COMP2012H: Honors Object-Oriented Programming and Data Structures

Topic 3 (Supplementary): Integrated Problems on C++ Basics and Controls

Prof. Gary Chan

Department of Computer Science & Engineering
The Hong Kong University of Science and Technology
Hong Kong SAR, China

Part I

Guess The Number

LAB

Game Description

- The game program picks a random number in the range of 1 to 100.
- Two players take turns to guess the number.
- After each guess, the program should tell the player if the number is correct, larger than or smaller than their guessed number.
- Whoever first guesses correctly wins the game.

Typical Output

```
Player 1, please enter your guess:
15
Sorry, the number is smaller than 15
Player 2, please enter your guess:
9
Sorry, the number is bigger than 9
Player 1, please enter your guess:
10
Player 1, you win!!!
```

Program Requirement

- Validate that a guessed number is in the range set by the program.
  - request a player to enter again until the input is valid.
- Determine if a guess is correct.
- Give suitable feedback to the players.
- Keep running until a guess is correct.

First Attempt: 1 Player and 1 Round

```cpp
#include <iostream>      /* File: guess1.cpp */
using namespace std;

int main()               // 1st attempt: 1 player, 1 round
{
    int number = 10;     // The answer is fixed beforehand
    int guess;

    cout << "Player 1, please enter your guess:" << endl;
    cin >> guess;

    if (guess == number)
        cout << "Player 1, you win!!!" << endl;

    else if (guess < number)
        cout << "Sorry, the number is bigger than " << guess << endl;

    else
        cout << "Sorry, the number is smaller than " << guess << endl;

    return 0;
}
```

Second Attempt: 1 Player and Multiple Rounds

```
1   #include <iostream>      /* File: guess2.cpp */
2   using namespace std;
3
4   int main()               // 2nd attempt: 1 player, multiple rounds
5   {
6       int number = 10;     // The answer is fixed beforehand
7       int guess;
8
9       do                   // Add a loop to implement multiple rounds
10      {
11          cout << "Player 1, please enter your guess:" << endl;
12          cin >> guess;
13
14          if (guess == number)
15              cout << "Player 1, you win!!!" << endl;
16
17          else if (guess < number)
18              cout << "Sorry, the number is bigger than "
19                   << guess << endl;
20          else
21              cout << "Sorry, the number is smaller than "
22                   << guess << endl;
23      } while (guess != number);
24
25      return 0;
26  }
```

Third Attempt: 1 Player, Multiple Rounds, Fixed Range

```
1   #include <iostream>     /* File: guess3.cpp */
2   using namespace std;
3
4   int main()    // 3rd attempt: 1 player, multiple rounds, fixed range
5   {
6       int number = 10;                // The answer is fixed beforehand
7       int guess;
8       int low = 1, high = 100;  // Add 2 variables to record the range
9
10      do // Add a loop to implement multiple rounds
11      {
12          cout << "Player 1, please enter your guess:" << endl;
13          cin >> guess;
14
15          while (guess < low || guess > high) // Input validation loop
16          {
17              cout << "Invalid input, please enter a number between "
18                   << low << " and " << high << endl;
19              cin >> guess;
20          }   // Can this loop be replaced with do-while?
21
22          if (guess == number)
23              cout << "Player 1, you win!!!" << endl;
24
25          else if (guess < number)
26          {
27              cout << "Sorry, the number is bigger than "
```

Third Attempt: 1 Player, Multiple Rounds, Fixed Range ..

```
28                      << guess << endl;
29                  low = guess + 1; // Update the lower bound of the range
30              }
31              else
32              {
33                  cout << "Sorry, the number is smaller than "
34                      << guess << endl;
35                  high = guess - 1; // Update the upper bound of the range
36              }
37          } while (guess != number);
38
39          return 0;
40      }
```

Final Code with a Randomly Generated Guess Number

```
1   #include <iostream>     /* File: guess-number.cpp */
2   #include <stdlib.h>     // Needed for calling the rand() function
3   #include <time.h>       // May need for calling the time() function
4   using namespace std;
5
6   int main()   // 2 players, multiple rounds, fixed range, random number
7   {
8       /* Random number generation */
9       srand(time(0));     // Seed the random number generator
10      int number = rand() % 100 + 1;  // Generate a random no. in [1..100]
11
12      int guess;
13      int low = 1, high = 100;
14      int player = 1;     // Set Player 1 as the current player
15
16      cout << "The generated number is: " << number << endl;
17      do
18      {
19          cout << "Player " << player
20               << ", please enter your guess: " << endl;
21          cin >> guess;
22
23          while (guess < low || guess > high) // Input validation loop
24          {
25              cout << "Invalid input, please enter a number between "
26                   << low << " and " << high << endl;
27              cin >> guess;
```

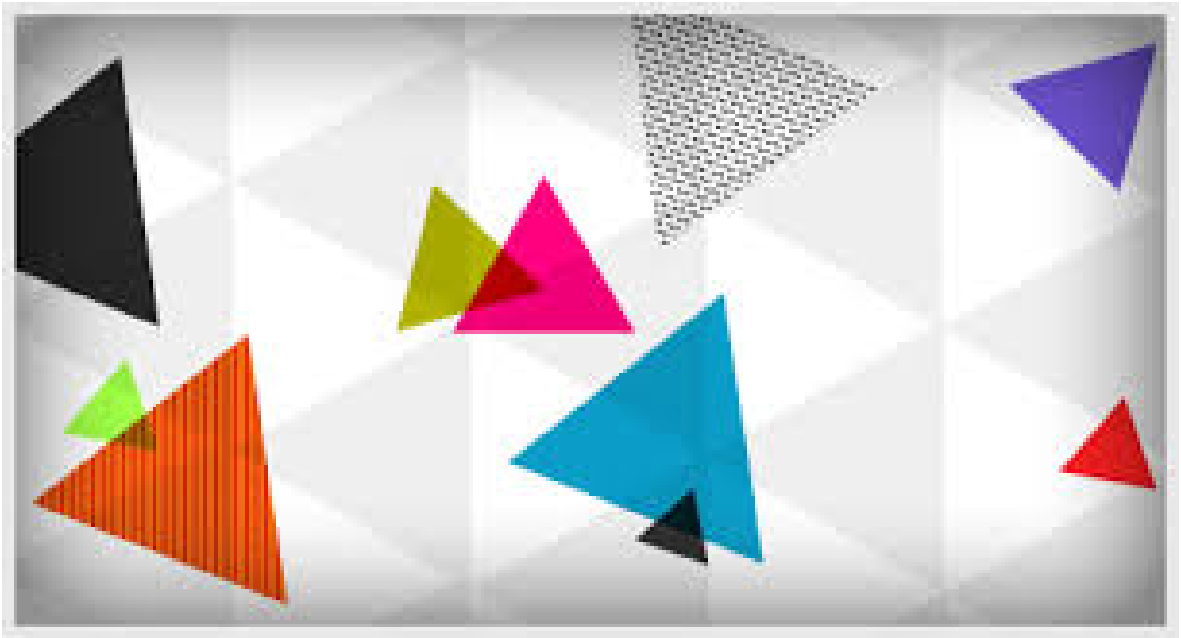
Final Code with a Randomly Generated Guess Number ..

```
28          }
29
30          if (guess == number)
31              cout << "Player " << player <<", you win!!!" << endl;
32
33          else if (guess < number)
34          {
35              cout << "Sorry, the number is bigger than "
36                   << guess << endl;
37              low = guess + 1; // Update the lower bound of the range
38          }
39          else
40          {
41              cout << "Sorry, the number is smaller than "
42                   << guess << endl;
43              high = guess - 1; // Update the upper bound of the range
44          }
45
46          player = (player % 2) + 1; // This makes 1 → 2 and 2 → 1
47
48      } while (guess != number);
49
50      return 0;
51  }
```

Part II

Draw an Isosceles Right-Angled Triangles (RATs)

LAB



Draw Triangles

- Design a program that prints some isosceles right-angled triangles (RAT), and allows users to set their size.
- A RAT that has a size of 4 looks like this:

```
*
**
***
****
```

- Furthermore, try the following variations:

Fat RAT	Hollow RAT	Upside-down RAT
`*`	`*`	`*****`
`***`	`**`	`****`
`*****`	`* *`	`***`
`*******`	`*  *`	`**`
`*********`	`*****`	`*`

A Single RAT

```
1  #include <iostream>      /* File: one-rat.cpp */
2  using namespace std;
3
4  int main()
5  {
6      cout << "Size of a RAT: " << endl;
7      int size;                                  // height = width = size
8      cin >> size;
9
10     for (int width = 1; width <= size; width++) // #iters=height
11     {
12         // Draw one row of a RAT
13         for (int j = 0; j < width ; j++)        // width of a row
14             cout << '*';
15
16         cout << endl;
17     }
18
19     return 0;
20 }
```

Various RATs

```
1  #include <iostream>     /* File: various-rats.cpp */
2  using namespace std;
3
4  int main()
5  {
6      cout << "Size of a RAT: " << endl;
7      int size;
       ↪  // height = width = size
8      cin >> size;
9
10     cout << "A fat RAT" << endl;
11     for (int i = 1; i <= size; i++)          // #iterations = height
12     {
13         for (int j = 0; j < i*2 - 1 ; j++) // width of a row
14             cout << '*';
15         cout << endl;
16     }
17
18     cout << "A hollow RAT" << endl;
19     for (int i = 1; i <= size; i++)
20     {
21         for (int j = 0; j < i ; j++)
```

Various RATs ..

```
22              cout << ((j == 0 || j == i - 1 || i == size) ? '*' :
                ↪  ' ');
23          cout << endl;
24      }
25
26
27      cout << "An upside-down RAT" << endl;
28      for (int i = size; i >= 1; i--)
29      {
30          for (int j = 0; j < i; j++)
31              cout << '*';
32          cout << endl;
33      }
34
35      return 0;
36  }
```

A Bug in a RAT: What's Wrong?

```
1   #include <iostream>     /* File: one-bad-rat.cpp */
2   using namespace std;
3
4   int main()
5   {
6       cout << "Size of a RAT: " << endl;
7       int size;
8       cin >> size;
9
10      cout << "A simple RAT:" << endl;
11      for (int i = 0; i < size; i++)
12      {
13          for (int j = 0; j <= i; j++)
14              cout << '*';
15          cout << endl;
16      }
17
18      cout << "Is this a RAT?" << endl;
19      for (int i = 1; i <= size; i++)
20          for (int j = 0; j < i * 2 - 1 ; j++)
21          {
22              cout << '*';
23              cout << endl;
24          }
25
26      return 0;
27  }
```

A Row of RATs

Now try this:

```
*    *    *    *    *    *    *    *    *    *
**   **   **   **   **   **   **   **   **   **
***  ***  ***  ***  ***  ***  ***  ***  ***  ***
**** **** **** **** **** **** **** **** **** ****
**********************************************
```

You'll need to measure the width of your screen first.

Bugs in RATs: What's Wrong?

```
1  #include <iostream>     /* File: row-of-bad-rats1.cpp */
2  using namespace std;
3
4  int main()
5  {
6      cout << "Size of a triangle: " << endl;
7      int size;
8      cin >> size;
9
10     // Find out the number of RATs in a row
11     const int TOTAL_NUM_COLUMNS = 105; // Assumed screen width
12     int num_RATs = TOTAL_NUM_COLUMNS / size;
13
14     for (int i = 1; i <= size; i++)
15     {
16         for (int n = 0; n < num_RATs; n++)
17             for (int j = 0; j < i ; j++)
18                 cout << '*';
19
20         cout << endl;
21     }
22
23     return 0;
24 }
```

Bugs in RATs Again: What's Wrong?

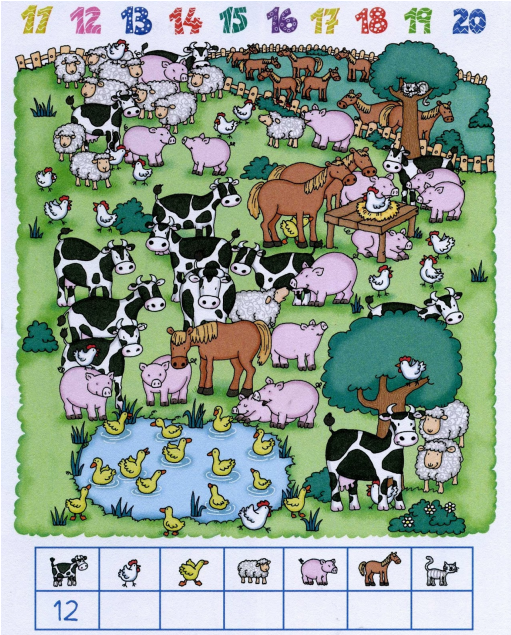
```
1  #include <iostream>     /* File: row-of-bad-rats2.cpp */
2  using namespace std;
3
4  int main()
5  {
6      cout << "Size of a triangle: " << endl;
7      int size;
8      cin >> size;
9
10     const int TOTAL_NUM_COLUMNS = 105; // Assumed screen width
11     int num_RATs = TOTAL_NUM_COLUMNS / size;
12
13     for (int i = 1; i <= size; i++)
14         for (int n = 0; n < num_RATs; n++)
15         {
16             for (int j = 0; j < i ; j++)
17                 cout << '*';
18             for (int j = 0; j < (size-i); j++)
19                 cout << ' '; // Print enough spaces after a RAT
20
21             cout << endl;
22         }
23
24     return 0;
25 }
```

A Row of Good RATs

```
1   #include <iostream>                /* File: row-of-rats.cpp */
2   using namespace std;
3
4   int main()
5   {
6       cout << "Size of a triangle: " << endl;
7       int size;
8       cin >> size;
9
10      // Find out the number of RATs in a row
11      const int TOTAL_NUM_COLUMNS = 105; // Assumed screen width
12      int num_RATs = TOTAL_NUM_COLUMNS / size;
13
14      for (int i = 1; i <= size; i++)
15      {
16          for (int n = 0; n < num_RATs; n++)
17          {
18              for (int j = 0; j < i ; j++)
19                  cout << '*';
20              for (int j = 0; j < (size-i); j++)
21                  cout << ' '; // Print enough spaces after each RAT
22          }
23          cout << endl;
24      }
25
26      return 0;
27  }
```

Part III

Count Animals



The Count Animals Problem

- There are two types of animals, pigs and sheeps in a farm.
- Each pig weighs 4.5 units and each sheep weighs 3 units.
- The total weight of animals in a barn should be exactly 36 units.
- List out all possible combinations of bigs and sheeps in the farm.

Solution:

$$0 * 4.5 + 12 * 3 = 36$$
$$2 * 4.5 + 9 * 3 = 36$$
$$4 * 4.5 + 6 * 3 = 36$$
$$6 * 4.5 + 3 * 3 = 36$$
$$8 * 4.5 + 0 * 3 = 36$$

First Attempt: What's Wrong?

```
1  #include <iostream>      /* File: two-animals-v1.cpp */
2  using namespace std;
3
4  int main()
5  {
6      float wt_pig = 4.5;
7      float wt_sheep = 3.0;
8      float total_wt = 36;
9
10     for (int num_pigs = 0; num_pigs * wt_pig <= total_wt;
       ↪  num_pigs++)
11     {
12         float remain_wt = total_wt - num_pigs * wt_pig;
13         int num_sheeps = remain_wt / wt_sheep;
14         remain_wt = remain_wt % wt_sheep;
15
16         if (remain_wt == 0)
17             cout << num_pigs << " * " << wt_pig << " + "
18                  << num_sheeps << " * " << wt_sheep << " = "
19                  << total_wt << endl;
20     }
21     return 0;
22 }
```

Second Attempt: Any Problem?

```
1   #include <iostream>     /* File: two-animals-v2.cpp */
2   using namespace std;
3
4   int main()
5   {
6       float wt_pig = 4.5;
7       float wt_sheep = 3.0;
8       float total_wt = 36;
9
10      for (int num_pigs = 0; num_pigs * wt_pig <= total_wt;
        ↪  num_pigs++)
11      {
12          float remain_wt = total_wt - num_pigs * wt_pig;
13          int num_sheeps = remain_wt / wt_sheep;
14          remain_wt -= num_sheeps * wt_sheep;
15
16          if (remain_wt == 0)
17              cout << num_pigs << " * " << wt_pig << " + "
18                   << num_sheeps << " * " << wt_sheep << " = "
19                   << total_wt << endl;
20      }
21      return 0;
22  }
```

Problems of Comparing Floating-point Numbers

```
1   #include <iostream>      /* File: float-comparison-v1.cpp */
2   using namespace std;
3
4   int main()
5   {
6       float x = 0.1;
7       float product = 10.0 * x;
8
9       float sum = 0.0;
10      for (int i = 0; i < 10; ++i)
11          sum += x;
12
13      cout << "sum = " << sum << endl;
14      cout << "product = " << product << endl;
15      cout << "10.0 * x = " << 10.0 * x << endl;
16      cout << (sum == product) << endl;
17
18      return 0;
19  }
```

Problems of Comparing Floating-point Numbers ..

```
1  #include <iostream>      /* File: float-comparison.cpp */
2  using namespace std;
3
4  int main()
5  {
6      float x = 0.1;
7      float product = 10.0 * x;
8
9      float sum = 0.0;
10     for (int i = 0; i < 10; ++i)
11         sum += x;
12
13     // Set output precision to 10 significant figures
14     cout.precision(10);
15     // Print boolean outputs as true or false instead of 1 and 0
16     cout << boolalpha;
17
18     cout << "sum = " << sum << endl;
19     cout << "product = " << product << endl;
20     cout << "10.0 * x = " << 10.0 * x << endl;
21     cout << (sum == product) << endl;
22     return 0;
23 }
```

Count Animals: Further Work

- Further check ways to compare floating point numbers here.
- What if the total number of animals is not more than 10.
- What if we have three types of animal instead of two? (You may ignore the constraint on the total number of animals.)
- For those who know recursion, can you work out a recursive solution?

Part IV

GPA Calculator

LAB

GPA Calculator

- Assume the following letter grade to grade point conversion:

Letter Grade	Grade Point
A	4.0
B	3.0
C	2.0
D	1.0
F	0.0

- Design a program that calculates a student's GPA (grade point average).

Typical Output

```
No.  of credits of your course (0 to stop):  3
Your letter grade (A, B, C, D or F): A
No.  of credits of your course (0 to stop):  4
Your letter grade (A, B, C, D or F): B
No.  of credits of your course (0 to stop):  2
Your letter grade (A, B, C, D or F): E
Invalid input, please enter your grade again!
No.  of credits of your course (0 to stop):  2
Your letter grade (A, B, C, D or F): D
No.  of credits of your course (0 to stop):  0
You have taken a total of 9 credits ...
and your GPA is 2.88889
```

Program Requirements

- A student first enters the number of credits of his/her course.
- The program stops if the number of credits is ≤ 0.
- The student then enters the letter grade A, B, C, D or F.
- Invalid letter grades are ignored and the student is prompted to re-enter the grade.
- The program shall calculate the total number of credits earned by the student and his/her GPA according to the following formula:

$$\frac{\sum_{i=1}^{n} (grade_i * credit_i)}{\sum_{i=1}^{n} credit_i}$$

Program Design

Major components of the program:

1. A loop for each taken course to
   a. ask for the number of credits
   b. ask for the letter grade
   c. convert the letter grade to grade points
   d. accumulate the total credits and grade points
2. Calculate and output the GPA.

You will need some variables to hold:

- the number of credits
- the letter grade
- the converted grade points
- the sum of credits
- the sum of grade points

Variables

```
1  char grade;
2  /* Don't forget to initialize some of these variables */
3  int num_credits, total_num_credits = 0;
4  int total_grade_points = 0;
   ↪  // Is it a good idea to use integer type here?
5
6  // Think about the output
7  cout << "You have taken a total of " << total_num_credits
8       << " credits ..." << endl << "and your GPA is "
9       << total_grade_points / total_num_credits << endl;
```

Recall the usual arithmetic conversion rules for binary operations:

- If all operands are int
  - compute using integer arithmetic
- If one operand is double/float
  - convert the other operand to double/float
  - compute using floating-point arithmetic
  - return the result in double/float

GPA Calculator: Using if

```
1   char grade;
2   int num_credits, total_num_credits = 0;
3   double total_grade_points = 0;
4
5   cout << "No. of credits of your course (0 to stop): ";
6   cin >> num_credits;
7   cout << "Your letter grade (A, B, C, D or F): ";
8   cin >> grade;
9   total_num_credits += num_credits; // Update total no. of credits
10
11  if (grade == 'A')        // Convert letter grade to grade point
12      total_grade_points += num_credits * 4;
13  else if (grade == 'B')
14      total_grade_points += num_credits * 3;
15  else if (grade == 'C')
16      total_grade_points += num_credits * 2;
17  else if (grade == 'D')
18      total_grade_points += num_credits * 1;
19  else if (grade == 'F')
20      total_grade_points += num_credits * 0;
21  else
22      total_num_credits -= num_credits;
```

GPA Calculator: Using switch

```
1   /*
2    * Codes for variables definition and initialization, and inputs
3    */
4
5   switch (grade)          // Convert letter grade to grade point
6   {
7       case 'A':
8           total_grade_points += num_credits * 4; break;
9       case 'B':
10          total_grade_points += num_credits * 3; break;
11      case 'C':
12          total_grade_points += num_credits * 2; break;
13      case 'D':
14          total_grade_points += num_credits * 1; break;
15      case 'F':
16          total_grade_points += num_credits * 0; break;
17      default:
18          total_num_credits -= num_credits;
19  }
```

GPA Calculator: Using if .. Allowing Small Case

```
1   /*
2    * Codes for variables definition and initialization, and inputs
3    */
4
5   if ((grade == 'A') || (grade == 'a'))
6       total_grade_points += num_credits * 4;
7
8   else if ((grade == 'B') || (grade == 'b'))
9       total_grade_points += num_credits * 3;
10
11  else if ((grade == 'C') || (grade == 'c'))
12      total_grade_points += num_credits * 2;
13
14  else if ((grade == 'D') || (grade == 'd'))
15      total_grade_points += num_credits * 1;
16
17  else if ((grade == 'F') || (grade == 'f'))
18      total_grade_points += num_credits * 0;
19
20  else
21      total_num_credits -= num_credits;
```

GPA Calculator: Using switch .. Allowing Small Case

```
1   switch (grade)          // Convert letter grade to grade point
2   {
3       case 'A':
4       case 'a':
5           total_grade_points += num_credits * 4; break;
6       case 'B':
7       case 'b':
8           total_grade_points += num_credits * 3; break;
9       case 'C':
10      case 'c':
11          total_grade_points += num_credits * 2; break;
12      case 'D':
13      case 'd':
14          total_grade_points += num_credits * 1; break;
15      case 'F':
16      case 'f':
17          total_grade_points += num_credits * 0; break;
18      default:
19          total_num_credits -= num_credits;
20  }
```

GPA Calculator: Complete Program .. Using constants

```
1   #include <iostream>     /* File: gpa.cpp */
2   using namespace std;
3
4   const double A = 4.0;   // Definition of Constants
5   const double B = 3.0;
6   const double C = 2.0;
7   const double D = 1.0;
8   const double F = 0.0;
9
10  int main()
11  {   // Variables definition and initialization
12      char grade;
13      int num_credits, total_num_credits = 0;
14      double total_grade_points = 0;
15
16      do
17      {
18          cout << "No. of credits of your course (0 to stop): ";
19          cin >> num_credits;
20
21          if (num_credits <= 0) // What does this do?
22              break;
23
24          cout << "Your letter grade (A, B, C, D or F): ";
25          cin >> grade;
26          total_num_credits += num_credits; // Update total no. of credits
27
```

GPA Calculator: Complete Program .. Using constants ..

```
28          switch (grade)  // Convert letter grade to grade point
29          {
30              case 'A':   // No break here; execute code in case 'a'
31              case 'a':
32                  total_grade_points += num_credits * A; break;
33              case 'B':
34              case 'b':
35                  total_grade_points += num_credits * B; break;
36              case 'C':
37              case 'c':
38                  total_grade_points += num_credits * C; break;
39              case 'D':
40              case 'd':
41                  total_grade_points += num_credits * D; break;
42              case 'F':
43              case 'f':
44                  total_grade_points += num_credits * F; break;
45              default :
46                  cout <<
                    ↪  "Invalid input, please enter your grade again!\n";
47                  total_num_credits -= num_credits;
48          }
49      } while (true);     // Why is this not an infinite loop?
50
51
52
```

GPA Calculator: Complete Program .. Using constants ..

```
53
54        cout << "You have taken a total of " << total_num_credits
55             << " credits ..." << endl << "and your GPA is "
56             << total_grade_points / total_num_credits << endl;
57
58        return 0;
59    }
```