```lisp
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;
; __preable '(__settings __macros __globals)
;;;; Ynot
(defpackage :ynot (:use :cl))
(in-package :ynot)

(defun help (lst)
  (terpri)
  (format t "ynot (v1.0) : not-so-supervised multi-objective optimization~%")
  (format t "(c) 2022 Tim Menzies, MIT (2 clause) license~%")
  (format t "~%OPTIONS:~%")
  (loop for (x(s y)) on lst by #'cddr do
    (format t " -~(~10a~) ~a = ~a~%" x s y)))

; Define settings.
(defvar *settings*
  '(enough ("how many numbers to keep    "   512)
     far    ("where to search for far items" .9)
     file   ("load data from file       "   "../data/auto93.csv")
     help   ("show help                 "   nil)
     p      ("distance coeffecient      "   2)
     seed   ("random number seed        "   10019)
     some   ("how many items to sample  "   512)
     todo   ("start up action           "   "nothing")))

; List for test cases
(defvar *demos* nil)

; Counter for test failures (this number will be the exit status of this code).
(defvar *fails* 0)

; To reset random number generator, reset this variable.
(defvar *seed* 10019)

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;;; Macros.

; Shorthand for accessing settings.
(defmacro ? (x) `(second(getf *settings* ',x)))

; Shorthand for nested struct access.
(defmacro o (s x &rest xs)
  (if xs `(o (slot-value ,s ',x) ,@xs) `(slot-value ,s ',x)))

; Anaphoic if.
(defmacro aif (expr then &optional else)
  `(let (it) (if (setf it ,expr) ,then ,else)))

; Loop over file
(defmacro with-csv ((lst file &optional out) &body body)
  (let ((str (gensym)))
    `(let (,lst)
       (with-open-file (,str ,file)
         (loop while (setf ,lst (read-line ,str nil)) do ,@body)
         ,out))))

; Ensure `a` has a cells `(x . number)` (where number defaults to 0).
(defmacro has (key dictionary)
  `(cdr (or (assoc ,key ,dictionary :test #'equal)
            (car (setf ,dictionary (cons (cons ,key 0) ,dictionary))))))

; Define a demo function (see examples at end of file).
(defmacro defdemo (name params &body body)
  `(progn (pushnew ',name *demos*) (defun ,name ,params  ,@body)))
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;;; Library

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;; coerce
; Cull silly white space.
(defun trim (s) (string-trim '(#\Space #\Tab) s))

; String to number (if we can).
(defun asAtom (s &aux (s1 (trim s)))
  (if (equal s1 "?") #\? (let ((x (ignore-errors (read-from-string s1))))
                           (if (numberp x) x s1))))

; String to list of strings
(defun asList (s &optional (sep #\,) (x 0) (y (position sep s :start (1+ x))))
  (cons (subseq s x y) (and y (asList s sep (1+ y)))))

; String to list of atoms
(defun asAtoms(s) (mapcar #'asAtom (asList s)))

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;; Random
; Unlike LISP, it is easy to set the seed of this random number genertor.
(labels ((park-miller () (setf *seed* (mod (* 16807.0d0 *seed*) 2147483647.0d00)
)
                           (/ *seed* 2147483647.0d0)))
  (defun randf (&optional (n 1)) (*   n (- 1.0d0 (park-miller)))) ;XX check this
  (defun randi (&optional (n 1)) (floor (* n (park-miller)))))

; Return sample from normal distribution.
(defun normal (&optional (mu 0) (sd 1))
  (+ mu (* sd (sqrt (* -2 (log (randf)))) (cos (* 2 pi (randf))))))

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;; round
(defun round2s (seq &optional (digits 2))
  (map 'list (lambda (x) (round2 x digits)) seq))

(defun round2 (number &optional (digits 2))
  (let* ((div (expt 10 digits))
         (tmp (/ (round (* number div)) div)))
    (if (zerop digits) (floor tmp) (float tmp))))

;; Stats
; Project 0..1
(defun abc2x (a b c)
  (max 0 (min 1 (/ (+ (* a a) (* c c) (- (* b b))) (+ (* 2 c) 1E-32)))))

; Normalize zero to one.
(defun norm (lo hi x)
  (if (< (abs (- hi lo)) 1E-9) 0 (/ (- x lo) (- hi lo))))

; Any item
(defun anv (seq)    (elt seq (randi (length seq))))
(defun many (seq n) (let (a) (dotimes (i n a) (push (any seq) a))))

; Return `p`-th item from seq.
(defun per (seq &optional (p .5) &aux (v (coerce seq 'vector)))
  (elt v (floor (* p (length v)))))

; Find sd from a sorted list.
(defun sd (seq &optional (key #'identity))
  (if (<= (length seq) 5) 0
    (/ (- (funcall key (per seq .9)) (funcall key (per seq .1))) 2.56)))

; Return entropy of symbols in an assoc list.
(defun ent (alist &aux (n 0) (e 0))
  (dolist (two alist) (incf n (cdr two)))
  (dolist (two alist e) (let ((p (/ (cdr two) n))) (decf e (* p (log p 2))))))

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;; misc
; For each setting `x`, look for `-x` on the command line.
(defun update-settings-from-command-line (lst)
  (let ((args #+clisp ext:*args*
              #+sbcl  sb-ext:*posix-argv*))
    (loop for (slot (help b4)) on lst by #'cddr do
      (setf (second (getf lst slot))
            (aif (member (format nil "-~a" slot) args :test #'equalp)
              (cond ((eq b4 t)   nil) ; boolean flags flip the default
                    ((eq b4 nil) t)   ; boolean flags flip the default
                    (t (asAtom (elt it 1))))
              b4)))))

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(defun pretty (lst &optional pre)
  (labels ((item (lst pre) (when lst (pretty (first lst) pre)
                                     (when (rest lst)
                                       (format t "~%~{~a~}" pre)
                                       (item (rest lst) pre)))))
    (cond ((null lst)  (princ "()"))
          ((atom lst)  (princ lst))
          ((listp lst) (princ "(") (item lst (cons "  " pre)) (princ ")")))))

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; Handle tests within a test function"
(defun ok (test &optional (msg " "))
  (cond (test (format t "~aPASS ~a~%" #\Tab  msg))
        (t    (incf *fails* )
              (if (? dump)
                (assert test nil msg)
                (format t "~aFAIL ~a~%" #\Tab msg)))))
(defun stop (&optional (status 0))
  #+clisp (ext:exit status) #+sbcl (sb-ext:exit :code status))

; Update *options* from command-line. Show help or run demo suite.
; Before demo, reset random number seed (and the settings).
; Return the number of fails to the operating system.
(defun main (&aux defaults)
  (labels ((fun (x) (find-symbol (string-upcase x)))
           (demo (todo) (when (fboundp todo)
                          (format t "~a~%"  todo)
                          (setf *settings* (copy-tree defaults)
                                *seed*     (? seed))
                          (funcall todo))))
    (update-settings-from-command-line *settings*)
    (setf defaults (copy-tree *settings*))
    (cond ((? help)                    (help *settings*))
          ((equalp "all" (? todo)) (dolist (one *demos*) (demo (fun one))))
          (t                           (demo (fun (? todo)))))
    (stop *fails*)))
```

```lisp
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;;; Classes

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; The first/last char of a column name defines meta-knowledge for that column.
(defun is (s kind)
  (let
    ((post '((ignore #\X) (klass #\!) (less #\-) (more #\+) (goal #\+ #\- #\!)))
     (pre  '((num #\$))))
    (or (member (char s (1- (length s))) (cdr (assoc kind post)))
        (member (char s 0)               (cdr (assoc kind pre))))))
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;.        /
;; Sym
(defstruct (sym  (:constructor %make-sym )) (n 0) at name all mode (most 0))

(defun make-sym (&optional (at 0) (name ""))
  (%make-sym :at at :name name))

(defmethod add ((self sym) x)
  (with-slots (n all mode most) self
    (unless (eq x #\?)
      (incf n)
      (let ((now (incf (has x all))))
        (if (> now most)
          (setf most now
                mode x)))))
  x)

(defmethod div ((self sym)) (ent (sym-all self)))
(defmethod mid ((self sym)) (sym-mode self))

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;; Num
(defstruct (num  (:constructor %make-num ))
  (n 0) at name
  (all (make-array 5 :fill-pointer 0 :adjustable t ))
  (max (? enough))
  ok w (hi -1E32) (lo 1E32))

(defun make-num (&optional (at 0) (name ""))
  (%make-num :at at :name name :w (if (is name 'less) -1 1)))

(defmethod add ((self num) x)
  (with-slots (n lo hi ok all max) self
    (unless (eq x #\?)
      (incf n)
      (setf lo (min x lo)
            hi (max x hi))
      (cond ((< (length all) max)  (setf ok nil) (vector-push-extend x all))
            ((< (randf) (/ max n)) (setf ok nil)
                                   (setf (elt all (randi (length all))) x)))))
  x)

(defmethod holds ((self num))
  (with-slots (ok all) self
    (unless ok (setf all (sort all #'<)))
    (setf ok t)
   all))

(defmethod div ((self num)) (sd  (holds self)))
(defmethod mid ((self num)) (per (holds self)))

;.      _   _   |  _
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;; cols
(defstruct (cols (:constructor %make-cols)) all x y names klass)

(defun make-cols (names &aux (at -1) x y klass all)
  (dolist (s names (%make-cols :names names :all (reverse all)
                               :x x :y y :klass klass))
    (let ((now (funcall (if (is s 'num)  #'make-num #'make-sym) (incf at) s)))
      (push now all)
      (when (not (is s 'ignore))
        (if (is s 'goal)  (push  now y) (push now x))
        (if (is s 'klass) (setf klass now))))))

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;; egs
(defstruct (egs (:constructor %make-egs))
 cols (rows (make-array 5 :fill-pointer 0 :adjustable t)))

(defun make-egs (&optional data &aux (self (%make-egs)))
   (if data (adds self data) self))

(defmethod mid ((self egs) &aux (cols (o self cols y)))
   (mapcar #'mid cols))

(defmethod adds ((self egs) (file string))
  (with-csv (row file self) (add self (asAtoms row))))

(defmethod adds ((self egs) seq)
  (map nil #'(lambda (row) (add self row)) seq)
 self)

(defmethod add ((self egs) row)
  (with-slots (rows cols) self
    (if cols
      (vector-push-extend (mapcar #'add (o cols all) row) rows)
      (setf cols (make-cols row)))))

(defmethod size ((self egs)) (length (o self rows)))

(defmethod clone ((self egs) &optional data)
  (adds (make-egs (list (o self cols names))) data))

(defmethod better ((self egs) row1 row2 &aux (s1 0) (s2 0))
  (let ((n (length (o egs cols y))))
    (dolist (col (o egs cols y)  (< (/ s1 n) (/ s2 n)))
      (let* ((a0 (elt row1 (o col at)))
             (b0 (elt row2 (o col at)))
             (a  (norm (o col lo) (o col hi) a0))
             (b  (norm (o col lo) (o col hi) b0)))
        (decf s1 (exp (/ (* (o col w) (- a b)) n)))
        (decf s2 (exp (/ (* (o col w) (- b a)) n)))))))
```

```lisp
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;;; Cluster

(defmethod dist ((self egs) row1 row2)
  (let ((n 0) (d 0) (p (? p)))
    (dolist (col (o self cols x) (expt (/ d n) (/ 1  p)))
      (let ((inc (dist col (elt row1 (o col at))
                           (elt row2 (o col at)))))
        (incf d (expt inc p))
        (incf n)))))

(defmethod dist ((self num) x y)
  (with-slots (lo hi) self
    (cond ((and (eq x #\?) (eq y #\?)) (return-from dist 1))
          ((eq x #\?) (setf y (norm lo  hi y)
                            x (if (< y .5) 1  0)))
          ((eq y #\?) (setf x (norm lo  hi x)
                            y (if (< x .5) 1 0)))
          (t          (setf x (norm lo hi x)
                            y (norm lo hi y))))
    (abs (- x y))))

(defmethod dist ((self sym) x y)
  (if (and (eq x #\?) (eq y #\?))
    0
    (if (equal x y) 0 1)))

(defmethod neighbors ((self egs) row1 &optional (rows (o self rows)))
  (labels ((f (row2) (cons (dist self row1 row2) row2)))
    (sort (map 'vector #'f rows) #'< :key #'car)))

(defmethod far ((self egs) row &optional (rows (o self rows)))
  (cdr (per (neighbors self row rows) (? far))))

(defmethod projections ((self egs) left right c)
  (labels ((f (r)  (cons (abc2x (dist self left r) (dist self right r) c) r)))
    (map 'list #'f (o self rows))))

(defmethod divide-in-half ((self egs) &optional (rows (o self rows)))
  (let* ((some     (many rows (? some)))
         (anywhere (any some))
         (left     (far self anywhere some))
         (right    (far self left some))
         (c        (dist self left right))
         (lefts    (clone self))
         (rights   (clone self))
         (nleft    (floor (* .5 (length rows)))))
    (dolist (one  (sort (projections self left right c) #'< :key #'first))
      (add (if (>= (decf nleft) 0) lefts rights) (cdr one)))
    (values lefts rights left right c (elt (o rights rows) 1))))

(defstruct (cluster (:constructor %make-cluster)) egs top (rank 0) lefts rights)

(defmethod leaf ((self egs)) (not (o self lefts) (o self rights)))

(defun make-cluster (top &optional (egs top))
  (multiple-value-bind (half top (o egs rows))
    (lefts rights left right border c)
    (let ((self (%make-cluster :egs egs :top top :left left :right right
                               :c c :border border)))
      (when (>= (size egs) (* 2 (expt (size top) (? minItems))))
        (when (<  (size lefts) (size egs))
          (setf (o self lefts)  (cluster top lefts)
                (o self rights) (cluster top rights))))
     self)))
```

```
; (defmethod show ((self cluster) &optional (pre ""))
;   (let ((front (format t "~a~a" pre (length (o egs rows)))))
;     (if  (leaf (o self egs))
;       (format t "~20a~a" front (mid (o self egs) (o self egs cols y)))
;       (progn
;         (print front)
;         (if (o self lefts)  (show (o lefts)  (format nil "|.. ~a" pre)))
;         (if (o self rights) (show (o rights) (format nil "|.. ~a" pre)))))))
;.    ___  ____ _  _ ____ ____/
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;;; Demos

(defdemo .rand() (print (randf)))

(defdemo .egs()
  (let ((eg (make-egs (? file))))
    (holds (second (o eg cols y)))
    (print (o eg cols y))))

(defdemo .dist1(&aux (eg (make-egs (? file))))
  (print (sort (loop repeat 64 collect
                 (round2 (dist eg (any (o eg rows)) (any (o eg rows))) 2)) #'<))
)

(defdemo .dist2(&aux (out t) (eg (make-egs (? file))))
  (loop repeat 64 do
    (let ((a (any (o eg rows)))
          (b (any (o eg rows)))
          (c (any (o eg rows))))
      (setf out (and out (>= (+ (dist eg a b) (dist eg b c)) (dist eg a c))
                         (=      (dist eg a b) (dist eg b a))
                         (zerop (dist eg a a))))))
  (ok out "ands"))

(defdemo .clone(&aux (eg1 (make-egs (? file))))
  (let ((eg2 (clone eg1 (o eg1 rows))))
    (ok (equal (div (first (o eg1 cols y)))
               (div (first (o eg2 cols y)))))))

(defdemo .neighbors (&aux (eg (make-egs (? file))))
  (loop repeat 2 do
    (let* ((x (any (o eg rows)))
           (y (far eg x)))
      (format t "~%      ~a~%" x)
      (print (neighbors eg x (many (o eg rows) 10)))
      (format t "~%      ~a~a~%"  y (dist eg x y)))))

(defdemo .mid (&aux (eg (make-egs (? file))))
  (format t "~a = ~a~%" (mapcar #'(lambda (c) (o c name)) (o eg cols y)) (mid eg)
))

(defdemo .half (&aux (eg (make-egs (? file))))
  (multiple-value-bind (lefts rights left right c border)
    (divide-in-half eg)
    (format t "~a ~a~%~a ~a~%~a ~a" (mid eg) (size eg)
                            (mid lefts) (size lefts)
                            (mid rights) (size rights))))

(main)
```