

(Downloaded from <https://cs.stanford.edu/~knuth/programs.html> and typeset on May 28, 2023)

1. Data for dancing. This program creates data suitable for the DANCE routine, given the description of a board to be covered and a set of polyomino shapes.

The first line of input names all the board positions, in any order. Each position is a two-digit number representing x and y coordinates; each “digit” is a single character, 0–9 or a–z representing the numbers 0–35. For example,

11 12 13 21 22 23 31 32 33

is one way to describe a 3×3 board.

The second line of input names all the pieces. Each piece name consists of at most three characters; the name should also be distinguishable from a board position. (The program does not check this.)

The remaining lines of input describe the polyominoes. First comes the name, followed by two integers s and t , meaning that the shape should appear in s rotations and t transpositions. Then come two-digit coordinates for each cell of the shape. For example, the line

P 4 2 00 10 01 11 02

describes a pentomino that can appear in 8 orientations; it is equivalent to eight lines

P 1 1 00 10 01 11 02
P 1 1 00 10 01 11 21
P 1 1 10 01 11 02 12
P 1 1 00 10 20 11 21
P 1 1 00 01 10 11 20
P 1 1 00 01 02 11 12
P 1 1 01 10 11 20 21
P 1 1 00 01 10 11 12

obtained by rotating the original shape, then transposing and rotating again. The values of s and t depend on the symmetry of the piece; six cases (1, 1), (1, 2), (2, 1), (2, 2), (4, 1), and (4, 2) can arise, for pieces with full symmetry, swastika symmetry, double-reflection symmetry, 180° symmetry, reflection symmetry, and no symmetry. If s had been 2 instead of 4, only the first, second, fifth, and sixth of these eight orientations would have been generated.

After optional rotation and/or translation, each piece is translated in all possible ways that fit on the given board, by adding constant values (x, y) to all of its coordinate pairs. For example, if the piece P 1 1 00 10 01 11 02 is specified with the 3×3 board considered above, it will lead to two possible rows in the exact cover problem, namely P 11 21 12 22 13 and P 21 31 22 23.

```
#define max_pieces 100    /* at most this many shapes */
#define buf_size 36*36*3+8 /* upper bound on line length */
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <ctype.h>
  (Global variables 4)
  (Subroutines 3);
main()
{
  register char *p, *q;
  register int j, k, n, x, y, z;
  (Read and output the board 2);
  (Read and output the piece names 5);
  (Read and output the pieces 6);
}
```

```

2. #define panic(m)
    { fprintf(stderr, "%s!\n%s", m, buf); exit(-1); }

⟨Read and output the board 2⟩ ≡
    fgets(buf, buf_size, stdin);
    if (buf[strlen(buf) - 1] ≠ '\n') panic("Input_line_too_long");
    bxmin = bymin = 35; bxmax = bymax = 0;
    for (p = buf; *p; p += 3) {
        while (isspace(*p)) p++;
        if (¬*p) break;
        x = decode(*p);
        if (x < 0) panic("Bad_x_coordinate");
        y = decode*(p + 1);
        if (y < 0) panic("Bad_y_coordinate");
        if (¬isspace*(p + 2)) panic("Bad_board_position");
        if (board[x][y]) panic("Duplicate_board_position");
        if (x < bxmin) bxmin = x;
        if (x > bxmax) bxmax = x;
        if (y < bymin) bymin = y;
        if (y > bymax) bymax = y;
        board[x][y] = 1;
    }
    if (bxmin > bxmax) panic("Empty_board");
    fwrite(buf, 1, strlen(buf) - 1, stdout);    /* output all but the newline */

```

This code is used in section 1.

```

3. ⟨Subroutines 3⟩ ≡
    int decode(c)
        char c;
    {
        if (c ≤ '9') {
            if (c ≥ '0') return c - '0';
        } else if (c ≥ 'a') {
            if (c ≤ 'z') return c + 10 - 'a';
        }
        return -1;
    }

```

See also section 12.

This code is used in section 1.

```

4. ⟨Global variables 4⟩ ≡
    char buf[buf_size];
    int board[36][36];    /* cells present */
    int bxmin, bxmax, bymin, bymax;    /* used portion of the board */

```

See also section 7.

This code is used in section 1.

```

5. ⟨Read and output the piece names 5⟩ ≡
    if (¬fgets(buf, buf_size, stdin)) panic("No_piece_names");
    printf("_ %s", buf);    /* just pass the piece names through */

```

This code is used in section 1.

6. \langle Read and output the pieces 6 $\rangle \equiv$

```

while (fgets(buf, buf_size, stdin)) {
  if (buf[strlen(buf) - 1] != '\n') panic("Input_line_too_long");
  for (p = buf; isspace(*p); p++) ;
  if (!*p) panic("Empty_line");
  for (q = p + 1; !isspace(*q); q++) ;
  if (q > p + 3) panic("Piece_name_too_long");
  for (q = name; !isspace(*p); p++, q++) *q = *p;
  *q = '\0';
  for (p++; isspace(*p); p++) ;
  s = *p - '0';
  if ((s != 1 & s != 2 & s != 4) || !isspace(*(p + 1))) panic("Bad_s_value");
  for (p += 2; isspace(*p); p++) ;
  t = *p - '0';
  if ((t != 1 & t != 2) || !isspace(*(p + 1))) panic("Bad_t_value");
  n = 0;
  xmin = ymin = 35; xmax = ymax = 0;
  for (p += 2; *p; p += 3, n++) {
    while (isspace(*p)) p++;
    if (!*p) break;
    x = decode(*p);
    if (x < 0) panic("Bad_x_coordinate");
    y = decode(*(p + 1));
    if (y < 0) panic("Bad_y_coordinate");
    if (!isspace(*(p + 2))) panic("Bad_board_position");
    if (n == 36 * 36) panic("Pigeonhole_principle_says_you_repeated_a_position");
    xx[n] = x, yy[n] = y;
    if (x < xmin) xmin = x;
    if (x > xmax) xmax = x;
    if (y < ymin) ymin = y;
    if (y > ymax) ymax = y;
  }
  if (n == 0) panic("Empty_piece");
   $\langle$  Generate the possible piece placements 8  $\rangle$ ;
}

```

This code is used in section 1.

7. \langle Global variables 4 $\rangle + \equiv$

```

char name[4]; /* name of current piece */
int s, t; /* symmetry type of current piece */
int xx[36 * 36], yy[36 * 36]; /* coordinates of current piece */
int xmin, xmax, ymin, ymax; /* range of coordinates */

```

8. \langle Generate the possible piece placements 8 $\rangle \equiv$
while (t) {
 for ($k = 1$; $k \leq 4$; $k++$) {
 if ($k \leq s$) \langle Output translates of the current piece 11 \rangle ;
 \langle Rotate the current piece 10 \rangle ;
 }
 \langle Transpose the current piece 9 \rangle ;
 $t--$;
}

This code is used in section 6.

9. \langle Transpose the current piece 9 $\rangle \equiv$
for ($j = 0$; $j < n$; $j++$) {
 $z = xx[j]$;
 $xx[j] = yy[j]$;
 $yy[j] = z$;
}
 $z = xmin$; $xmin = ymin$; $ymin = z$;
 $z = xmax$; $xmax = ymax$; $ymax = z$;

This code is used in section 8.

10. \langle Rotate the current piece 10 $\rangle \equiv$
for ($j = 0$; $j < n$; $j++$) {
 $z = xx[j]$;
 $xx[j] = 35 - yy[j]$;
 $yy[j] = z$;
}
 $z = xmin$; $xmin = 35 - ymax$; $ymax = xmax$; $xmax = 35 - ymin$; $ymin = z$;

This code is used in section 8.

11. \langle Output translates of the current piece 11 $\rangle \equiv$
for ($x = bxmin - xmin$; $x \leq bxmax - xmax$; $x++$)
 for ($y = bymin - ymin$; $y \leq bymax - ymax$; $y++$) {
 for ($j = 0$; $j < n$; $j++$)
 if ($\neg board[x + xx[j]][y + yy[j]]$) **goto** *nope*;
 $printf(name)$;
 for ($j = 0$; $j < n$; $j++$) $printf("\%c\%c", encode(x + xx[j]), encode(y + yy[j]))$;
 $printf("\n")$;
 nope: ;
 }

This code is used in section 8.

12. \langle Subroutines 3 $\rangle + \equiv$
char *encode*(x)
 int x ;
 {
 if ($x < 10$) **return** '0' + x ;
 return 'a' - 10 + x ;
 }

13. Index.

board: 2, 4, 11.
buf: 2, 4, 5, 6.
buf_size: 1, 2, 4, 5, 6.
bxmax: 2, 4, 11.
bxmin: 2, 4, 11.
bymax: 2, 4, 11.
bymin: 2, 4, 11.
c: 3.
decode: 2, 3, 6.
encode: 11, 12.
exit: 2.
fgets: 2, 5, 6.
fprintf: 2.
fwrite: 2.
isspace: 2, 6.
j: 1.
k: 1.
main: 1.
max_pieces: 1.
n: 1.
name: 6, 7, 11.
nope: 11.
p: 1.
panic: 2, 5, 6.
printf: 5, 11.
q: 1.
s: 7.
stderr: 2.
stdin: 2, 5, 6.
stdout: 2.
strlen: 2, 6.
t: 7.
x: 1, 12.
xmax: 6, 7, 9, 10, 11.
xmin: 6, 7, 9, 10, 11.
xx: 6, 7, 9, 10, 11.
y: 1.
ymax: 6, 7, 9, 10, 11.
ymin: 6, 7, 9, 10, 11.
yy: 6, 7, 9, 10, 11.
z: 1.

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POLYOMINOES

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