

(See <https://cs.stanford.edu/~knuth/programs.html> for date.)

**1. Intro.** This program computes the up-up-or-down-down permutation of  $\{1, 2, \dots, 2n-1\}$  that corresponds to a given  $2 \times n$  whirlpool permutation. The latter permutation appears on the command line, as a permutation of  $\{0, 1, \dots, 2n-1\}$ , with 0 in the bottom left corner.

(I've made no attempt to be efficient.)

(But I didn't go out of my way to be inefficient.)

(Apologies for doing this hurriedly.)

```
#define maxn 100
#include <stdio.h>
#include <stdlib.h>
int a[2 * maxn];
int used[2 * maxn];
int answer[2 * maxn];
main(int argc, char *argv[])
{
    register int i, j, k, n, nn, t, saven;
    ⟨Process the command line 2⟩;
    for (; n > 1; n--) ⟨Reduce the problem from n to n - 1 4⟩;
    ⟨Print the answer 5⟩;
}
```

**2.**  $\langle \text{Process the command line } 2 \rangle \equiv$

```

if ( $argc < 5 \vee ((argc \& 1) \equiv 0)$ ) {
    fprintf(stderr, "Usage: %s a11 a12 ... a1n 0 a22 ... a2n\n", argv[0]);
    exit(-1);
}
nn = argc - 1, n = sa ven = nn/2;
if ( $n > maxn$ ) {
    fprintf(stderr, "Recompile me: This program has maxn=%d!\n", maxn);
    exit(-99);
}
for ( $k = 0; k < nn; k++$ ) {
    if ( $sscanf(argv[k + 1], "%d", \&a[k]) \neq 1$ ) {
        fprintf(stderr, "Bad matrix entry '%s'!\n", argv[k + 1]);
        exit(-2);
    }
    if ( $a[k] < 0 \vee a[k] \geq nn$ ) {
        fprintf(stderr, "Matrix entry '%d' out of range!\n", a[k]);
        exit(-3);
    }
    if ( $used[a[k]]$ ) {
        fprintf(stderr, "Duplicate matrix entry '%d'!\n", a[k]);
        exit(-4);
    }
    used[a[k]] = 1;
}
if ( $a[n]$ ) {
    fprintf(stderr, "Matrix entry a21 should be zero, not %d!\n", a[n]);
    exit(-5);
}
 $\langle \text{Verify the whirlpool criteria } 3 \rangle;$ 

```

This code is used in section 1.

**3.**  $\langle \text{Verify the whirlpool criteria } 3 \rangle \equiv$

```

for ( $k = n + 1; k < nn; k++$ ) {
    if ( $((((a[k - n - 1] < a[k - n]) + (a[k - n] < a[k]) + (a[k] < a[k - 1]) + (a[k - 1] < a[k - n - 1])) \& 1) \equiv 0)$ )
    {
        fprintf(stderr, "Not a vortex! (%d %d / %d %d)\n", a[k - n - 1], a[k - n], a[k - 1], a[k]);
        exit(-6);
    }
}

```

This code is used in section 2.

4.  $\langle$  Reduce the problem from  $n$  to  $n - 1$  4  $\rangle \equiv$

```

{
  register int t, nnp;
  nnp = n + n - 2;
  answer[nnp + 1] = a[0], answer[nnp] = a[1];
  for (k = 1; k < n; k++) {
    t = a[k];
    if (t > answer[nnp + 1]) t--;
    a[k - 1] = t - 1;
    t = a[k + saven];
    if (t > answer[nnp + 1]) t--;
    a[k + saven - 1] = t - 1;
  }
  for (t = nnp - a[saven], k = 0; k < n - 1; k++) {
    a[k] = (a[k] + t) % nnp;
    a[k + saven] = (a[k + saven] + t) % nnp;
  }
}

```

This code is used in section 1.

5. At this point  $n = 1$ , and *answer* contains numbers that need to be “uncompressed” because they were the results of a recursive computation on a compressed problem.

$\langle$  Print the answer 5  $\rangle \equiv$

```

n = saven;
answer[1] = 1;
for (k = 0; k < nn; k++) used[k] = 0;
used[answer[nn - 1]] = used[answer[nn - 2]] = 1;
for (k = nn - 4; k ≥ 0; k -= 2) {
  t = answer[k + 1];
  for (j = 1; j ≤ t; j++)
    if (used[j]) t++;
  answer[k + 1] = t;
  t = answer[k];
  for (j = 1; j ≤ t; j++)
    if (used[j]) t++;
  answer[k] = t;
  used[t] = used[answer[k + 1]] = 1;
}
for (k = nn - 1; k; k--) printf("␣%d", answer[k]);
printf("\n");

```

This code is used in section 1.

**6. Index.**

*a*: [1](#).  
*answer*: [1](#), [4](#), [5](#).  
*argc*: [1](#), [2](#).  
*argv*: [1](#), [2](#).  
*exit*: [2](#), [3](#).  
*fprintf*: [2](#), [3](#).  
*i*: [1](#).  
*j*: [1](#).  
*k*: [1](#).  
*main*: [1](#).  
*maxn*: [1](#), [2](#).  
*n*: [1](#).  
*nn*: [1](#), [2](#), [3](#), [5](#).  
*nnp*: [4](#).  
*printf*: [5](#).  
*saven*: [1](#), [2](#), [4](#), [5](#).  
*sscanf*: [2](#).  
*stderr*: [2](#), [3](#).  
*t*: [1](#), [4](#).  
*used*: [1](#), [2](#), [5](#).

- ⟨ Print the answer 5 ⟩    Used in section 1.
- ⟨ Process the command line 2 ⟩    Used in section 1.
- ⟨ Reduce the problem from  $n$  to  $n - 1$  4 ⟩    Used in section 1.
- ⟨ Verify the whirlpool criteria 3 ⟩    Used in section 2.

WHIRLPOOL2N-ENCODE

	Section	Page
Intro .....	<a href="#">1</a>	1
Index .....	<a href="#">6</a>	4