

```

1 local b4={}; for k,v in pairs(_ENV) do b4[k]=v end --[[
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4 a little lile
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6 ZWA learning
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8 library
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20 what = "Small sample multi-objective optimizer.",
21 usage= "(c) 2021 Tim Menzies <tm@ieee.org> unlicense.org",
22 about= [[
23 Sort N examples on multi-goals using a handful of 'hints'; i.e.
24
25 - Evaluate and rank, a few examples (on their y-values);
26 - Sort other examples by x-distance to the ranked ones;
27 - Recurse on the better half (so we sample more and more
28   from the better half, then quarter, then eighth...).
29
30 A regression tree learner then explores the examples (sorted
31 left to right, worst to best). By finding branches that
32 reduce the variance of the index of those examples, this
33 tree reports what attribute ranges select for the better (or
34 worse) examples. ]],
35
36 how= {{"file", "-f", "-./data/aut93.csv", "read data from file"},
37       {"help", "-h", false, "show help"},
38       {"hints", "-H", 4, "hints per generation"},
39       {"p", "-p", 2, "distance calc exponent"},
40       {"small", "-s", .5, "div list t into t*small"},
41       {"seed", "-S", 10019, "random number seed"},
42       {"train", "-t", .5, "size of training set"},
43       {"trivial", "-T", .35, "small delta=trivial*sd"},
44       {"todo", "-I", "all", "run unit test, or 'all'"},
45       {"wild", "-W", false, "run tests, no protection"}},
46
47 local fmt,help,cli,the
48 fmt = string.format
49 -- Pretty print help text.
50 function help(opt)
51   print(fmt("OPTIONS\n%s\n%s\n\nOPTIONS\n",arg[0],opt.usage,opt.what))
52   for _,t in pairs(opt.how) do print(fmt("%4s %-9s\n",t[2],t[3] and t[1] or "", t[4] and t[3] and "=" or "", t[3] or "")) end
53   print("\n..opt.about); os.exit() end
54
55 -- Update any "-x" flag with "-x" arguments from the command line.
56 function cli(opt, u)
57   u={}
58   for _,t in pairs(opt.how) do
59     u[t[1]] = t[3]
60     for n,word in ipairs(arg) do if word==t[2] then
61       u[t[1]] = t[3] and (tonumber(arg[n+1]) or arg[n+1]) or true end end end
62   if u.help then help(opt) end
63   math.randomseed(u.seed or 100019)
64   return u end
65
66 -- Make a global for our options e.g. the = {seed=10019, help=false, p=2...}
67 the = cli(options)
68

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199 -- ## Stuff for tracking 'Sym'bol Counts.
200
201 -- 'Sym's track symbol counts and the 'mode' (most frequent symbol).
202 local Sym=obj"Sym"
203 function Sym:new(inits, self)
204   self= has(Sym, {has={}, n=0, mode=nil, most=0})
205   for _,one in pairs(inits or {}) do self:add(one) end
206   return self end
207
208 function Sym:add(x)
209   self.n = self.n + 1
210   self.has[x] = 1 + (self.has[x] or 0)
211   if self.has[x] > self.most then self.most, self.mode = self.has[x], x end end
212
213 function Sym:mid() return self.mode end
214
215 -----
216 -- ## Stuff for tracking 'Num'bers.
217
218 -- 'Num's track a list of number, and can report it sorted.
219 local Num=obj"Num"
220 function Num:new(inits, self)
221   self= has(Num, {has={}, n=0, lo=1E32, hi =1E-32, ready=true})
222   for _,one in pairs(inits or {}) do self:add(one) end
223   return self end
224
225 function Num:add(x)
226   if x>self.hi then self.hi = x
227   elseif x<self.lo then self.lo = x end
228   push(self.has,x), self.n=self.n+1; self.ready=false end
229
230 -- Ensure that the returned list of numbers is sorted.
231 function Num:all(x)
232   if not self.ready then table.sort(self.has) end
233   self.ready = true
234   return self.has end
235
236 -- Combine two 'num's.
237 function Num:merge(other, new)
238   new = Num.new(self.has)
239   for _,x in pairs(other.has) do new:add(x) end
240   return new end
241
242 -- Return a merged item if that combination
243 -- is simpler than its parts.
244 function Num:mergeable(other, new,b4)
245   new = self:merge(other)
246   b4 = (self.n*self.sd() + other.n*other.sd()) / new.n
247   if b4 >= new.sd() then return new end end
248
249 -- The 'mid' is the 50th percentile.
250 function Num:mid() return self:per(.5) end
251
252 -- Return 'x' normalized 0..1, lo,hi.
253 function Num:norm(x, lo,hi)
254   if x=="?" then return x end
255   lo,hi = self.lo, self.hi
256   return abs(hi - lo) < 1E-32 and 0 or (x - lo)/(hi - lo) end
257
258 -- Return the 'p'-th percentile number.
259 function Num:per(p, t)
260   t = self:all()
261   p = p*#t/1
262   return #t<2 and t[1] or t[p < 1 and 1 or p>#t and #t or p] end
263
264 -- The 10th to 90th percentile is 2.56 times the standard deviation.
265 function Num:sd() return (self:per(.9) - self:per(.1))/ 2.56 end
266
267 -----
268 -- Samples store examples. Samples know about
269 -- (a) lo,hi ranges on the numerics
270 -- and (b) what are independent 'x' or dependent 'y' columns.
271 local Sample=obj"Sample"
272 function Sample:new( src,self)
273   self = has(Sample, {names=nil, all={}, ys={}, xs={}, eggs={}})
274   if src then
275     if type(src)=="string" then for x in csv(src) do self:add(x) end end
276     if type(src)=="table" then for _,x in pairs(src) do self:add(x) end end end
277   return self end
278
279 function Sample:clone( inits,out)
280   out = Sample.new():add(self.names)
281   for _,eg in pairs(inits or {}) do out:add(eg) end
282   return out end
283
284 function Sample:add(eg, name,datum)
285   function name(col,new, weight, where, what)
286     if new:find"*" then return end
287     weight= new:find"*" and -1 or 1
288     what = {col=col, w=weight, seen=(new:match("[A-Z]",x) and Num() or Sym())}
289     where = (new:find("[*]") or new:find("-")) and self.ys or self.xs
290     push(self.all, what)
291     push(where, what)
292   end
293   -----
294   function datum(one,new)
295     if new ~= "?" then one.seen:add(new) end
296   end
297   if not self.names
298   then self.names = eg
299   map(eg, function(col,x) name(col,x) end)
300   else push(self.egs, eg)
301   map(self.all, function(_,col) datum(col,eg[col.col]) end)
302   end
303   return self end
304
305 function Sample:stats(cols)
306   return lap(cols or self.ys,function(col) return col.seen:mid() end) end
307
308 -- bins his
309 -- bins sorts
310
311 function Sample:tree(min, node,min,sub)
312   node = {node=self, kids={}}
313   min = min or (#self.egs)^the.small
314   if #self.egs >= 2*min then
315     -- here
316     for _,span in pairs(splits.best(sample)) do
317       sub = self:clone()
318       for _,at in pairs(span.has) do sub:add(self.egs[at]) end
319       push(node.kids, span)
320       span.has = sub:tree(min) end end
321     return node end
322
323 -- at node
324 function Sample:where(tree,eg, max,x,default)
325   if #kid.has==0 then return tree end
326   max = 0
327   for _,kid in pairs(tree.node) do
328     if #kid.has > max then default,max = kid,#kid.has end
329     x = eg[kid.col]
330     if x ~= "?" then
331       if x <= kid.hi and x >= kid.lo then
332         return self:where(kid.has.eg) end end end
333   return self:where(default, eg) end
334

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335 -- discretization tricks
336 local splits={}
337 function splits.best(sample, best,tmp,xpect,out)
338   best = maths.huge
339   for _,x in pairs(sample.xs) do
340     tmp, xpect = splits.whatif(x.at,self)
341     if xpect < best
342     then out,best = tmp,xpect end end
343   return out end
344
345 function splits.whatif(col,sample, out)
346   out = splits.spans(col,sample)
347   xpect = sum(out, function(x) return x.has.n*x:sd() end)/#sample.egs
348   out = map(out, function(_,x) x.has=x.has:all(); x.col= col end)
349   return out, xpect end
350
351 function splits.spans(col,sample, xs, symbolic,x)
352   xys,xs, symbolic = {}, Num(), sample.nums[col]
353   for rank,eg in pairs(sample.egs) do
354     x = eg[col]
355     if x ~= "?" then
356       xs:add(x)
357       if symbolic
358       then in symbolic columns, xys are the indexes seen with each symbol
359       xys[x] = xys[x] or {}
360       push(xys[x], rank)
361       else -- in numeric columns, xys are each number paired with its row id
362       push(xys, {x=x,y=rank}) end end
363   end
364   if symbolic
365   then return map(xys, function(x,t) return {lo=x, hi=x, has=Num(t)} end)
366   else return splits.merge(
367     splits.div(xys, #xs^the.small, sd(sort(xs))*the.trivial)) end end
368
369 -- Generate a new range when
370 -- 1. there is enough left for at least one more range; and
371 -- 2. the lo,hi delta in current range is not boringly small; and
372 -- 3. there are enough x values in this range; and
373 -- 4. there is natural split here
374 -- Fuse adjacent ranges when:
375 -- 5. the combined class distribution of two adjacent ranges
376 -- is just as simple as the parts.
377 function splits.div(xys, tiny, dull, now,out,x,y)
378   xys = sort(xys, function(a,b) return a.x < b.x end)
379   now = {lo=xys[1].x, hi=xys[1].x, has=Num() }
380   out = {now}
381   for j,xy in pairs(xys) do
382     x, y = xy.x, xy.y
383     if j<#xys-tiny and x==xys[j+1].x and now.has.n>tiny and now.hi-now.lo>dull
384     then now = {lo=x, hi=x, has=Num()}
385     push(out, now) end
386     now.hi = x
387     now.has:add(y) end
388   return out end
389
390 function splits.merge(b4, j,tmp,a,n,hasnew)
391   j, n, tmp = 0, #b4, {}
392   while j<n do
393     j = j + 1
394     a = b4[j]
395     if j < n-1 then
396       better = a.has:mergeable(b4[j+1].has)
397       if better then
398         j = j + 1
399         a = {lo=a.lo, hi= b4[j+1].hi, has=better} end end
400     push(tmp,a) end
401   return #tmp==#b4 and b4 or merge(tmp) end
402
403 -----
404 -- ordered object
405 -- per sd add sort here. mergabe
406
407 -----
408 -- geometry tricks
409 -- y column rankings
410 local dist, better,betters
411 function dist(eg1,eg2,sample, a,b,d,n,inc,dist1)
412   function dist1(num,a,b)
413     if not num then return a==b and 0 or 1 end
414     if a=="?" then b=norm(b, num.lo, num.hi); a = b>.5 and 0 or 1
415     elseif b=="?" then a=norm(a, num.lo, num.hi); b = a>.5 and 0 or 1
416     else a,b = norm(a, num.lo, num.hi), norm(b, num.lo, num.hi)
417     end
418     return abs(a-b)
419   end
420   d,n=0,0
421   for _,x in pairs(sample.xs) do
422     a,b = eg1[x.col], eg2[x.col]
423     inc = a=="?" and b=="?" and 1 or dist1(x._is=="Num",a,b)
424     d = d + inc^the.p
425     n = n + 1 end
426   return (d/n)^(1/the.p) end
427
428 function better(eg1,eg2,sample)
429   return sort(egs,function(a,b) return better(a,b,sample) end) end
430
431 function better(eg1,eg2,sample, e,n,a,b,s1,s2)
432   n,s1,s2 = #sample.ys, 0, 0, 2.71828
433   for _,num in pairs(sample.ys) do
434     a = num.seen:norm(eg1[num.col])
435     b = num.seen:norm(eg2[num.col])
436     s1 = s1 - e^(num.w * (a-b)/n)
437     s2 = s2 - e^(num.w * (b-a)/n) end
438   return s1/n < s2/n end
439
440 -----
441 -- sample sorting
442 local hints={}
443 function hints.default(eg) return eg end
444
445 function hints.sort(sample,score, test,train,evals)
446   sample = Sample.new(the.file)
447   train,test = {}, {}
448   for i,eg in pairs(shuffle(sample.egs)) do
449     push(i<= the.train*#sample.egs and train or test, eg) end
450   evals,train = hints.recurse(sample, train,0,
451     score or hints.default, {}, (#train)^the.small)
452   return evals,sample:clone(train), sample:clone(test) end
453
454 function hints.recurse(sample, eggs, evals, scorefun, out, small, worker)
455   if #egs < small then
456     for i=1,#egs do push(out, pop(egs)) end
457     return evals,out
458   end
459   local scores = {}
460   function worker(eg) return hints.locate(scores,eg,sample) end
461   for j=1,the.hints do evals=evals+1;
462     push(scores, scorefun(pop(egs))) end
463   scores = better(scores, sample)
464   eggs = lap(sort(lap(egs, worker),firsts),second)
465   for i=1,#egs/2 do push(out, pop(egs)) end
466   return hints.recurse(sample, eggs,evals, scorefun, out, small)
467 end
468
469 function hints.locate(scores,eg,sample, closest,rank,tmp)
470   closest, rank, tmp = 1E32, 1E32, nil
471   for rank0, scored in pairs(scores) do
472     tmp = dist(eg, scored, sample)
473     if tmp < closest then closest,rank = tmp,rank0 end end
474   return {rank+closest/10^6, eg} end
475
476 -----
477 local eg,fail,example={},0
478 function example(k, f,ok,msg)
479   f= eg[k]; assert(f, "unknown action"..k)
480

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```

484 the=cl(options)
485 if the.wild then return f() end
486 ok,msg = pcall(f)
487 if ok then print(green("PASS"),k)
488 else print(red("FAIL"), k,msg); fail=fail+1 end end
489
490 function eg.lap()
491   assert(3==lap({1,2},function(x) return x+1 end)[2]) end
492
493 function eg.map()
494   assert(3==map({1,2},function(_,x) return x+1 end)[2]) end
495
496 function eg.tables()
497   assert(20==sort(shuffle({{10,20},{30,40},{40,50}}),firsts)[1][2]) end
498
499 function eg.csv( n,z)
500   n=0
501   for eg in csv(the.file) do n=n+1; z=eg end
502   assert(n==399 and z[#z]==50) end
503
504 function eg.rnds( t)
505   assert(10.2 == first(rnds({10.22,81.22,22.33},1))) end
506
507 function eg.sym( s)
508   s=Sym("a","a","a","a","b","b","c")
509   assert("a"==s.mode) end
510
511 function eg.num1( n)
512   n=Num(10,20,30,40,50,10,20,30,40,50,10,20,30,40,50)
513   assert(.375 == n:norm(25))
514   assert(15.625 == n:sd()) end
515
516 function eg.num2( n1,n2,n3,n4)
517   n1=Num(10,20,30,40,50,10,20,30,40,50,10,20,30,40,50)
518   n2=Num(10,20,30,40,50,10,20,30,40,50,10,20,30,40,50)
519   assert(n1:mergeable(n2)==nil)
520   n3=Num(10,20,30,40,50,10,20,30,40,50,10,20,30,40,50)
521   n4=Num(100,200,300,400,500,100,200,300,400,500,100,200,300,400,500)
522   assert(n3:mergeable(n4)==nil) end
523
524 function eg.sample( s,tmp,d1,d2,n)
525   s=Sample(the.file)
526   assert(2110 == last(s.egs)[s.all[3].col])
527   local sort1= better(s.egs,s)
528   local lo, hi = s:clone(), s:clone()
529   for i=1,20 do lo:add(sort1[i]) end
530   for i=#sort1,#sort1-30,-1 do hi:add(sort1[i]) end
531   shout(s:stats())
532   shout(lo:stats())
533   shout(hi:stats())
534   for m,eg in pairs(sort1) do
535     n = bchop(sort1, eg,function(a,b) return better(a,b,s) end)
536     assert(m-n <= 2) end
537
538   -- tmp = sort(map(shuffle(s.egs),
539   --               function(_,eg2) return (dist(eg2,s.egs[1],s), eg2) end),
540   --             firsts)
541   -- d1=dist(tmp[1][2], tmp[10][2], s)
542   -- d2=dist(tmp[1][2], tmp[#tmp][2], s)
543   -- assert(d1*10<d2)
544 end
545
546 function eg.hints( s,_,__,evals,sort1)
547   s=Sample(the.file)
548   sort1= better(s.egs,s)
549   for _,eg in pairs(sort1) do lap(s.ys, function(col) return eg[col.col] end ) end
550   -- assert(s.ys[4].lo==1613)
551   -- evals, train, __ = hints.sort(s)
552   -- print("=",evals)
553   -- for m,eg in pairs(sort1) do
554   --   n = bchop(sort1, eg,function(a,b) return better(a,b,s) end)
555   --   print(m,n) end
556 end
557
558 if the.todo=="all" then lap(keys(eg),example) else example(the.todo) end
559
560 -----
561 -- trick for checking for rogues.
562 for k,v in pairs(_ENV) do if not b4[k] then print("?rogue:",k,type(v)) end end
563 os.exit(fail)
564
565
566

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```

567 --[[
568 needs stats on samples
569
570 teaching:
571 - sample is v.useful
572
573
574 --]]

```