Tutorial 01 - Basic C++, Basic OOP, Analysis

CS2040C Semester 2 2018/2019

Question 1

(Basic) List ADT

List Array ADT

Imagine *list* as a *chain* of beads

You can add beads to the front and back

(and in between)

We will elaborate more about “**ADT**” in Tut 02.

For now, understand the syntax of C++ classes.

List Array ADT - Methods

`get(i)`

Gets the *i*-th element from the front (0-indexed)

`search(v)`

Return the **first** index which contains v

List Array ADT - Methods

`insert(i, v)`

Insert element *v* at index *i*.

`remove(i)`

Remove the element at index *i*.

List Array ADT - Methods

`printList()`

Prints the list from front to back.

`sortList()`

Sort the list, in default ascending order.

Question 1a, 1b, 1c

```
class ListArray {
  private:
    int N;
    int A[10];              // question 1a
  public:
    ListArray() : N(0) {} // question 1b
    int get(int i) {
        return A[i];        // question 1c
    }
}
```

Question 1a

```
class ListArray {
  private:
    int N;
    int A[10];
  public:
    ListArray() : N(0) {}
    int get(int i) {
        return A[i];
    }
}
```

Anything wrong with this line?

Question 1a

```
class ListArray {
  private:
    int N;
    int A[10];
  public:
    ListArray() : N(0) {}
    int get(int i) {
        return A[i];
    }
}
```

Anything wrong with this line?

Limited to **10** items!

Question 1b

```
class ListArray {
  private:
    int N;
    int A[10];
  public:
    ListArray() : N(0) {}
    int get(int i) {
        return A[i];
    }
}
```

What does this line mean?

Question 1b

```
class ListArray {
  private:
    int N;
    int A[10];
  public:
    ListArray() : N(0) {}
    int get(int i) {
        return A[i];
    }
}
```

What does this line mean?

Pass `0` to constructor of integer `N`. Effectively:

```
ListArray() {
    N = 0;
}
```

Question 1c

```
class ListArray {
  private:
    int N;
    int A[10];
  public:
    ListArray() : N(0) {}
    int get(int i) {
        return A[i];
    }
}
```

Anything potential issues with this line?

Question 1c

```
class ListArray {
  private:
    int N;
    int A[10];
  public:
    ListArray() : N(0) {}
    int get(int i) {
        return A[i];
    }
}
```

Anything potential issues with this line?

No “safeguard”!

What if `i > N - 1`?
What if `i` is negative?

Question 1d, 1e, 1f

```
void insert(int i, int v) {
  if ((N == 10) || (i < 0) || (i > N))  // question 1d
    return;
  for (int j = i; j <= N-1; j++)        // question 1e
    A[j+1] = A[j];
  A[i] = v;
  N++;
}

void remove(int i) {
  for (int j = i; j < N-1; j++)         // question 1f
    A[j] = A[j+1];
  N--;
}
```

Question 1d

```
void insert(int i, int v) {
  if ((N == 10) || (i < 0) || (i > N))
    return;
  for (int j = i; j <= N-1; j++)
    A[j+1] = A[j];
  A[i] = v;
  N++;
}
```

What does this line mean?

Question 1d

```
void insert(int i, int v) {
  if ((N == 10) || (i < 0) || (i > N))
    return;
  for (int j = i; j <= N-1; j++)
    A[j+1] = A[j];
  A[i] = v;
  N++;
}
```

What does this line mean?

If …
`N` is `10` or
`i` is negative or
`i > N`

Stop inserting.

Question 1d

```
void insert(int i, int v) {
  if ((N == 10) || (i < 0) || (i > N))
    return;
  for (int j = i; j <= N-1; j++)
    A[j+1] = A[j];
  A[i] = v;
  N++;
}
```

What does this line mean?

If …
`N` is `10` or
`i` is negative or
`i > N`

Stop inserting.

Is there anything wrong with this?
How many possible values of `i` are accepted?

Question 1d

```
void insert(int i, int v) {
  if ((N == 10) || (i < 0) || (i > N))
    return;
  for (int j = i; j <= N-1; j++)
    A[j+1] = A[j];
  A[i] = v;
  N++;
}
```

What does this line mean?

If …
N is 10 or
i is negative or
i > N

Stop inserting.

Is there anything wrong with this?
How many possible values of i are accepted?

N+1 possible insertion points

Question 1e

```
void insert(int i, int v) {
  if ((N == 10) || (i < 0) || (i > N))
    return;
  for (int j = i; j <= N-1; j++)
    A[j+1] = A[j];
  A[i] = v;
  N++;
}
```

Any potential issues with this line?

Question 1e

```
void insert(int i, int v) {
  if ((N == 10) || (i < 0) || (i > N))
    return;
  for (int j = i; j <= N-1; j++)
    A[j+1] = A[j];
  A[i] = v;
  N++;
}
```

Any potential issues with this line?

Values are being overwritten in the wrong order!

```
A[i+1] = A[i];
A[i+2] = A[i+1];
A[i+3] = A[i+2];
```

… etc

Question 1f

```
void remove(int i) {
  for (int j = i; j < N-1; j++)
    A[j] = A[j+1];
  N--;
}
```

Any potential issues with this line?

No. This is correct.

```
A[i]   = A[i+1];
A[i+1] = A[i+2];
A[i+2] = A[i+3];
```
… etc;

Can also add safeguard `i` in [0..N-1]

Question 1g

```
void sortList() { // sort array A, question 1g
    // ...
}
```

Implement this routine using any sorting algorithm that you know!

Question 1g

```
void sortList() { // sort array A, question 1g
    for (int i = 0; i < N; i++) {
        for (int j = 1; j < N; j++) {
            if (A[j-1] > A[j])
                swap(A[j-1], A[j]);
        }
    }
}
```

Implement this routine using any sorting algorithm that you know!

Approach: manual implementation

Question 1g

```
void sortList() { // sort array A, question 1g
    sort(A, A+N);
}
```

Implement this routine using any sorting algorithm that you know!

Approach: Use std library

Question 1h

```
int main() {
    ListArray* LA = new ListArray();
    LA->insert(0, 5);
    LA->insert(0, 1);
    // ...
}
```

Can we just write `ListArray LA;` in this line?

Question 1h

```
int main() {
    ListArray* LA = new ListArray();
    LA->insert(0, 5);
    LA->insert(0, 1);
    // ...
}
```

Can we just write `ListArray LA;` in this line?

Yes, but we need to modify the way we call methods:

```
ListArray LA;
LA.insert(0, 5);
cout << LA.get(1) << endl;
```

Question 1h

What’s the difference between the two methods?

```
ListArray LA;
LA.insert(0, 5);
cout << LA.get(1) << endl;
```

```
ListArray *LA = new ListArray();
LA->insert(0, 5);
cout << LA->get(1) << endl;
```

Question 3

Analysis/ Order of Growth

Complexity analysis

- Is a rough estimate of how execution time will grow with size of input. I.E. *Order of growth*
- *Time complexity* is commonly used as a metric for comparing the performance of different algorithms on the same task
- The expression ignores constants
- Just retain the *largest power* for each variable in the expression
- When order of growth is applied to measure memory consumption of algorithms, we call that *space complexity*

Real life application?

Single thread computer: ~108 operations/sec

Sorting **N = 106** numbers

$O(N^2)$	~ 2.5 hours
$O(N \log N)$	~ 0.2 sec

Question 3

What is the bound to the following functions?

a. $F(n) = log(2^n) + \sqrt{n} + 100\ 000\ 000$

b. $F(n) = n + \frac{1}{2} n + \frac{1}{3} n + \frac{1}{4} n + ... + 1$

c. $G(n) = n + \frac{1}{2} n + \frac{1}{4} n + \frac{1}{8} n + ... + 1$

Question 3.a)

$$
\begin{aligned}
F(n) &= \log(2^n) + \sqrt{n} + 100\,000\,000 \\
O(F(n)) &= O(\log(2^n) + \sqrt{n} + 100\,000\,000) \\
&= O(n * \mathbf{\log 2} + \sqrt{n}) \\
&= O(n + \sqrt{n}) \\
&= \mathbf{O(n)}
\end{aligned}
$$

Question 3.b)

$$F(n) = n + \tfrac{1}{2}n + \tfrac{1}{3}n + \tfrac{1}{4}n + \ldots + 1$$

$$O(F(n)) = O(n + \tfrac{1}{2}n + \tfrac{1}{3}n + \tfrac{1}{4}n + \ldots + 1)$$

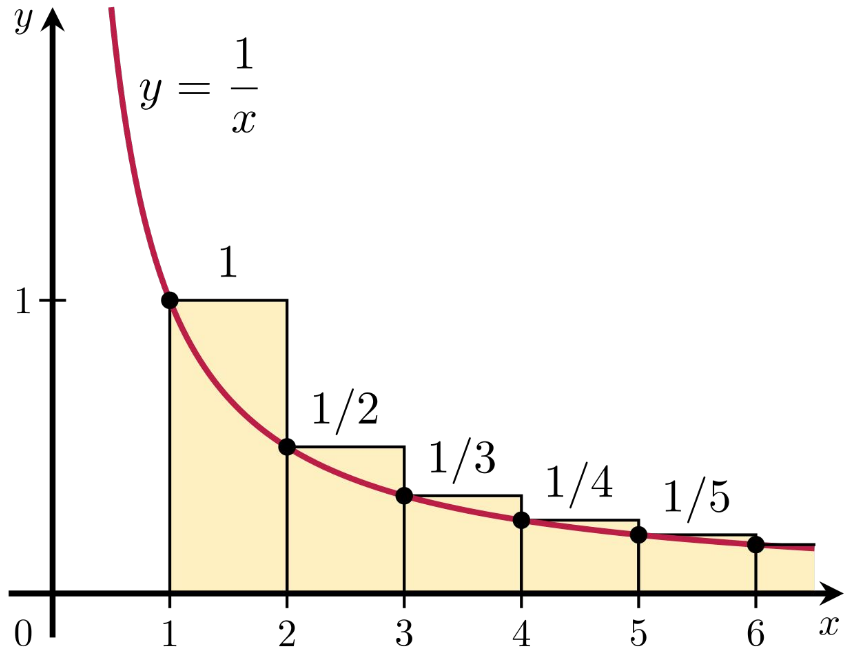
$$= O(n\,(\underbrace{1 + \tfrac{1}{2} + \tfrac{1}{3} + \tfrac{1}{4} + \ldots + 1/n}_{\text{How to deal with this?}}))$$

Harmonic Series

$$\sum_{n=1}^{\infty} \frac{1}{n} = 1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{5} + \cdots$$

Using integration:

$$\sum_{n=1}^{k} \frac{1}{n} > \int_{1}^{k+1} \frac{1}{x}\, dx = \ln(k+1).$$



Question 3.b)

From Harmonic Series

$$O(1 + \tfrac{1}{2} + \tfrac{1}{3} + \tfrac{1}{4} + \ldots + 1/n) = O(\log n)$$

$$O(F(n)) = O(n\,(1 + \tfrac{1}{2} + \tfrac{1}{3} + \tfrac{1}{4} + \ldots + 1/n))$$

$$= \boldsymbol{O(n \log n)}$$

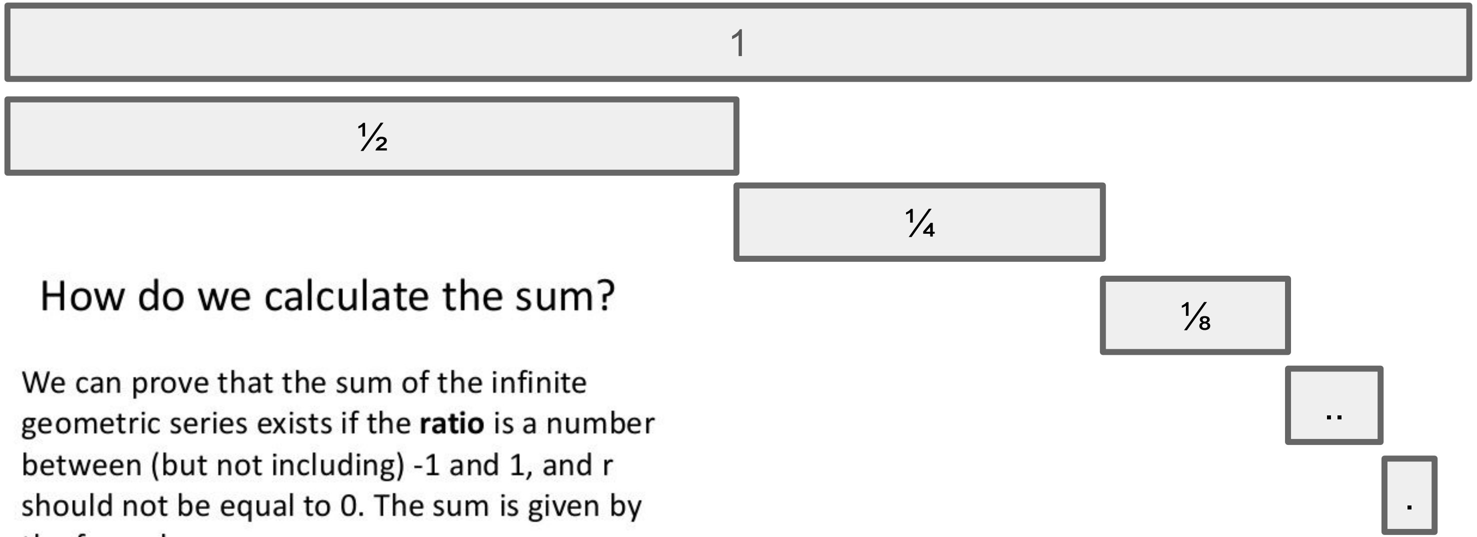
Question 3.c)

$$G(n) = n + \tfrac{1}{2} n + \tfrac{1}{4} n + \tfrac{1}{8} n + \ldots + 1$$

$$O(G(n)) = O(n + \tfrac{1}{2} n + \tfrac{1}{4} n + \tfrac{1}{8} n + \ldots + 1)$$

$$= O(n\,(\underbrace{1 + \tfrac{1}{2} + \tfrac{1}{4} + \tfrac{1}{8} + \ldots + 1/n}_{\text{How to deal with this?}}))$$

Convergent Geometric Series



How do we calculate the sum?

We can prove that the sum of the infinite geometric series exists if the **ratio** is a number between (but not including) -1 and 1, and r should not be equal to 0. The sum is given by the formula:

$$\sum_{k=0}^{\infty} ar^k = a + ar + ar^2 + ar^3 + \cdots = \frac{a}{1-r}$$

Question 3.c)

From Convergent Geometric Series

$$O(1 + \tfrac{1}{2} + \tfrac{1}{4} + \tfrac{1}{8} + \ldots + 1/n) = O(1 / (1 - \tfrac{1}{2}))$$

$$= O(2)$$

$$= O(1)$$

$$O(G(n)) = O(n\,(1 + \tfrac{1}{2} + \tfrac{1}{4} + \tfrac{1}{8} + \ldots + 1/n))$$

$$= \boldsymbol{O(n)}$$

Additional questions

Example (AY17/18 S1 Midterm Paper)

What’s the time complexity?

```
int N, counter = 0;
cin >> N;
for (int i = N; i >= 1; i--) {
    for (int j = 1; j <= N/i; j++) {
        counter++;
    }
}
cout << counter << endl;
```

What’s the time complexity?

```
int N, counter = 0;
cin >> N;
for (int i = 0; i < N; i++) {
    for (int j = 0; j < i; j++) {
        counter += j;
    }
}
cout << counter << endl;
```

What’s the time complexity?

```
int N, counter = 0;
cin >> N;
for (int i = 0; i < N; i++) {
    for (int j = 0; j < N; j++) {
        counter++;
        i++;
    }
}
cout << counter << endl;
```

Questions