

\check if a number is a member of the used set
: isused ( n -- bool )
  \loop through all set elements
  usedcounter @ 0 ?do
    \compare n with elt i
    dup used i cells + @
    \return true if its a match
    = if drop -1 unloop exit then
  loop
  \return false
  drop 0
;

If you are meticulous about documenting how the stack is used, it is much easier to catch low-level mistakes.
It can make it harder to read and follow the higher-level flow of the word, however, so use this technique judiciously. For example, you might write a word this way, test it, and then convert it into the first version (shown above) once you are confident that it is correct.

**Overview**

I suggest representing states in two ways:

- Store three values on the stack for a single state: near, m, and c. near is true if the boat is on the near side of the river. m and c are the number of missionaries and cannibals on the near side of the river, respectively.

- Store all three values in a single integer. This is the “packed” format. While less convenient to work with, this format makes it easier to store states in stacks and sets.

The overall flow of the program will follow this pseudo-code:

- push the start state on the candidate stack
- search:
  - print the candidate stack
  - pop a candidate state off the candidate stack
  - push a copy on the bread-crumbs trail stack
  - if it is the goal state
    - print out the contents of the bread-crumbs trail in order. this is the solution to the puzzle.
  - else
    - generate a list of successor states (there should be exactly 5)
    - push the valid, legal, fresh successors on the candidate stack
    - for each successor generated in this step:
      - call search recursively
  - pop the state off the bread-crumbs trail stack

I suggest writing lots of helper words. Avoid complexity in the search word, since it will already be the most difficult part to test. What follows is one suggested implementation. You are free to write it a different way if you would prefer.

**Implementation**

Start by writing some helper words. The first few are described adequately by their names and stack-effect comments:

```plaintext
: 3dup ( x y z -- x y z x y z ) ... ;
: 3drop ( x y z -- ) ... ;
: pack ( near m c -- packedstate ) ... ;
: unpack ( packedstate -- near m c ) ... ;
: printstate ( side m c -- ) ... ;
```

Write each of these and test them thoroughly. To load code from a source file, give the name of the source file when loading gforth:

```
gforth missionaries.fs
```

Next, implement basic stack and set data structures:

```plaintext
\ test if n is in the used set
\ isused ( n -- bool ) ... ;
\ add n to the used set
\ addused ( n -- ) ... ;
\ push a value on the candidate stack
\ pushcandidate ( n -- ) ... ;
\ pop a value off the candidate stack
\ popcandidate ( -- n ) ... ;
\ push a value on the bread crumb trail stack
\ pushcrumb ( n -- ) ... ;
```
For debugging, I suggest writing words to print out the entire contents of each of these data structures:

```forth
: printused ( -- ) ... ;
: printcandidates ( -- ) ... ;
: printcrumbs ( -- ) ... ;
```

Next, start the words to work with states:

```forth
: startstate ( -- near m c ) ... ;
: isgoal ( near m c -- bool ) ... ;
: isvalid ( near m c -- bool ) ... ;
```

The next two generate, record, and report on potential next moves from a given state:

```forth
: addcandidate ( -- near m c ) ... ;
: successors ( near m c -- n )
```

addcandidate requires a bit more explanation. It should:

- check if the (packed) state is valid (reject it and print a message if not)
- check if the (packed) state is already used (reject it and print a message if not)
- otherwise:
  - print a message indicating that it is a fresh state
  - add the packed state to the used list
  - add the packed state to the candidate stack

addcandidate is a helper for successors, which generates all (5) possible successors for a given state, handing each one to addcandidate, which filters some of them out and adds the rest to the candidate stack.

Then comes the main search loop:

```forth
: search ( -- )
```

search assumes that a state is already on the candidate stack, and it uses the words already described to implement the pseudo-code given earlier. For a word to call itself recursively, it uses the special word recurse instead of the normal word name (search in this case).

Finally, write a start word that resets the stacks and the used set, puts the start state on the candidate stack, adds it to the used set, and calls search.

### Example

Here is the output of my solution:

```
$ gforth missionaries.fs
redefined search   Gforth 0.7.2, Copyright (C) 1995-2008 Free Software Foundation, Inc.
Gforth comes with ABSOLUTELY NO WARRANTY; for details type `license'
Type `bye' to exit
start
```
candidates:
[ near 3 3 ]
fresh [ far 3 2 ]
fresh [ far 3 1 ]
fresh [ far 2 2 ]
invalid [ far 2 3 ]
invalid [ far 1 3 ]
candidates:
[ far 3 2 ]
[ far 3 1 ]
[ far 2 2 ]
invalid [ near 2 3 ]
invalid [ near 2 4 ]
repeat [ near 3 3 ]
fresh [ near 3 2 ]
invalid [ near 4 2 ]
candidates:
[ far 3 2 ]
[ far 3 1 ]
[ near 3 2 ]
repeat [ far 3 1 ]
fresh [ far 3 0 ]
invalid [ far 2 1 ]
repeat [ far 2 2 ]
invalid [ far 1 2 ]
candidates:
[ far 3 2 ]
[ far 3 1 ]
[ far 3 0 ]
fresh [ near 3 1 ]
repeat [ near 3 2 ]
invalid [ near 4 1 ]
invalid [ near 4 0 ]
invalid [ near 5 0 ]
candidates:
[ far 3 2 ]
[ far 3 1 ]
[ near 3 1 ]
repeat [ far 3 0 ]
invalid [ far 3 -1 ]
invalid [ far 2 0 ]
invalid [ far 2 1 ]
fresh [ far 1 1 ]
candidates:
[ far 3 2 ]
[ far 3 1 ]
[ far 1 1 ]
invalid [ near 1 2 ]
invalid [ near 1 3 ]
fresh [ near 2 2 ]
invalid [ near 2 1 ]
repeat [ near 3 1 ]
candidates:
[ far 3 2 ]
[ far 3 1 ]
[ near 2 2 ]
invalid [ far 2 1 ]
invalid [ far 2 0 ]
repeat [ far 1 1 ]
invalid [ far 1 2 ]
fresh [ far 0 2 ]
candidates:
[ far 3 2 ]
[ far 3 1 ]
[ far 0 2 ]
fresh [ near 0 3 ]
invalid [ near 0 4 ]
invalid [ near 1 3 ]
invalid [ near 1 2 ]
repeat [ near 2 2 ]

candidates:
[ far 3 2 ]
[ far 3 1 ]
[ near 0 3 ]
repeat [ far 0 2 ]
fresh [ far 0 1 ]
invalid [ far -1 2 ]
invalid [ far -1 3 ]
invalid [ far -2 3 ]

candidates:
[ far 3 2 ]
[ far 3 1 ]
[ far 0 1 ]
fresh [ near 0 2 ]
repeat [ near 0 3 ]
invalid [ near 1 2 ]
fresh [ near 1 1 ]
invalid [ near 2 1 ]

candidates:
[ far 3 2 ]
[ far 3 1 ]
[ near 0 2 ]
[ near 1 1 ]
invalid [ far 1 0 ]
invalid [ far 1 -1 ]
fresh [ far 0 0 ]
repeat [ far 0 1 ]
invalid [ far -1 1 ]

candidates:
[ far 3 2 ]
[ far 3 1 ]
[ near 0 2 ]
[ far 0 0 ]

solution found

.............
[ near 3 3 ]
[ far 2 2 ]
[ near 3 2 ]
[ far 3 0 ]
[ near 3 1 ]
[ far 1 1 ]
[ near 2 2 ]
[ far 0 2 ]
[ near 0 3 ]
[ far 0 1 ]
[ near 1 1 ]
[ far 0 0 ]
backtracking
backtracking

candidates:
[ far 3 2 ]
[ far 3 1 ]
[ near 0 2 ]
repeat [ far 0 1 ]
repeat [ far 0 0 ]
invalid [ far 0 1 ]
invalid [ far -1 2 ]
invalid [ far -2 2 ]
backtracking
backtracking
backtracking
backtracking
backtracking
backtracking
backtracking
backtracking
backtracking
backtracking

candidates:
[ far 3 2 ]
[ far 3 1 ]
repeat    [ near 3 2 ]
repeat    [ near 3 3 ]
invalid   [ near 4 2 ]
invalid   [ near 4 1 ]
invalid   [ near 5 1 ]
backtracking

candidates:
[ far 3 2 ]
repeat    [ near 3 3 ]
invalid   [ near 3 4 ]
invalid   [ near 4 3 ]
invalid   [ near 4 2 ]
invalid   [ near 5 2 ]
backtracking
backtracking
ok