ITI 1121. Introduction to Computing II *

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Abstract

- Queues-based algorithms
  - Asynchronous processes
  - Simulations
  - State-space search

*These lecture notes are meant to be looked at on a computer screen. Do not print them unless it is necessary.

Summary

Queues are implemented with arrays or linked elements.

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Several implementations are possible: using **sentinel values**, destroying the array, using a **boolean value** to indicate if the queue is full/empty or to maintain a **count** of the number of elements in the queue. Of course, the details of the implementation of each method will vary with the implementation.

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The operation **dequeue()** is sometimes called **serve()**; because queues are often used in the context of client/server applications.

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Asynchronous processes:

- The client insert data into a queue (enqueue);
- The server removes data from the queue (dequeue) whenever it's ready for processing.

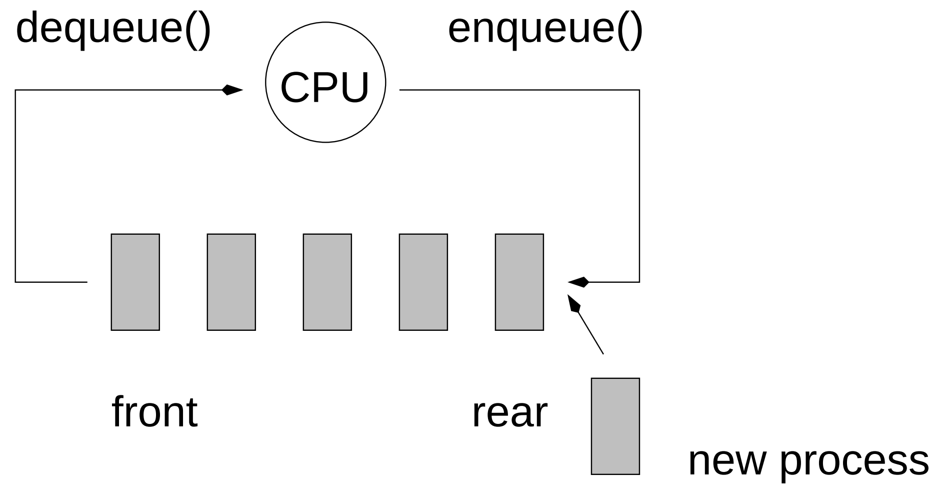
In this context, the queue is sometimes called a **buffer**.

Asynchronous processes

In particular, *inter-process communications* in operating systems work like this.

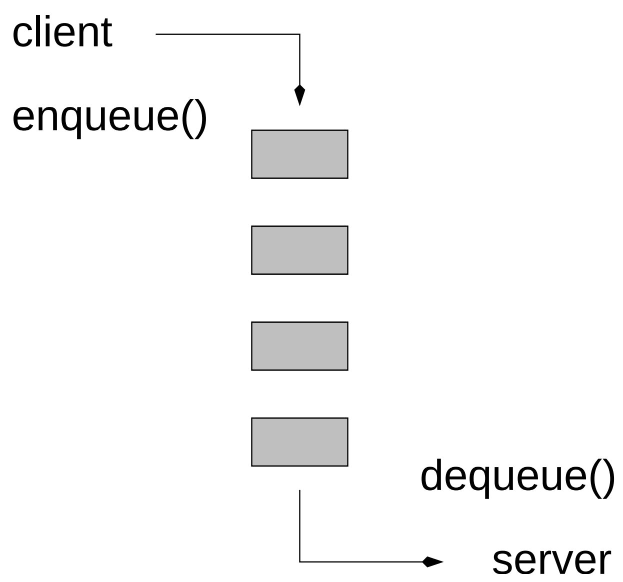
1. *printer spooler*;
2. *buffered i/o*;
3. disk accesses;
4. sending messages (packets) across the network.

Time-shared applications



All modern operating systems operate in time-shared mode. One of the frequent techniques to share time is called *round-robin*. The first process in the queue is allocated a slice of time (dequeue) after which it is suspended and put at the end of the queue (enqueue), time is allocated for the next process.

Inter-process communications



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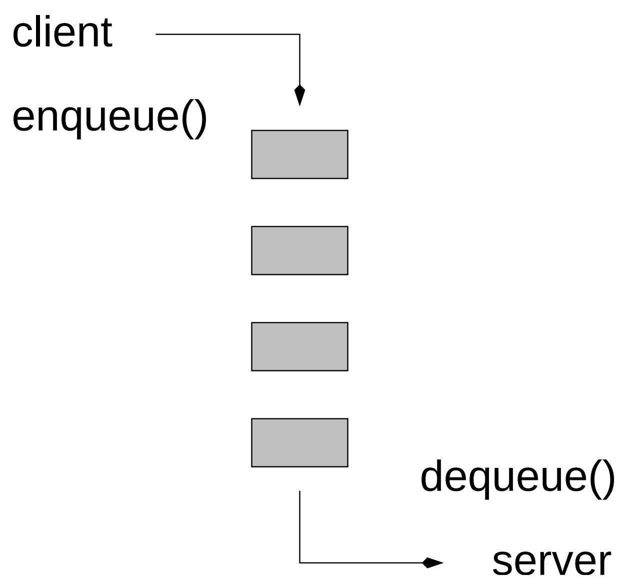
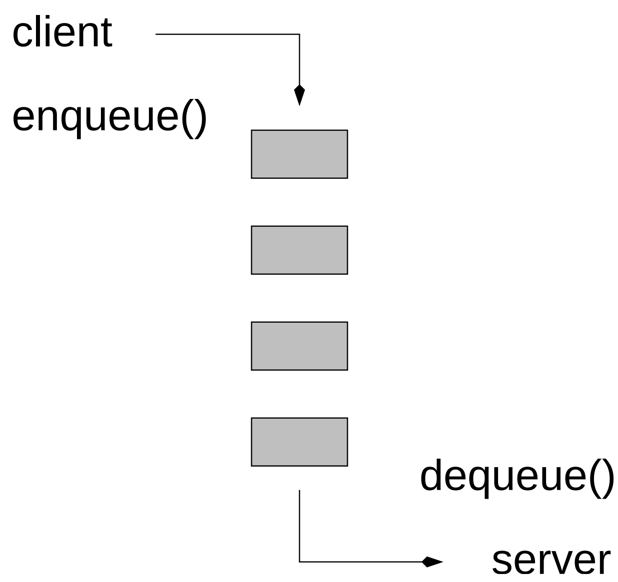



```
while ( true ) {
    while ( ! q.isFull() ) {
        q.enqueue( ... );
    }
}
```

Inter-process communications

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while ( true ) {
    while ( ! q.isFull() ) {
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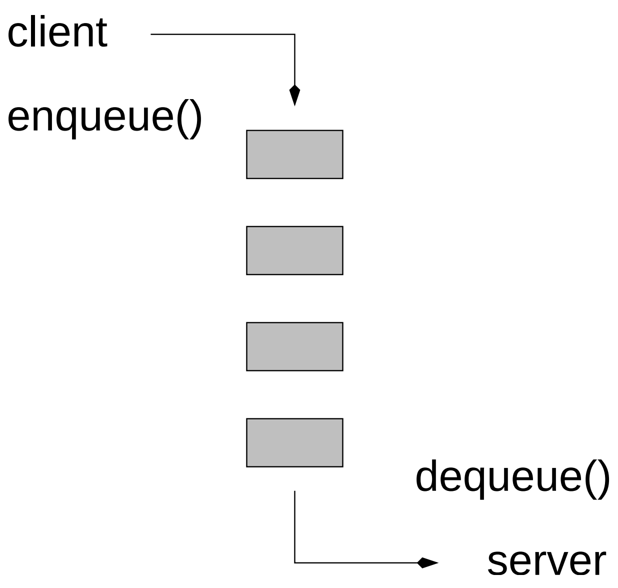
```
while ( true ) {
    while ( ! q.empty() ) {
        process( q.dequeue() )
    }
}
```

Inter-process communications

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    }
}
```

⇒ *inter-process communication* (IPC), *buffered i/o*, etc.

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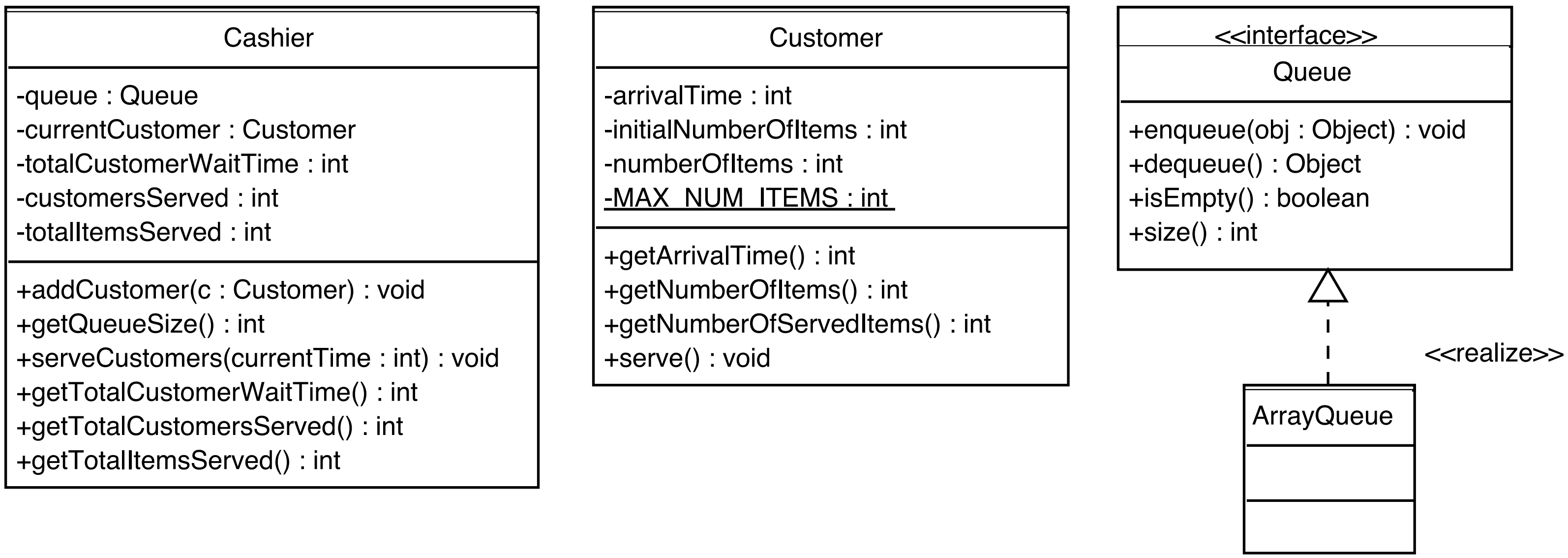

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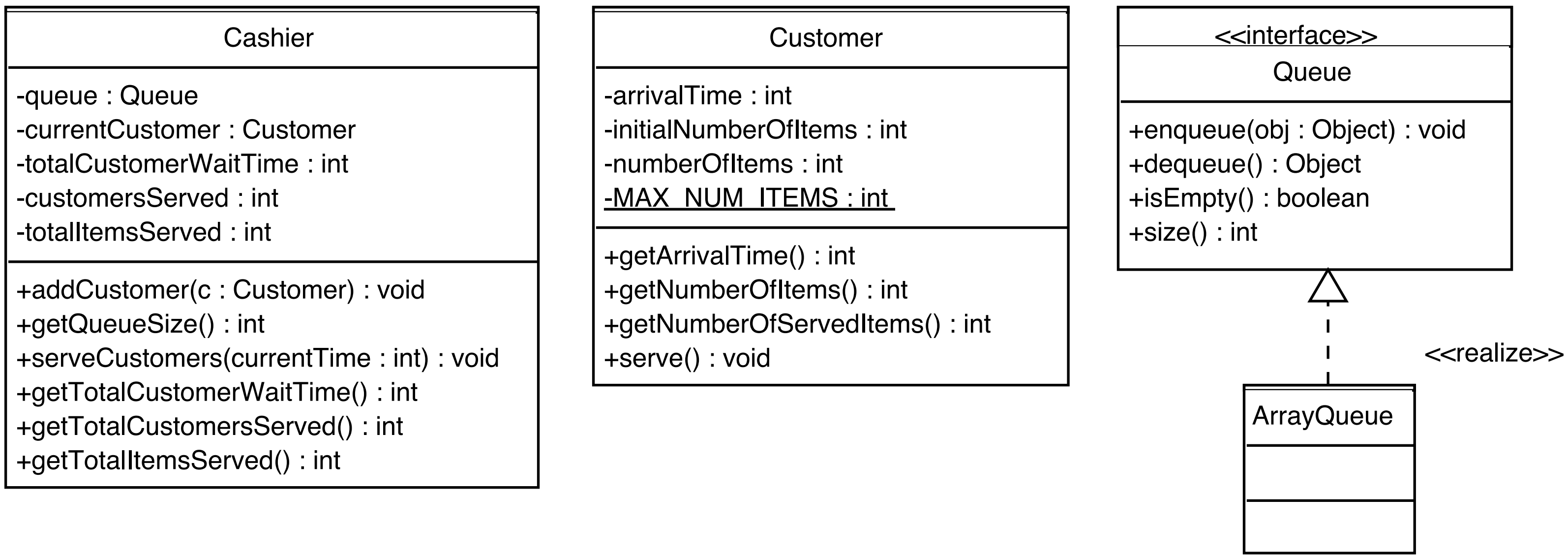

2. Queue-based algorithms (breadth-first search, labyrinth).

Queue-based algorithms

Algorithm:

1. enqueue “”
2. while true
   (a) s ← dequeue
   (b) enqueue “s + 0”
   (c) enqueue “s + 1”

What does the above algorithm do?

Queue-based algorithms

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It generates **all** the possible sequences of 0s and 1s **in increasing order of length**, 0, 1, 00, 01, 10, 11, 000, 001, . . .

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In other words the ensemble of all character strings, S, such that:

$$S \equiv [s \leftarrow \{0, 1, s' + 0, s' + 1\}; s' \in S]$$

```
new queue            []
enqueue(0)           [0]
enqueue(1)           [0,1]
s = 0 = dequeue()    [1]
enqueue(s+0 = 0+0)   [1,00]
enqueue(s+1 = 0+1)   [1,00,01]
s = 1 = dequeue()    [00,01]
enqueue(s+0 = 1+0)   [00,01,10]
enqueue(s+1 = 1+1)   [00,01,10,11]
s = 00 = dequeue()   [01,10,11]
enqueue(s+0 = 00+0)  [01,10,11,000]
enqueue(s+1 = 00+1)  [01,10,11,000,001]
s = 01 = dequeue()   [10,11,000,001]
enqueue(s+0 = 01+0)  [10,11,000,001,010]
enqueue(s+1 = 01+1)  [10,11,000,001,010,011]
s = 10 = dequeue()   [11,000,001,010,011]
enqueue(s+0 = 10+0)  [11,000,001,010,011,100]
enqueue(s+1 = 10+1)  [11,000,001,010,011,100,101]
```

Generalization

The generalization to sequences over any finite alphabet is trivial.

In particular, let's consider the following alphabet: $\Sigma = \{L, R, U, D\}$.

1. enqueue ""
2. while true
   (a) s $\leftarrow$ dequeue
   (b) enqueue "s + L"
   (c) enqueue "s + R"
   (d) enqueue "s + U"
   (e) enqueue "s + D"

```
new queue             []
enqueue("")           [""]
s = "" = dequeue()    []
enqueue(s+L = L)      [L]
enqueue(s+R = R)      [L,R]
enqueue(s+U = U)      [L,R,U]
enqueue(s+D = D)      [L,R,U,D]
s = L = dequeue()     [R,U,D]
enqueue(s+L = L+L)    [R,U,D,LL]
enqueue(s+R = L+R)    [R,U,D,LL,LR]
enqueue(s+U = L+U)    [R,U,D,LL,LR,LU]
enqueue(s+D = L+D)    [R,U,D,LL,LR,LU,LD]
s = R = dequeue()     [U,D,LL,LR,LU,LD]
enqueue(s+L = R+L)    [U,D,LL,LR,LU,LD,RL]
enqueue(s+R = R+R)    [U,D,LL,LR,LU,LD,RL,RR]
enqueue(s+U = R+U)    [U,D,LL,LR,LU,LD,RL,RR,RU]
enqueue(s+D = R+D)    [U,D,LL,LR,LU,LD,RL,RR,RU,RD]
s = U = dequeue()     [D,LL,LR,LU,LD,RL,RR,RU,RD]
enqueue(s+L = U+L)    [D,LL,LR,LU,LD,RL,RR,RU,RD,UL]
enqueue(s+R = U+R)    [D,LL,LR,LU,LD,RL,RR,RU,RD,UL,UR]
```

Let's give a meaning to those strings

What are those Ls, Rs, Us and Ds?

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Let's say that each symbol of this alphabet corresponds to a direction:

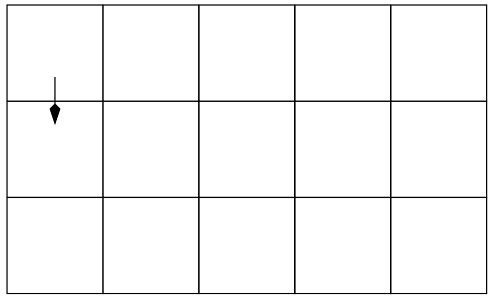
L = *left*;

R = *right*;

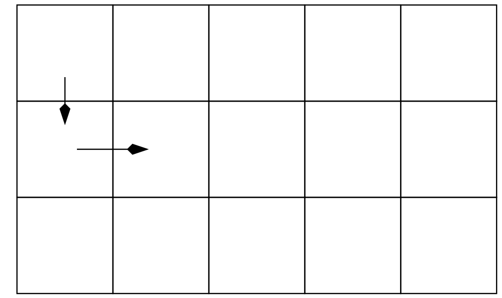
U = *up*;

D = *down*;

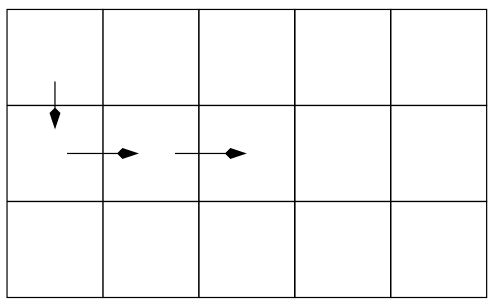
Each character string correspond to a **path** in a two dimensional plane.



D



DR



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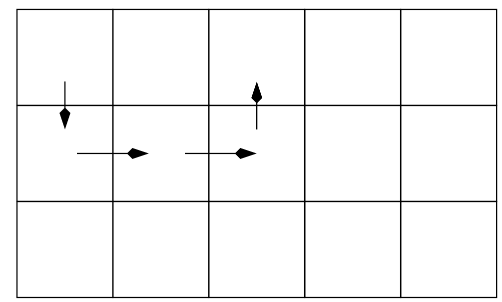
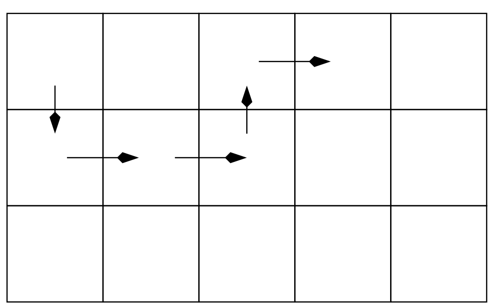


DRRU



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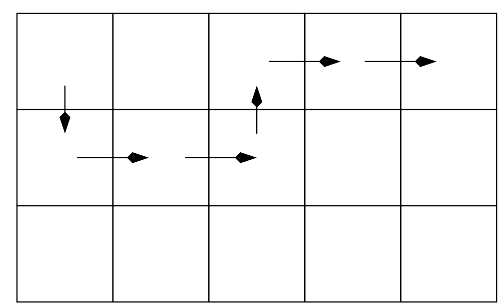
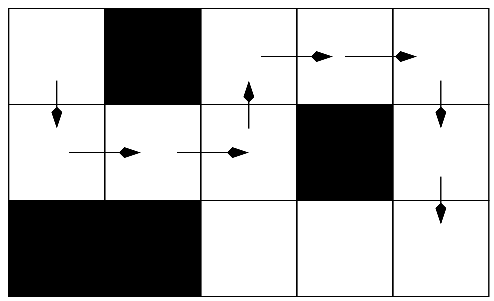
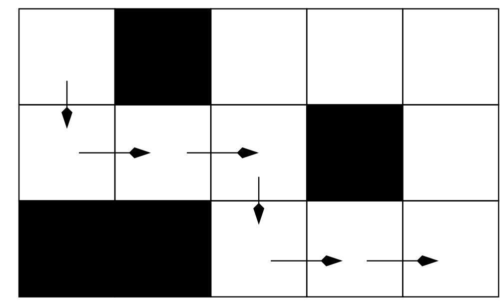


DRRURR

Adding obstacles



DRRURRDD



DRRDRR

⇒ What are the necessary modifications to our string generating algorithm so that it only generates valid paths? and finds the exit?

Auxiliary methods

Verifying that a path is valid: **checkPath(String path)**.

Has the exit been found: **reachesGoal(String path)**.

Data structures

A two dimensional array of characters:

char[][] maze;

A position is not accessible (wall) if it contains a '#', a cell is empty if ' ' and visited if '+'.

```
#+#####
#+# # #
#++ # #
###   #
##### #
```

checkpath(String path)

```
private boolean checkPath( String path ) {

    boolean[][] visited = new boolean [ MAX_ROW ][ MAX_COL ];

    int row, col;

    row = 0; // let’s assume that the entrance is found at (0,0)
    col = 0;

    int pos=0;

    boolean valid = true;
```

checkpath(String path)

```
...
while ( valid && pos < path.length() ) {
    char direction = path.charAt( pos++ );
    switch ( direction ) {
    case LEFT:
        col--;
        break;
    case RIGHT:
        col++;
        break;
    case UP:
        row--;
        break;
    case DOWN:
        row++;
        break;
    default:
        valid = false;
    }
    ...
```

checkpath(String path)

```
        // after each move, we check that the current position is valid,
        // i.e. inside the maze, not inside a wall and has not been visited!

        if ( (row >= 0) && (row < MAX_ROW) && (col >= 0) && (col < MAX_COL) )
            if ( visited[ row ][ col ] || grid[ row ][ col ] == WALL )
                valid = false;
            else
                visited[ row ][ col ] = true;
        else
            valid = false;

    } // end of while loop

    return valid;
}
```

Are we done yet!

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```
private boolean reachesGoal( String path ) {
    int row = 0;
    int col = 0;
    for ( int pos=0; pos < path.length(); pos++ ) {
        char direction = path.charAt( pos );
        switch ( direction ) {
        case LEFT:  col--; break;
        case RIGHT: col++; break;
        case UP:    row--; break;
        case DOWN:  row++; break;
        }
    }
    return grid[ row ][ col ] == OUT;
}
```

Labyrinth

A queue-based algorithm to find a path through a labyrinth.

This algorithm has the property that it is guaranteed to find the shortest path if it exists!

Our queue-based algorithm to solve the maze problem is similar to our algorithm to generate all stings, in increasing order of length, over a finite-size alphabet.

```
q.enqueue( "" )
while ( true )
  s <- q.dequeue()
  for each char in the alphabet
      q.enqueue( s + char )
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⇒ The main difference being that the elements are filtered before being put into the queue — i.e. only valid prefixes are added to the rear of the queue.

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What would occur if no solution exist? How to detected such sitution?

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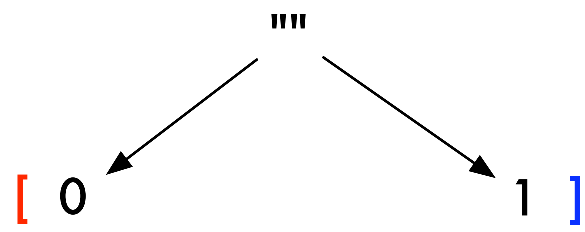
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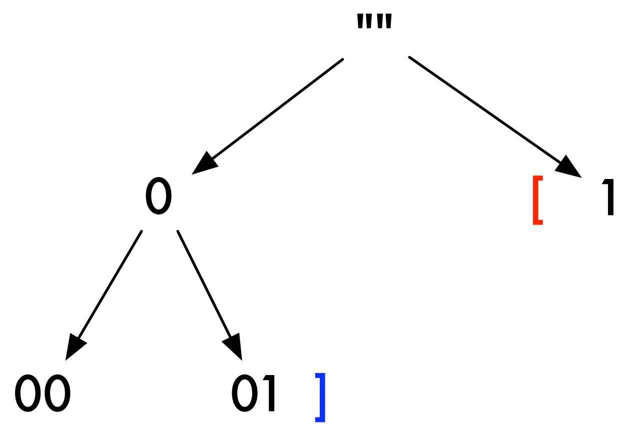
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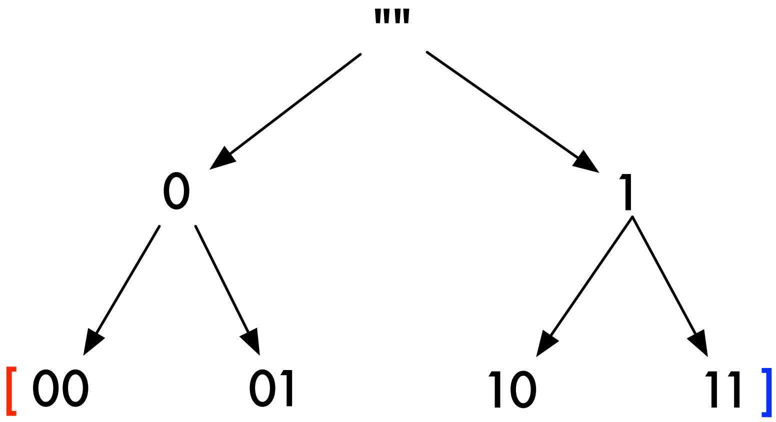
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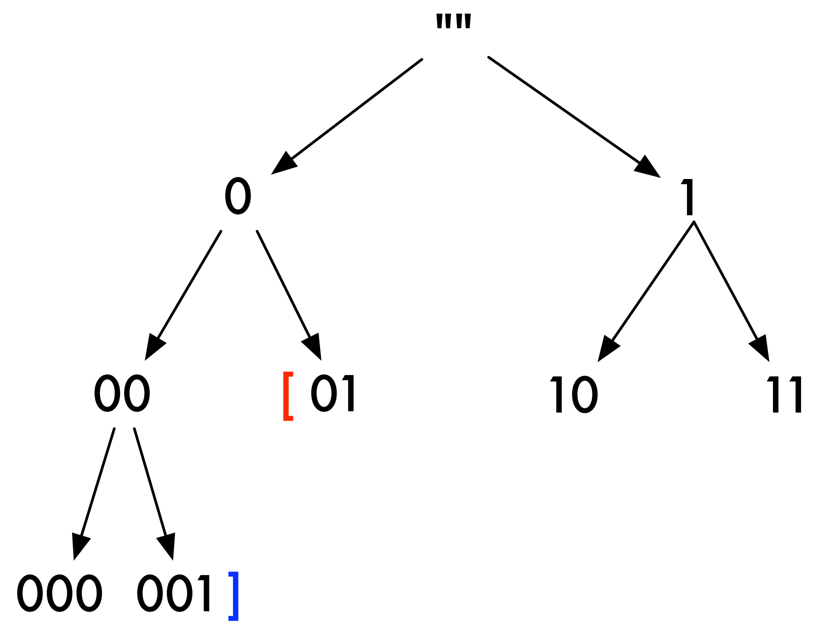
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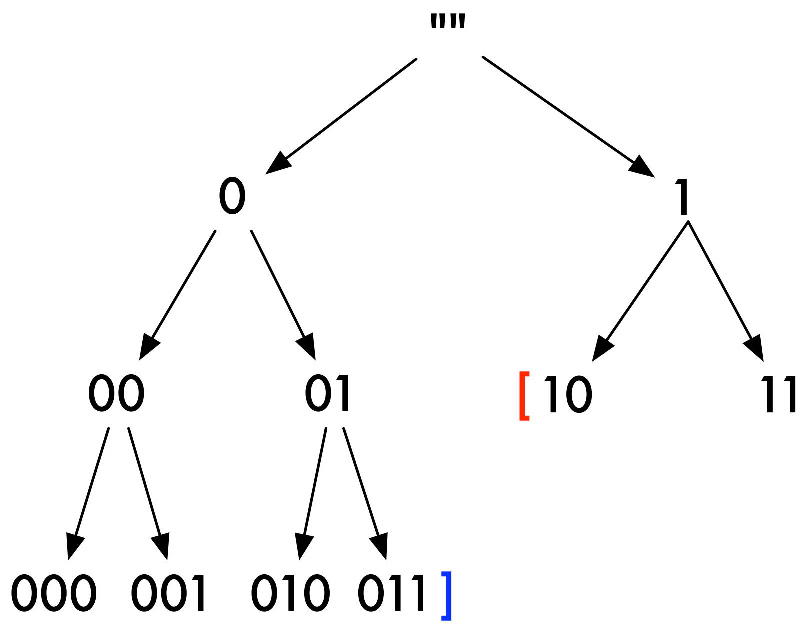
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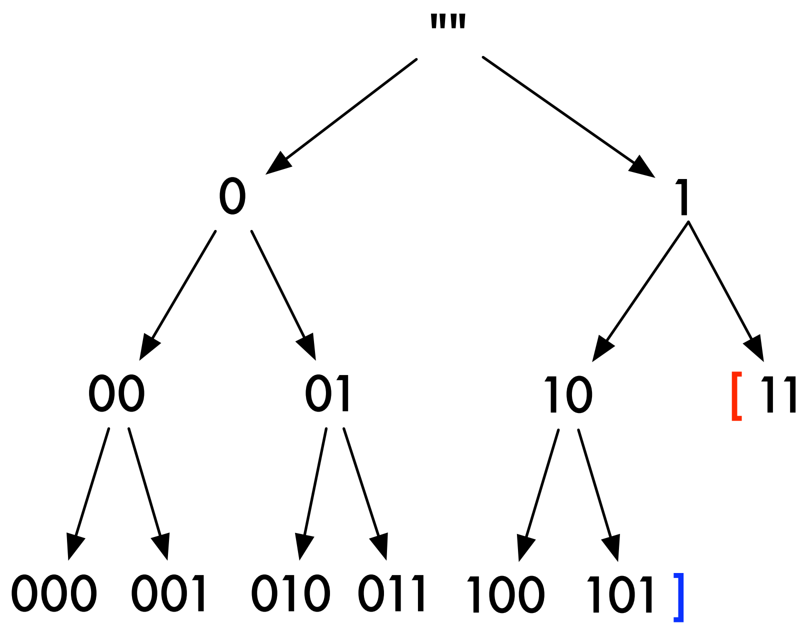
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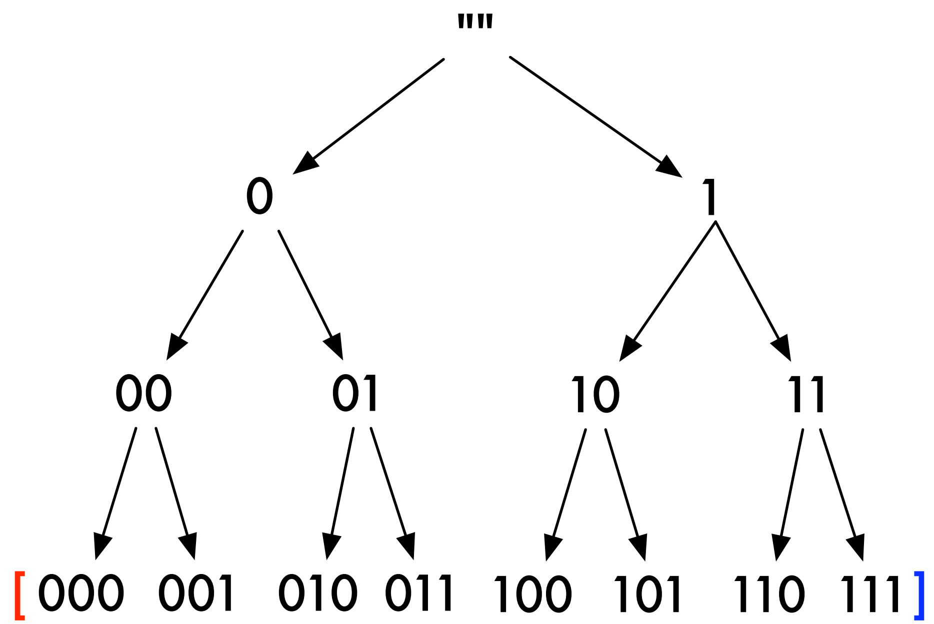
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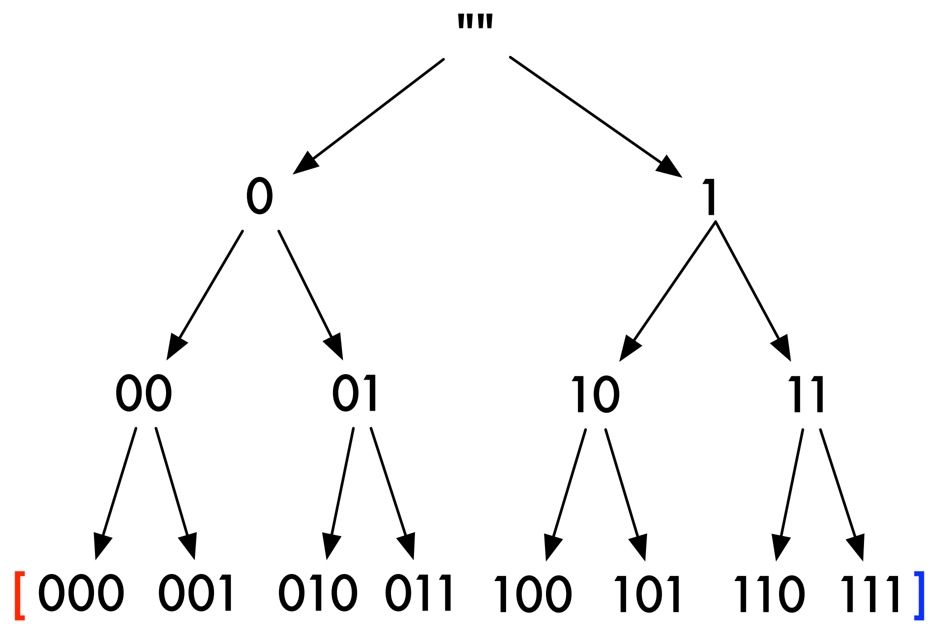
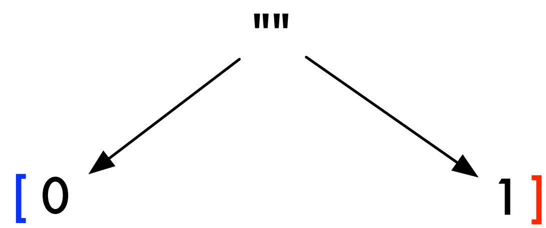


The **queue**-based implementation of the search is called "**breadth-first search**".

The **search tree** is built layer by layer, all the sequences on the same level (i.e. sequences of the same length) are processed before processing the sequences of the next level.

[""]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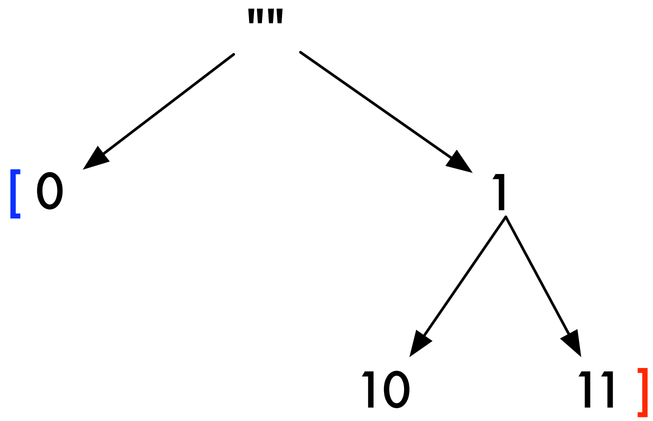
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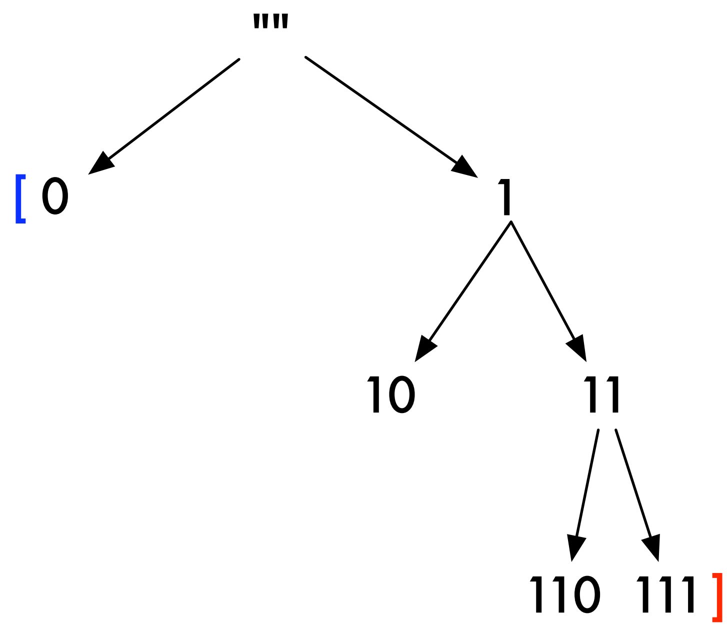
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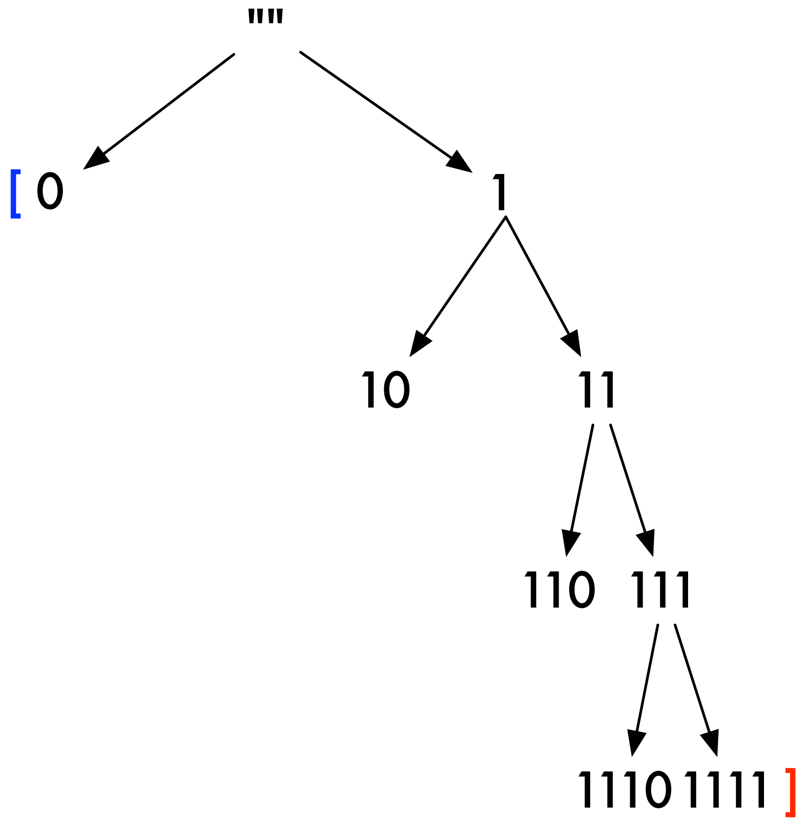

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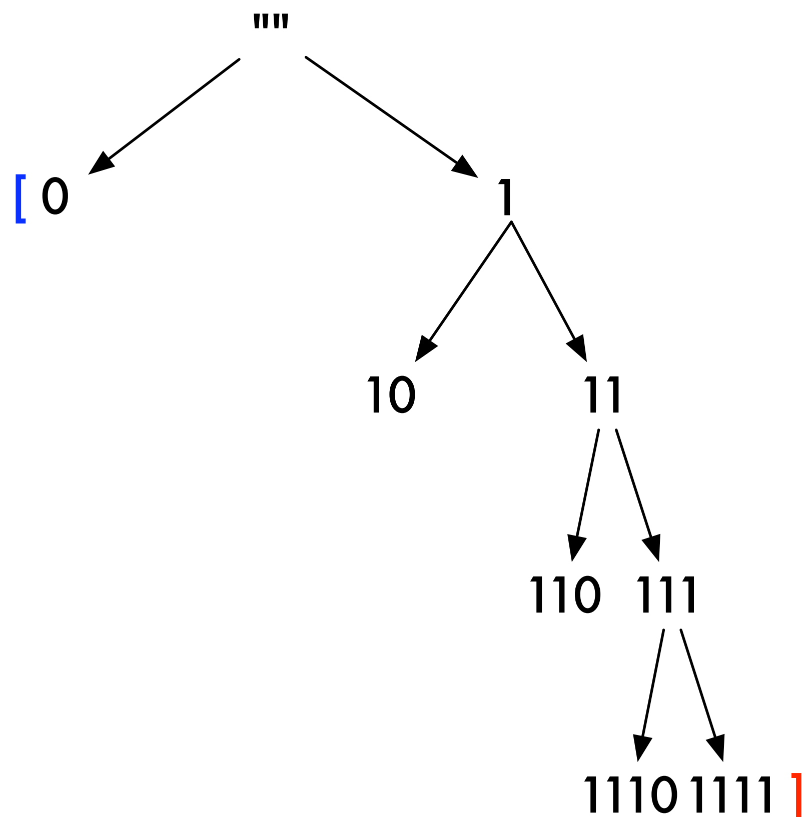

The **stack**-based implementation of the search is called "**depth-first search**".

The **search tree** is built branch by branch, a sequence is selected and repeatedly expanded until a dead-end occurs. The algorithm then backtracks to the next sequence onto the stack. Hence the surname **backtracking algorithm**.

```
#I#############
#    ####     #
## # #    ### #
# ##   ####   #
#    # ## # ###
## ### ## #  ##
#  ###     ####
## ######### ##
#            ##
############O##
```