Connect 4 Project

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Implement connect 4 game in `https://www.cbc.ca/kids/games/all/connect-4`. We use colored shapes, not just balls. To indidate a win, we replace the shapes in a trace to similar ones.

Warning:

1. This is copyrighted materials; you are not allowed to upload to the Internet.
2. Our project is different from similar products in Internet. We use shapes instead of balls.
   (a) Ask help only from teaching staff of this course.
   (b) Use solutions from ChatGPT or online tutoring websites like, but not limited to, chegg.com, violates academic integrity and is not allowed.

1 Rules

1. A Board object has several bins.
2. All bins have the same capacity, that is, the maximum number of elements a bin can hold.
3. Rules for moving are listed as follows.
   (a) At any time, number of elements in a bin cannot exceed its capacity.
   (b) The shapes in a bin are filled from bottom to top.
   (c) After adding a shape to a bin, check wether there are at least 4 consecutive shapes in one of the following directions: horizontal, vertical, diagonal, or anti-diagonal.
      i. If so, the game is finished and a winner is declared.
      ii. Otherwise, the game continues until there is no more spot to add a shape.
      iii. If all empty spots are filled, and there is no winner, then the game is tied.

2 Files of the Project

We use Object-oriented Programming approach.

1. Create directory `connect4` to hold codes of the project **if** you have not done so. Said differently, you only need to run the following command once.

   ```
   mkdir connect4
   ```

2. Move to the above directory.

   ```
   cd connect4
   ```

3. Create `Board.hpp` with the following contents. **Warning:** do not write `Board.hpp` as `board.hpp`. C++ is a case-sensitive language.

   `Board.hpp` is the header file of Board class that **declares** data members and operations (aka methods) on those data members.

```
#ifndef BOARD_H
#define BOARD_H
#include <vector>
class Board {
public:
    Board(); //6 bins, each bin holds at most 4 balls
    Board(int numBins, int capacity); //numBins, each bin holds at
       most capacity many shapes
    void display() const;
    int add(int player);
        //Given a player,
        //return which bin the player is added to.

    int winInHorizontal(int bin);
    int winInVertical(int bin);
    int winInDiagonal(int bin);

    int win(int bin); //column must be the most recent ball in that
       bin

    void play();

//private: //TODO: comment private: for gradescope test purpose only
    int numBins; //number of bins
    int capacity; //maximum number of shapes held in each bin
    //need to compile using -std=c++11
    //if using std::vector<std::vector<int>>, otherwise
    //need to use std::vector<std::vector<int> >
    //with a space after the last > >.

    std::vector<std::vector<int> > grid;
    //If not using c++11, need to have space between the last two > >
    //std::vector<std::vector<int> > grid;
    //The above statement cannot write as
    //std::vector<int> grid(numBins, capacity);
    //which results in a one-dimensional array
    //of numBins elements, each element equals capacity.
};
#endif
```

4. Your task is to implement `Board.cpp`, which **defines** constructors and methods declared in Board.hpp.

   (a) Note that, in `Board.hpp`, data members are declared but not yet initialized. The data members are initialized in constructors.

   (b) Similarly, constructors and methods are declared (have function header) in `Board.hpp` but not defined (no function body).

   (c) **Warning:** do NOT put main function in `Board.cpp`.

3 Data Members in Board.hpp

The details of data members, constructors and methods in Board class of the game are discussed as follows.

```
+--+--+--+--+--+--+
|  |  |  |  |  |  |
+--+--+--+--+--+--+
|  |  |  |  |  |  |
+--+--+--+--+--+--+
|  |  |  |  |  |  |
+--+--+--+--+--+--+
|  |  |  |  |  |  |
+--+--+--+--+--+--+
  0  1  2  3  4  5
```

1. Data member `numBins` is an integer representing the number of bins. In the above example, `numBins` is 6. One column is a bin.

2. Data member `capacity` is an integer representing the maximum number of element each bin can hold. In the previous example, `capacity` is 4.

3. Data member `grid` of type `std::vector<std::vector<int>>` is a two dimensional array of integers.

   (a) A vector is a one-dimensional array that can grow or shrink. It is a template class, documentation can be found at `https://cplusplus.com/reference/vector/vector/`.

   (b) To use vector, need to include the library.
   `include <vector>`

      i. If you do not use standard namespace std, then need to add `std::` before vector.

      ii. Example: declare a vector as an array of integers with 4 elements. Each element is initialized to be 1.

```cpp
#include <iostream>
#include <vector>
#include <string>
//using namespace std;

```

```
int main() {
    std::vector<int> oneBin = {1, 1, 1, 1};
        //oneBin is a vector of integers with elements 1, 1,
           1, 1.

    for (int i = 0; i < oneBin.size(); i++)
        std::cout << oneBin[i] << std::endl;
    return 0;
}
```

(c) Each bin is represented by a vector of integers, similar to a one-dimensional array of integers. A bin may be empty.

(d) In the beginning, data member `grid` has six bins, each bin is empty.

(e) When displaying, map integer 0 to red circle and integer 1 to blue pentagon. More mapping details are shown in `display` method.

You may think `grid` in the previous example has six bins, each bin can hold at most four (same value as capacity) elements.

Note that data member `capacity` does not suppose a limit on the size of the vector. When this capacity is exhausted and more is needed, it is automatically expanded by the container (reallocating it storage space).

However, for this game, we need to make sure that no bin can have more `capacity` elements at any time. When there is `capacity` elments in a bin, we stop adding elements to that bin.

4 Task A: Define constructors in Board.cpp

The purpose of constructor is to initialize data members. A class may have multiple constructors. Different constructors have different parameter lists. Each constructor has exactly the same name as class, no return type, not even void.

4.1 The default constructor `Board()`

The default constructor does not take any parameter. It does the following:

1. Set data members `numBins` to be 6.
2. Set data member `capacity` to be 4.

Warning: the following code is wrong. `int` before `numBins` means to the varialbe is a local variable for constructor `Board`, but not data member `numBins`.

```
Board::Board() {
    int numBins = 6;
    ... //omit other code
}
```

Correct way:

```
Board::Board() {
    numBins = 6;
    ... //omit other code
}
```

3. You may use the hints from the following code to initialize data member `grid`.

```
//for each shape, do the following:
for (int i = 0; i < ?; i++) { //TODO: fill in ?
    std::vector<int> oneBin;
       //that is, oneBin is an empty vector
       //You may think oneBin as a bin in our application.


    //add the one-dimensional array oneBin to grid
    grid.push_back(??); //TODO: fill in ??
}
```

4.2 A nondefault constructor `Board(int numBins, int capacity)`

1. If given parameter `numBins` is smaller than 5, reset it to be 5.
2. If given parameter `capacity` is smaller than 4, reset it to be 4.
3. Now given parameters are correct, use them to set the corresponding data members. Note that if a formal parameter has exactly the same name as a data member, we need to put `this->` before the data member, where `this` is a pointer to the current object.

You may notice that there are a lot of common codes among those constructors. A better way is to define `Board(int numBins, int capacity)`. Then use constructor delegate to define `Board()`.

No need to define destructor in this project since we did not dynamically allocate memories for data members.

4.3 Finish Task A

1. Define constructors in `Board.cpp`.

```
#include "Board.hpp"
#include <iostream> //cout
#include <iomanip> //setw
#include <algorithm> //swap

//TODO: fill in ? and ?? in the parentheses.
//Hint: what are the values of numBins and capacity for a default
   Board object?
//Question: after calling Board(?, ??) to create a Board object with
//? means number of bins,
```

```
//each bin holds at most ?? elements,
Board::Board() : Board(?, ??) {
    //No more code is needed
}

Board::Board(int numBins, int capacity) {
    //TODO: If given parameter numBins is smaller than 5,
    //reset it to be 5.


    //TODO: If given parameter capacity is smaller than 4,
    //reset it to be 4.


    //Now given parameters are correct,
    //use them to set the corresponding data members.
    //Note that if a formal parameter has exactly
    //the same name as a data member,
    //we need to put this-> before the data member,
    //where this is a pointer to the current object.

    //TODO: use formal parameter numBins to set data member numBins


    //TODO: use formal parameter capacity to set data member capacity



    //TODO: initialize data member grid

    //for i in [0, numBins):
    //begin
    //   instantiate an empty bin, call it oneBin
    //   push oneBin back to data members grid
    //end









}
```

2. Implement method `display`.

   See the following hints.

   We provide a non-member function `print`.

```
//not a method from Board class,
//hence cannot access data member capacity directly,
//need to pass capacity as a parameter
void print(int numBins) {
    //No need to print spaces before the first +
    //std::cout << "   ";
    std::cout << "+";
    for (int i = 0; i < numBins; i++)
        std::cout << "--+";

    std::cout << std::endl;
}
```

Here is a skeleton of method display.

```
    //map 0 to a red \033[31m ball \u2b24
    //map 1 to a blue \033[34m pentagon \u2b1f
    //map 2 to a red double circle \033[31m\u25c9
    //map 3 to a blue empty pentagon \033[31m\u2b54
    //For more shapes, see https://jrgraphix.net/r/Unicode/25A0-25FF
    std::string mapping[] = {"\033[31m\u2b24\033[0m", "\033[34m\u2b1f
       \033[0m", "\033[31m\u25c9\033[0m", "\033[34m\u2b54\033[0m"};
       //\033[32m is green color

    print(numBins);
    for (int j = capacity-1; j >= 0; j--) {
        //Your codes goes here.
        //Instead of printing grid[i][j],
        //where i is bin index,
        //you may consider using mapping[grid[i][j]].




    }

    //TODO: print labels

}
```

3. Implement method add.

```
int Board::add(int player) {
    //TODO:
    //(1) Given player,
    //    choose a bin index that is valid,
    //    ie, in [0, numBins),
    //    and is not full.
```

```
    //(2) push back this player id to that bin.
    //(3) return the bin index chosen.



}
```

4. Test codes locally.

   (a) Comment private: line in `Board.hpp` as `//private:`. This is for debug purpose.

   (b) Edit main.cpp as follows. This file can be downloaded from `https://onlinegdb.com/aedvljUjk`.

```
#include <iostream>
#include <vector>
#include "Board.hpp"
//g++ -std=c++11 Board.cpp main.cpp -o test
//test default constructor using
//./test A or ./test 'A'
//./test B or ./test 'B'
//...
//./test H or ./test 'H'


int main(int argc, const char *argv[]) {
    if (argc != 2) {
       std::cout << "Need 'A'-'C' in parameters" << std::endl;
       return -1;
    }

    //unit-testing for constructors and the destructor
    char type = *argv[1];
    std::string prompt;
    Board *game;
    int** arr;

    if (type == 'A') {
       prompt = "default constructor,";
       game = new Board;

//Sample output:
//After default constructor, data member numBins is 6
//After default constructor, data member capacity is 4
//number of elements of bin 0 is: 0
//number of elements of bin 1 is: 0
//number of elements of bin 2 is: 0
//number of elements of bin 3 is: 0
```

```
35 //number of elements of bin 4 is: 0
36 //number of elements of bin 5 is: 0
37     }
38     else if (type == 'B') {
39             prompt = "Board game(7, 5);";
40             game = new Board(7, 5);
41
42 //Sample output:
43 //After Board game(7, 5); data member numBins is 7
44 //After Board game(7, 5); data member capacity is 5
45 //number of elements of bin 0 is: 0
46 //number of elements of bin 1 is: 0
47 //number of elements of bin 2 is: 0
48 //number of elements of bin 3 is: 0
49 //number of elements of bin 4 is: 0
50 //number of elements of bin 5 is: 0
51 //number of elements of bin 6 is: 0
52     }
53     else if (type == 'C') {
54             prompt = "Board game(5, 1);";
55             game = new Board(5, 1);
56
57 //sample output:
58 //After Board game(5, 1); data member numBins is 5
59 //After Board game(5, 1); data member capacity is 4
60 //number of elements of bin 0 is: 0
61 //number of elements of bin 1 is: 0
62 //number of elements of bin 2 is: 0
63 //number of elements of bin 3 is: 0
64 //number of elements of bin 4 is: 0
65     }
66     else if (type == 'D') {
67             game = new Board;
68
69             game->grid[0].push_back(0);
70             game->grid[0].push_back(1);
71             game->grid[1].push_back(0);
72             game->grid[1].push_back(1);
73             game->grid[2].push_back(0);
74             game->grid[3].push_back(1);
75             game->display();
76
77 //sample output:
78 //+--+--+--+--+--+--+
79 //|  |  |  |  |  |  |
80 //+--+--+--+--+--+--+
```

```
81  //|   |   |   |   |   |   |
82  //+--+--+--+--+--+--+
83  //|    |    |   |   |   |   |
84  //+--+--+--+--+--+--+
85  //|    |    |    |     |   |   |
86  //+--+--+--+--+--+--+
87  //  0   1   2   3   4   5
88      }
89      else if (type == 'E') {
90              game = new Board;
91
92              game->grid[0].push_back(2);
93              game->grid[0].push_back(1);
94              game->grid[1].push_back(2);
95              game->grid[1].push_back(1);
96              game->grid[2].push_back(2);
97              game->grid[2].push_back(1);
98              game->grid[3].push_back(2);
99              game->display();
100 //sample output:
101 //+--+--+--+--+--+--+
102 //|   |   |   |   |   |   |
103 //+--+--+--+--+--+--+
104 //|   |   |   |   |   |   |
105 //+--+--+--+--+--+--+
106 //|    |    |    |   |   |   |
107 //+--+--+--+--+--+--+
108 //|    |    |    |    |   |   |
109 //+--+--+--+--+--+--+
110 //  0   1   2   3   4   5
111     }
112     else if (type == 'F') {
113             game = new Board;
114
115             game->grid[0].push_back(0);
116             game->grid[1].push_back(3);
117             game->grid[0].push_back(0);
118             game->grid[1].push_back(3);
119             game->grid[0].push_back(0);
120             game->grid[1].push_back(3);
121             game->grid[3].push_back(0);
122             game->grid[1].push_back(3);
123             game->display();
124
125 //sample output:
126 //+--+--+--+--+--+--+
```

```
127 //|  |    |  |  |  |  |
128 //+--+--+--+--+--+--+
129 //|    |    |  |  |  |  |
130 //+--+--+--+--+--+--+
131 //|    |    |  |  |  |  |
132 //+--+--+--+--+--+--+
133 //|    |    |  |    |  |  |
134 //+--+--+--+--+--+--+
135 //  0  1  2  3  4  5
136     }
137     else if (type == 'G') {
138             game = new Board;
139             int bin = game->add(0); //choose a bin for player
                    with id 0
140             int bin2 = game->add(1); //choose a bin for player
                    with id 1
141
142             std::cout << "The layout of the bins are as follows."
                    << std::endl;
143             for (int i = 0; i < game->numBins; i++) {
144                 if (game->grid[i].size() == 0)
145                    std::cout << "empty" << std::endl;
146                 else {
147                       for (int j = 0; j < game->grid[i].size(); j
                             ++)
148                           std::cout << game->grid[i][j] << " ";
149                       std::cout << std::endl;
150                 }
151             }
152
153 //sample output:
154 //Enter a bin index in [0, 6) that is not full: -1
155 //invalid bin index, needs to be in [0, 6)
156 //Re-enter a bin index in [0, 6) that is not full: 7
157 //invalid bin index, needs to be in [0, 6)
158 //Re-enter a bin index in [0, 6) that is not full: 0
159 //Enter a bin index in [0, 6) that is not full: -2
160 //invalid bin index, needs to be in [0, 6)
161 //Re-enter a bin index in [0, 6) that is not full: 10
162 //invalid bin index, needs to be in [0, 6)
163 //Re-enter a bin index in [0, 6) that is not full: 1
164 //The layout of the bins are as follows.
165 //0
166 //1
167 //empty
168 //empty
```

```
169 //empty
170 //empty
171     }
172     else if (type == 'H') {
173             //When a bin is full, cannot add more element to it.
174             game = new Board;
175             game->grid[0].push_back(0);
176             game->grid[0].push_back(1);
177             game->grid[0].push_back(0);
178             game->grid[0].push_back(1);
179             int bin = game->add(0); //choose a bin for player
                    with id 0
180 
181             std::cout << "The layout of the bins are as follows."
                     << std::endl;
182             for (int i = 0; i < game->numBins; i++) {
183                 if (game->grid[i].size() == 0)
184                    std::cout << "empty" << std::endl;
185                 else {
186                       for (int j = 0; j < game->grid[i].size(); j
                             ++)
187                         std::cout << game->grid[i][j] << " ";
188                       std::cout << std::endl;
189                 }
190             }
191 //sample output:
192 //Enter a bin index in [0, 6) that is not full: 0
193 //the bin is full
194 //Re-enter a bin index in [0, 6) that is not full: 1
195 //The layout of the bins are as follows.
196 //0 1 0 1
197 //0
198 //empty
199 //empty
200 //empty
201 //empty
202     }
203 
204     //When type is 'A' - 'C', work on constructors
205     if (type == 'A' || type == 'B' || type == 'C') {
206        std::cout << "After " << prompt
207             << " data member numBins is " << game->numBins << std
                    ::endl;
208        std::cout << "After " << prompt
209             << " data member capacity is " << game->capacity <<
                    std::endl;
```

```
210
211         for (int i = 0; i < game->numBins; i++) {
212             std::cout << "number of elements of bin "
213                 << i << " is: "
214                 << game->grid[i].size() << std::endl;
215
216          }
217     }
218
219     delete game;
220     game = nullptr;
221
222     return 0;
223 }
```

(c) Run the following command to compile main.cpp and Board.cpp.

```
g++ -std=c++11 main.cpp Board.cpp -o test
```

(d) If there is no compilation errors, run the following command.

```
./test A
```

(e) You should be able see something like the following.

```
1 After default constructor, data member numBins is 6
2 After default constructor, data member capacity is 4
3 number of elements of bin 0 is: 0
4 number of elements of bin 1 is: 0
5 number of elements of bin 2 is: 0
6 number of elements of bin 3 is: 0
7 number of elements of bin 4 is: 0
8 number of elements of bin 5 is: 0
```

(f) Test non-default construtor `Board(int numBins, int capacity)` by using

```
./test B
```

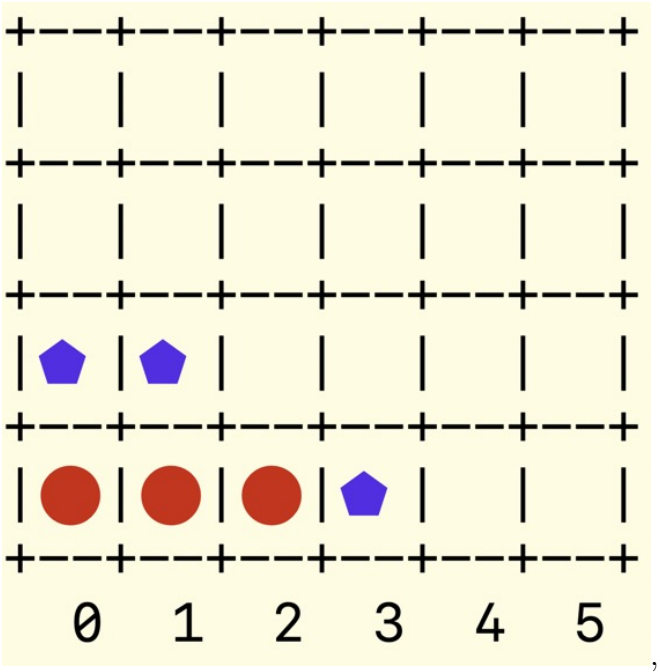
You should see the following output.

```
1 After Board game(7, 5); data member numBins is 7
2 After Board game(7, 5); data member capacity is 5
3 number of elements of bin 0 is: 0
4 number of elements of bin 1 is: 0
5 number of elements of bin 2 is: 0
6 number of elements of bin 3 is: 0
7 number of elements of bin 4 is: 0
8 number of elements of bin 5 is: 0
9 number of elements of bin 6 is: 0
```

5. Run `./test C`, we get the following output.

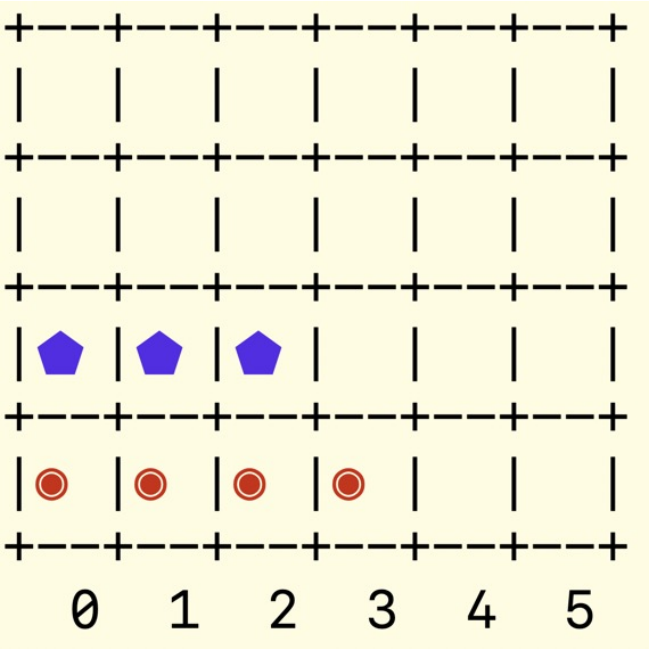
```
After Board game(5, 1); data member numBins is 5
After Board game(5, 1); data member capacity is 4
number of elements of bin 0 is: 0
number of elements of bin 1 is: 0
number of elements of bin 2 is: 0
number of elements of bin 3 is: 0
number of elements of bin 4 is: 0
```

6. Run `./test D`. Get the following output.



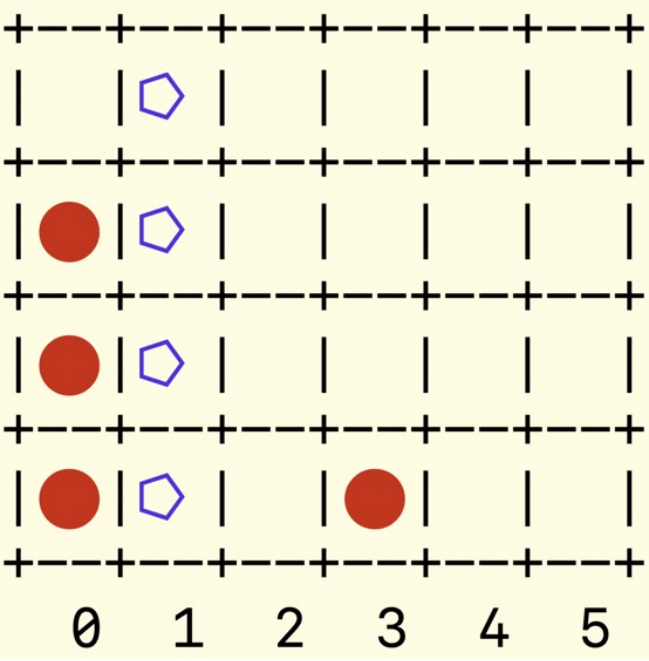
,

7. Run `./test E`. Get the following output.



,

8. Run `./test F`. Get the following output.



,

9. Or you can test the code in `https://www.onlinegdb.com/online_c++_compiler`.

   Upload main.cpp, Board.hpp (comment private: line) and Board.cpp to onlinegdb. In the textbox right to **Command line arguments:**, enter A to H.

10. If the code runs correctly in a local computer, upload `Board.cpp` to gradescope.

11. Again, do not add `main` function in `Board.cpp`.

5 Task B: define winHorizontal, winVertical, winDiagonal, and win methods

After a player puts a shape to a bin using `add` method in Task A, an id (either 0 or 1) representing that player is pushed back to the bin. There is a chance the player could win.

5.1 A win or not

To find out whether there is an actual win or not, define method `winInHorizontal`, given a bin, check whether its top element (including itself) has 4 or more same-value neighbors in horizontal direction. Simiarly, methods `winInVertical` and `winInDiagonal` (including diagonal and anti-diagonal) are defined.

5.2 With a win, save the locations of four or more consecutive same-value elements in the corresponding direction

Furthermore, once a win occurs, we would like to mark out those 4 or more consecutive elements in the correspondin direction. To do so, we need to record the location of an element.

Use type `Coord` to save the location of an element, where `bin` is the bin index and `idx` is the index of the element in `bin`.

```
1 struct Coord {
2     int bin; //bin index of data member grid
3     int idx; //index inside the bin
4 };
```

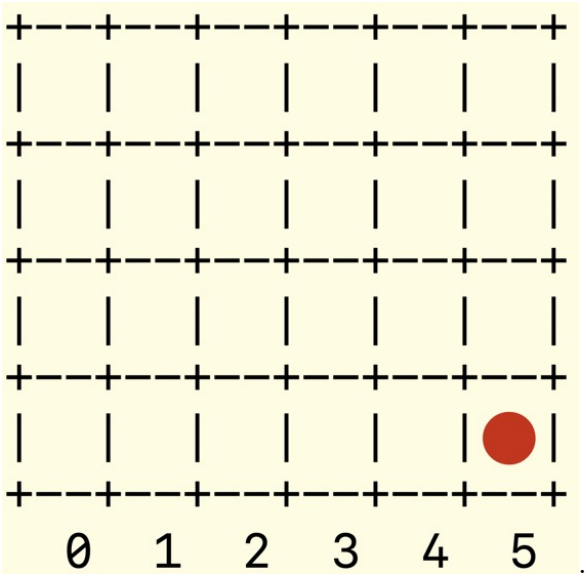
Some students ask the differences between `struct` and `class` in C++.

1. Both `struct` and `class` define a type.
2. `struct` also works in C. Unlike an array, which is a collection of same-type data residing in consecutive memory, a `struct` consists of members of different types, but without methods or constructor (this part changes in C++), while `class` is defined in C++.
3. By default, members in `struct` are public.
4. By default, members in `class` are private.
5. According to `https://stackoverflow.com/questions/54585/when-should-you-use-a-class-vs-a-str` we can do the following.
   (a) Use struct for plain-old-data structures without any class-like features.
   (b) Use class when you make use of features such as private or protected members, non-default constructors and operators.

Put the locations of those elements in a vector. If the size of that vector is larger than or equal to 4, increase the value of those elements by 2. In this way, those four or more consecutive elements in the path can be marked out, so we can see clearly why a player wins.

We illustrate a run of method `winInHorizontal`.

1. In the beginning, player red (with id 0) puts 0, which maps to a red circle, into bin 5.

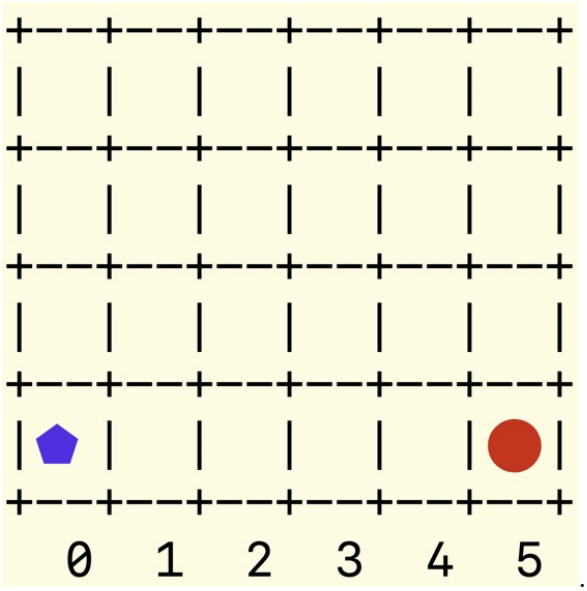


The above process is achieved by the following statements, taken from `main.cpp` to test methods in Task B.

Note that we do not call methods to put elements to bins in case other methods are not properly defined. We just concentrate on testing on `winInHorizontal` method.

```
game = new Board; //default constructor
game->grid[5].push_back(0);
//game->display(); //optional,
```

2. Next, player blue (with id 1) puts a 1, which maps to a blue pentagon, into bin 0.

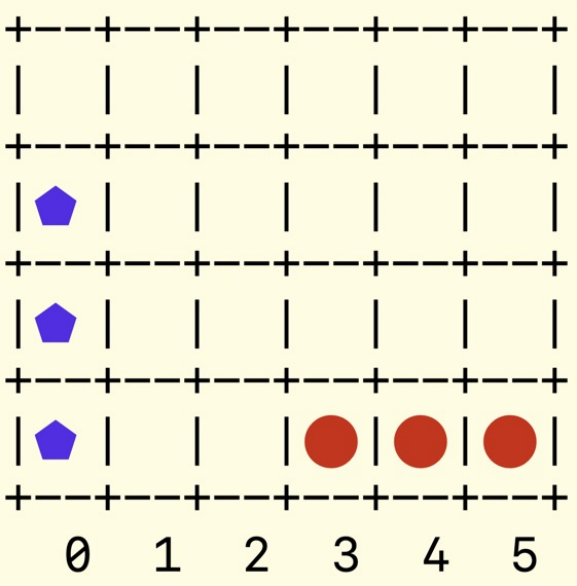


This is achieved by adding the following statements to the above codes.

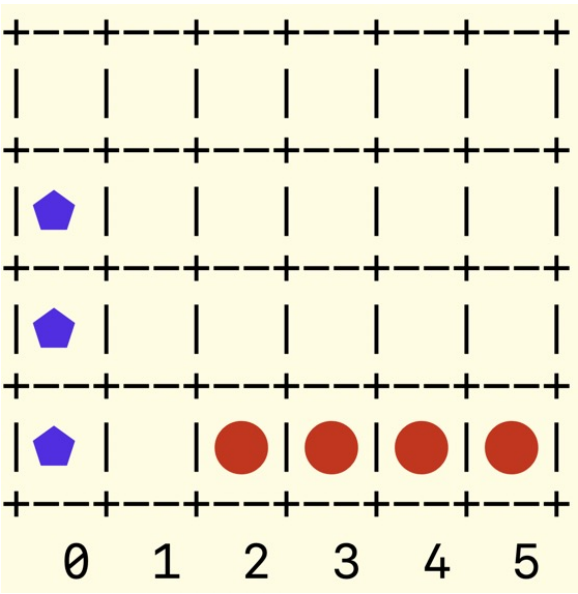
```
game->grid[0].push_back(1);
```

3. Fastforward, the layout of bins are as follows after player 0 chooses bin 4, player 1 choose bin 0, then player 0 chooses bin 3, player 1 chooses bin 0.

```
game->grid[4].push_back(0); //player 0 chooses bin 4
game->grid[0].push_back(1); //player 1 chooses bin 0
game->grid[3].push_back(0); //player 0 chooses bin 3
game->grid[0].push_back(1); //player 1 chooses bin 0
```



4. Now is the turn of player 0. If bin 2 is chosen, then four 0s (each 0 is mapped to a red circle) are aligned consecutively in horizontal direction.




```
game->grid[2].push_back(0);
```

5. Test `winInHorizontal` method in bin 2, the most recent bin with a new element added.

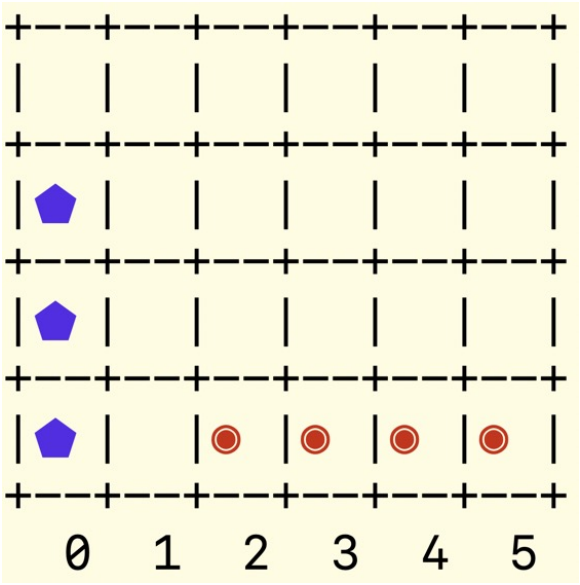
```
player = game->winInHorizontal(2);
```

The return should be 0, which means player 0 wins in horizontal direction.

6. Now call `winInHorizontal` method on bin 2. If there is a winner, return the corresponding id, otherwise, return -1.

```
player = game->winInHorizontal(2);
```

7. To show users why player 0 wins, we display the corresponding elements in slightly different shapes, from the original red circles to double red circles. To do so, we add 2 to the original value 0. By the mapping in display method, label 2 is mapped to a double red circle.



Here is expected result after test option 1 in the above main function, where each column represents a bin. Display the elements for each bin from top to bottom, if there is no element, use a space.

The first bin has three blue pentagons, represented by id 1. In bins indexed at 2, 3, 4, 5, each has one element 2, which implies that player 0 wins.

```
player 0 wins in horizontal
 , , , , , ,
1, , , , , ,
1, , , , , ,
1, ,2,2,2,2,
```

5.3 Method `winInHorizontal`

In short, method `int winInHorizontal(int bin)` does the following.

1. Find out the player id in the top of `bin`. (Hint: what is the last index of `bin`, a vector of integers?
2. Count the number of consecutive same-value as the above player id elements in horizontal direction.
   (a) Record the locations, that is, bin index and the index in the bin, to a vector variable.

3. If the number of consecutive same-value elements in horizontal direction is at least four, set the player id as the winner.

4. Increase the corresponding elements contributed to the win by 2. That is, if the original value is 0, the new value is 2. If the original value is 1, the new value would be 3.

Here is a skeleton of method `winInHorizontal`.

```
int Board::winInHorizontal(int bin) {
     //Find out the last index of bin.

     //Find out the player residing at that last index of bin.
     //Save in an int variable called player.

     //Declare candidates as a vector of Coord.

     //candidates saves the locations of
     //all horizontal neighbors of the top elements of the given
        parameter bin
     //that share the same value of that top element,
     //which is saved in player.


     //Who can be the first element of candidates?


     //count consecutive elements equaling player to the left of grid[bin
        ][idx]. Save their locations to candidates.

     //count consecutive elements equaling player to the right of grid[
        bin][idx]. Save their locations to candidates.

     if (count >= 4) {
        //change all elements in candidates to e player +2

        return player;
     }

     //Return -1 when no winner in horizontal direction
}
```

Define `winInVertical` method.

Define `winInDiagonal` method, need to consider both diagonal and anti-diagonal directions.

Define `win` method, which calls `winInHorizontal`, `winInVertical`, and `winInDiagonal` methods, if one of them return a value other than -1, then a winner is found, return the corresponding player id, otherwise, return -1.

5.4 Test code locally

1. Create a subdirectory called `taskB` under `connect4`.
2. In `taskB`, copy `Board.cpp` from Task A.
   (a) Define `winInHorizontal`, `winInVertical`, `winInDiagonal`, and `win` methods in `Board.cpp`.
3. Download the following `main.cpp` and `Board.hpp` from `https://onlinegdb.com/7buWVilKs` to subdirectory `taskB`.
   (a) Run command

```
g++ -std=c++11 Board.cpp main.cpp -o test
```

   Test methods in Task B using the following commands. Compare the output with sample output in each test case of `main.cpp`.

```
./test 1
```

   There are 9 cases to test. Change 1 to 2, 3, ..., 9 if necessary.
   If codes run fine, upload `Board.cpp` to gradescope.
   Warning: some unicode symbols are not shown in the following codes, download from the previous onlinegdb link or brightspace.

```
#include <iostream>
#include <vector>
#include "Board.hpp"
//g++ -std=c++11 Board.cpp main.cpp -o test
//test different methods using
//./test 1 or ./test '1'
//./test 2 or ./test '2'
//...
//./test 9 or ./test '9'


int main(int argc, const char *argv[]) {
    if (argc != 2) {
       std::cout << "Need 'A'-'C' in parameters" << std::endl;
       return -1;
    }

    //unit-testing for constructors and the destructor
    char type = *argv[1];
    std::string prompt;
    Board *game;
    int player = -2; //a not-exist value

    if (type == '1') {
       //test player 0 wins in winInHorizontal
```

```
26          game = new Board; //default constructor
27          game->grid[5].push_back(0);
28          //game->display();
29          game->grid[0].push_back(1);
30          //game->display();
31          game->grid[4].push_back(0);
32          //game->display();
33          game->grid[0].push_back(1);
34          //game->display();
35          game->grid[3].push_back(0);
36          //game->display();
37          game->grid[0].push_back(1);
38          //game->display();
39          game->grid[2].push_back(0);
40          //game->display();
41
42          player = game->winInHorizontal(2);
43          prompt = " in horizontal";
44
45          //game->display();
46  //Sample output:
47  //player 0 wins in horizontal
48  //  ,  ,  ,  ,  ,  ,
49  //1,  ,  ,  ,  ,  ,
50  //1,  ,  ,  ,  ,  ,
51  //1,  ,2,2,2,2,
52  //+--+--+--+--+--+--+
53  //|   |   |   |   |   |   |
54  //+--+--+--+--+--+--+
55  //|     |   |   |   |   |   |
56  //+--+--+--+--+--+--+
57  //|     |   |   |   |   |   |
58  //+--+--+--+--+--+--+
59  //|     |   |     |     |     |     |
60  //+--+--+--+--+--+--+
61  //  0   1   2   3   4   5
62      }
63      else if (type == '2') {
64          //test no one wins in winInHorizontal
65          game = new Board; //default constructor
66          game->grid[5].push_back(0);
67          game->grid[0].push_back(1);
68          game->grid[4].push_back(0);
69          game->grid[0].push_back(1);
70          game->grid[3].push_back(0);
71          game->grid[0].push_back(1);
```

```
72
73          player = game->winInHorizontal(0);
74          prompt = " in horizontal";
75          //game->display();
76  //Sample output:
77  //no player wins in horizontal
78  // , , , , , ,
79  //1, , , , , ,
80  //1, , , , , ,
81  //1, , ,0,0,0,
82  //Visual result
83  //+--+--+--+--+--+--+
84  //|  |  |  |  |  |  |
85  //+--+--+--+--+--+--+
86  //|     |  |  |  |  |  |
87  //+--+--+--+--+--+--+
88  //|     |  |  |  |  |  |
89  //+--+--+--+--+--+--+
90  //|     |  |  |     |     |     |
91  //+--+--+--+--+--+--+
92  //  0  1  2  3  4  5
93      }
94      else if (type == '3') {
95          //win in vertical
96          game = new Board;
97
98          game->grid[0].push_back(0);
99          game->grid[1].push_back(1);
100         game->grid[0].push_back(0);
101         game->grid[1].push_back(1);
102         game->grid[0].push_back(0);
103         game->grid[1].push_back(1);
104         game->grid[3].push_back(0);
105         game->grid[1].push_back(1);
106         //game->display();
107
108         player = game->winInVertical(1);
109         prompt = " in vertical";
110
111 //sample output:
112 //player 1 wins in vertical
113 // ,3, , , , ,
114 //0,3, , , , ,
115 //0,3, , , , ,
116 //0,3, ,0, , ,
117 //+--+--+--+--+--+--+
```

```
118 //|  |    |  |  |  |  |
119 //+--+--+--+--+--+--+
120 //|    |    |  |  |  |  |
121 //+--+--+--+--+--+--+
122 //|    |    |  |  |  |  |
123 //+--+--+--+--+--+--+
124 //|    |    |  |    |  |  |
125 //+--+--+--+--+--+--+
126 //  0  1  2  3  4  5
127     }
128     else if (type == '4') {
129         //no win in vertical
130         game = new Board;
131 
132         game->grid[0].push_back(0);
133         game->grid[1].push_back(1);
134         game->grid[0].push_back(0);
135         game->grid[1].push_back(1);
136         game->grid[0].push_back(0);
137         game->grid[1].push_back(1);
138         //game->display();
139 
140         player = game->winInVertical(1);
141         prompt = " in vertical";
142 //Sample output:
143 //+--+--+--+--+--+--+
144 //|  |  |  |  |  |  |
145 //+--+--+--+--+--+--+
146 //|    |    |  |  |  |  |
147 //+--+--+--+--+--+--+
148 //|    |    |  |  |  |  |
149 //+--+--+--+--+--+--+
150 //|    |    |  |  |  |  |
151 //+--+--+--+--+--+--+
152 //  0  1  2  3  4  5
153 //no player wins in vertical
154 // , , , , , ,
155 //0,1, , , , ,
156 //0,1, , , , ,
157 //0,1, , , , ,
158     }
159     else if (type == '5') {
160         //win in diagonal
161         game = new Board;
162         game->grid[0].push_back(0);
163         game->grid[1].push_back(1);
```

```
164         game->grid[1].push_back(0);
165         game->grid[2].push_back(1);
166         game->grid[3].push_back(0);
167         game->grid[2].push_back(1);
168         game->grid[2].push_back(0);
169         game->grid[3].push_back(1);
170         game->grid[3].push_back(0);
171         game->grid[4].push_back(1);
172         game->grid[3].push_back(0);
173 
174         player = game->winInDiagonal(0);
175         prompt = " in diagonal";
176 
177         //game->display();
178 
179 //Sample output:
180 //player 0 wins in diagonal
181 // , , ,2, , ,
182 // , ,2,0, , ,
183 // ,2,1,1, , ,
184 //2,1,1,0,1, ,
185 //+--+--+--+--+--+--+
186 //|  |  |  |  |  |  |
187 //+--+--+--+--+--+--+
188 //|  |  |  |  |  |  |
189 //+--+--+--+--+--+--+
190 //|  |  |  |  |  |  |
191 //+--+--+--+--+--+--+
192 //|  |  |  |  |  |  |
193 //+--+--+--+--+--+--+
194 //  0  1  2  3  4  5
195     }
196     else if (type == '6') {
197             //win in anti-diagonal
198         game = new Board;
199         game->grid[0].push_back(0);
200         game->grid[1].push_back(1);
201         game->grid[2].push_back(0);
202         game->grid[3].push_back(1);
203         game->grid[0].push_back(0);
204         game->grid[2].push_back(1);
205         game->grid[0].push_back(0);
206         game->grid[0].push_back(1);
207         game->grid[1].push_back(0);
208         game->grid[1].push_back(1);
209 
```

```
210         player = game->winInDiagonal(1);
211         prompt = " in anti-diagonal";
212 
213         //game->display();
214 
215 //sample output:
216 //+--+--+--+--+--+--+
217 //|  |  |  |  |  |  |
218 //+--+--+--+--+--+--+
219 //|  |  |  |  |  |  |
220 //+--+--+--+--+--+--+
221 //|  |  |  |  |  |  |
222 //+--+--+--+--+--+--+
223 //|  |  |  |  |  |  |
224 //+--+--+--+--+--+--+
225 //  0  1  2  3  4  5
226 //player 1 wins in anti-diagonal
227 //3, , , , , ,
228 //0,3, , , , ,
229 //0,0,3, , , ,
230 //0,1,0,3, , ,
231     }
232     else if (type == '7') {
233         //no win, a tie
234         //msg = '0 1  0 2 0  0 3 1 2 1 1 2 3  3 5  3 5 5 4 4 4 5
                4  2\n'
235         game = new Board;
236         game->grid[0].push_back(0);
237         game->grid[1].push_back(1);
238         game->grid[0].push_back(0);
239         game->grid[2].push_back(1);
240         game->grid[0].push_back(0);
241         game->grid[0].push_back(1);
242         game->grid[3].push_back(0);
243         game->grid[1].push_back(1);
244         game->grid[2].push_back(0);
245         game->grid[1].push_back(1);
246         game->grid[1].push_back(0);
247         game->grid[2].push_back(1);
248         game->grid[3].push_back(0);
249         game->grid[3].push_back(1);
250         game->grid[5].push_back(0);
251         game->grid[3].push_back(1);
252         game->grid[5].push_back(0);
253         game->grid[5].push_back(1);
254         game->grid[4].push_back(0);
```

```
255         game->grid[4].push_back(1);
256         game->grid[4].push_back(0);
257         game->grid[5].push_back(1);
258         game->grid[4].push_back(0);
259         game->grid[2].push_back(1);
260 
261         player = game->win(1);
262 
263         //game->display();
264 //sample output:
265 //+--+--+--+--+--+--+
266 //|  |  |  |  |  |  |  |
267 //+--+--+--+--+--+--+
268 //|  |  |  |  |  |  |  |
269 //+--+--+--+--+--+--+
270 //|  |  |  |  |  |  |  |
271 //+--+--+--+--+--+--+
272 //|  |  |  |  |  |  |  |
273 //+--+--+--+--+--+--+
274 //  0  1  2  3  4  5
275 //no player wins
276 //1,0,1,1,0,1,
277 //0,1,1,1,0,1,
278 //0,1,0,0,1,0,
279 //0,1,1,0,0,0,
280     }
281     else if (type == '8') {
282         //msg = '0 1 0 2 1 3 0 4\n'
283         game = new Board;
284         game->grid[0].push_back(0);
285         game->grid[1].push_back(1);
286         game->grid[0].push_back(0);
287         game->grid[2].push_back(1);
288         game->grid[1].push_back(0);
289         game->grid[3].push_back(1);
290         game->grid[0].push_back(0);
291         game->grid[4].push_back(1);
292 
293         player = game->win(4); //4 is the most recent bin with
               balls added
294 
295         //game->display();
296 //sample output:
297 //+--+--+--+--+--+--+
298 //|  |  |  |  |  |  |  |
299 //+--+--+--+--+--+--+
```

```
300 //|     |   |   |   |   |   |
301 //+--+--+--+--+--+--+
302 //|     |     |   |   |   |   |
303 //+--+--+--+--+--+--+
304 //|     |     |     |     |     |   |
305 //+--+--+--+--+--+--+
306 //  0   1   2   3   4   5
307 //player 1 wins
308 // , , , , , ,
309 //0, , , , , ,
310 //0,0, , , , ,
311 //0,3,3,3,3, ,
312     }
313     else if (type == '9') {
314         //msg = '1 0 1 2 1 3 1\n'
315         game = new Board;
316         game->grid[1].push_back(0);
317         game->grid[0].push_back(1);
318         game->grid[1].push_back(0);
319         game->grid[2].push_back(1);
320         game->grid[1].push_back(0);
321         game->grid[3].push_back(1);
322         game->grid[1].push_back(0);
323 
324         player = game->win(1); //1 is the most recent bin with
               balls added
325 
326 //         game->display();
327 //sample output:
328 //+--+--+--+--+--+--+
329 //|   |     |   |   |   |   |
330 //+--+--+--+--+--+--+
331 //|   |     |   |   |   |   |
332 //+--+--+--+--+--+--+
333 //|   |     |   |   |   |   |
334 //+--+--+--+--+--+--+
335 //|     |     |     |     |   |   |
336 //+--+--+--+--+--+--+
337 //  0   1   2   3   4   5
338 //player 0 wins
339 // ,2, , , , ,
340 // ,2, , , , ,
341 // ,2, , , , ,
342 //1,2,1,1, , ,
343     }
344 
```

```
345     if (player != -1)
346        std::cout << "player " << player << " wins";
347     else std::cout << "no player wins";
348 
349     std::cout << prompt << std::endl;
350 
351     for (int j = game->capacity-1; j>=0; j--) {
352            for (int i = 0; i < game->numBins; i++) {
353                if (j < game->grid[i].size())
354                   std::cout << game->grid[i][j] << ",";
355                else std::cout << " ,";
356            }
357            std::cout << std::endl;
358        }
359 
360     delete game;
361     game = nullptr;
362 
363     return 0;
364 }
```