


```

151 #
152 #
153 #
154 #
155 #
156 #
157 #
158 #
159 def any(a:list) -> Any:
160     "Return a random item."
161     return a[anywhere(a)]
162
163 def anywhere(a:list) -> int:
164     "Return a random index of list 'a'."
165     return random.randint(0, len(a)-1)
166
167 big = sys.maxsize
168
169 def atom(x):
170     "Return a number or trimmed string."
171     x=x.strip()
172     if x=="True": return True
173     elif x=="False": return False
174     else:
175         try: return int(x)
176         except: return float(x)
177         except: return x.strip()
178
179 def demo(do,all):
180     "Maybe run a demo, if we want it, resetting random seed first."
181     todo = dir(all)
182     if do and do != "all":
183         todo = [x for x in dir(all) if x.startswith(do)]
184     for one in todo:
185         fun = all.__dict__[one]
186         if type(fun)==type(demo):
187             random.seed(the.seed)
188             doc = re.sub(r'\n\s+', "\n", fun.__doc__ or "")
189             try:
190                 fun()
191                 print("PASS:", doc)
192             except Exception as e:
193                 all.fails += 1
194                 if the.cautious: traceback.print_exc(); exit(1)
195                 else: print("FAIL:", doc, e)
196             exit(all.fails)
197
198 def file(f):
199     "Iterator. Returns one row at a time, as cells."
200     with open(f) as fp:
201         for line in fp:
202             line = re.sub(r'([\n\r\v\ ]|#.*)', '', line)
203             if line:
204                 yield [atom(cell.strip()) for cell in line.split(",")]
205
206 def first(a:list) -> Any:
207     "Return first item."
208     return a[0]
209
210 def merge(b4:list) -> list:
211     "While we can find similar adjacent things, merge them."
212     j,n,now = -1,len(b4),[]
213     while j < n-1:
214         j += 1
215         a = b4[j]
216         if j < n-2:
217             if merged := a.merge(b4[j+1]):
218                 a = merged
219                 j += 1 # we will continue, after missing one
220             now += [a]
221         # if 'now' is same size as 'b4', look for any other merges.
222     return b4 if len(now)==len(b4) else merge(now)
223
224 class o(object):
225     "Class that can pretty print its slots, with fast inits."
226     def __init__(i, **d): i.__dict__.update(**d)
227     def __repr__(i):
228         pre = i.__class__.__name__ if isinstance(i,o) else ""
229         return pre+str(
230             {k: v for k, v in sorted(i.__dict__.items()) if str(k)[0] != "_"})
231
232 def options(doc:str) -> o:
233     """Convert 'doc' to options dictionary using command line args.
234     Args cause two 'shorthands': (1) boolean flags have no arguments (and mentioning
235     those on the command line means 'flip the default value'; (2) args need only
236     mention the first few of a key (e.g. -s is enough to select for -seed)."""
237     d={}
238     for line in doc.splitlines():
239         if line and line.startswith(" -"):
240             key, _, x = line.strip()[1:].split("#") # get 1st,last word on each line
241             for j,flag in enumerate(sys.argv):
242                 if flag and flag[0]=="-" and key.startswith(flag[1:]):
243                     x= "True" if x=="False" else "False" if x=="True" else sys.argv[j+1])
244             d[key] = atom(x)
245         if d["help"]: exit(print(re.sub(r'\n#.*', "", doc, flags=re.S)))
246     return o(**d)
247
248 def r() -> float:
249     "Return random number 0..1"
250     return random.random()
251
252 def rn(x:float, n=3) -> float:
253     "Round a number to three decimals."
254     return round(x,n)
255
256 def rN(a:list, n=3) -> list:
257     "Round a list of numbers to three decimals."
258     return [rn(x,n=n) for x in a]
259
260 def second(a:list) -> Any:
261     "Return second item."
262     return a[1]
263
264 #
265 #
266 #
267 #
268 #
269 #
270 #
271 #
272 #
273 #
274 #
275 #
276 #
277 class Span(o):
278     """Given two 'Sample's and some 'x' range 'lo..hi'.
279     a 'Span' holds often that range appears in each 'Sample'."""
280     def __init__(i,col, lo, hi, ys=None,):
281         i.col, i.lo, i.hi, i.ys = col, lo, hi, ys or Sym()
282
283     def add(i, x:float, y:Any, inc=1) -> None:
284         "y' is a label identifying one 'Sample' or another."
285         i.lo = min(x, i.lo)
286         i.hi = max(x, i.hi)
287         i.ys.add(y,inc)
288
289     def merge(i, j): # -> Span|None
290         "If the merged span is simpler, return that merge."
291         a, b, c = i.ys, j.ys, i.ys.merge(j.ys)
292         if (i.ys.n==0 or j.ys.n==0 or
293             c.div()*.99 <= (a.n*a.div() + b.n*b.div())/(a.n + b.n)):
294             return Span(i.col, min(i.lo,j.lo),max(i.hi,j.hi), ys=c)
295
296     def selects(i,row:list) -> bool:
297         "True if the range accepts the row."
298         x = row[i.col.at]; return x=="?" or i.lo<=x and x<i.hi
299
300     def show(i, positive=True) -> None:
301         "Show the range."
302         txt = i.col.txt
303         if positive:
304             if i.lo == i.hi: return f"[txt] == {i.lo}"
305             elif i.lo == -big: return f"[txt] < {i.hi}"
306             elif i.hi == big: return f"[txt] >= {i.lo}"
307             else: return f"[i.lo] <= [txt] < {i.hi}"
308         else:
309             if i.lo == i.hi: return f"[txt] != {i.lo}"
310             elif i.lo == -big: return f"[txt] >= {i.hi}"
311             elif i.hi == big: return f"[txt] < {i.lo}"
312             else: return f"[txt] < {i.lo} or [txt] >= {i.hi}"
313
314     def support(i) -> float:
315         "Returns 0..1."
316         return i.ys.n / i.col.n
317
318 @staticmethod
319 def sort(spans : list) -> list:
320     "Good spans have large support and low diversity."
321     divs, supports = Num(), Num()
322     sn = lambda s: supports.norm( s.support())
323     dn = lambda s: divs.norm( s.ys.div())
324     f = lambda s: ((1 - sn(s))*2 + dn(s)**2)**.5/2***.5
325     for s in spans:
326         divs.add( s.ys.div())
327         supports.add(s.support())
328     return sorted(spans, key=f)
329
330 #
331 #
332 #
333 #
334 #
335 #
336 class Col(o):
337     "Summarize columns."
338     def __init__(i,at=0,txt=""):
339         i.n,i.at,i.txt,i.w=0,at,txt,(-1 if "-" in txt else 1)
340
341     def dist(i,x:Any, y:Any) -> float:
342         return 1 if x=="?" and y=="?" else i.dist1(x,y)
343
344 #
345 #
346 #
347 #
348 #
349 #
350 class Sym(Col):
351     "Summarize symbolic columns."
352     def __init__(i,**kw):
353         super().__init__(**kw)
354         i.has, i.mode, i.mode = {}, None, 0
355
356     def add(i, x:str, inc:int=1) -> str:
357         "Update symbol counts in 'has', updating 'mode' as we go."
358         if x != " ":
359             i.n += inc
360             tmp = i.has[x] = inc + i.has.get(x,0)
361             if tmp > i.mode: i.mode, i.mode = tmp, x
362         return x
363
364     def dist(i,x:str, y:str) ->float:
365         "Distance between two symbols."
366         return 0 if x==y else 1
367
368     def div(i):
369         "Return diversity of this distribution (using entropy)."
370         p = lambda x: x / (1E-31 + i.n)
371         return sum( -p(x)*math.log(p(x),2) for x in i.has.values() )
372
373     def merge(i, j):
374         "Merge two 'Sym's."
375         k = Sym(at=i.at, txt=i.txt)
376         for x,n in i.has.items(): k.add(x,n)
377         for x,n in j.has.items(): k.add(x,n)
378         return k
379
380     def mid(i):
381         "Return central tendency of this distribution (using mode)."
382         return i.mode
383
384     def spans(i, j, out):
385         """For each symbol in 'i' and 'j', count the
386         number of times we see it on either side."""
387         xys = [(x,"this",n) for x,n in i.has.items()] + [
388             (x,"that",n) for x,n in j.has.items()]
389         one, last = None,None
390         all = []
391         for x,y,n in sorted(xys, key=first):
392             if x != last:
393                 last = x
394                 one = Span(i, x, x)
395                 all += [one]
396             one.add(x,y,n)
397         if len(all) > 1 : out += all

```

```

396 #
397 #
398 #
399 #
400 class Num(Col):
401     "Summarize numeric columns."
402     def __init__(i,**kw):
403         super().__init__(**kw)
404         i._all, i.lo, i.hi, i.max, i.ok = [], 1E32, -1E32, the.Max, False
405
406     def add(i,x: float ,inc=1):
407         "Reservoir sampler. If '_all' is full, sometimes replace an item at random."
408         if x != "":
409             i.n += inc
410             i.lo = min(x,i.lo)
411             i.hi = max(x,i.hi)
412             if len(i._all) < i.max : i.ok=False; i._all += [x]
413             elif r() < i.max/i.n: i.ok=False; i._all[anywhere(i._all)] = x
414         return x
415
416     def all(i):
417         "Return '_all', sorted."
418         if not i.ok: i.ok=True; i._all.sort()
419         return i._all
420
421     def dist1(i,x,y):
422         if x=="?": y=i.norm(y); x=(1 if y<.5 else 0)
423         elif y=="?": x=i.norm(x); y=(1 if x<.5 else 0)
424         else : x,y = i.norm(x), i.norm(y)
425         return abs(x-y)
426
427     def div(i):
428         """"Report the diversity of this distribution (using standard deviation).
429         &pm;2, 2.56, 3 &sigma; is 66,90,95%, of the mass. 2&sigma;. So one
430         standard deviation is (90-10)th divide by 2.4 times &sigma;."""
431         return (i.per(.9) - i.per(.1)) / 2.56
432
433     def merge(i,j):
434         "Return two 'Num's."
435         k = Num(at=i.at, txt=i.txt)
436         for x in i._all: k.add(x)
437         for x in j._all: k.add(x)
438         return k
439
440     def mid(i):
441         "Return central tendency of this distribution (using median)."
442         return i.per(.5)
443
444     def norm(i,x):
445         "Normalize 'x' to the range 0..1."
446         return 0 if i.hi-i.lo < 1E-9 else (x-i.lo)/(i.hi-i.lo)
447
448     def per(i,p:float=.5) -> float:
449         "Return the p-th ranked item."
450         a = i.all(); return a[ int(p*len(a)) ]
451
452     def spans(i,j, out):
453         """"Divide the whole space 'lo' to 'hi' into, say, 'xsmall'=16 bin,
454         then count the number of times we hit the bin on other side.
455         Then merge similar adjacent bins."""
456         lo = min(i.lo, j.lo)
457         hi = max(i.hi, j.hi)
458         gap = (hi-lo) / (6/the.xsmall)
459         xys = [(x,"this",1) for x in i._all] + [
460             (x,"that",1) for x in j._all]
461         one = Span(i.lo,lo)
462         all = [one]
463         for x,y,n in sorted(xys, key=first):
464             if one.hi - one.lo > gap:
465                 one = Span(i, one.hi,x)
466                 all += [one]
467             one.add(x,y,n)
468         all = merge(all)
469         all[0].lo = -big
470         all[-1].hi = big
471         if len(all) > 1: out += all
472 #
473 #
474 #
475 #
476 #
477
478 class Explain(o):
479     "Tree with 'yes','no' branches for samples that do/do not match a 'span'."
480     def __init__(i,here):
481         i.here, i.span, i.yes, i.no = here, None, None, None
482
483     def show(i,pre=""):
484         if not pre:
485             tmp = i.here.mid(i.here.y)
486             print(f"{':40} : {len(i.here.rows):5} : {tmp}")
487         if i.yes:
488             s=f"{pre}{i.span.show(True)}"
489             tmp = i.yes.here.mid(i.yes.here.y)
490             print(f"{s:40} : {len(i.yes.here.rows):5} : {tmp}")
491             i.yes.show(pre + "|. ")
492         if i.no:
493             s=f"{pre}{i.span.show(False)}"
494             tmp = i.no.here.mid(i.no.here.y)
495             print(f"{s:40} : {len(i.no.here.rows):5} : {tmp}")
496             i.no.show(pre + "|. ")
497
498 #
499 #
500 #
501 #
502 #
503 class Cluster(o):
504     "Tree with 'left','right' samples, broken at median between far points."
505     def __init__(i,here,x=None,y=None,c=None,mid=None):
506         i.here,i.x,i.y,i.c,i.mid,i.left,i.right = here,x,y,c,mid,None,None
507
508     def show(i,pre=""):
509         s = f"{pre:40} : {len(i.here.rows):5}"
510         print(f"{s} if i.left else f'{s} : {i.here.mid(i.here.y))")
511         for kid in [i.left,i.right]:
512             if kid: kid.show(pre + "|. ")

```

```

513 #
514 #
515 #
516 #
517 #
518
519 class Sample(o):
520     "Load, then manage, a set of examples."
521     def __init__(i,init=[]):
522         i.rows, i.cols, i.x, i.y, i.klass = [], [], [], [], None
523         if str == type(inits): [i.add(row) for row in file(inits)]
524         if list == type(inits): [i.add(row) for row in inits]
525
526     def add(i,a):
527         def col(at,txt):
528             what = Num if txt[0].isupper() else Sym
529             now = what(at=at, txt=txt)
530             where = i.y if "x" in txt or "-" in txt or "!" in txt else i.x
531             if txt[-1] != " ":
532                 where += [now]
533             if "!" in txt: i.klass = now
534             return now
535         #-----
536         if i.cols: i.rows += [[col.add(a[col.at]) for col in i.cols]]
537         else: i.cols = [col(at,txt) for at,txt in enumerate(a)]
538
539     def clone(i,init=[]):
540         out = Sample()
541         out.add([col.txt for col in i.cols])
542         [out.add(x) for x in inits]
543         return out
544
545     def cluster(i,top=None):
546         """"Split the data using random projections. Find the span that most
547         separates the data. Divide data on that span."""
548         here = Cluster(i)
549         top = top or i
550         if len(i.rows) >= 2*(len(top.rows)**the.enough):
551             left,right,x,y,c,mid = i.half(top)
552             if len(left.rows) < len(i.rows):
553                 here = Cluster(i,x,y,c,mid)
554             here.left = left.cluster(top)
555             here.right = right.cluster(top)
556         return here
557
558     def dist(i,x,y):
559         d = sum( col.dist(x[col.at], y[col.at])**the.p for col in i.x )
560         return (d/len(i.x)) ** (1/the.p)
561
562     def div(i,cols=None):
563         return [col.div() for col in (cols or i.all)]
564
565     def far(i, x, rows=None):
566         tmp = sorted([(i.dist(x,y),y) for y in (rows or i.rows)],key=first)
567         return tmp[ int(len(tmp)*the.far) ]
568
569     def half(i, top=None):
570         "Using two faraway points 'x,y' break data at median distance."
571         some = i.rows if len(i.rows)<the.Some else random.choices(i.rows, k=the.Some)
572         top = top or i
573         w = any(some)
574         _,x= top.far(w, some)
575         c,y= top.far(x, some)
576         tmp = [r for _,r in sorted([(top.proj(r,x,y,c),r)
577                                     for r in i.rows],key=first))]
578         mid= len(tmp)//2
579         return i.clone(tmp[:mid]), i.clone(tmp[mid:]), x, y, c, tmp[mid]
580
581     def mid(i,cols=None):
582         return [col.mid() for col in (cols or i.all)]
583
584     def proj(i,row,x,y,c):
585         "Find the distance of a 'row' on a line between 'x' and 'y'."
586         a = i.dist(row,x)
587         b = i.dist(row,y)
588         return (a**2 + c**2 - b**2) / (2*c)
589
590     def xplain(i,top=None):
591         """"Split the data using random projections. Find the span that most
592         separates the data. Divide data on that span."""
593         here = Explain(i)
594         top = top or i
595         tiny = len(top.rows)**the.enough
596         if len(i.rows) >= 2*tiny:
597             left, right, *_ = i.half(top)
598             spans = []
599             [icol.spans(rcol,spans) for lcol,rcol in zip(left.x, right.x)]
600             if len(spans) > 0:
601                 here.span = Span.sort(spans)[0]
602                 yes, no = i.clone(), i.clone()
603                 [yes if here.span.selects(row) else no].add(row) for row in i.rows]
604                 if tiny <= len(yes.rows) < len(i.rows): here.yes = yes.xplain(top=top)
605                 if tiny <= len(no.rows ) < len(i.rows): here.no = no.xplain(top=top)
606             return here
607
608

```

```

600 #
601 #
602 #
603 #
604 #
605 #
606 #
607 #
608 #
609 #
610 #
611 #
612 #
613 #
614 #
615 #
616 #
617 class Demos:
618     "Possible start-up actions."
619     fails=0
620     def opt():
621         "show the config"
622         [print(f"{k}>10}={v}") for k,v in the.__dict__.items()]
623
624     def seed():
625         "seed"
626         assert .494 <= r() <= .495
627
628     def num():
629         "check 'Num'."
630         n = Num()
631         for _ in range(100): n.add(r())
632         assert .30 <= n.div() <= .31, "in range"
633
634     def sym():
635         "check 'Sym'."
636         s = Sym()
637         for x in "aaaabbc": s.add(x)
638         assert 1.37 <= s.div() <= 1.38, "entropy"
639         assert 'a' == s.mid(), "mode"
640
641     def rows():
642         "count rows in a file."
643         assert 399 == len([row for row in file(the.data)])
644
645     def sample():
646         "sampling"
647         s = Sample(the.data)
648         assert 398 == len(s.rows), "length of rows"
649         assert 249 == s.x[-1].has[1], "symbol counts"
650
651     def dist():
652         "distance between rows"
653         s = Sample(the.data)
654         assert .84 <= s.dist(s.rows[1], s.rows[-1]) <= .842
655
656     def far():
657         "distant items"
658         s = Sample(the.data)
659         for _ in range(32):
660             a,_ = s.far(any(s.rows))
661             assert a>.5, "large?"
662
663     def clone():
664         "cloning"
665         s = Sample(the.data)
666         s1 = s.clone(s.rows)
667         d1,d2 = s.x[0].__dict__, s1.x[0].__dict__
668         for k,v in d1.items():
669             assert d2[k] == v, "clone test"
670
671     def half():
672         "divide data in two"
673         s = Sample(the.data); s1,s2,*_ = s.half()
674         print(s1.mid(s1.y))
675         print(s2.mid(s2.y))
676
677     def cluster():
678         "divide data in two"
679         s = Sample(the.data)
680         s.cluster().show(); print("")
681
682     def xplain():
683         "divide data in two"
684         s = Sample(the.data)
685         s.xplain().show(); print("")
686
687 #-----
688 the=options(__doc__)
689 if __name__ == "__main__": demo(the.todo,Demos)
690
691 """
692 all config local to Sample
693 Example class
694 """

```