 end end

  function report(    p,out,a,b,c,d,pd,pf,pn,f,acc,g,prec)
    p = function (z) return math.floor(100*z + 0.5) end
    out= {}
    for x,_ in pairs( i.known ) do
      pd,pf,pn,prec,g,f,acc = 0,0,0,0,0,0,0
      a= (i.a[x] or 0); b= (i.b[x] or 0); c= (i.c[x] or 0); d= (i.d[x] or 0);
      if b+d > 0     then pd   = d     /  (b+d)        end
      if a+c > 0     then pf   = c     /  (a+c)        end
      if a+c > 0     then pn   = (b+d) /  (a+c)        end
      if c+d > 0     then prec = d     /  (c+d)        end
      if 1-pf+pd > 0 then g=2*(1-pf) * pd / (1-pf+pd) end
      if prec+pd > 0 then f=2*prec*pd / (prec + pd)   end
      if i.yes + i.no > 0 then
         acc= i.yes / (i.yes + i.no) end
      out[x] = {data=i.data,rx=i.rx,num=i.yes+i.no,a=a,b=b,c=c,d=d,acc=p(acc),
                prec=p(prec), pd=p(pd), pf=p(pf),f=p(f), g=p(g), class=x} end
    return out end

  function pretty(t)
    print""
    local s1  = "%10s | %10s | %4s | %4s | %4s | %4s "
    local s2  = "| %3s | %3s| %3s | %4s | %3s | %3s |"
    local d,s = "---", (s1 .. s2)
    print(fmt(s,"db","rx","a","b","c","d","acc","pd","pf","prec","f","g"))
    print(fmt(s,d,d,d,d,d,d,d,d,d,d,d,d))
    for _,x in pairs(slots(t)) do
      local u = t[x]
      print(fmt(s.." %s", u.data,u.rx,u.a, u.b, u.c, u.d,
                          u.acc, u.pd, u.pf, u.prec, u.f, u.g, x)) end end
  -- start
  for _,one in pairs(gotwants) do
    exists(one.want)
    exists(one.got)
    if one.want == one.got then i.yes=i.yes+1 else i.no=i.no+1 end
    for x,_ in pairs(i.known) do
      if   one.want == x
      then inc(one.want == one.got and i.d or i.b, x)
      else inc(one.got  == x       and i.c or i.a, x) end end end
  return show and pretty(report()) or report() end
```

```lua
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function nb3(data,  log)
  local tmp, xnums = {}
  local function discretize(c,x,   col)
    if x ~= "?" then
      col = xnums[c]
      if col then
        for _,bin in pairs(col.bins) do
          if bin.lo <= x and x < bin.hi then return bin.id end end end end
    return x end
  local function xnum(c,name)
    if ako.xnum(name) then return {name=name, xys={},bins={}} end end
  local function train(c,x,row)
    if xnums[c] and x ~= "?" then push(xnums[c].xys, {x=x,y= row[#row]}) end end
  -- start
  for row in items(data) do
    push(tmp,row)
    if   xnums then collect(row, function(c,x) return train(c,x,row) end)
    else xnums = collect(row,xnum) end end
  for where,col in pairs(xnums) do col.bins = bins(col.xys,where); print(col.name,#col.bins) end
  for j=2,#tmp do tmp[j] = collect(tmp[j], discretize) end
  return nb1(tmp)
  end

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local argmin
function bins(xys,where)
  xys                    = sort(xys, upx)
  local triviallySmall = the.cohen*(per(xys,.9).x - per(xys, .1).x)/2.56
  local enoughItems    = #xys / the.bins
  local out            = {}
  argmin(1,#xys, xys, triviallySmall, enoughItems, -math.huge, where, out)
  out[#out].hi =  math.huge
  return out end

function argmin(lo, hi, xys, triviallySmall, enoughItems, b4, where, out)
  local function add(f,z) f[z] = (f[z] or 0) + 1 end
  local function sub(f,z) f[z] =  f[z] - 1       end
  local lhs, rhs, cut, div, xpect, xy = {},{}
  for j=lo,hi do add(rhs, xys[j].y) end
  div = ent(rhs)
  if hi-lo+1 > 2*enoughItems then
    for j=lo,hi - enoughItems do
      add(lhs, xys[j].y)
      sub(rhs, xys[j].y)
      local n1,n2 = j - lo +1, hi-j
      if   n1        > enoughItems and
           n2        > enoughItems and
           xys[j].x ~= xys[j+1].x and  -- there is a break here
           xys[j].x  - xys[lo].x > triviallySmall and
           xys[hi].x - xys[j].x  > triviallySmall
      then xpect = (n1*ent(lhs) + n2*ent(rhs)) / (n1+n2)
           if xpect < div then  -- cutting here simplifies things
             cut, div = j, xpect end end end
  end -- end if
  if   cut
  then b4 = argmin(lo,    cut, xys, triviallySmall, enoughItems, b4, where, out)
       b4 = argmin(cut+1, hi , xys, triviallySmall, enoughItems, b4, where, out)
  else b4 = push(out,{id=#out+1, where=where,
                      lo=b4, hi=xys[hi].x, n=hi-lo+1, div=div}).hi end
  return b4 end
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function create(names)
  local i = it.cols()
  i.names = names
  for at,name in pairs(names) do
    local now = ako.num(name) and it.num() or it.sym()
    now.at, now.name, now.w = at, name, ako.weight(name)
    push(i.xy, now)
    if not ako.ignore(name)  then
      if not ako.goal(name)  then now.indep = true end
      if     ako.klass(name) then i.klass=now      end
      push(now.indep and i.x or i.y, now)          end end
  return i end

function update(i,row)
  local function num(col,x,   d)
    col.lo = math.min(x, col.lo)
    col.hi = math.max(x, col.hi)
    d      = x - col.mu
    col.mu = col.mu + d/col.n
    col.m2 = col.m2 + d*(x - col.mu)
    col.sd = ((col.m2<0 or col.n<2) and 0) or ((col.m2/(col.n - 1))^0.5) end
  local function sym(col,x)
    col.has[x] = 1 + (col.has[x] or 0)
    if col.has[x] > col.most then
      col.mode,col.most = x,col.has[x] end end
  -- start
  for _,col in pairs(i.cols.xy) do
    local x = row[col.at]
    if x ~= "?" then
      col.n = col.n + 1
      (col.nump and num or sym)(col,x) end end
  return row end

function mid(i,cols)
   local function mid(col) return col.nump and col.mu or col.mode end
   return map(cols or i.cols.y, mid) end

function div(i,cols)
   local function div(col) return col.nump and col.sd or ent(col.has) end
   return map(cols or i.cols.y, div) end

function clone(old,rows)
  local i={rows={}, cols=create(old.cols.names)}
  for _,row in pairs(rows or {}) do update(i,row) end
  return i end

function sorted(i)
  return sort(i.rows, function(a,b) return better(i,a,b) end) end

function better(i,row1,row2)
  local s1, s2, n, e = 0, 0, #i.cols.y, math.exp(1)
  for _,col in pairs(i.cols.y) do
    local a  = norm(col.lo, col.hi, row1[col.at] )
    local b  = norm(col.lo, col.hi, row2[col.at] )
    s1 = s1 - e^(col.w * (a - b) / n)
    s2 = s2 - e^(col.w * (b - a) / n) end
  return s1 / n < s2 / n  end

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function xplain(data)
  local i = {rows={}, cols=nil}
  local function num(col, best, rest)
    local tmp = {}
    for klass,rows in pairs{rest,best} do
      for _,row in pairs(rows) do
        local x = row[col.at]
        if x~="?" then push(tmp, {x=x, y=klass}) end end end
    return bins(tmp, col.at)
  end
  local function sym(col, best, rest)
    local tmp = {}
    for klass,rows in pairs{rest,best} do
      for _,row in pairs(rows) do
        local x = row[col.at]
        if x ~= "?" then
          tmp[x]  = tmp[x] or {id=x, where=col.at, lo=x, hi=x, n=0, tmp={}}
          local r  = tmp[x].tmp
          r[klass] = 1 + (r[klass] or 0) end end end
    for x,t in pairs(tmp) do t.div,t.n = ent(t.tmp) end
    return tmp
  end
  for row in items(data) do
    if not i.cols then i.cols=create(row) else push(i.rows,update(i,row)) end end
  i.rows = sorted(i)
  local n    = (#i.rows)^the.best
  local best = slice(i.rows, 1, n)
  local rest = many(i.rows, n*the.rest, n+1)
  for _,col in pairs(i.cols.x) do
    print""
    print(col.at)
    map((col.nump and num or sym)(col, best, rest),oo) end
  return i end

function dist(i,row1,row2)
  local function sym(_,x,y) return x==y and 0 or 1 end
  local function num(c,x,y)
    if     x=="?" then y = norm(c.lo, c.hi, y); x=y<.5 and 1 or 0
    elseif y=="?" then x = norm(c.lo, c.hi, x); y=x<.5 and 1 or 0
    else             x,y = norm(c.lo, c.hi, x), norm(c.lo, c.hi, y) end
    return math.abs(x-y) end
  local function dist(c,x,y)
    return x=="?" and y=="?" and 1 or (c.nump and num or sym)(c,x,y) end
  local d, n = 0, #i.cols.x
  for _,c in pairs(i.cols.x) do d= d + dist(c, row1[c.at], row2[c.at])^the.e end

  return (d/n)^(1/the.e) end

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function per(t,p) return t[ (p or .5)*#t//1 ] end

function ent(t)
  local n=0; for _,m in pairs(t) do n = n+m end
  local e=0; for _,m in pairs(t) do if m>0 then e= e+m/n*math.log(m/n,2) end end
  return -e,n end

function norm(lo,hi,x) return math.abs(hi-lo)<1E-9 and 0 or (x-lo)/(hi - lo) end

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function ish(x,y,z) return math.abs(x-y) <= (z or 0.001) end

local fails=0
function ok(test,msg)
  print("", test and "PASS "or "FAIL ",msg or "")
  if not test then
    fails = fails+1
    if the and the.dump then assert(test,msg) end end end

function rogues()
  for k,v in pairs(_ENV) do if not b4[k] then print("??",k,type(v)) end end end

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---

function inc(f,a,n)      f=f or{};f[a]=(f[a] or 0) + (n or 1) return f end
function inc2(f,a,b,n)   f=f or{};f[a]=inc( f[a] or {},b,n);  return f end
function inc3(f,a,b,c,n) f=f or{};f[a]=inc2(f[a] or {},b,c,n);return f end

function has(f,a)      return f[a]                  or 0 end
function has2(f,a,b)   return f[a] and has( f[a],b)   or 0 end
function has3(f,a,b,c) return f[a] and has2(f[a],b,c) or 0 end

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function push(t,x) t[1 + #t] = x; return x end

function map(t, f, u) u={};for k,v in pairs(t) do u[1+#u]=f(v) end;return u end
function collect(t,f, u) u={};for k,v in pairs(t) do u[k]=f(k,v)end;return u end
function copy(t,   u)
  if type(t) ~= "table" then return t end
  u={}; for k,v in pairs(t) do u[copy(k)] = copy(v) end; return u end

function powerset(s)
  local function aux(s)
    local t = {{}}
    for i = 1, #s do
      for j = 1, #t do
        t[#t+1] = {s[i],table.unpack(t[j])} end end
    return t end
  return sort(aux(s), function(a,b) return #a < #b end) end

function sort(t,f) table.sort(t,f); return t end

function upx(a,b)   return a.x < b.x end
function up1(a,b)   return a[1] < b[1] end
function down1(a,b) return a[1] > b[1] end

function slots(t, u)
  local function public(k) return tostring(k):sub(1,1) ~= "_" end
  u={};for k,v in pairs(t) do if public(k) then u[1+#u]=k end end
  return sort(u) end

function any(a,lo,hi)
  lo,hi = lo or 1, hi or #a; return a[ (lo+(hi-lo)*math.random())//1 ] end

function many(a,n,lo,hi,  u)
  u={}; for j=1,n do push(u,any(a,lo,hi)) end; return u end

function slice(a,lo,hi,    u)
  u,lo,hi = {},lo or 1,hi or #a; for j=lo,hi do u[1+#u]=a[j] end; return u end
---
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function words(s,sep,   t)
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  sep="([^" .. (sep or ",")  .. "]+)"
  t={}; for y in s:gmatch(sep) do t[1+#t] = y end; return t end

function things(s) return map(words(s), thing) end

function thing(x)
  x = x:match"^%s*(.-)%s*$"
  if x=="true" then return true elseif x=="false" then return false end
  return tonumber(x) or x end

function items(src,f)
  local function file()
    src,f = io.input(src),f or things
    return function() x=io.read();if x then return f(x) else io.close(src) end e
nd end
  local function tbl(   x)
    x,f = 0, f or function(z) return z end
    return function() if x< #src then x=x+1; return f(src[x]) end end end
  return type(src) == "string" and file() or tbl() end

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fmt = string.format

function oo(t) print(o(t)) end

function o(t,  seen, u)
  if type(t)~="table" then return tostring(t) end
  seen = seen or {}
  if seen[t] then return "..." end
  seen[t] = t
  local function show1(x) return o(x, seen) end
  local function show2(k) return fmt(":%s %s",k, o(t[k],seen)) end
  u = #t>0 and map(t,show1) or map(slots(t),show2)
  return (t.s or "").."{"..table.concat(u," ").."}" end

function rnds(t,f) return map(t, function(x) return rnd(x,f) end) end
function rnd(x,f)
  return fmt(type(x)=="number" and (x~=x//1 and f or "%5.2f") or "%s",x) end

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function cli(help)
  local d,used = {},{}
  help:gsub("\n ([-]([^%s]+))[%s]+(-[^%s]+)[^\n]*%s([^%s]+)",
    function(long,key,short,x)
      assert(not used[short], "repeated short flag ["..short.."]")
      used[short]=short
      for n,flag in ipairs(arg) do
        if flag==short or flag==long then
          x = x=="false" and true or x=="true" and "false" or arg[n+1] end end
       d[key] = x==true and true or thing(x) end)
  if d.help then os.exit(print(help)) end
  return d end

```

```
-----------------------------------------------------------------------------
---    ___  ____ _  _ ____ ____
---    |  \ |___ |\/| |  | [__
---    |__/ |___ |  | |__| ___]

local eg={}
function eg.copy(     t,u)
  t={a={b={c=10},d={e=200}}, f=300}
  u= copy(t)
  t.a.b.c= 20
  print(u.a.b.c)
  oo(t)
  oo(u)
  end

function eg.create()
  oo(create{"Name","Age","gender","Weight-"}.y[1]) end

function eg.clone(   i,t,best,rest)
  i={rows={},cols=nil}
  the.file = "../etc/data/auto93.csv"
  i = xplain(the.file) end

 function eg.collect()
  local function aux(x,y) return x*y end
  oo(collect({10,20,30},aux)) end

function eg.ent()
  ok(ish(ent{a=9,b=7}, .98886), "entropy")  end

function eg.items()
  for  x in items{10,20,30} do print(x) end
  local n=0
  for  x in items(the.file) do n=n+1; if n<=5 then oo(x) end end end

function eg.powerset()
  for _,x in pairs(powerset{10,20,30,40,50}) do oo(x) end end

local function qq(i,q)
  print(q[1], fmt("%15s = %-8s best= %s/%s rest= %s/%s",i.cols[q[2]].name, q[3],q[4],q[5
],q[6],q[7])) end

function eg.nb1()
  local i = nb1(the.file);
  local acc, out = score(i); print(acc); map(out,function(q) qq(i,q) end) end

function eg.nb2()
  the.file = "../etc/data/diabetes.csv"
  the.goal = "positive"
  local i = nb2(the.file);
  abcd(i.log,true)
end

function eg.nb2a()
  the.file = "../etc/data/diabetes.csv"
  the.goal = "positive"
  for _,bins in pairs{2,5,9} do
    print(bins)
    the.bins = bins
    local i = nb2(the.file);
    abcd(i.log,true)
    --local acc, out = score(i); print(acc)
    --map(out,function(q) q4(i,q) end)  end end
end end

function eg.bins(   t)
  local t,n = {},30
  for j=1,n do push(t, {x=j, y=j<.6*n and 1 or j<.8*n and 2 or 3}) end
  map(bins(t,20),oo)
end

function eg.many( t)
  t={};for j = 1,1000 do t[#t+1] = j end
  print(900,"+", o(many(t,10,900)))
  print(1,100,o(many(t,10,1,100)))
  print(300,700, o(many(t,10,300,700))) end

function eg.nb3()
  the.file = "../etc/data/diabetes.csv"
  the.goal = "positive"
  the.bins = 16
  local i = nb3(the.file);
  abcd(i.log,true)
  local acc, out = score(i);  map(out,function(q) qq(i,q) end)
end
```

```
--------------------------------------------------------------------------------
---    ___ ___ ___ ___ ___
---    |__  |  |__| |__/  |
---    ___] |  |  | |  \  |

fails = 0
local defaults=cli(help)
local todos = defaults.todo == "all" and slots(eg) or {defaults.todo}
for _,todo in pairs(todos) do
  the = copy(defaults)
  math.randomseed(the.seed or 10019)
  if eg[todo] then eg[todo]() end end

rogues()
os.exit(fails)

---              .---------.
---              |         |
---            -= _________ =-
---               ___   ___
---              |   )=(   |
---               ---   ---
---                 ###
---                #   =   #            "This ain't chemistry.
---                #######              This is art."


-- nb1 and nb2 has "?"
-- nb3 needsa new train.
```