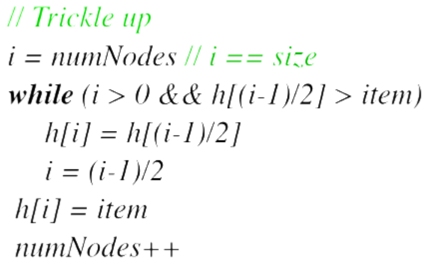
# CS010C

Lab8(No.8 Lab)

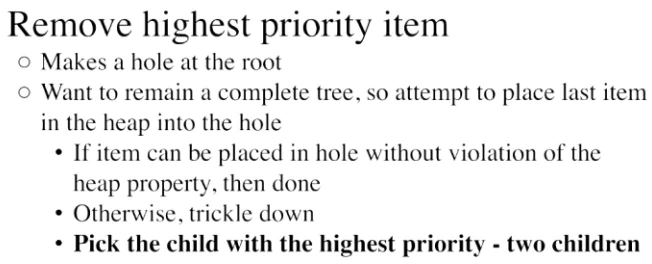
heap

# Min-Heap Review

- See slides
  - CANVAS -> modules -> week4 -> Binary Heap Slides
- We have $n$ nodes, from $0$ to $n-1$
  - Node $i$'s
    - Parent = $(i-1)/2$
    - Left Child = $2i + 1$
    - Right Child = $2i + 2$
  - Insert
    - Put the new node at $n$-th position, then trickle up
      - (iteratively compare with parent)
  - Remove_min
    - Remove the root, place last item into the hole, then trickle down
      - (iteratively compare with the smaller child - remember 2 children)
- Build heap
  - $O(n)$, rather than $O(n\text{logn})$



```
// Trickle up
i = numNodes // i == size
while (i > 0 && h[(i-1)/2] > item)
    h[i] = h[(i-1)/2]
    i = (i-1)/2
h[i] = item
numNodes++
```



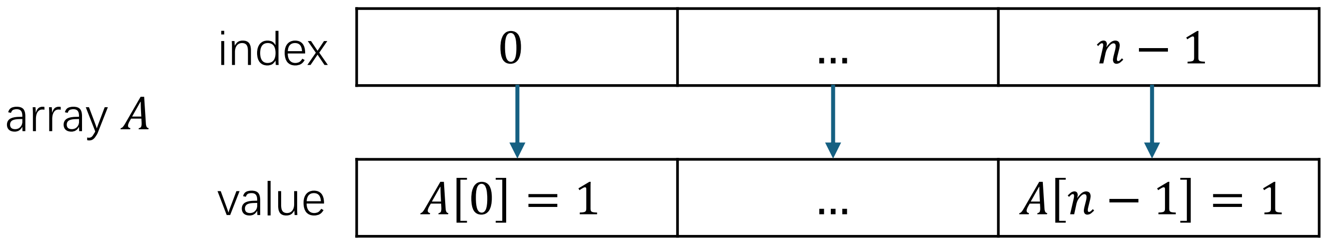
Remove highest priority item

- ○ Makes a hole at the root
- ○ Want to remain a complete tree, so attempt to place last item in the heap into the hole
  - If item can be placed in hole without violation of the heap property, then done
  - Otherwise, trickle down
  - **Pick the child with the highest priority - two children**

# map

powerful than vector/array

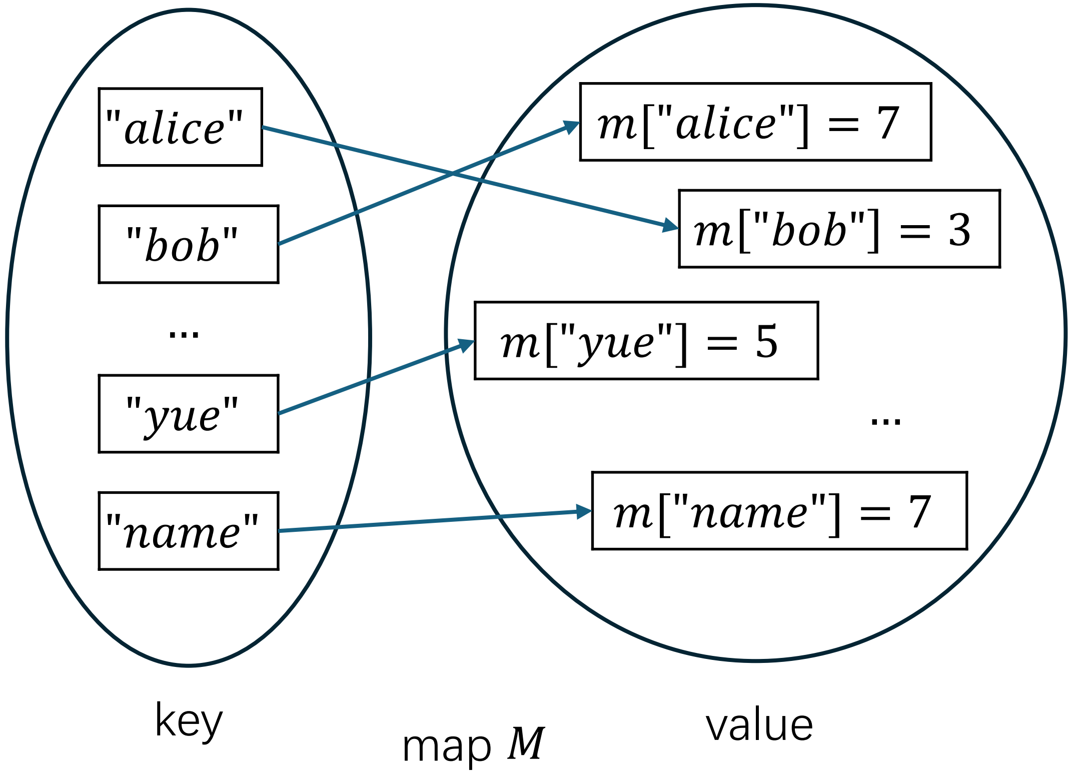
# map



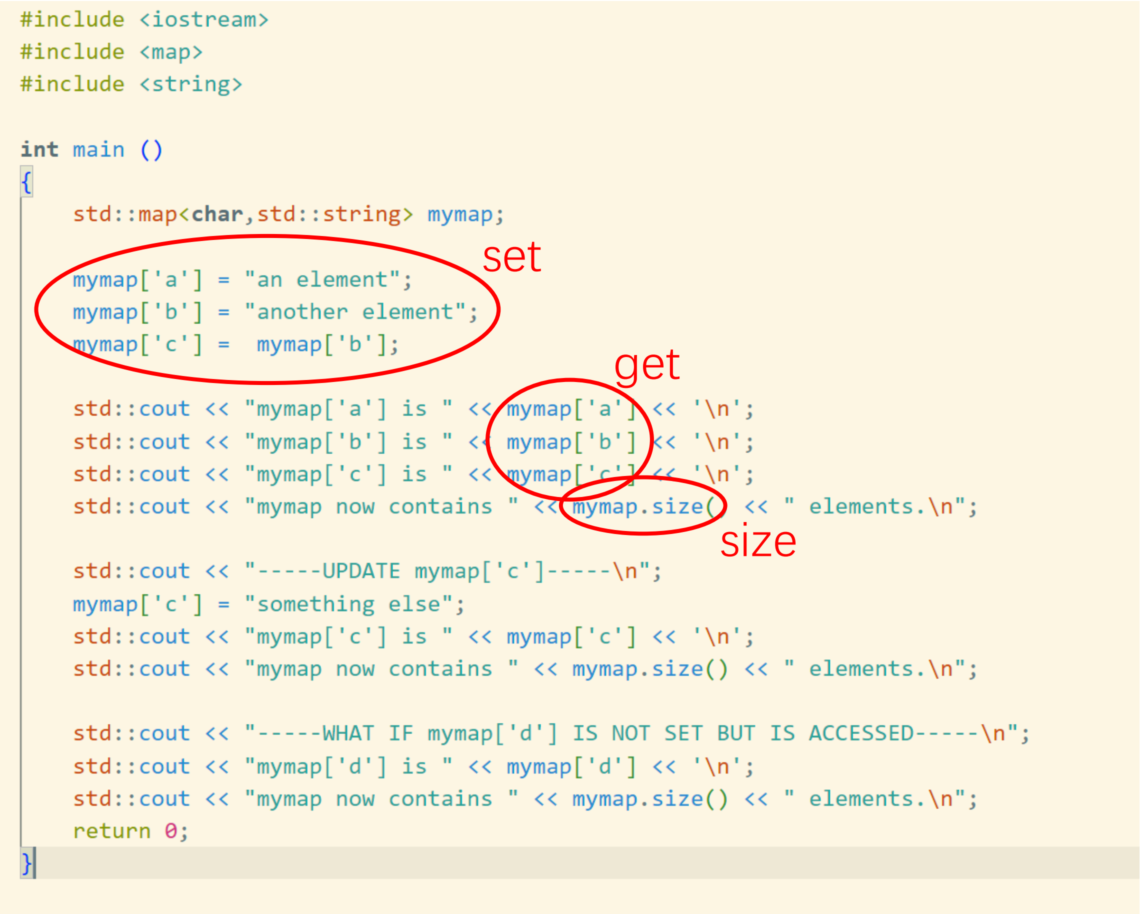
array $A$

| index | $0$ | … | $n-1$ |
|---|---|---|---|
| value | $A[0]=1$ | … | $A[n-1]=1$ |

- Review: what is an array? consists of index-value pairs
  - an $\boldsymbol{index}$, must be integer
  - you can get the $\boldsymbol{value}$ at the corresponding $\boldsymbol{index}$'s position
  - $\boldsymbol{index}$ is unique, $\boldsymbol{value}$ can be repeated
- A map: consists of key-value pairs
  - a $\boldsymbol{key}$, can be anything
  - you can look up the $\boldsymbol{value}$ by the $\boldsymbol{key}$
  - $\boldsymbol{key}$ is unique, $\boldsymbol{value}$ can be repeated

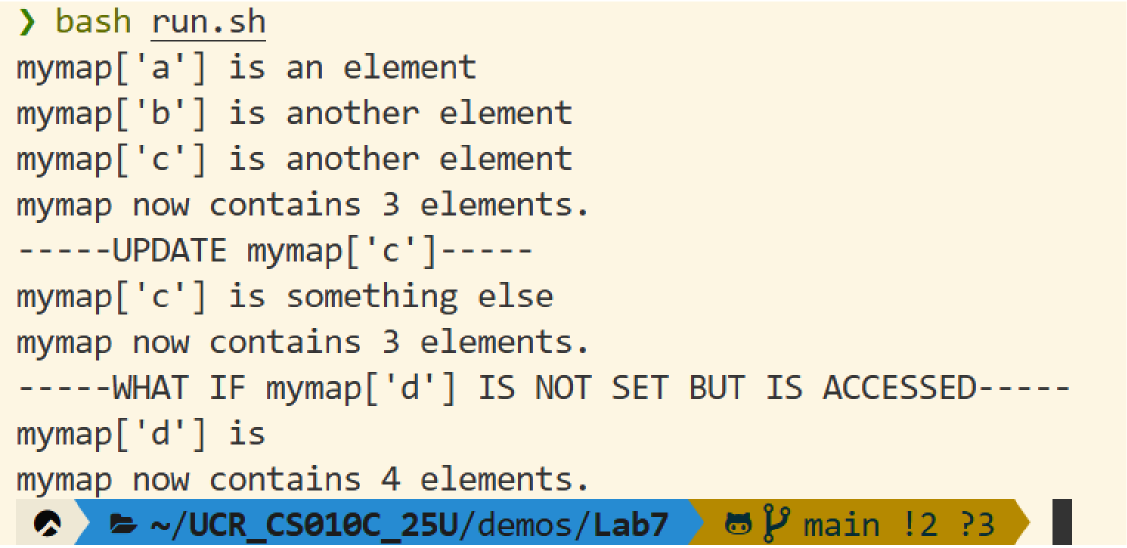


# std::map example



```cpp
#include <iostream>
#include <map>
#include <string>

int main ()
{
    std::map<char,std::string> mymap;

    mymap['a'] = "an element";
    mymap['b'] = "another element";
    mymap['c'] =  mymap['b'];

    std::cout << "mymap['a'] is " << mymap['a'] << '\n';
    std::cout << "mymap['b'] is " << mymap['b'] << '\n';
    std::cout << "mymap['c'] is " << mymap['c'] << '\n';
    std::cout << "mymap now contains " << mymap.size() << " elements.\n";

    std::cout << "-----UPDATE mymap['c']-----\n";
    mymap['c'] = "something else";
    std::cout << "mymap['c'] is " << mymap['c'] << '\n';
    std::cout << "mymap now contains " << mymap.size() << " elements.\n";

    std::cout << "-----WHAT IF mymap['d'] IS NOT SET BUT IS ACCESSED-----\n";
    std::cout << "mymap['d'] is " << mymap['d'] << '\n';
    std::cout << "mymap now contains " << mymap.size() << " elements.\n";
    return 0;
}
```

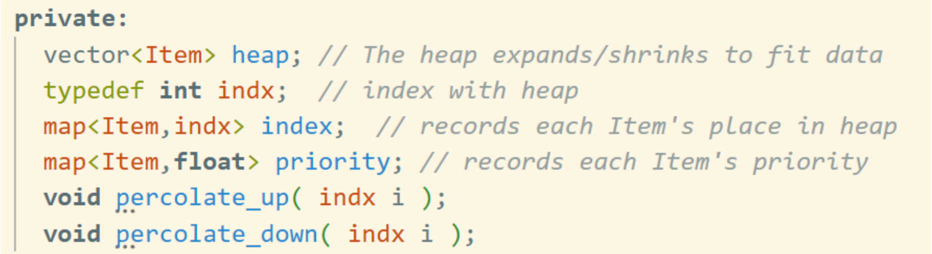
Example:
https://github.com/SJZHZ/UCR_CS010C_25U/blob/main/demos/Lab7/map.cpp



```
❯ bash run.sh
mymap['a'] is an element
mymap['b'] is another element
mymap['c'] is another element
mymap now contains 3 elements.
-----UPDATE mymap['c']-----
mymap['c'] is something else
mymap now contains 3 elements.
-----WHAT IF mymap['d'] IS NOT SET BUT IS ACCESSED-----
mymap['d'] is
mymap now contains 4 elements.
 ~/UCR_CS010C_25U/demos/Lab7   main !2 ?3
```

# priority queue

# pq_zero.H overview

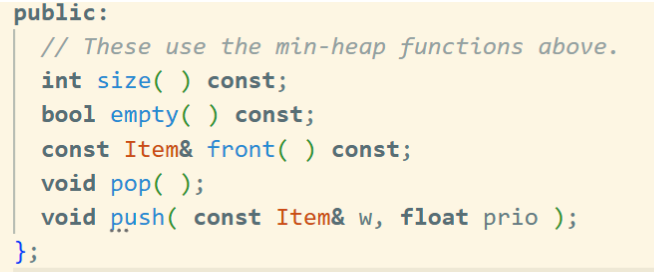


```
private:
  vector<Item> heap; // The heap expands/shrinks to fit data
  typedef int indx;  // index with heap
  map<Item,indx> index;  // records each Item's place in heap
  map<Item,float> priority; // records each Item's priority
  void percolate_up( indx i );
  void percolate_down( indx i );
```

- Completed
  - “heap” vector stores <Item>s
  - “index” map stores <Item,int> pairs
  - “priority” map stores <Item,float> pairs

Always remember we have these 3 variables!

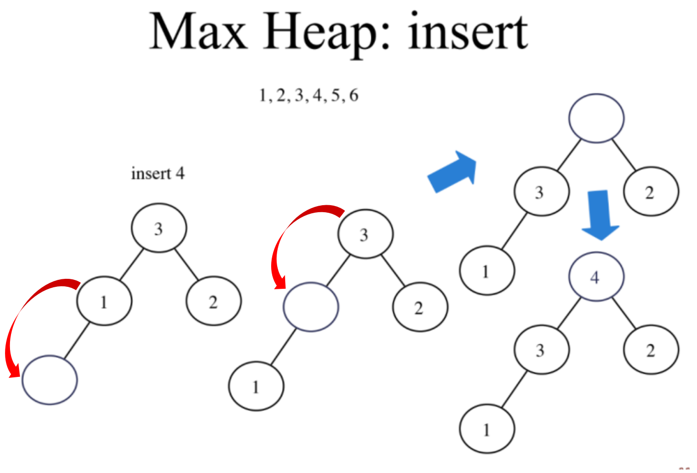
- Relatively complex
  - `void percolate_up( indx i );`
  - `void percolate_down( indx i );`
- Straightforward
  - Once you have completed the basic operations



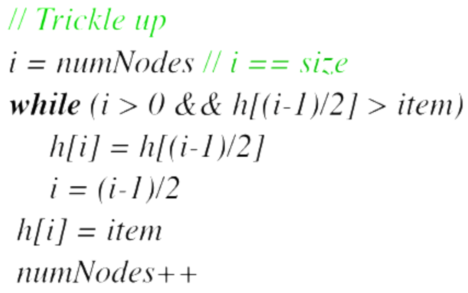
```
public:
  // These use the min-heap functions above.
  int size( ) const;
  bool empty( ) const;
  const Item& front( ) const;
  void pop( );
  void push( const Item& w, float prio );
};
```

# heap

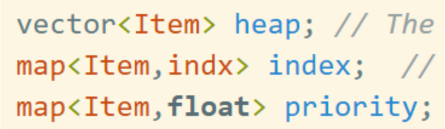
Parent = $(i-1)/2$
Left Child = $2i + 1$
Right Child = $2i + 2$



- element
  - only priority value — $h[i]$
- Given $i$, how to
  - Find parent/child
  - Get priority value — $h[i]$
  - Move to $j$ — $h[j] = h[i]$
  - Swap with $j$ — $temp = h[i], h[i] = h[j], h[j] = temp$
- percolate_up pseudocode
  - While (not_root && parent_larger)
    - Move parent to child
    - Go upward to parent's position
  - Put the item to current position
  - Count++
- Likewise for percolate_down

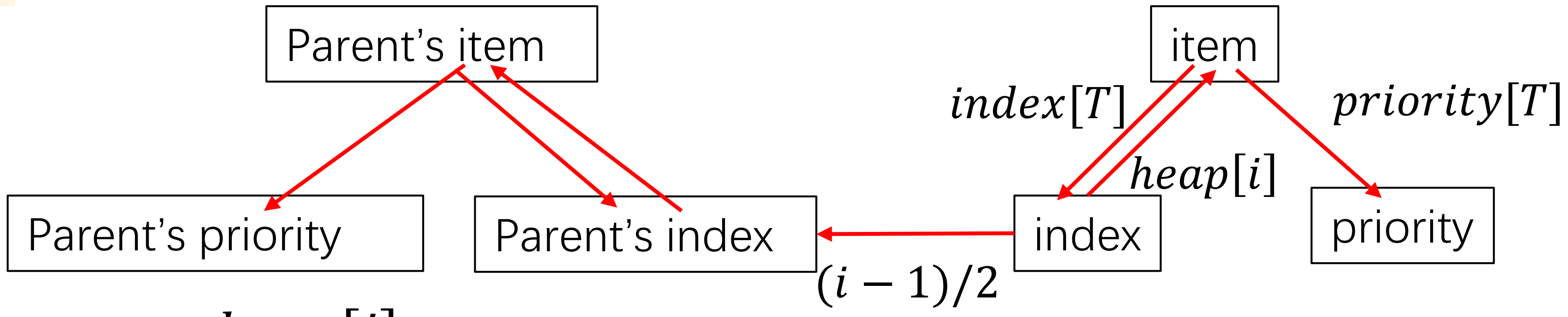


```
// Trickle up
i = numNodes // i == size
while (i > 0 && h[(i-1)/2] > item)
    h[i] = h[(i-1)/2]
    i = (i-1)/2
h[i] = item
numNodes++
```



```
vector<Item> heap; // The
map<Item,indx> index;  //
map<Item,float> priority;
```

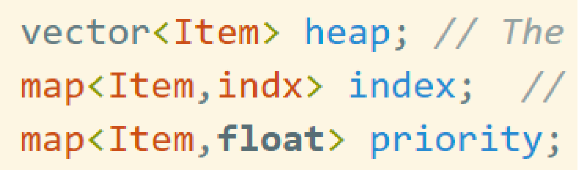
# Data structure



- Given index $i$, how to
  - Get item $heap[i]$
  - Get parent $(i-1)/2$
- Given item $T$, how to
  - Get index $index[T]$
  - Get priority $priority[T]$

- Puzzle
  - Given index $i$, how to get priority $priority[heap[i]]$
    - Index -> item -> priority!
  - Given item $T$, how to get its parent $heap[(index[T]-1)/2]$
    - Item -> index -> parents's index!

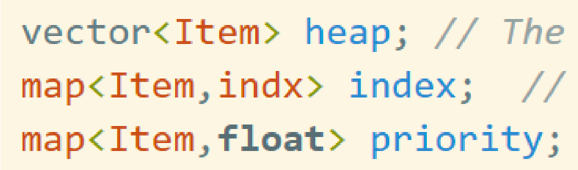
# Operation



```
vector<Item> heap; // The
map<Item,indx> index;   //
map<Item,float> priority;
```

- create a node at index $i$
  - $heap[i] = new\_item$
  - $index[new\_item] = i$
- Puzzle: how to swap $i$ and $j$ nodes
- We have “heap”, “index”, “priority”
  - What will change?
    - “heap” & “index”
    - “priority”? The relationship between item & priority remains unchanged!
  - How will they change?
    - $swap(\ heap[i], heap[j]\ );$ // swaps strings in heap
    - $swap(\ index[heap[i]], index[heap[j]]\ );$ // updates string's position in heap

# PQ



```
vector<Item> heap; // The
map<Item,indx> index;  //
map<Item,float> priority;
```

- `percolate_up`
  - Put the new item to last postion

    $heap[i] = new\_item$ (or use push_back)
    $index[new\_item] = i$

  - While (not_root && parent_larger)

    $priority[heap[i]] <= priority[heap[j]]$

    - swap parent and child

      $swap(\ heap[i], heap[j]\ );$
      $swap(\ index[heap[i]], index[heap[j]]\ );$

    - Go upward to parent’s position
  - Count++
- Likewise for `percolate_down`

# Conclusion

- Finish your implementation in “pq_zero.H”
  - First `empty, front, size` simple
  - Then `percolate_up, percolate_down` complex
  - Finally `pop, push` simple
- pq operations
  - Add item $T$ after the end
    - $heap.push\_back(T)$
    - $index[T] = heap.size() - 1$
  - Swap $i$-th and $j$-th nodes
    - $swap(\ heap[i], heap[j]);$
    - $swap(\ index[heap[i]], index[heap[j]]\ );$
  - Compare $i$-th and $j$-th nodes priority
    - $priority\left[heap[i]\right]\ \ ?\ \ priority[heap[j]]$