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25 -----
26 local b4={}; for k,_ in pairs(_ENV) do b4[k]=k end
27 local the,help={},{}
28
29 lua l5.lua [OPTIONS]
30 L5 == a very little LUA learning lab
31
32 OPTIONS (inference):
33 -boot -b P #bootstrap samples          DEFAULT
34 -cohen -c F cohen's small effect size    256
35 -cliffs -C F threshold on Cliff's delta  .35
36 -far -F F look no further than "far"     .147
37 -keep -k items to keep in a number      .9
38 -leaves -l leaf size                     512
39 -conf -n F confidence for stats tests    .5
40 -p -p P distance calcs coefficient        .05
41 -seed -S P random number seed           2
42 -some -s look only at "some" items       10019
43                                     512
44
45 OPTIONS (housekeeping):
46 -dump -d on error, exit+ stacktrace      false
47 -file -f S where to get data              ./etc/data/auto93.csv
48 -help -h show help                       false
49 -rnd -r S format string                   %5.2f
50 -todo -t S start-up action                nothing
51
52 --[[
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75 LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN
76 ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
77 POSSIBILITY OF SUCH DAMAGE. --]]
78
79 -----
80 -- ## Coding Conventions
81 --
82 -- - All config options in "the" (which is generated by parsing the help text)
83 -- - LOTS OF SHORT FUNCTIONS
84 -- - Line width = 80
85 -- - when you can, write functions down on one line
86 -- - "i" not "self" (so we can fit more on each line)
87 -- - for loop index variables, do not use i. try j,k instead.
88 -- - if something holds a list of thing, name the holding variable "all"
89 -- - no inheritance
90 -- - only define a method if that is for polymorphism
91 -- - all config items into a global "the" variable
92 -- - all the test cases (or demos) are "function Demo.xxx".
93 -- - If test case assertion crashed, add "1" to Demo.fail
94 -- - On exit return the value of Demo.fail as the exit status
95 -- - random seed reset so carefully, just once, at the end of the code.
96 -- - usually, no line with just "end" on it

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206 -----
207 --- MISC TOOLS
208 ---
209 ---
210 ---
211 local r = math.random
212 local fmt = string.format
213 local unpack = table.unpack
214 local function push(t,x) table.insert(t,x); return x end
215 ---
216 ---
217 ---
218 local thing,things,file2things
219 function thing(x)
220 x = x:match("%s*(-)%s*$")
221 if x=="true" then return true elseif x=="false" then return false end
222 return tonumber(x) or x end
223 ---
224 function things(x,sep, t)
225 t={}; for y in x:gmatch(sep or "([^\s]+)") do t[1+#t]=thing(y) end
226 return t end
227 ---
228 function file2things(file, x)
229 file = io.input(file)
230 return function()
231 x=io.read();
232 if x then return things(x) else io.close(file) end end end
233 ---
234 ---
235 ---
236 ---
237 local last,per,any,many
238 function last(a) return a[#a] end
239 function per(a,p) return a[(p*#a)//1] end
240 function any(a) return a[math.random(#a)] end
241 function many(a,n, u) u={}; for j=1,n do push(u,any(a)) end; return u end
242 ---
243 ---
244 ---
245 local firsts,sort,map,slots,copy
246 function firsts(a,b) return a[1] < b[1] end
247 function sort(t,f) table.sort(t,f); return t end
248 function map(t,f, u) u={};for k,v in pairs(t) do push(u,f(v)) end; return u end
249 function slots(t, u,s)
250 u={}
251 for k,v in pairs(t) do s=tosstring(k);if s:sub(1,1)~="_" then push(u,k) end end
252 return sort(u) end
253 ---
254 function copy(t, u)
255 if type(t)~="table" then return t end
256 u={}; for k,v in pairs(t) do u[copy(k)]=copy(v) end
257 return setmetatable(u, getmetatable(t)) end
258 ---
259 ---
260 ---
261 ---
262 ---
263 local oo,o, rnd, rnds
264 function oo(t) print(o(t)) end
265 function o(t,seen, key,xseen,u)
266 seen = seen or {}
267 if type(t)~="table" then return tostring(t) end
268 if seen[t] then return "..." end
269 seen[t] = t
270 key = function(k) return fmt("%.5s %s",k,o(t[k],seen)) end
271 xseen = function(x) return o(x,seen) end
272 u = #t>0 and map(t,xseen) or map(slots(t),key)
273 return (t.is or "")..'{'..table.concat(u,"")..'}' end
274 ---
275 function rnds(t,f) return map(t, function(x) return rnd(x,f) end) end
276 function rnd(x,f)
277 return fmt(type(x)=="number" and (x~=x//1 and f or the.rnd) or "%s",x) end
278 ---
279 ---
280 ---
281 local Demo, ok = {fails=0}
282 function ok(test,msg)
283 print(test and "PASS:" or "FAIL:",msg or "")
284 if not test then
285 Demo.fails=Demo.fails+1
286 if the.dump then assert(test,msg) end end end
287 ---
288 function Demo.main(todo,seed)
289 for k,one in pairs(todo=="all" and slots(Demo) or {todo}) do
290 if k ~="main" and type(Demo[one]) == "function" then
291 math.randomseed(seed)
292 Demo[one]() end end
293 for k,v in pairs(_ENV) do if not b4[k] then print("?",k,type(v)) end end
294 return Demo.fails end
295 ---
296 ---
297 ---
298 ---
299 local function settings(txt, d)
300 d={}
301 txt:gsub("\n ([-]|([^\s]+))([^\s]+)([^\s]+)%s*%s([^\s]+)",
302 function(long,key,short,x)
303 for n,flag in ipairs(arg) do
304 if flag==short or flag==long then
305 x = x=="false" and true or x=="true" and "false" or arg[n+1] end end
306 if x=="false" then the[key]=false elseif x=="true" then the[key]=true else
307 d[key] = tonumber(x) or x end end
308 if d.help then print(txt) end
309 return d end

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310 -----
311 --- USE CASES
312 ---
313 ---
314 ---
315 ---
316 --- update cols
317 ---
318 ---
319 local add
320 function add(i,x, inc)
321 inc = inc or 1
322 if not is.missing(x) then
323 i.n = i.n + inc
324 i:internalAdd(x,inc) end
325 return x end
326 ---
327 function Sym.internalAdd(i,x,inc)
328 i.all[x] = inc + (i.all[x] or 0)
329 if i.all[x] > i.most then i.most, i.mode = i.all[x], x end end
330 ---
331 function Num.internalAdd(i,x,inc, d)
332 for j=1,inc do
333 d = x - i.mu
334 i.mu = i.mu + d/i.n
335 i.m2 = i.m2 + d*(x - i.mu)
336 i.sd = (i.m2<0 or i.n<2) and 0 or ((i.m2/(i.n-1))^0.5)
337 i.lo = math.min(x, i.lo)
338 i.hi = math.max(x, i.hi)
339 if i.all < the.keep then i.ok=false; push(i.all,x)
340 elseif r() < the.keep/i.n then i.ok=false; i.all[r(#i.all)]=x end end end
341 ---
342 function Num.sorted(i)
343 if not i.ok then i.all = sort(i.all) end
344 i.ok=true
345 return i.all end
346 ---
347 ---
348 ---
349 local file2Egs -- not "local data" (since defined above)
350 function data(i,row)
351 push(i.all, row)
352 for _,col in pairs(i.cols) do add(col, row[col.at]) end
353 return i end
354 ---
355 function file2Egs(file, i)
356 for row in file2things(file) do
357 if i then data(i,row) else i = Egs(row) end end
358 return i end
359 ---
360 ---
361 ---
362 local mids
363 function mids(i,rows,cols) return i:clone(rows):mid(cols) end
364 ---
365 function Egs.mid(i,cols)
366 return map(cols or i.y,function(col) return col:mid(i) end) end
367 ---
368 function Sym.mid(i) return i.mode end
369 function Num.mid(i) return i.mu end
370 ---
371 function Num.div(i) return i.sd end
372 function Sym.div(i, e)
373 e=0; for _,n in pairs(i.all) do e = e + n/i.n*math.log(n/i.n,2) end
374 return -e end
375 ---
376 ---
377 ---
378 local far,furthest,neighbors,dist
379 function far(i,r1,rows,far)
380 return per(neighbors(i,r1,rows),far or the.far)[2] end
381 ---
382 function furthest(i,r1,rows)
383 return last(neighbors(i,r1,rows))[2] end
384 ---
385 function neighbors(i,r1,rows)
386 return sort(map(rows, function(r2) return {dist(i,r1,r2),r2} end),firsts) end
387 ---
388 function dist(i,row1,row2, d,n,a,b,inc)
389 d,n = 0,0
390 for _,col in pairs(i.x) do
391 a,b = row1[col.at], row2[col.at]
392 inc = is.missing(a) and is.missing(b) and 1 or col:dist1(a,b)
393 d = d + inc*the.p
394 n = n + 1 end
395 return (d/n)^(1/the.p) end
396 ---
397 function Sym.dist1(i,a,b) return a==b and 0 or 1 end
398 ---
399 function Num.dist1(i,a,b)
400 if is.missing(a) then b=i:norm(b); a=b<.5 and 1 or 0
401 elseif is.missing(b) then a=i:norm(a); b=a<.5 and 1 or 0
402 else a,b = i:norm(a), i:norm(b) end
403 return math.abs(a - b) end
404 ---
405 function Num.norm(i,x)
406 return i.hi - i.lo < 1E-32 and 0 or (x - i.lo)/(i.hi - i.lo) end

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407 --- c | | | | | | | | | |
408 ---
409 local half, cluster, clusters
410 function half(i, rows, project, row, some, left, right, lefts, rights, c, mid)
411 function project(row, a, b)
412 a = dist(i, left, row)
413 b = dist(i, right, row)
414 return {(a^2 + c^2 - b^2)/(2*c), row}
415 end
416 some = many(rows, the.some)
417 left = furthest(i, any(some), some)
418 right = furthest(i, left, some)
419 c = dist(i, left, right)
420 lefts, rights = {}, {}
421 for n, projection in pairs(sort(map(rows, project), firsts)) do
422 if n == #rows//2 then mid = row end
423 push(n <= #rows//2 and lefts or rights, projection[2]) end
424 return lefts, rights, left, right, mid, c end
425
426 function cluster(i, rows, here, lefts, rights)
427 rows = rows or i.all
428 here = {all=rows}
429 if #rows >= 2* (#i.all)^the.leaves then
430 lefts, rights, here.left, here.right, here.mid = half(i, rows)
431 if #lefts < #rows then
432 here.lefts = cluster(i, lefts)
433 here.rights = cluster(i, rights) end end
434 return here end
435
436 function clusters(i, format, t, pre, front)
437 if t then
438 pre = pre or ""
439 front = fmt("%s%s", pre, #t.all)
440 if not t.lefts and not t.rights then
441 print(fmt("%-20s", front, o(rnds(mids(i, t.all), format))))
442 else
443 print(front)
444 clusters(i, format, t.lefts, " | " .. pre)
445 clusters(i, format, t.rights, " | " .. pre) end end end
446
447 --- c | | | | | | | | | |
448 ---
449 local merge, merged, spans, bestSpan
450 function Sym.spans(i, j)
451 local xys, all, one, last, x, y, n = {}, {}
452 for x, n in pairs(i.all) do push(xys, {x, "lefts", n}) end
453 for x, n in pairs(j.all) do push(xys, {x, "rights", n}) end
454 for _, tmp in ipairs(sort(xys, firsts)) do
455 x, y, n = unpack(tmp)
456 if x ~= last then
457 last = x
458 one = push(all, {lo=x, hi=x, all=Sym(i.at, i.name)}) end
459 add(one.all, y, n) end
460 return all end
461
462 function Num.spans(i, j)
463 local xys, all, lo, hi, gap, one, x, y, n = {}, {}
464 lo, hi = math.min(i.lo, j.lo), math.max(i.hi, j.hi)
465 gap = (hi - lo) / (6/the.cohen)
466 for _, n in pairs(i.all) do push(xys, {n, "lefts", 1}) end
467 for _, n in pairs(j.all) do push(xys, {n, "rights", 1}) end
468 one = {lo=lo, hi=hi, all=Sym(i.at, i.name)}
469 all = {one}
470 for _, tmp in ipairs(sort(xys, firsts)) do
471 x, y, n = unpack(tmp)
472 if one.hi - one.lo > gap
473 then one = push(all, {lo=one.hi, hi=x, all=one.all:clone()}) end
474 one.hi = x
475 add(one.all, y, n) end
476 all = merge(all)
477 all[1].lo = -math.huge
478 all[#all].hi = math.huge
479 return all end
480
481 function merge(b4, j, n, now, a, b, both)
482 j, n, now = 0, #b4, {}
483 while j < #b4 do
484 j = j+1
485 a, b = b4[j], b4[j+1]
486 if b then
487 both = a.all:merged(b.all)
488 if both
489 then a = {lo=a.lo, hi=b.hi, all=both}
490 j = j + 1 end end
491 push(now, a) end
492 return #now == #b4 and b4 or merge(now) end
493
494 --- XXX make .marged and function
495 function Num.merge(i, j, k)
496 k = i:clone()
497 for _, x in pairs(i.all) do add(k, x) end
498 for _, x in pairs(j.all) do add(k, x) end
499 return k end
500
501 function Sym.merge(i, j, k)
502 k = i:clone()
503 for x, n in pairs(i.all) do add(k, x, n) end
504 for x, n in pairs(j.all) do add(k, x, n) end
505 return k end
506
507 function Sym.merged(i, j, k, ei, ej, ek)
508 k = i:merge(j)
509 ei, ej, ek = i:div(), j:div(), k:div()
510 if ek*.99 <= (i.n*ei + j.n*ej)/k.n then return k end end
511
512 function spans(egs1, egs2, spans, tmp, col1, col2)
513 spans = {}
514 for c, col1 in pairs(egs1.x) do
515 col2 = egs2.x[c]
516 tmp = col1:spans(col2)
517 if #tmp > 1 then
518 for _, one in pairs(tmp) do push(spans, one) end end end
519 return spans end
520
521 function bestSpan(spans)
522 local divs, ns, n, div, stats, dist2heaven = Num(), Num()
523 function dist2heaven(s) return {(1 - n(s))^2 + (0 - div(s))^2^.5, s} end
524 function div(s) return divs:norm(s.all:div()) end
525 function n(s) return ns:norm(s.all.n) end
526 for _, s in pairs(spans) do
527 add(divs, s.all:div())
528 add(ns, s.all.n) end
529 return sort(map(spans, dist2heaven), firsts)[1][2] end
530
531 ---
532 ---
533 ---
534
535 local xplain, xplans, selects, spanShow
536 function xplain(i, rows, used, stop, here, left, right, lefts0, rights0, lefts1, rights1)
537 used = used or {}
538 rows = rows or i.all
539 here = {all=rows}
540 stop = (#i.all)^the.leaves
541 if #rows >= 2*stop then
542 lefts0, rights0, here.left, here.right, here.mid, here.c = half(i, rows)
543 if #lefts0 < #rows then
544 here.selector = bestSpan(spans(i:clone(lefts0), i:clone(rights0)))
545 push(used, {here.selector.all.name, here.selector.lo, here.selector.hi})
546 lefts1, rights1 = {}, {}
547 for _, row in pairs(rows) do
548 push(selects(here.selector, row) and lefts1 or rights1, row) end
549 if #lefts1 > stop then here.lefts = xplain(i, lefts1, used) end
550 if #rights1 > stop then here.rights = xplain(i, rights1, used) end end end
551 return here end
552
553 function xplans(i, format, t, pre, how, sel, front)
554 pre, how = pre or "", how or ""
555 if t then
556 pre = pre or ""
557 front = fmt("%s%s%s", pre, how, #t.all, t.c and rnd(t.c) or "")
558 if t.lefts and t.rights then print(fmt("%-35s", front)) else
559 print(fmt("%-35s", front, o(rnds(mids(i, t.all), format))))
560 end
561 sel = t.selector
562 xplans(i, format, t.lefts, " | " .. pre, spanShow(sel, true))
563 xplans(i, format, t.rights, " | " .. pre, spanShow(sel, true) .. ":") end end
564
565 function selects(span, row, lo, hi, at, x)
566 lo, hi, at = span.lo, span.hi, span.all.at
567 x = row[at]
568 if is.missing(x) then return true end
569 if lo==hi then return x==lo else return lo <= x and x < hi end end
570
571 function spanShow(span, negative, hi, lo, x, big)
572 if not span then return "" end
573 lo, hi, x, big = span.lo, span.hi, span.all.name, math.huge
574 if not negative
575 then if lo == hi then return fmt("%s== %s", x, lo) end
576 if hi == big then return fmt("%s>= %s", x, lo) end
577 if lo == -big then return fmt("%s< %s", x, hi) end
578 return fmt("%s<= %s", lo, x, hi)
579 else if lo == hi then return fmt("%s!= %s", x, lo) end
580 if hi == big then return fmt("%s< %s", x, lo) end
581 if lo == -big then return fmt("%s>= %s", x, hi) end
582

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```

583 return fmt ("%s < %s and %s >= %s", x, lo, x, hi) end end
584 ---
585 ---
586 ---
587 local quintiles, smallfx, bootstrap
588 function quintiles(ts, width, nums, out, all, n, m)
589   width = width or 32
590   nums = Num(); for _, t in pairs(ts) do
591     for _, x in pairs(sort(t)) do add(nums, x) end end
592   all, out = nums.all, {}
593   for _, t in pairs(ts) do
594     local s, where = {}
595     where = function(n) return (width*nums:norm(n))/1 end
596     for j = 1, width do s[j] = " " end
597     for j = where(per(t, .1)), where(per(t, .3)) do s[j] = "-" end
598     for j = where(per(t, .7)), where(per(t, .9)) do s[j] = "-" end
599     s[where(per(t, .5))] = "|"
600     push(out, {display=table.concat(s),
601               data = t,
602               pers = map({.1, .3, .5, .7, .9},
603                         function(p) return rnd(per(t, p)) end)}) end
604   return out end
605
606 function smallfx(xs, ys, x, y, lt, gt, n)
607   lt, gt, n = 0, 0, 0
608   if #ys > #xs then xs, ys = ys, xs end
609   for _, x in pairs(xs) do
610     for j=1, math.min(64, #ys) do
611       y = any(ys)
612       if y < x then lt = lt + 1 end
613       if y > x then gt = gt + 1 end
614       n = n + 1 end end
615   return math.abs(gt - lt) / n <= the.cliffs end
616
617 function bootstrap(y0, z0)
618   local x, y, z, b4, yhat, zhat, bigger
619   local function obs(a, b, c)
620     c = math.abs(a.mu - b.mu)
621     return (a.sd + b.sd) == 0 and c or c/((x.sd^2/x.n + y.sd^2/y.n)^.5) end
622   local function adds(t, num)
623     num = num or Num(); map(t, function(x) add(num, x) end); return num end
624   y, z = adds(y0), adds(z0)
625   x = adds(y0, adds(z0))
626   b4 = obs(y, z)
627   yhat = map(y.all, function(y1) return y1 - y.mu + x.mu end)
628   zhat = map(z.all, function(z1) return z1 - z.mu + x.mu end)
629   bigger = 0
630   for j=1, the.boot do
631     if obs( adds(many(yhat, #yhat)), adds(many(zhat, #zhat))) > b4
632     then bigger = bigger + 1/the.boot end end
633   return bigger >= the.conf end
634
635 --- xxx mid has to be per and
636 --- XXXX implement same
637 --- XXXX need tests for stats
638 function scottKnot(nums, all, cohen)
639   local mid = function(z) return z.some:mid() end
640   local function summary(i, j, out)
641     out = copy(nums[i])
642     for k = i+1, j do out = out:merge(nums[k]) end
643     return out
644   end
645   local function div(lo, hi, rank, b4, cut, best, l, ll, r, rl, now)
646     best = 0
647     for j = lo, hi do
648       if j < hi then
649         l = summary(lo, j)
650         r = summary(j+1, hi)
651         now = (l.n*(mid(l) - mid(b4))^2 + r.n*(mid(r) - mid(b4))^2) / (l.n + r.n)
652         if now > best then
653           if math.abs(mid(l) - mid(r)) >= cohen then
654             cut, best, ll, rl = j, now, copy(l), copy(r)
655           end end end
656       if cut and not ll:same(rl, the) then
657         rank = div(lo, cut, rank, ll) + 1
658         rank = div(cut+1, hi, rank, rl)
659       else
660         for i = lo, hi do nums[i].rank = rank end end
661       return rank
662     end
663   end
664   table.sort(nums, function(x, y) return mid(x) < mid(y) end)
665   all = summary(1, #nums)
666   cohen = all.sd * the.cohen
667   div(1, #nums, 1, all)
668   return rank end
669
670
671 -----
672 ---
673 ---
674 ---
675 ---
676 function Demo.the() oo(the) end
677
678 function Demo.many(a)
679   a={1,2,3,4,5,6,7,8,9,10}; ok("1023" == o(many(a,3)), "manys") end
680
681 local function normal(m, s)
682   local pi, sqrt, cos, log = math.pi, math.sqrt, math.cos, math.log
683   local function z() return sqrt(-2*log(r())) * cos(2*pi*r()) end
684   return m + s*z() end
685
686 function Demo.tiles()
687   local function ns(m, s, r, u)
688     u={}; for j=1, r do u[1+#u] = normal(m, s) end; return u end
689   local ts={}
690   local m=100
691   for mu=8, 12, .25 do ts[1+#ts] = ns(mu, 5, m) end
692   ts = sort(map(ts, sort), function(a, b) return per(a, .5) < per(b, .5) end)
693   for j, one in pairs(quintiles(ts, 20)) do
694     print(fmt("[%s]", one.display), o(one.pers),
695           smallfx(ts[1], ts[j]),
696           bootstrap(ts[1], ts[j])) end end
697
698 function Demo.stats( t1, t2, inc, n, a, b)
699   for _, n in pairs(20) do --25, 50, 100, 250, 500, 1000 do
700     inc = inc or 1
701     while inc < 3 do
702       print("")
703       t1={}; for j=1, n do push(t1, j*r()) end
704       t2={}; for j, x in pairs(t1) do t2[j]=x+inc end
705       a, b = smallfx(t1, t2), bootstrap(t1, t2)
706       for _, x in pairs(quintiles(t1, t2)) do print(rnd(inc), x.display, a, b) end
707       inc = inc*1.1 end end end
708
709 function Demo.stats1(x)
710   x1={0.34, 0.49, 0.51, 0.6}
711   x2={ 0.6, 0.7, 0.8, 0.9}
712   x3={ 0.15, 0.25, 0.4, 0.35}
713   x4={ 0.6, 0.7, 0.8, 0.9}
714   x5={ 0.1, 0.2, 0.3, 0.4}
715   print(bootstrap(x5, x3))
716   print(bootstrap(x3, x1))
717   print(bootstrap(x1, x2))
718   print(bootstrap(x2, x4))
719   end
720
721
722 function Demo.egs()
723   ok(5140==file2Egs(the.file).y[1].hi, "reading") end
724
725 function Demo.dist(i)
726   i = file2Egs(the.file)
727   for n, row in pairs(i.all) do print(n, dist(i, i.all[1], row)) end end
728
729 function Demo.far( i, j, row1, row2, row3, d3, d9)
730   i = file2Egs(the.file)
731   for j=1, 10 do
732     row1 = any(i.all)
733     row2 = far(i, row1, i.all, .9)
734     d9 = dist(i, row1, row2)
735     row3 = far(i, row1, i.all, .3)
736     d3 = dist(i, row1, row3)
737     ok(d3 < d9, "closer far") end end
738
739 function Demo.half( i, lefts, rights)
740   i = file2Egs(the.file)
741   lefts, rights = half(i, i.all)
742   oo(mids(i, lefts))
743   oo(mids(i, rights))
744   end
745
746 function Demo.cluster( i)
747   i = file2Egs(the.file)
748   clusters(i, "%.0f", cluster(i)) end
749
750 function Demo.spans( i, lefts, rights)
751   i = file2Egs(the.file)
752   lefts, rights = half(i, i.all)
753   oo(bestSpan(spans(i:clone(lefts), i:clone(rights)))) end
754
755 function Demo.xplain( i, j, tmp, lefts, rights, used)
756   i = file2Egs(the.file)
757   used={}
758   xplains(i, "%.0f", xplain(i, i.all, used))
759   map(sort(used, function(a, b)
760     return ((a[1] < b[1]) or
761            (a[1]==b[1] and a[2] < b[2]) or
762            (a[1]==b[1] and a[2]==b[2] and a[3] < b[3]))end), oo) end
763
764
765 -----
766 the = settings(help)
767 Demo.main(the.todo, the.seed)

```