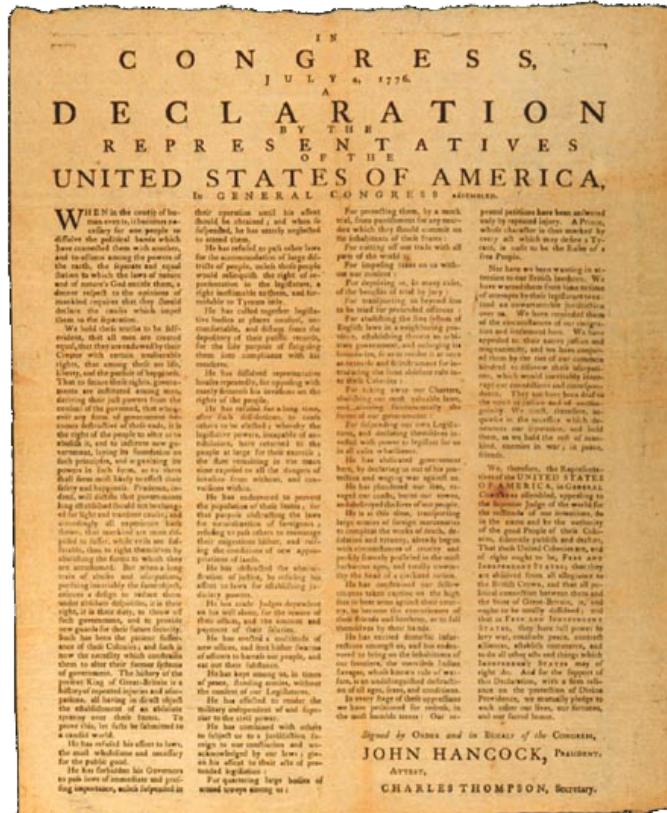


Algorithms and Analysis

Lesson 3: Declare your intentions (not your actions)



ADTs, stacks, queues, priority queues, sets, maps

Outline

1. Abstract Data Types (ADTs)

2. Stacks

3. Queues and Priority Queues

4. Lists, Sets and Maps

5. Putting it Together



Object Oriented Programming

- OO-programming allows you to build large systems reliably
- In the OO-methodology you separate the interface from the implementation
- The **interface** is the public methods (functions) of a class
- The implementation is hidden (**encapsulated**) and may be changed without affecting how the class is used
- There exist other ways of programming, but C++ is designed to support the OO-methodology

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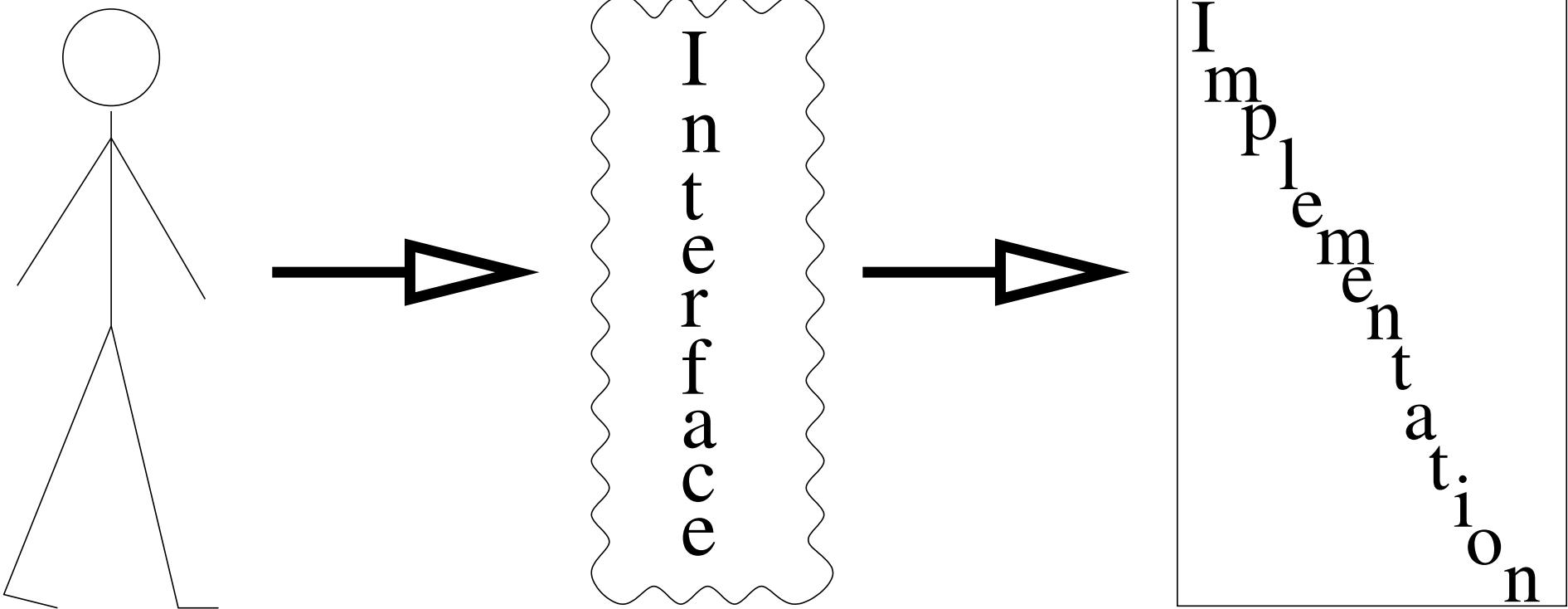
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Object-Oriented Classes



Abstract Data Types

- With data structures there are some traditional interfaces called **Abstract Data Types** or ADTs
- These are implementation free data structures
- They are mathematical abstractions of the data structure
- Their purpose is to allow you to declare your intentions
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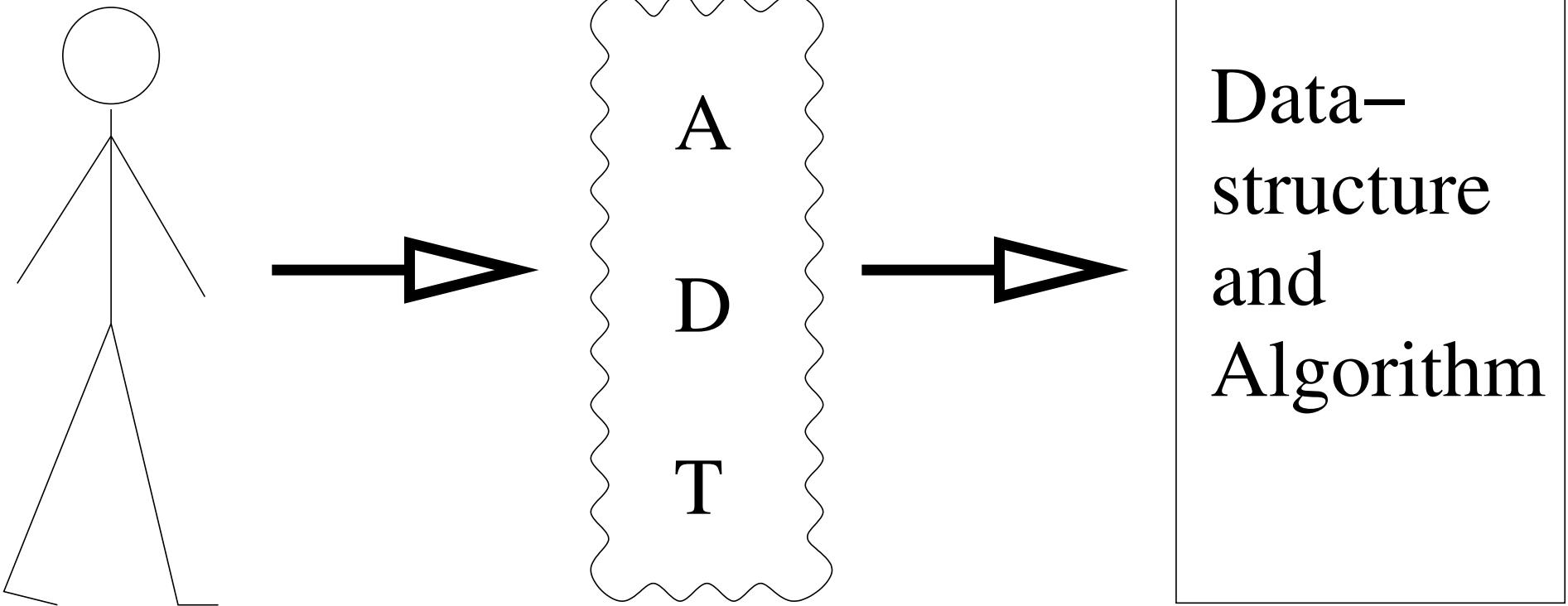
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ADTs



Say it with an ADT

- Common ADTs include stacks, queues, priority queues, sets, multisets and maps
- There are many possible implementations of these ADTs (some far from obvious)
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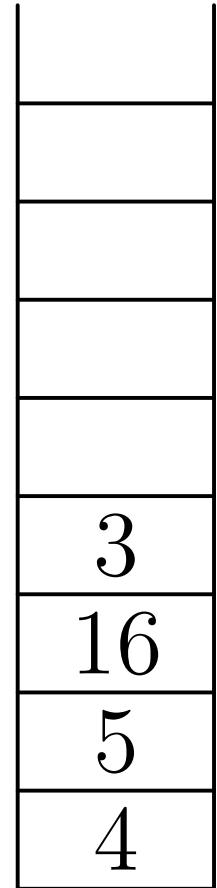
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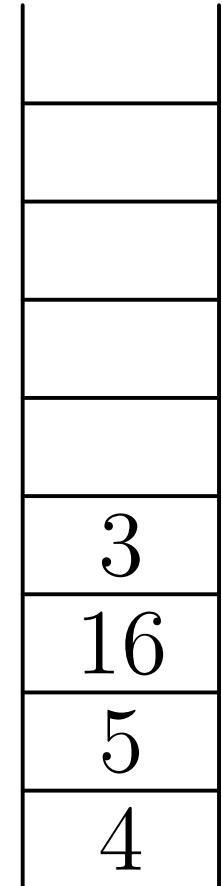
Stacks

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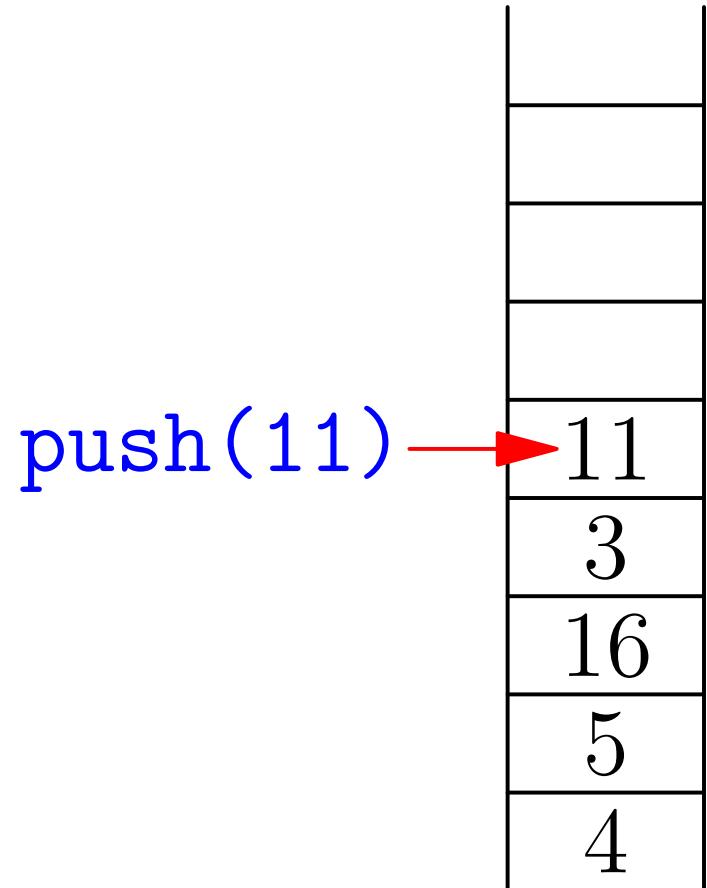
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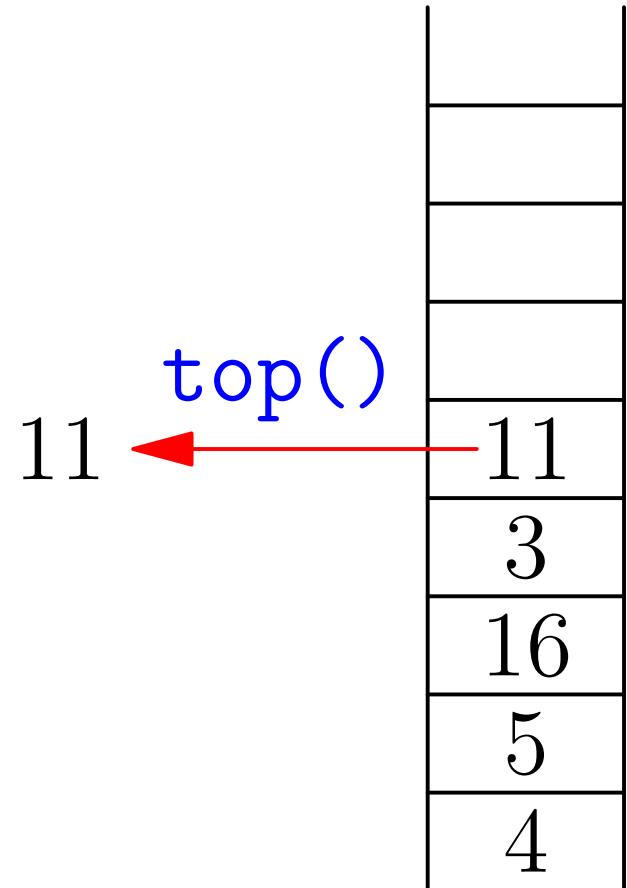
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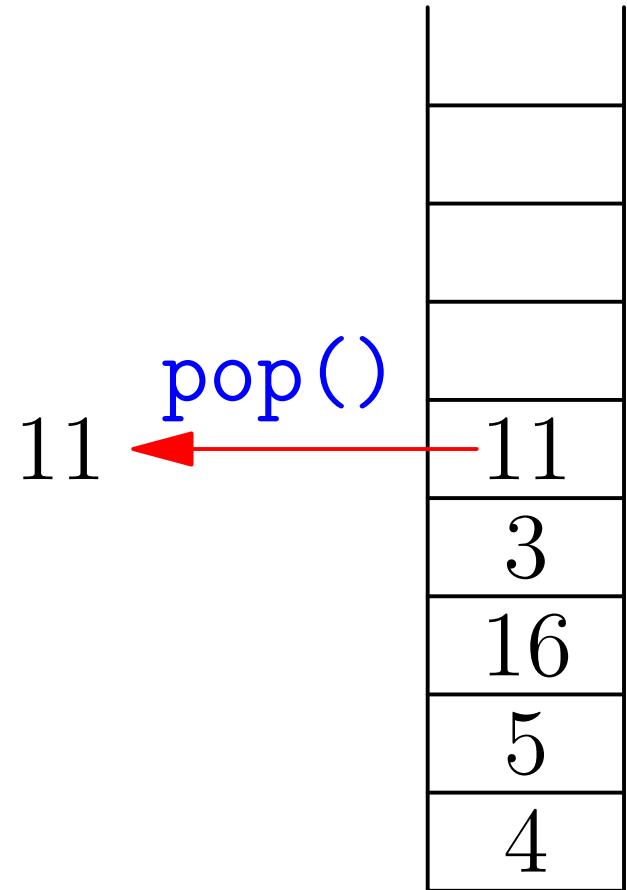
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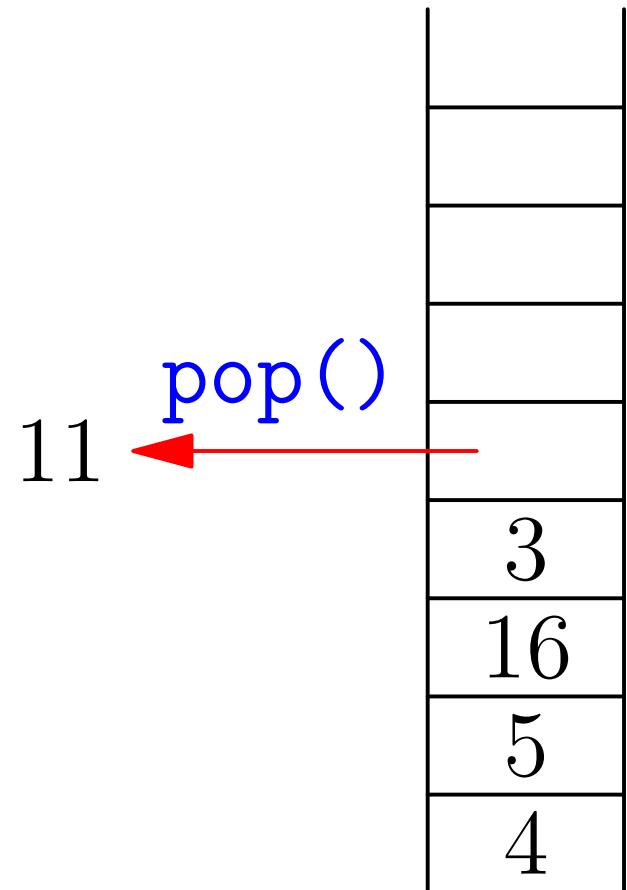
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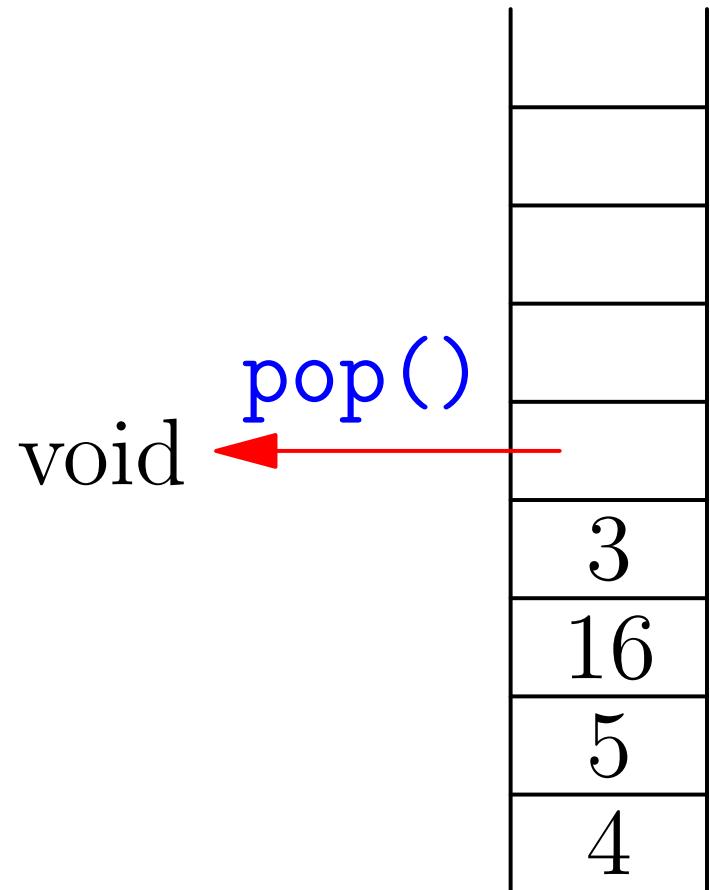
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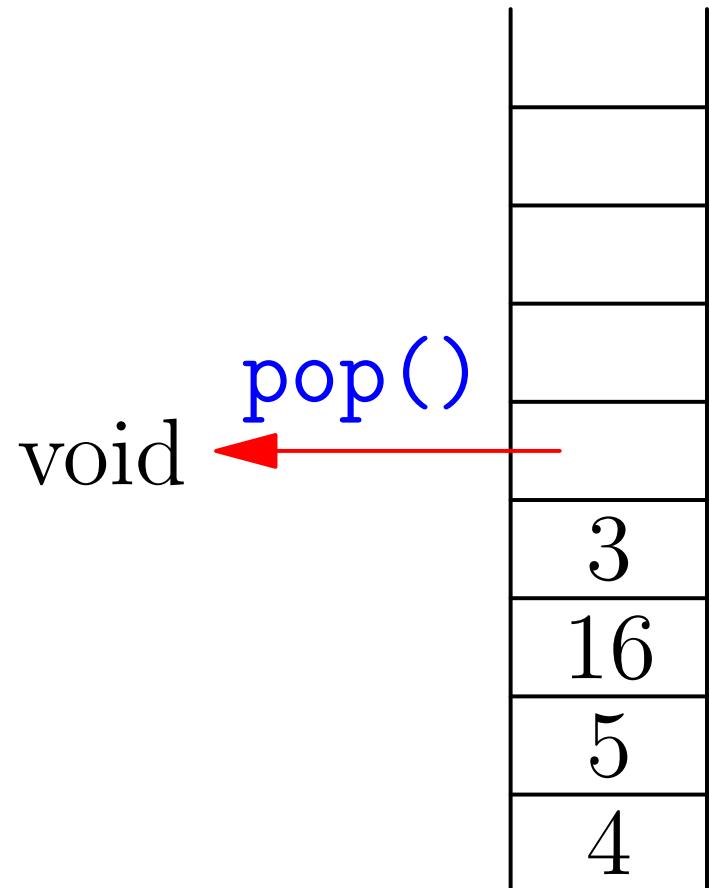
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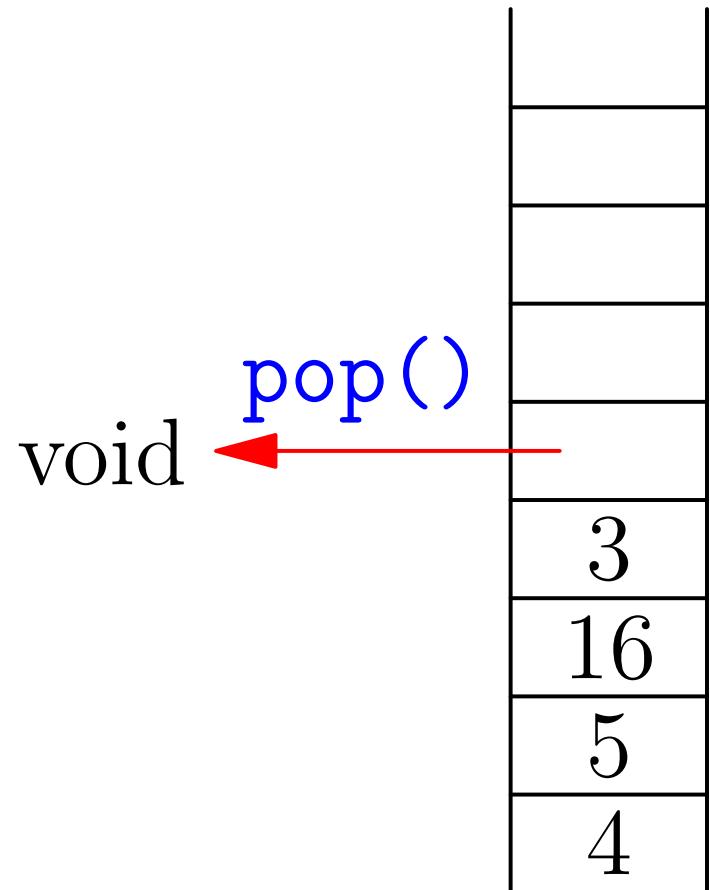
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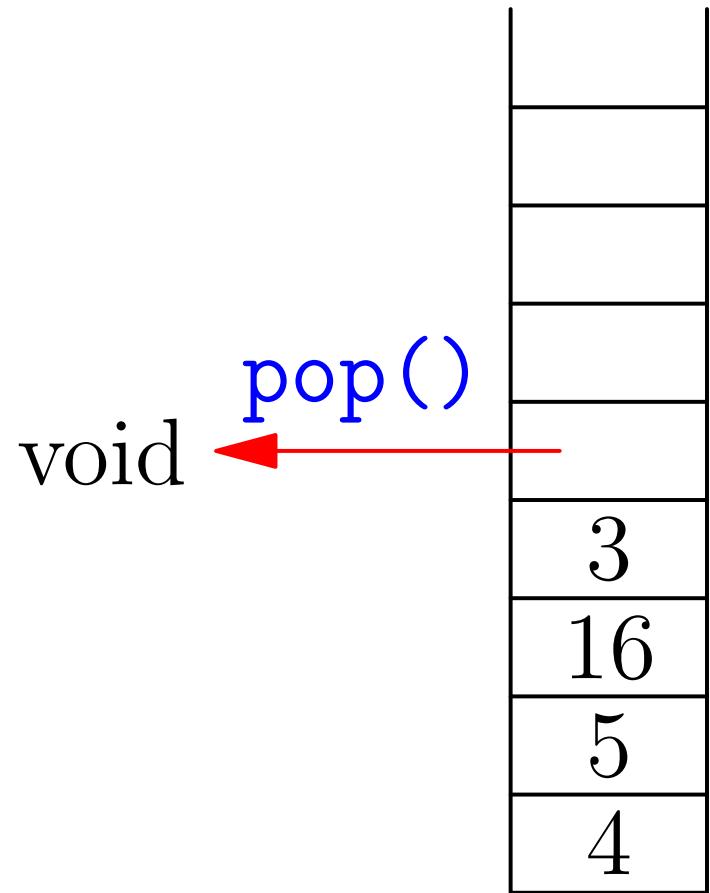
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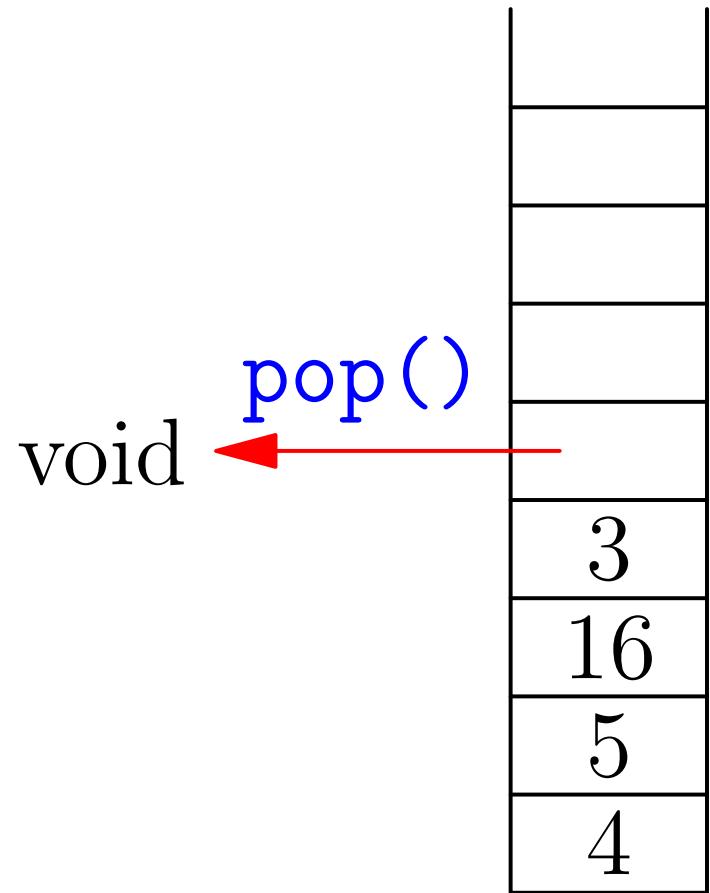
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- Seems counter intuitive to reduce what you can do
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- Parsing expression for compilers
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 - ★ matching XML tags
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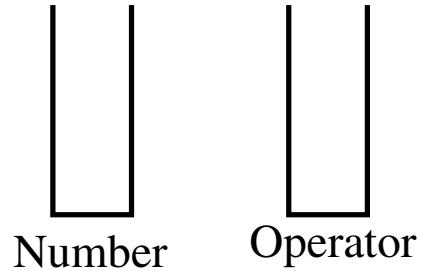
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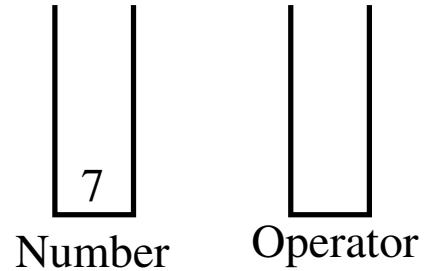
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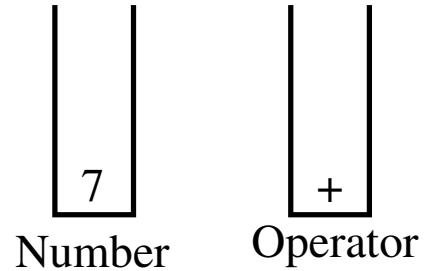
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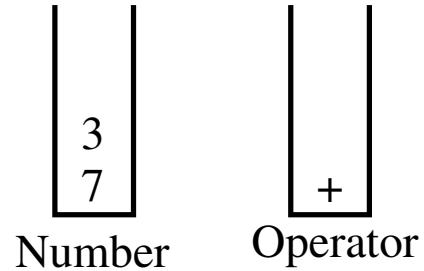
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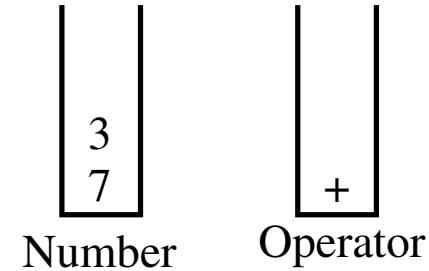
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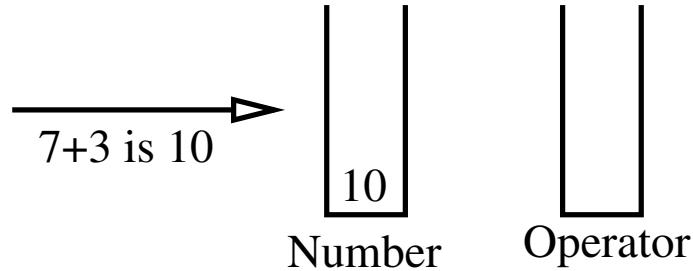


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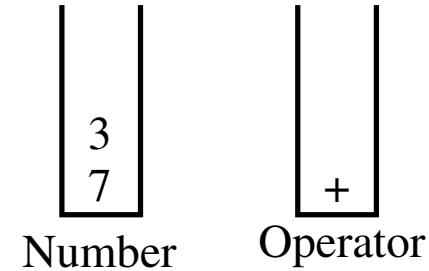


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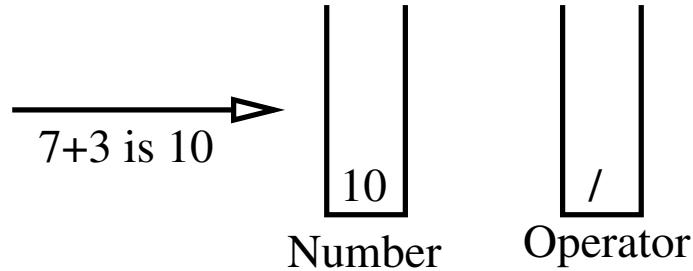


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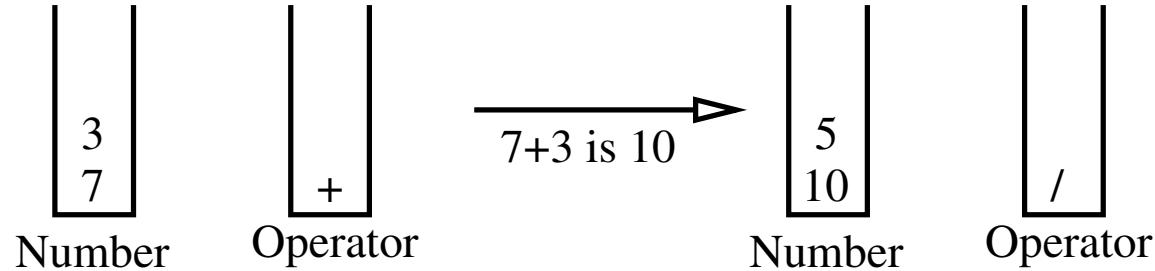
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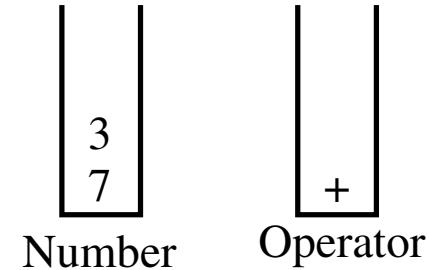
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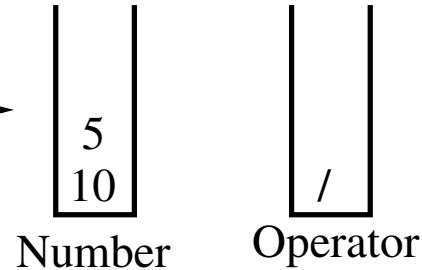


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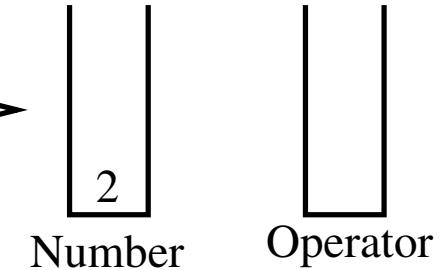
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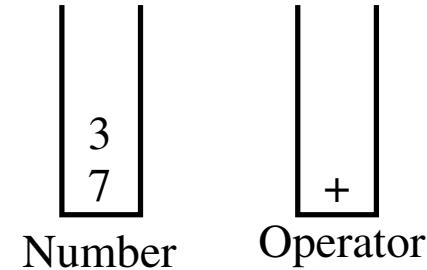


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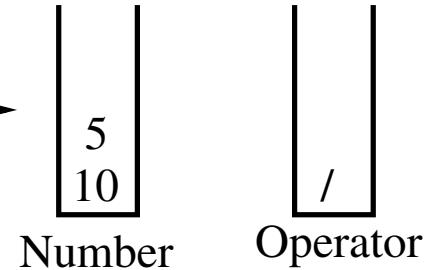
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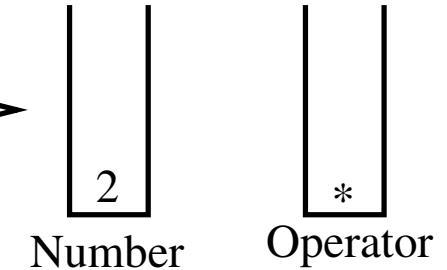
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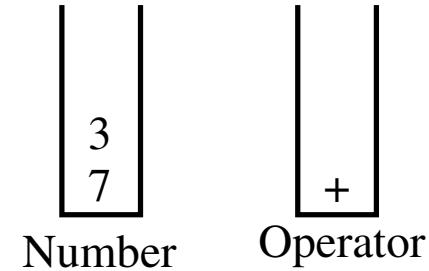


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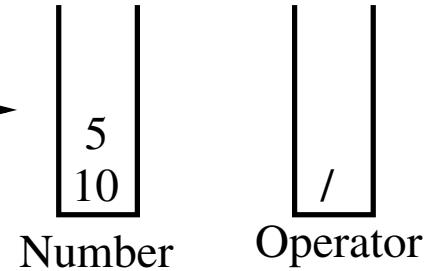
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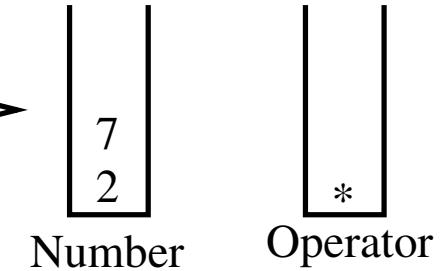
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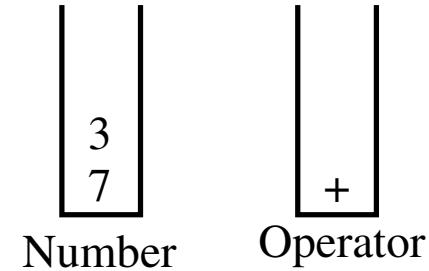


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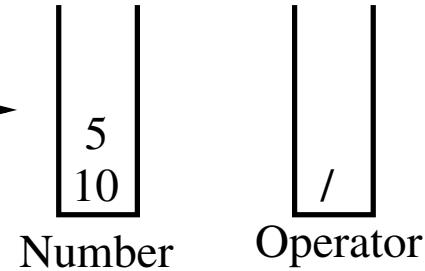
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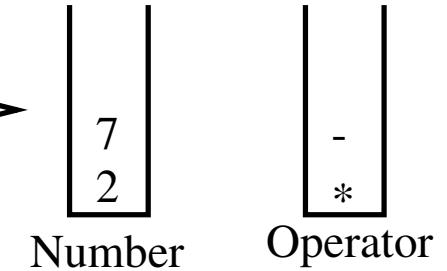
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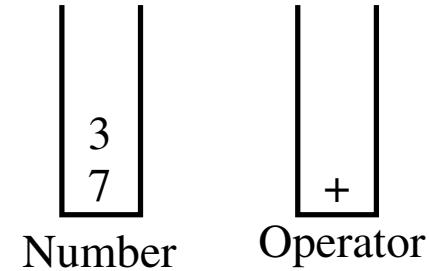


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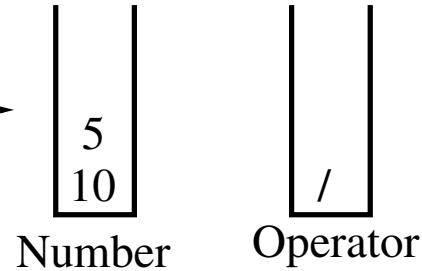
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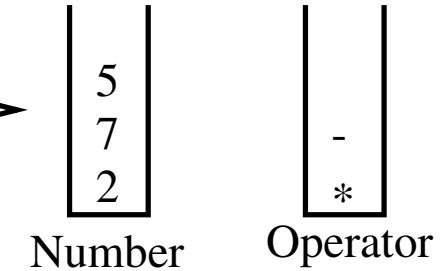
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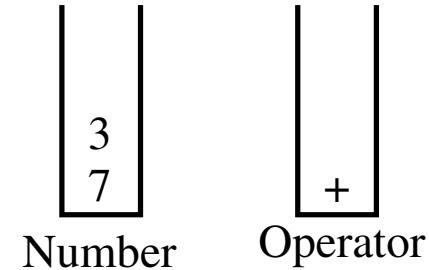


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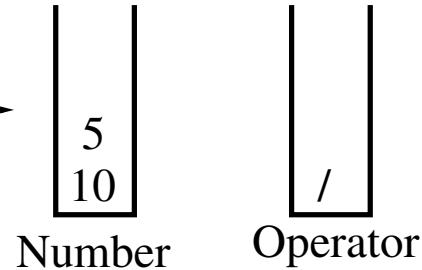


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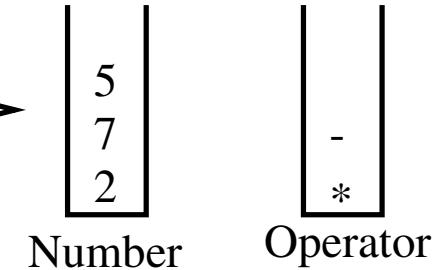
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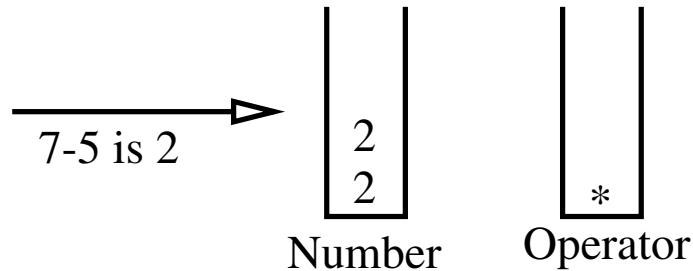
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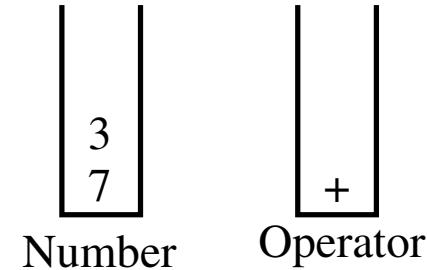


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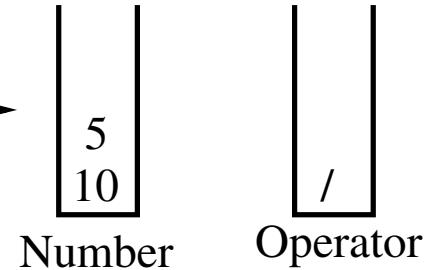


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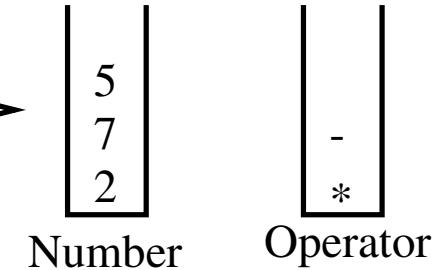
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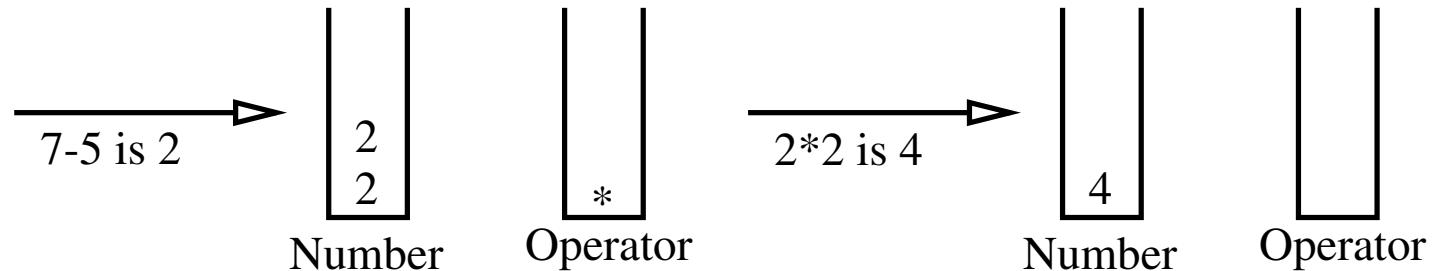
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Queues

- First-in-first-out (FIFO) memory model
- enqueue (elem)
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- dequeue ()
- C++ has a double ended queue (`deque`) with `push_front()`, `push_back()`, etc.



Uses of Queues

- Queues are heavily used in multi-threaded applications (e.g. operating systems)
- Multi-threaded applications need to minimise waiting and ensure the integrity of the data structure (for instance when an exception is thrown)
- Because of this they are more complicated than most data structures
- They can be implemented using linked-lists or circular arrays

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- Because of this they are more complicated than most data structures
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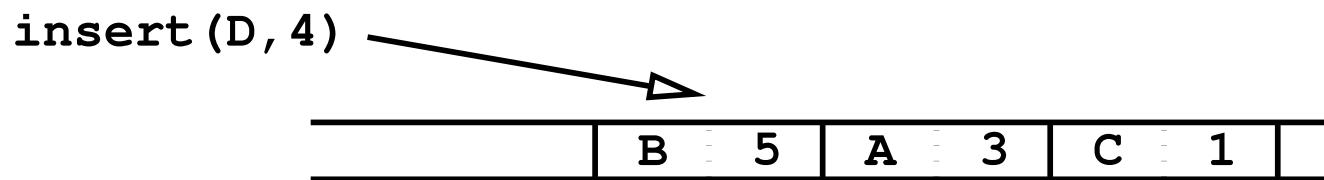
Priority Queues

- Queue with priorities



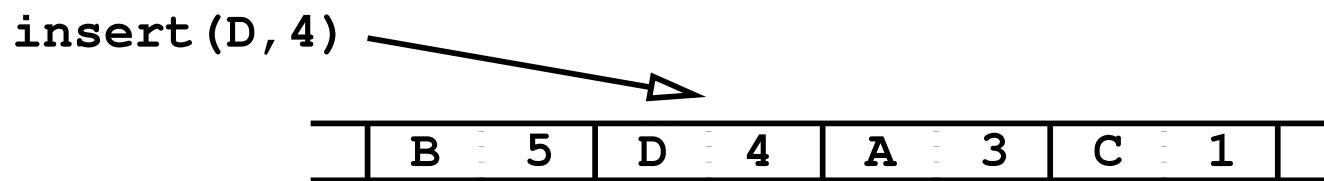
Priority Queues

- Queue with priorities
- `insert(elem, priority)` (in C++ `push()`)



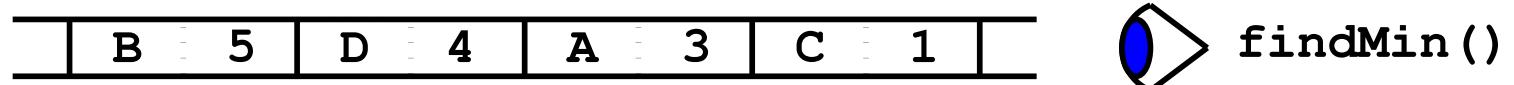
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Priority Queues

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Uses of Priority Queues

- Queues with priorities (e.g. which threads should run)
- Real time simulation
- Often used in “greedy algorithms”
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Implementation of Priority Queue

- Could be implemented using a binary tree or linked list
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Outline

1. Abstract Data Types (ADTs)
2. Stacks
3. Queues and Priority Queues
4. Lists, Sets and Maps
5. Putting it Together



Lists

- In C++ the standard list is known as `vector<T>`
- That is, it is a collection where the order in which you put items into the list matters
- You can have repetitions of elements
- It has random access, e.g. `v[i]`
- You can `push_back(i)`, `insert`, `erase`, etc.
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Sets

- Models mathematical sets
- Container with no ordering or repetitions
- Methods include `insert`, `find`, `size`, `erase`
- Provides fast search (`find`)
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Iterators

- Wish to act on all members of the set
- Performed using an iterator
- Iterators are used by many collections
- In C++ iterators follow the pointer convention

```
set<string> words;

words.insert("hello");
words.insert("world");

for(auto iter = words.begin(); iter != words.end(); ++iter) {
    cout << *iter << endl;
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 - ★ hash tables: `unordered_set<T>`
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Maps

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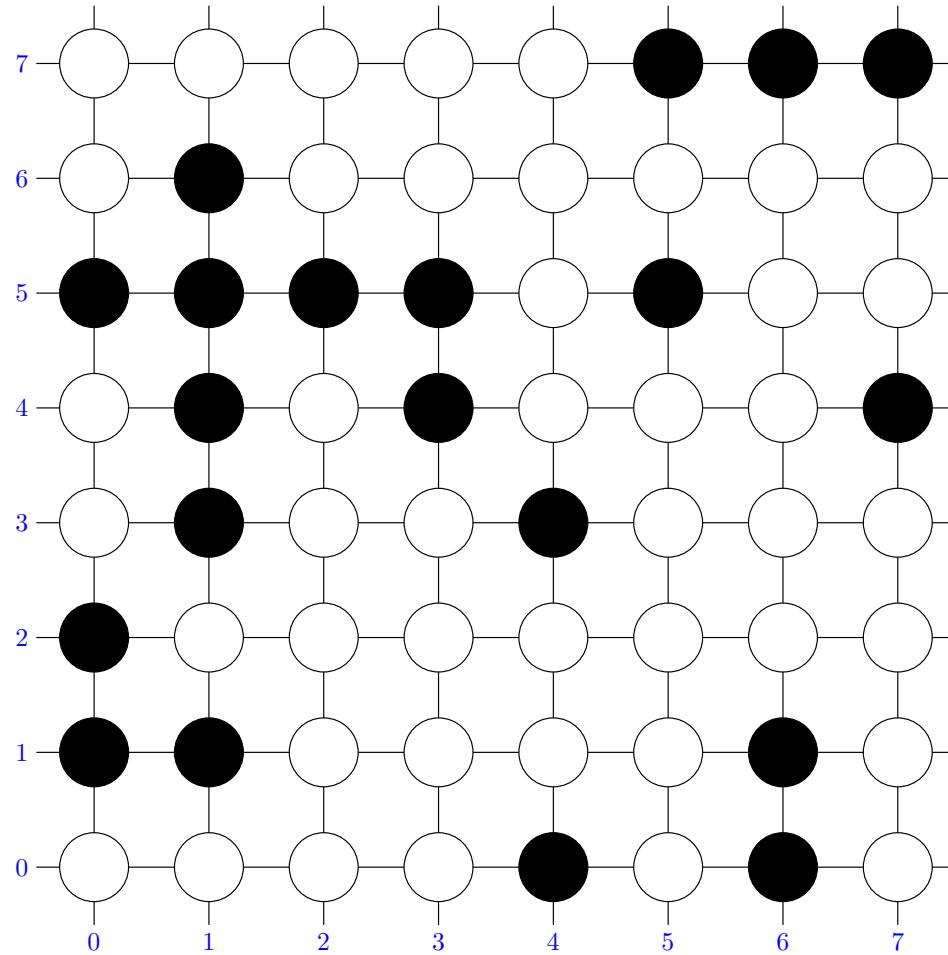
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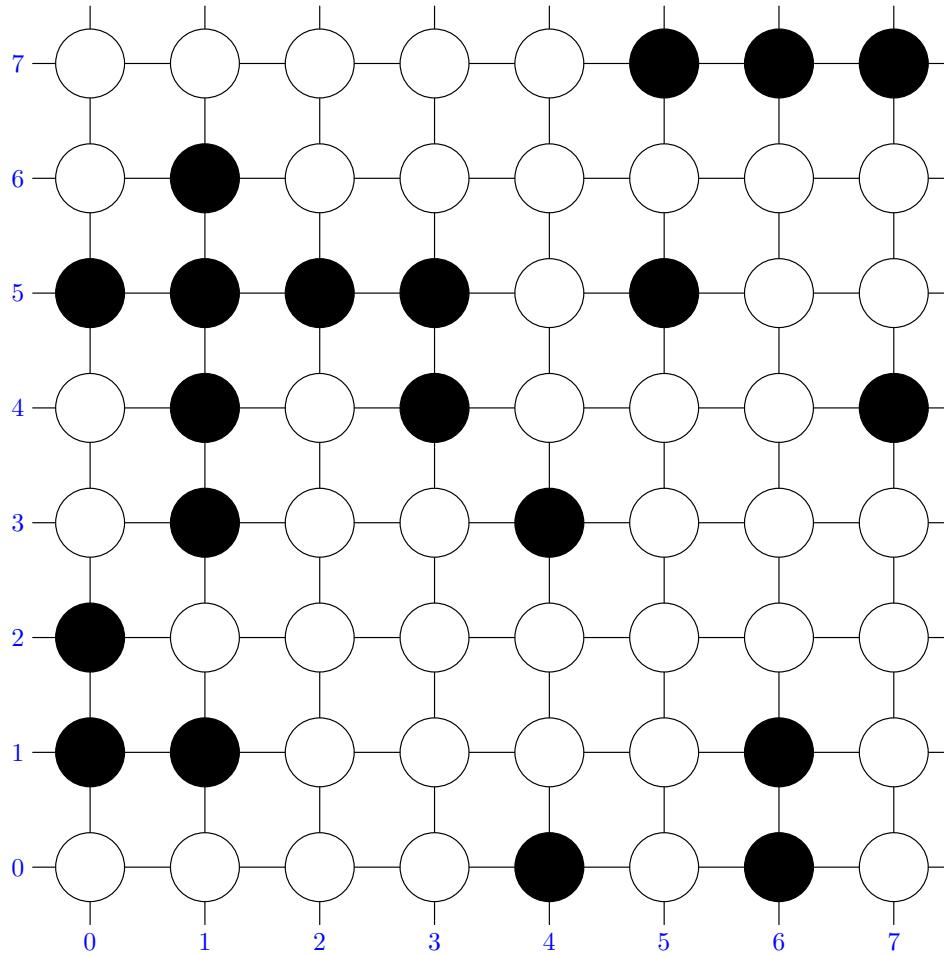


Connected Nodes



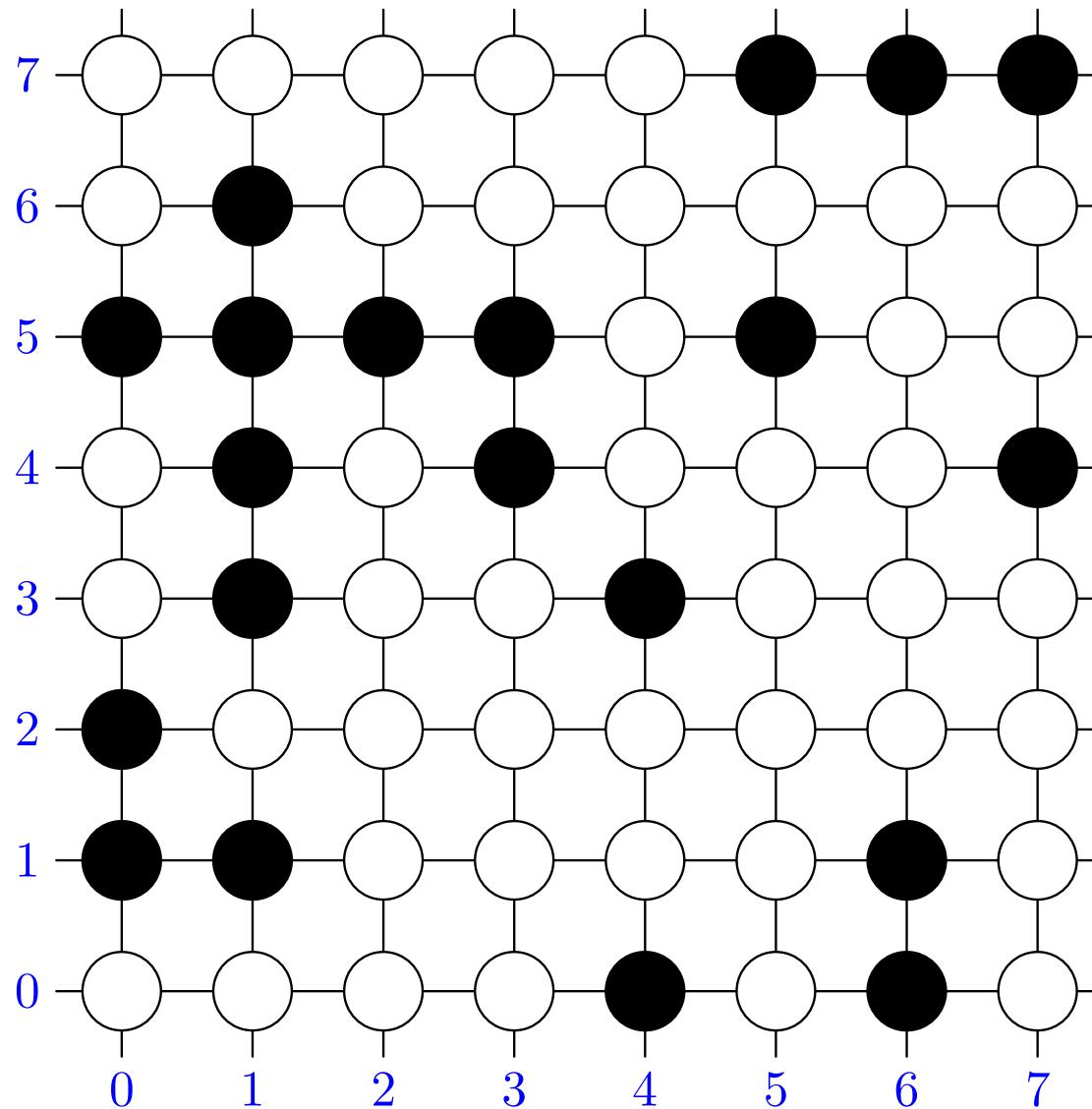
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- Applications in computer vision, computer go, graph connectedness, . . .

Connected Nodes

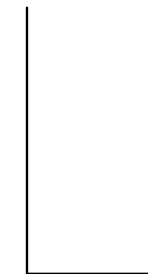


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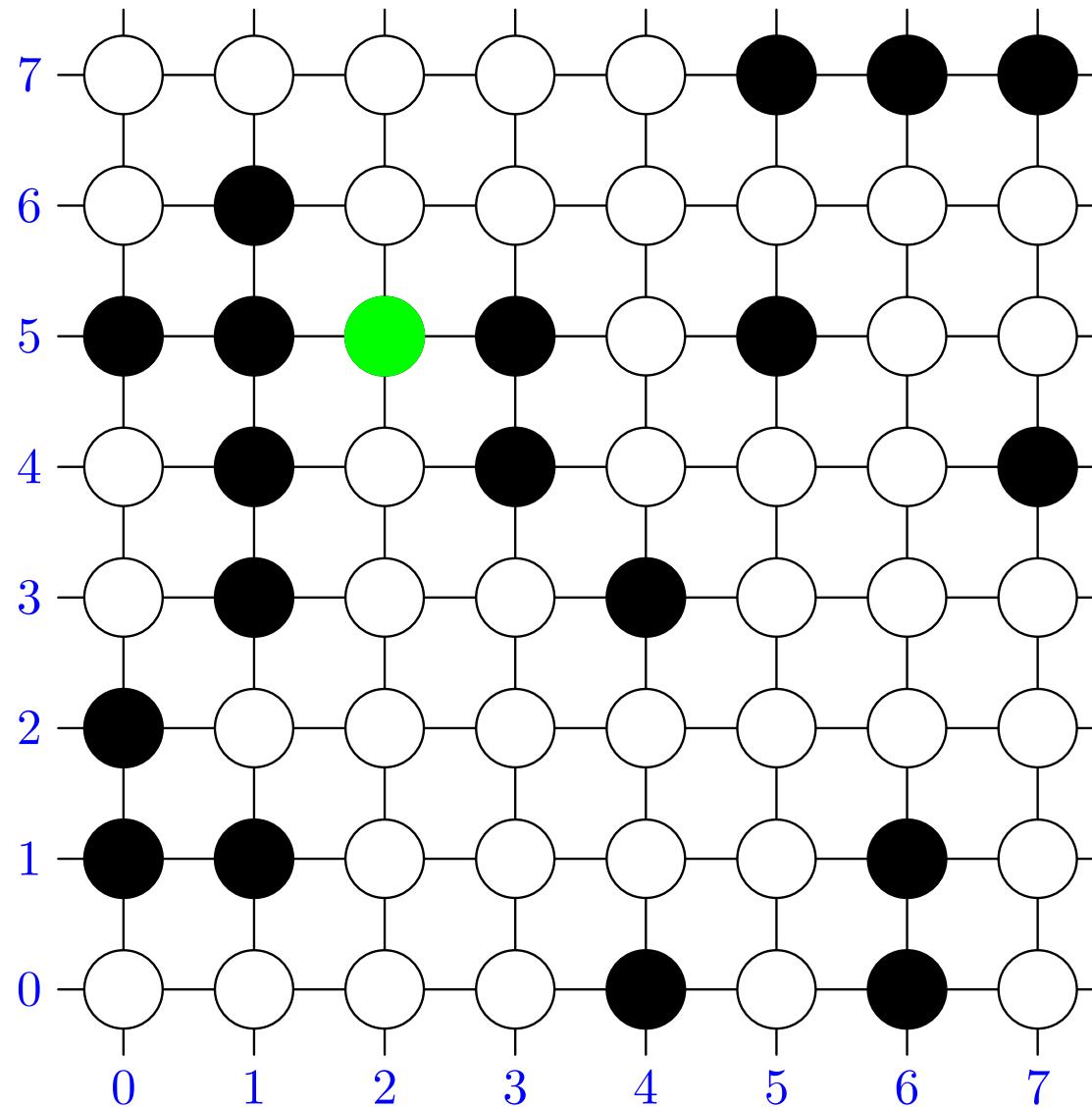


uncheckedNodes =



clusterNodes =
{}

Connected Nodes



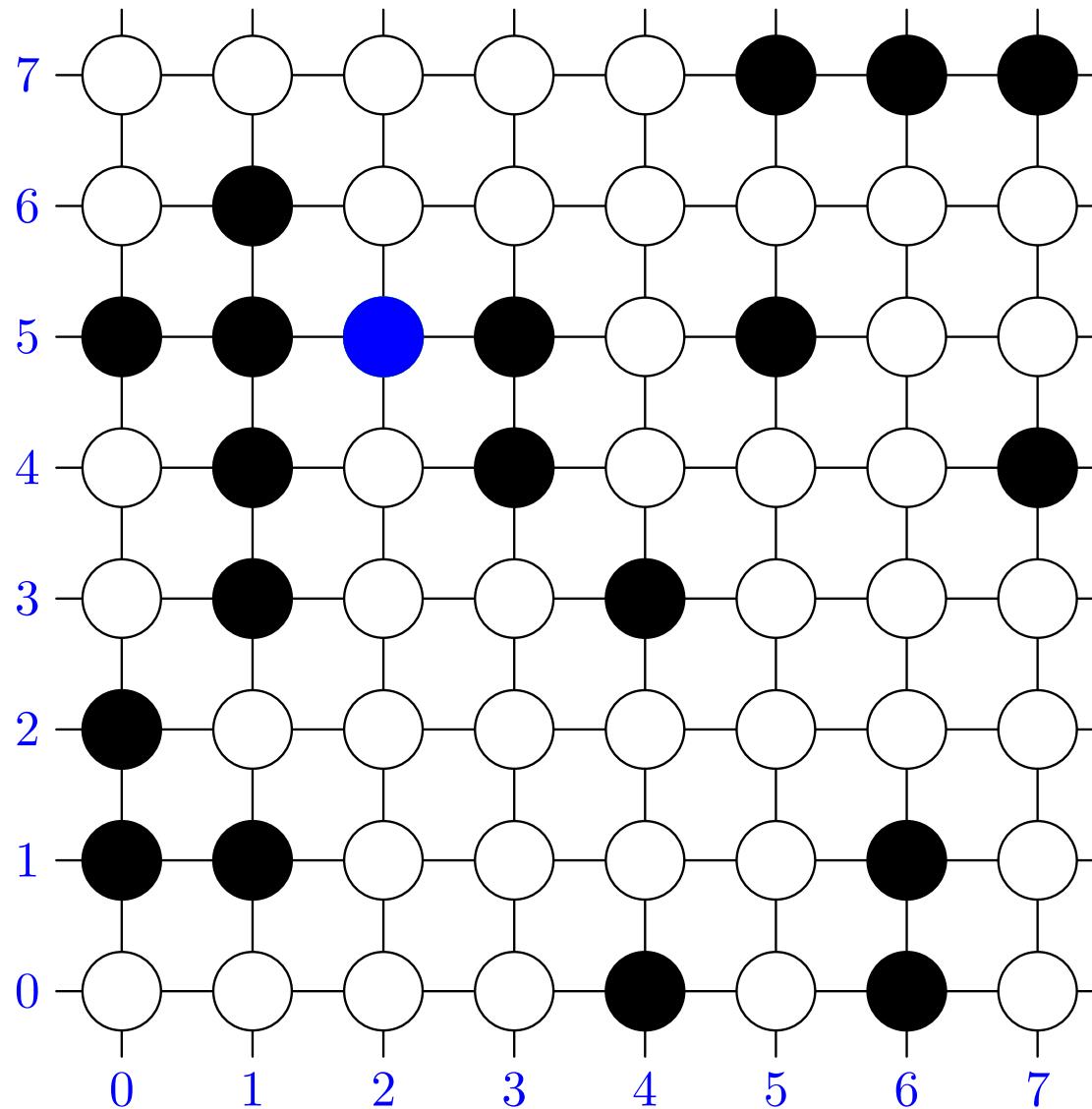
startNode = (2,5)

uncheckedNodes =

(2, 5)

clusterNodes =
{ (2, 5) }

Connected Nodes



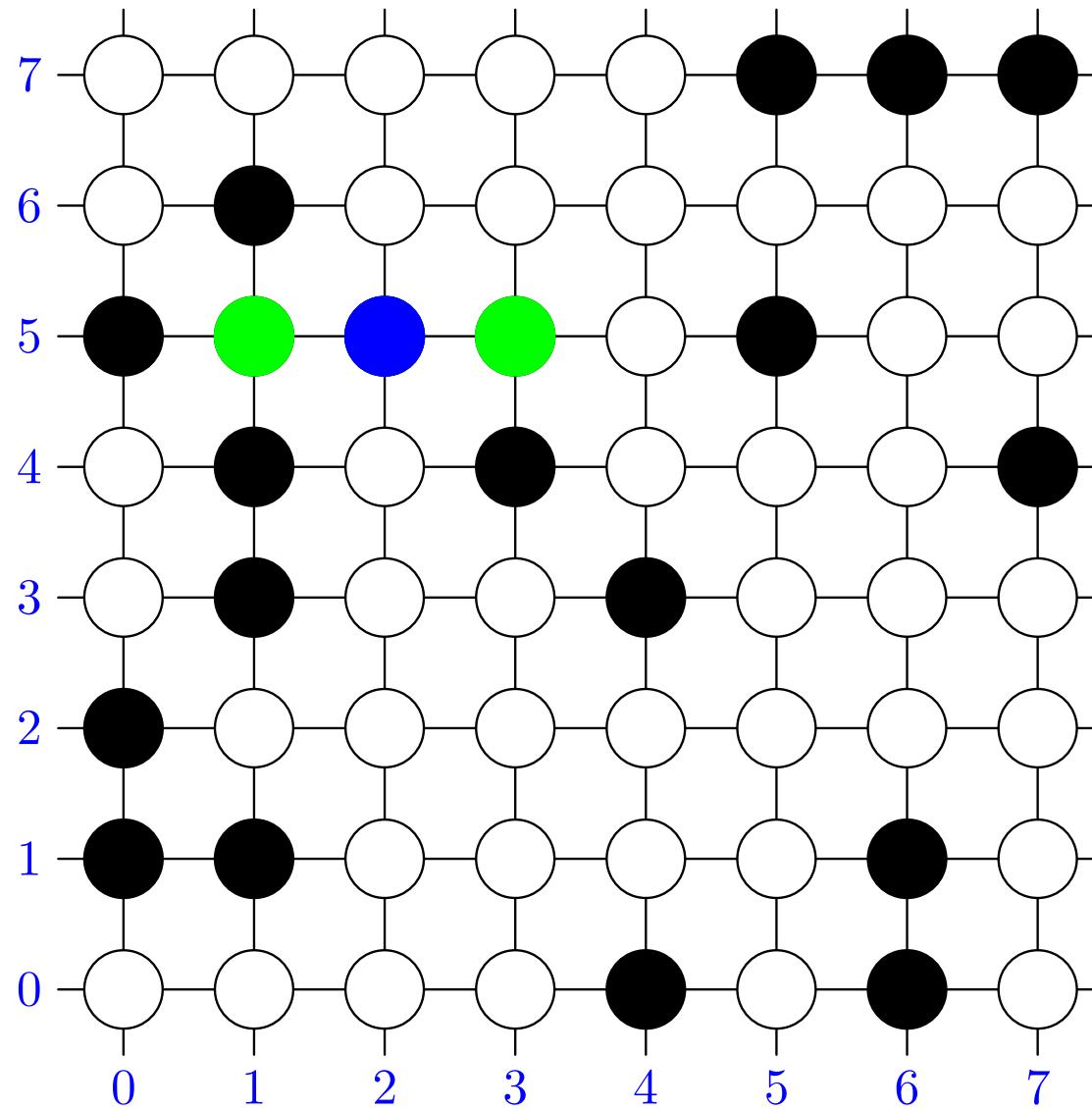
next = (2, 5)

uncheckedNodes =



clusterNodes =
{ (2, 5) }

Connected Nodes



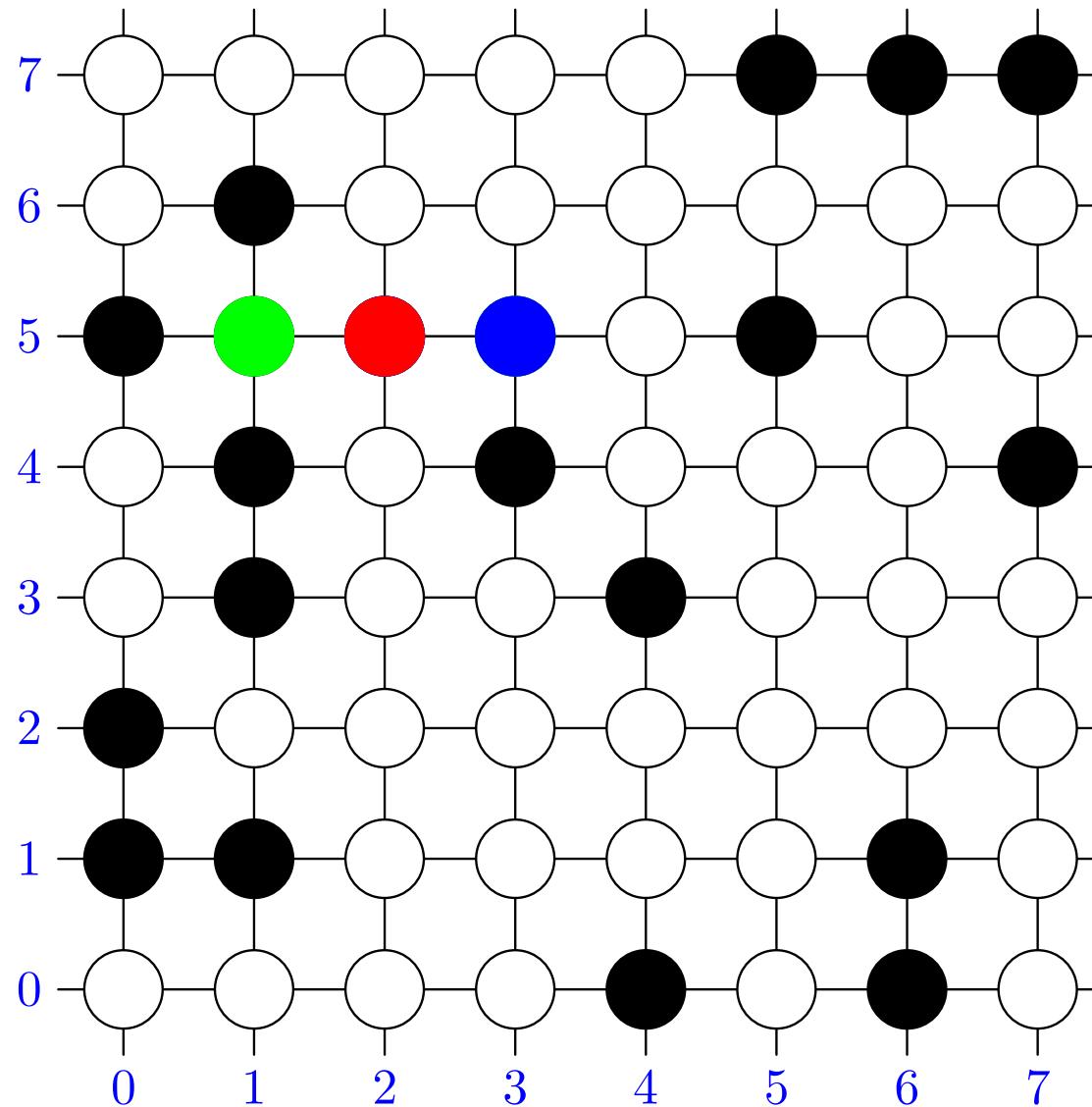
next = (2, 5)

uncheckedNodes =

(3, 5)
(1, 5)

clusterNodes =
{ (2, 5), (1, 5), (3, 5) }

Connected Nodes



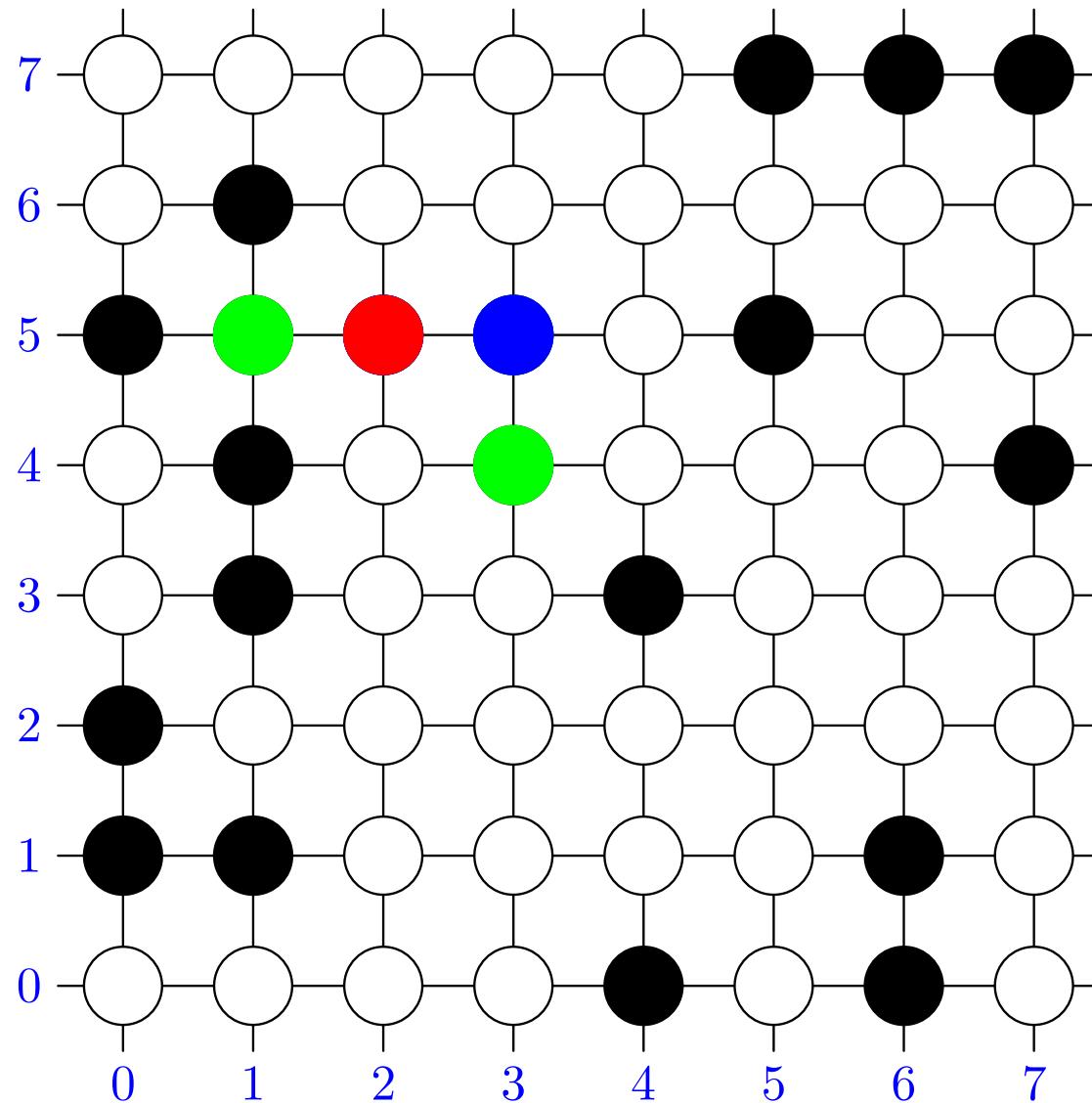
next = (3, 5)

uncheckedNodes =

(1, 5)

clusterNodes =
 $\{ (2, 5), (1, 5), (3, 5) \}$

Connected Nodes



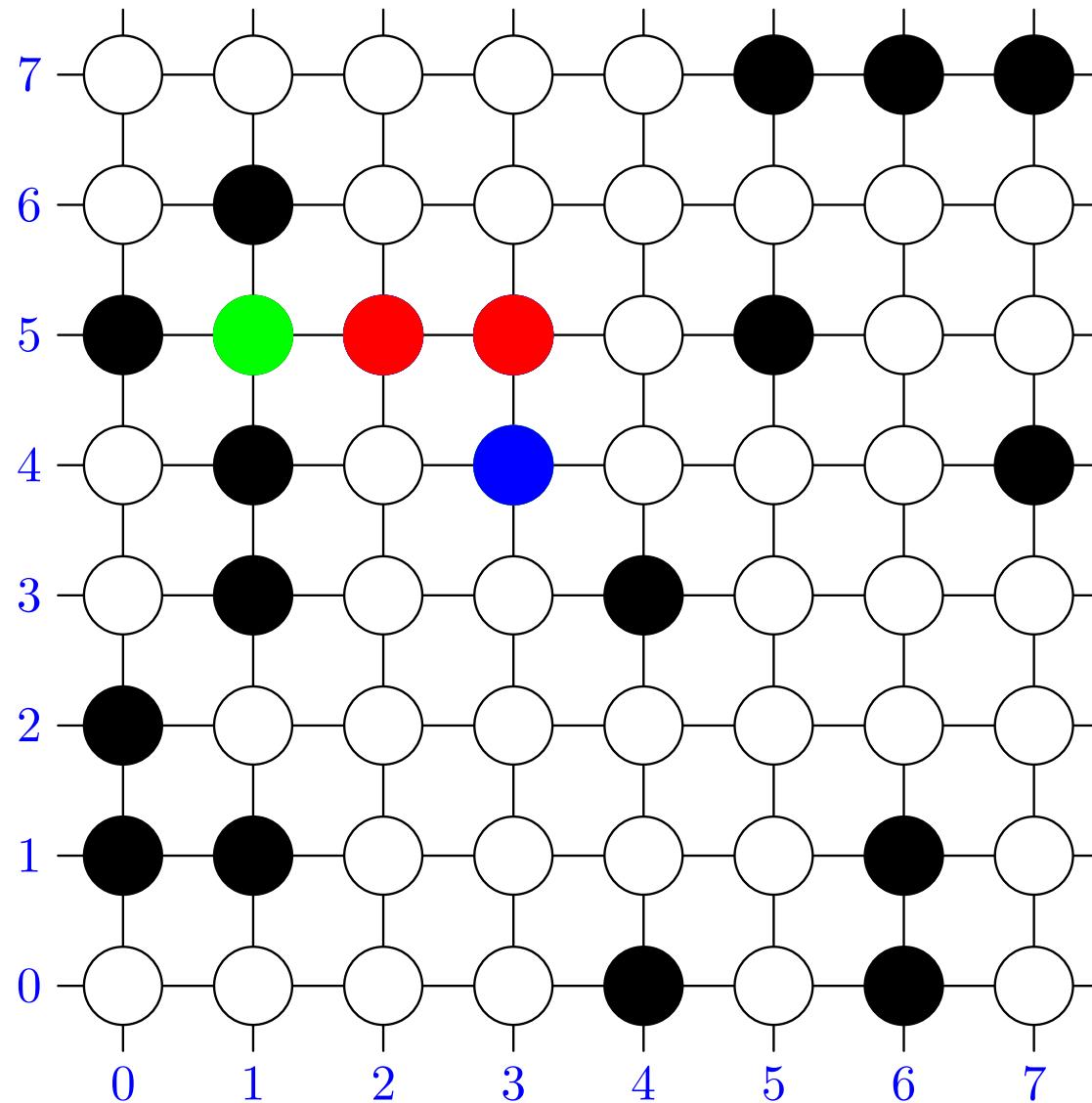
next = (3, 5)

uncheckedNodes =

(3, 4)
(1, 5)

clusterNodes =
{ (2, 5), (1, 5), (3, 5),
(3, 4) }

Connected Nodes



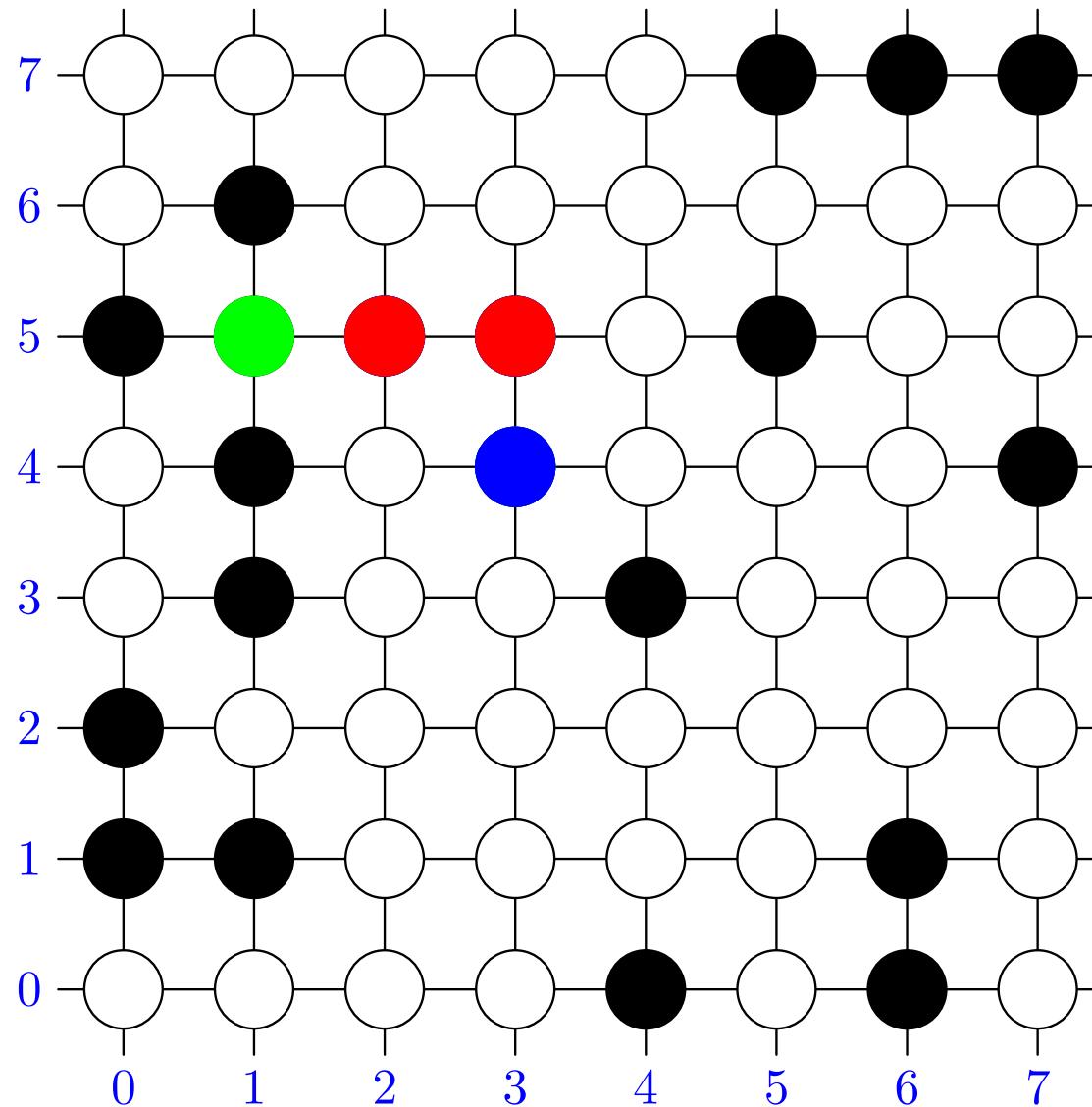
next = (3, 4)

uncheckedNodes =

(1, 5)

clusterNodes =
{ (2, 5), (1, 5), (3, 5),
(3, 4) }

Connected Nodes



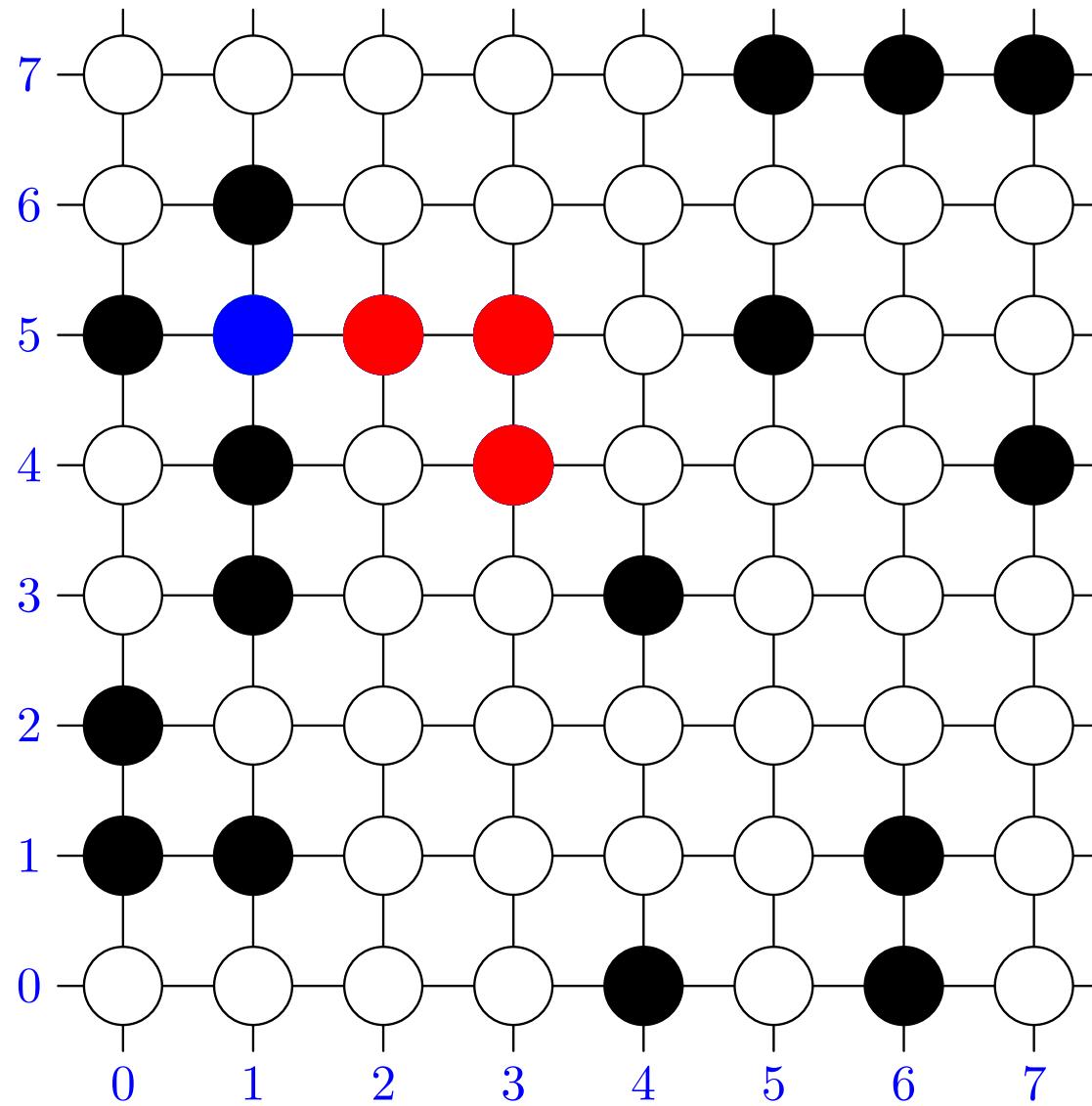
next = (3, 4)

uncheckedNodes =

(1, 5)

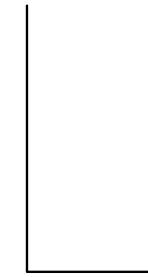
clusterNodes =
{ (2, 5), (1, 5), (3, 5),
(3, 4) }

Connected Nodes



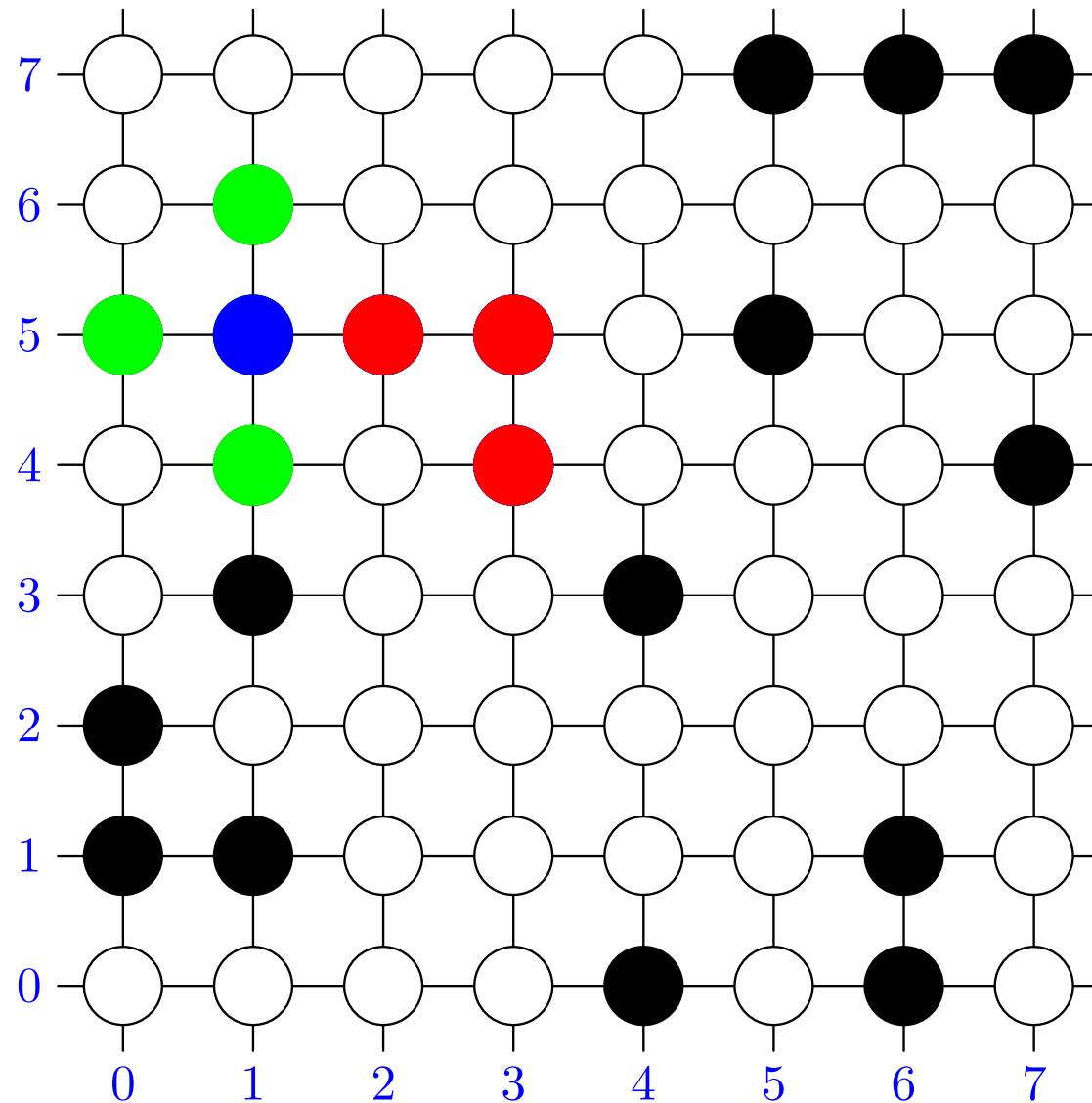
next = (1, 5)

uncheckedNodes =



clusterNodes =
{ (2, 5), (1, 5), (3, 5),
(3, 4) }

Connected Nodes



next = (1, 5)

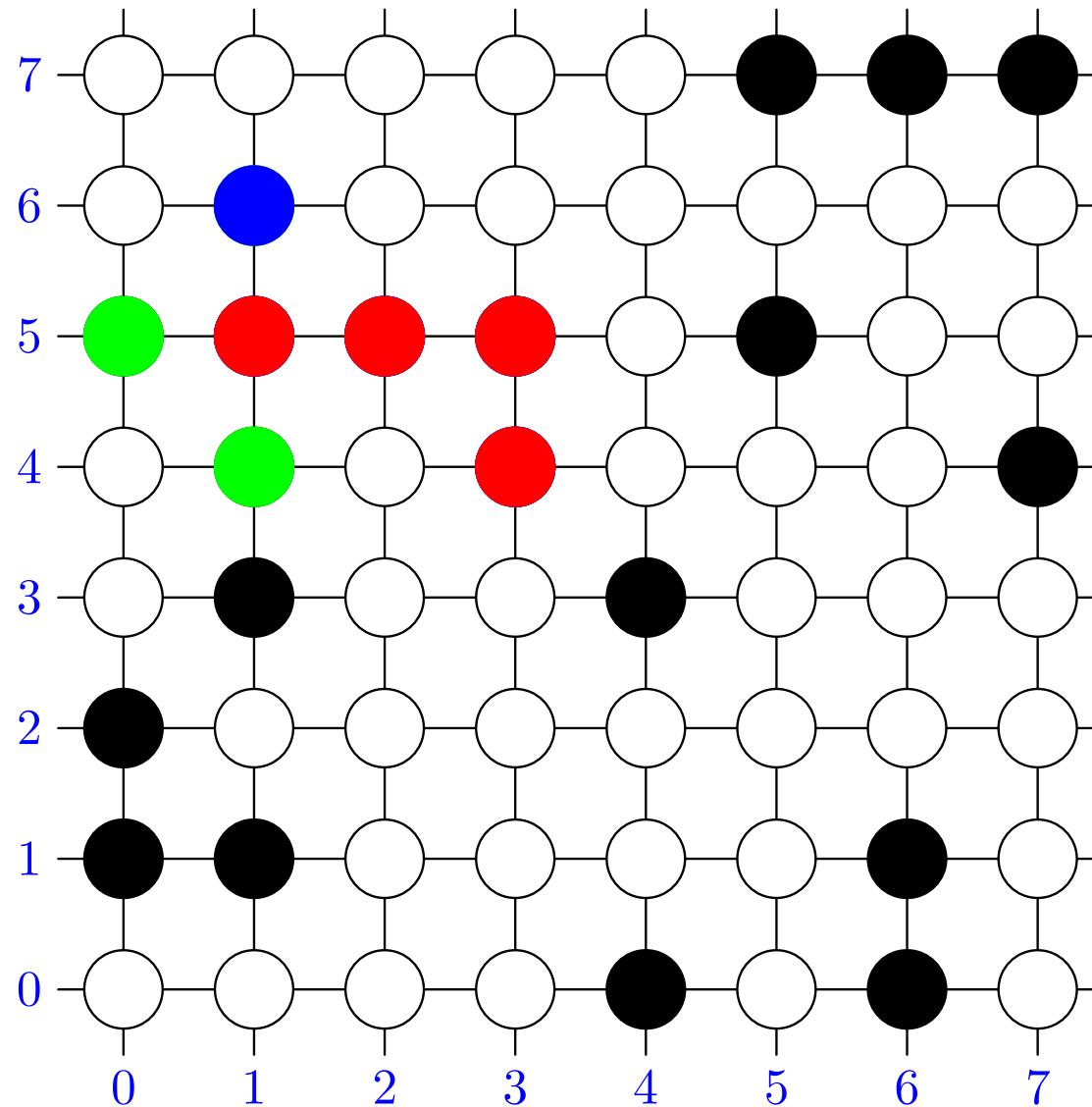
uncheckedNodes =

(1, 6)
(1, 4)
(0, 5)

clusterNodes =

{ (2, 5), (1, 5), (3, 5),
(3, 4), (0, 5), (1, 4),
(1, 6) }

Connected Nodes



next = (1, 6)

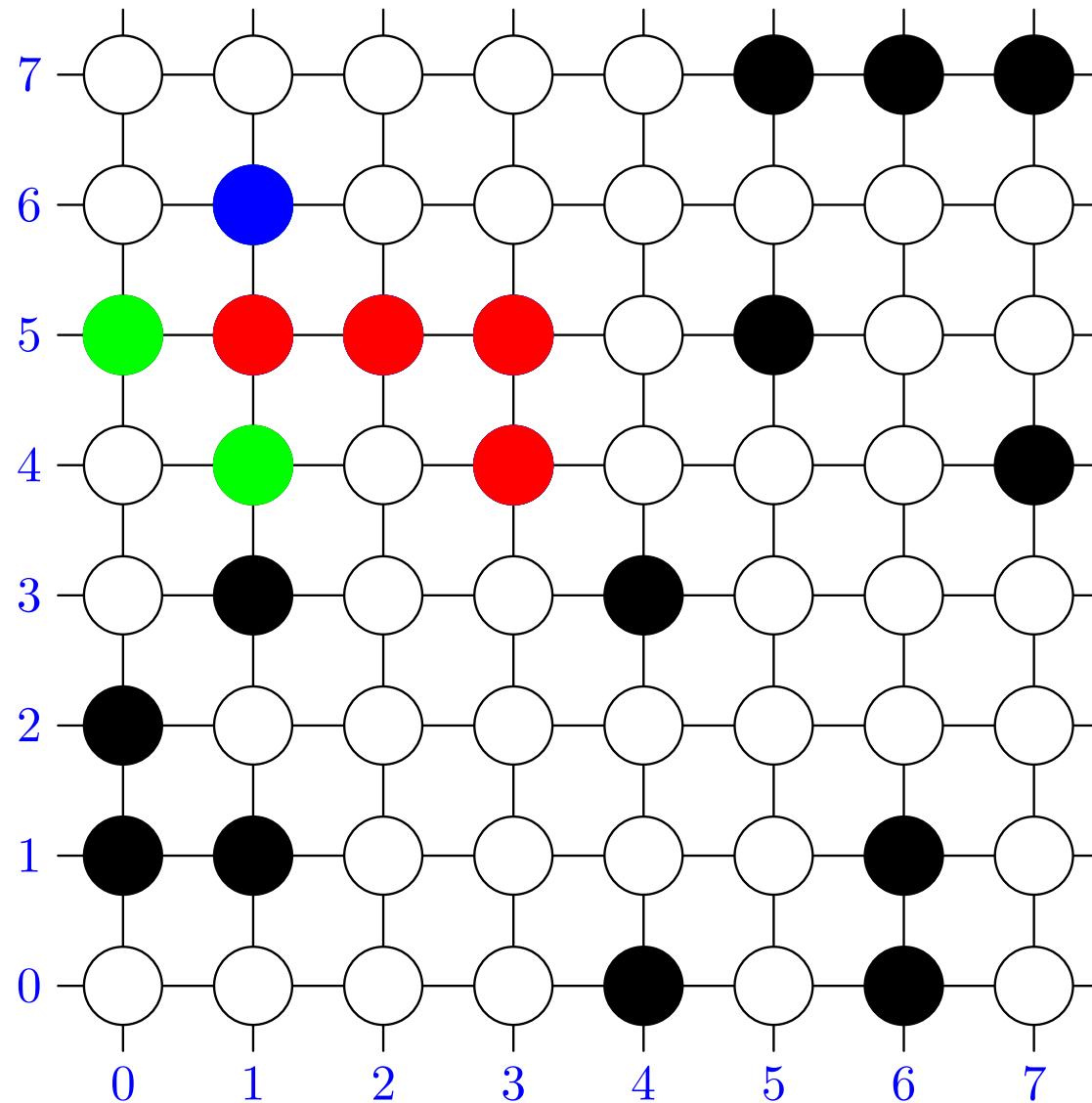
uncheckedNodes =

[
 (1, 4)
 (0, 5)
]

clusterNodes =

{ (2, 5), (1, 5), (3, 5),
(3, 4), (0, 5), (1, 4),
(1, 6) }

Connected Nodes



next = (1, 6)

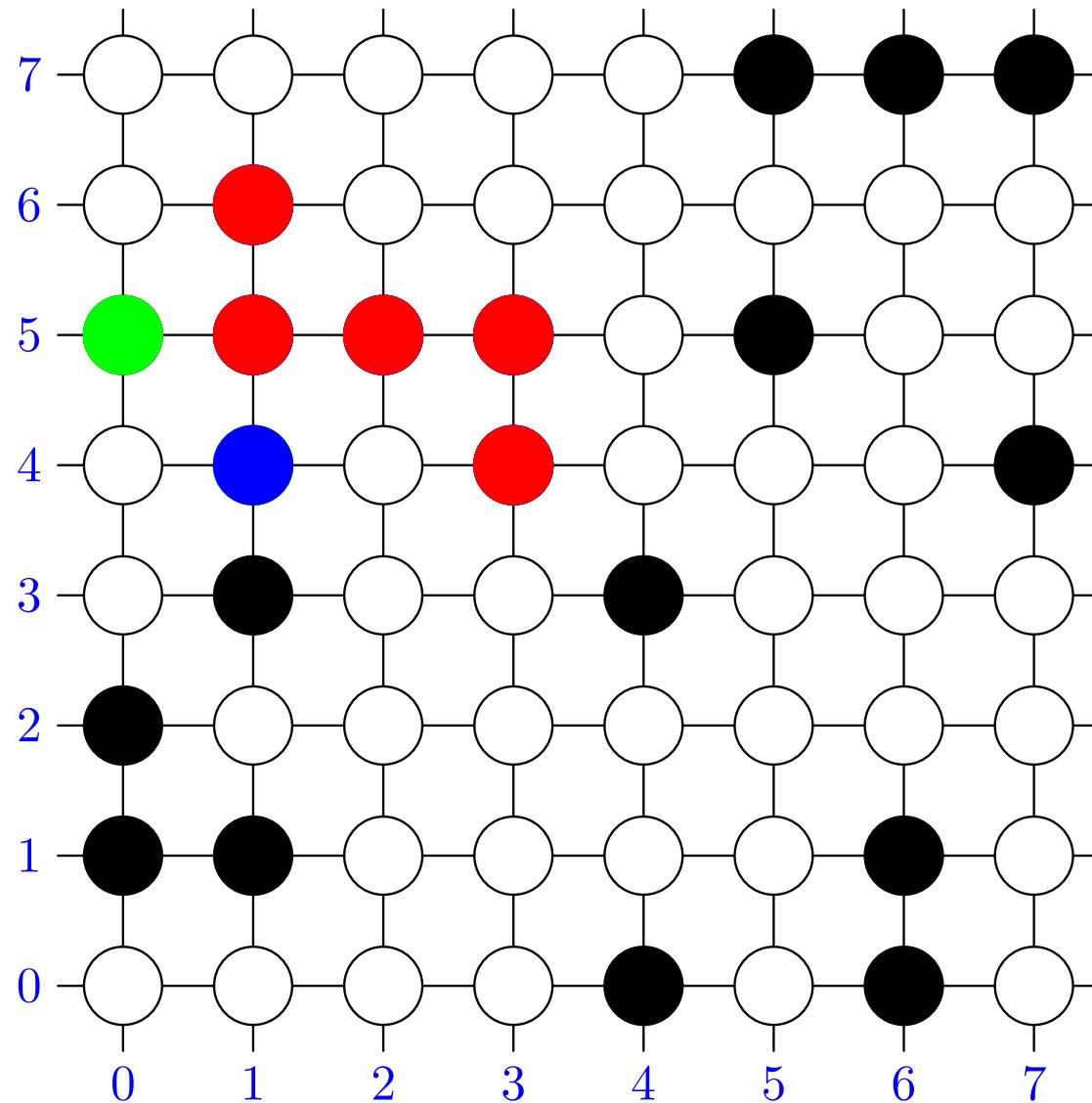
uncheckedNodes =

[
 (1, 4)
 (0, 5)
]

clusterNodes =

{ (2, 5), (1, 5), (3, 5),
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Connected Nodes



next = (1, 4)

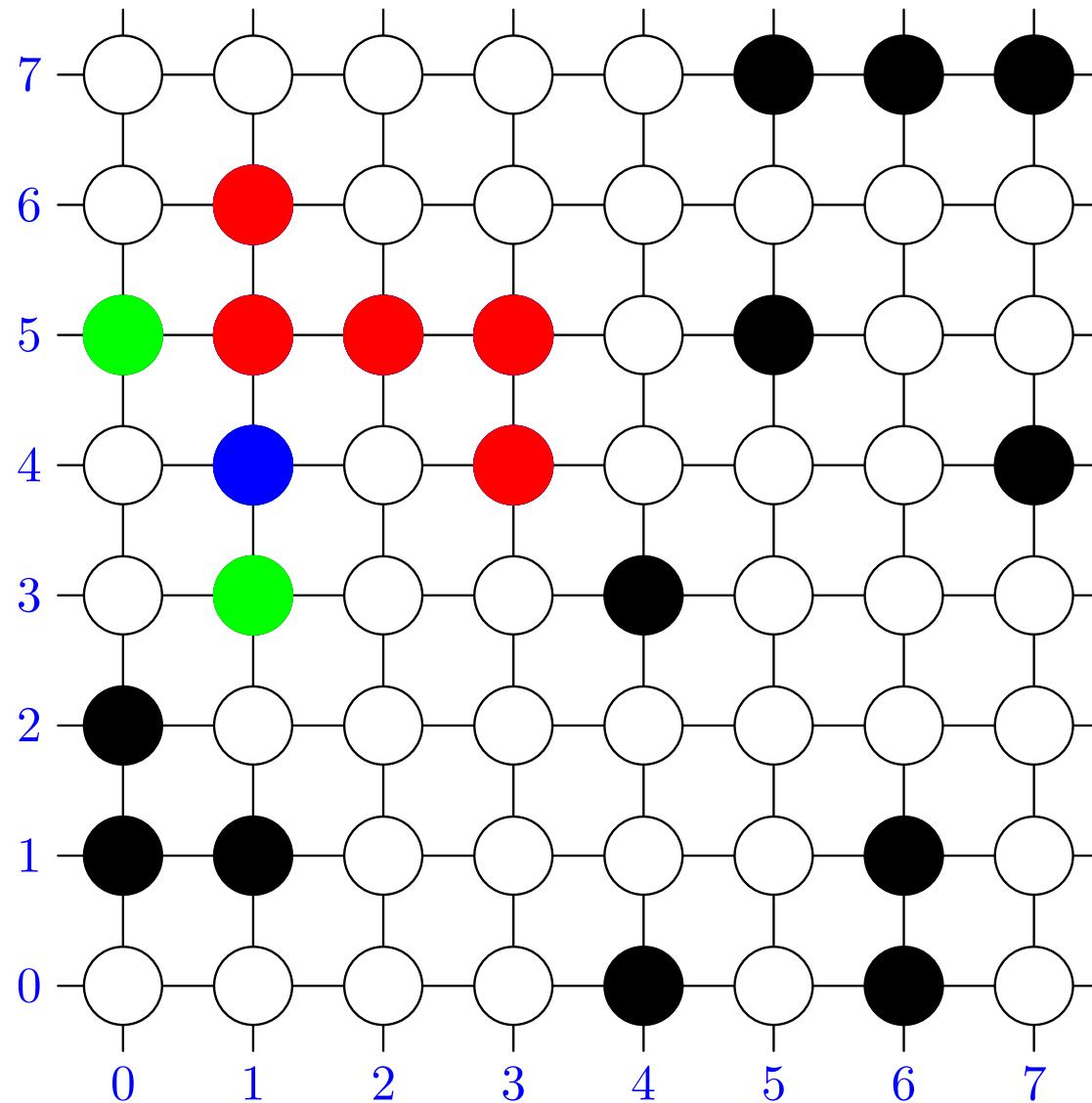
uncheckedNodes =

[
 (0, 5)
]

clusterNodes =

{ (2, 5), (1, 5), (3, 5),
(3, 4), (0, 5), (1, 4),
(1, 6) }

Connected Nodes



next = (1, 4)

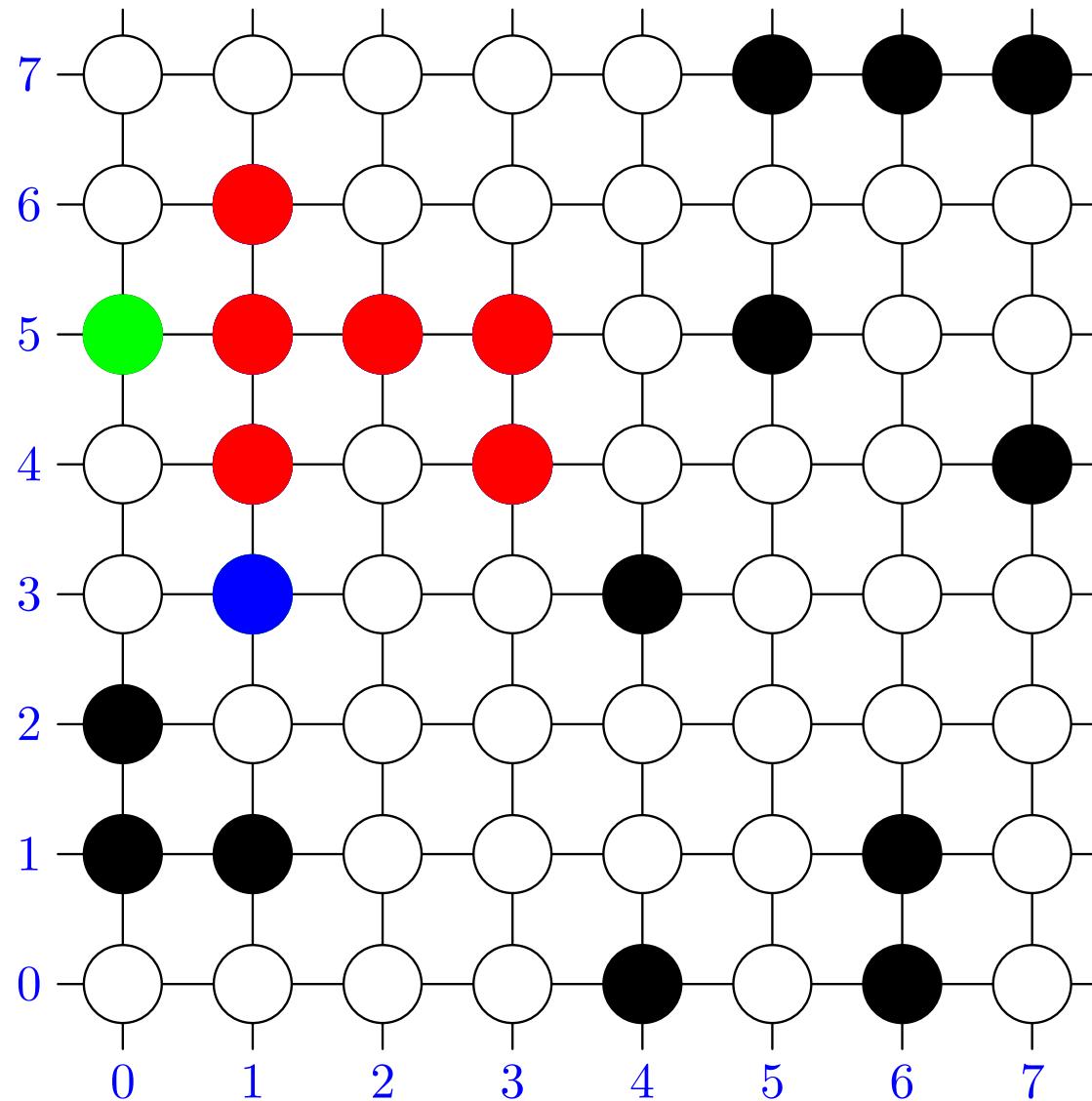
uncheckedNodes =

```
[  
  (1, 3)  
  (0, 5)]
```

clusterNodes =

```
{ (2, 5), (1, 5), (3, 5),  
  (3, 4), (0, 5), (1, 4),  
  (1, 6), (1, 3) }
```

Connected Nodes



next = (1, 3)

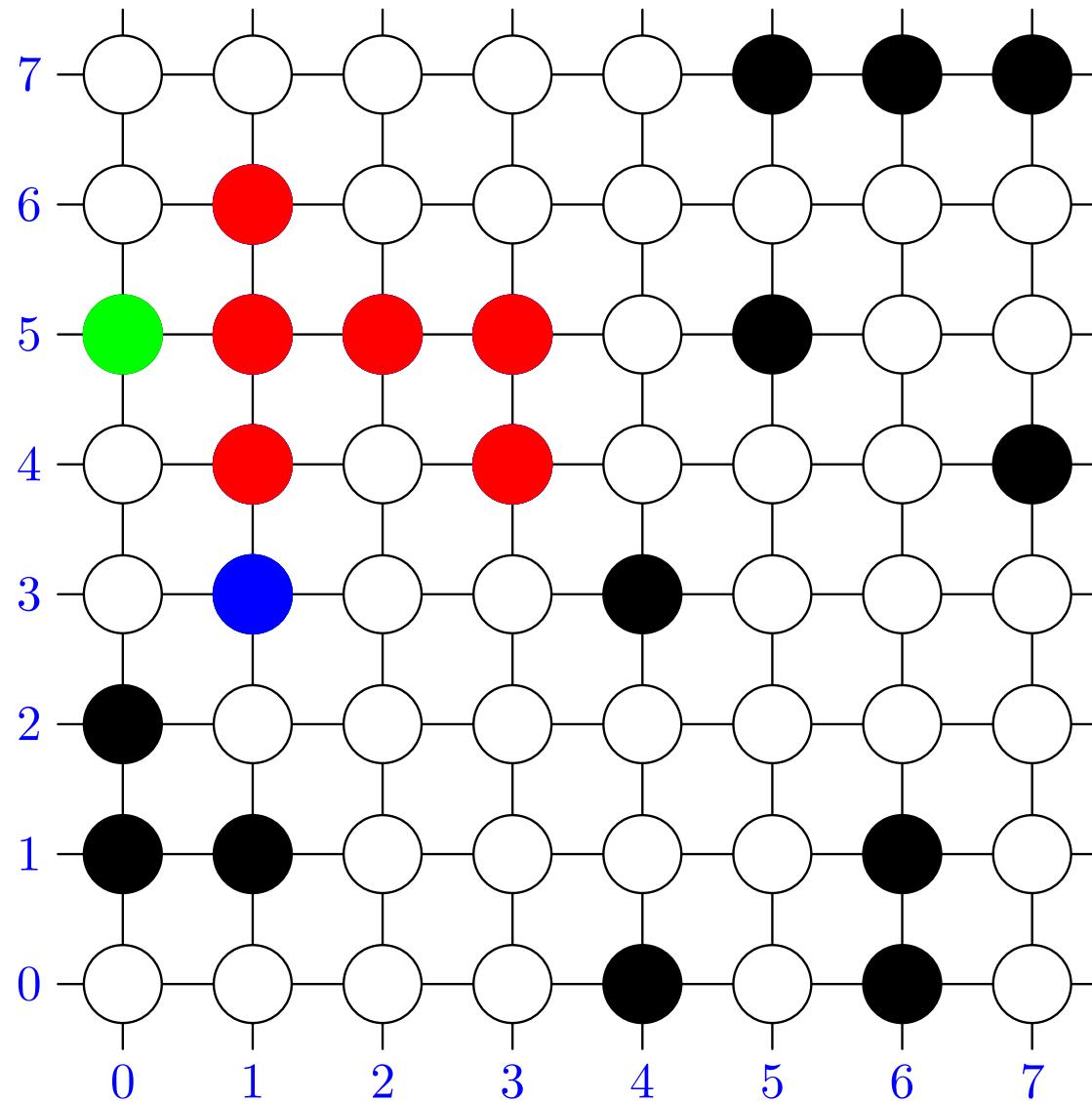
uncheckedNodes =

[
 (0, 5)
]

clusterNodes =

{ (2, 5), (1, 5), (3, 5),
(3, 4), (0, 5), (1, 4),
(1, 6), (1, 3) }

Connected Nodes



next = (1, 3)

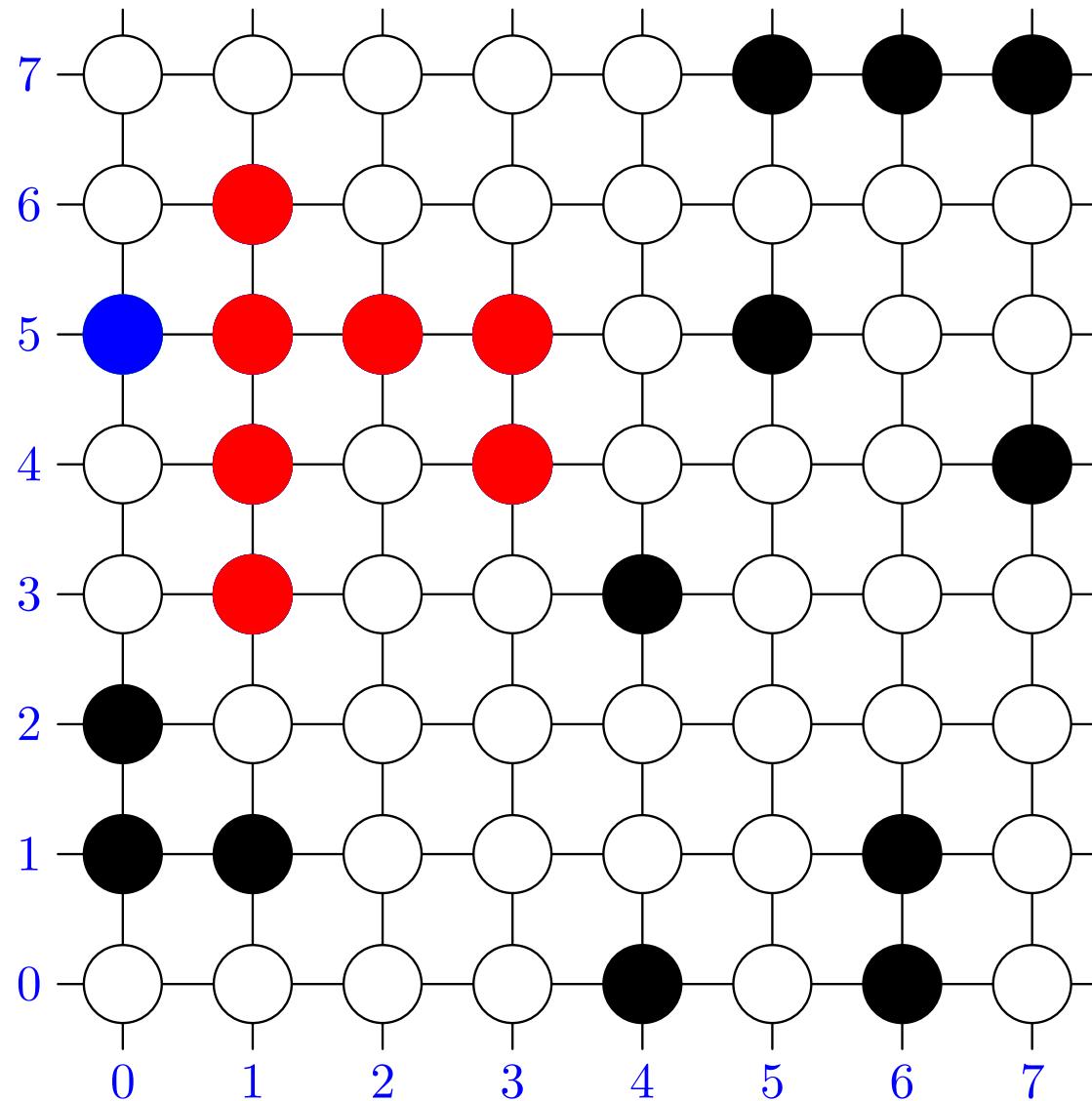
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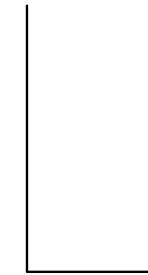
```
{ (2, 5), (1, 5), (3, 5),  
  (3, 4), (0, 5), (1, 4),  
  (1, 6), (1, 3) }
```

Connected Nodes



next = (0, 5)

uncheckedNodes =



clusterNodes =

{ (2, 5), (1, 5), (3, 5),
(3, 4), (0, 5), (1, 4),
(1, 6), (1, 3) }

Connected Node Algorithm

```
set<Node> findCluster(Node startNode, Graph graph)
```

Connected Node Algorithm

```
set<Node> findCluster(Node startNode, Graph graph)
{
    stack<Node> uncheckedNodes;
    set<Node> clusterNodes;
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Connected Node Algorithm

```
set<Node> findCluster(Node startNode, Graph graph)
{
    stack<Node> uncheckedNodes;
    set<Node> clusterNodes;

    uncheckedNodes.push(startNode);
    clusterNodes.insert(startNode);
```

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set<Node> findCluster(Node startNode, Graph graph)
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    uncheckedNodes.push(startNode);
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    while (!uncheckedNodes.empty()) {
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    uncheckedNodes.push(startNode);
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    while (!uncheckedNodes.empty()) {
        Node next = uncheckedNodes.top();    uncheckedNodes.pop();
        vector<Node> neighbours = graph.getNeighbours(next);
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        vector<Node> neighbours = graph.getNeighbours(next);
        for (Node neigh: neighbours) {
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            }
        }
    }
}
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                clusterNodes.insert(neigh);
            }
        }
    }

    return clusterNodes;
}
```

Lessons

- Abstract Data Types (ADT) are interfaces to data
- Their purpose is to allow the programmer to declare their intentions
- They often have different implementations with different properties
- The most efficient implementation is not always obvious—we will see many of these implementations as we go through this course
- You need to know the common ADTs (e.g. Stack, Queue, List, Set, Map) and how and when to use them

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