

Computer Programming

Dr. Deepak B Phatak
Dr. Supratik Chakraborty
Department of Computer Science and Engineering
IIT Bombay

Session: An Example Program using Member Functions

Quick Recap of Relevant Topics



- Structures representing objects
 - Groups of related variables, arrays, other structures
 - Member functions as interfaces for interaction
 - Accessing members (data and functions) of structures
 - Pointers to structures
 - Dynamic allocation and de-allocation of structures

Overview of This Lecture



- An interesting program using member functions
 - Two object-oriented implementations

Acknowledgment



- Some examples in this lecture are from
**An Introduction to Programming Through C++
by Abhiram G. Ranade
McGraw Hill Education 2014**
- All such examples indicated in slides with the citation
AGRBook

Recap: Vectors in 3 Dimensions [Ref. AGRBook]



- We want to reason about motion in 3-dimensional space
- Must deal with 3-dimensional vectors representing
 - Position
 - Velocity
 - Acceleration
- 3-dimensional vectors are basic entities (objects) in this program
 - Need to define a C++ structure to represent a vector
 - For simplicity, we will use Cartesian coordinates

Recap: Struct V3 with Member Functions

```
struct V3 {  
    double x, y, z;  
    double length() { return sqrt(x*x + y*y + z*z); }  
    V3 sum (V3 const &b) {  
        V3 v;  
        v.x = x + b.x; v.y = y + b.y; v.z = z + b.z; return v;  
    }  
    V3 scale (double const factor) {  
        V3 v;  
        v.x = x*factor; v.y = y*factor; v.z = z*factor; return v;  
    }  
};
```

A Simple Motion Simulator [Ref AGRBook]



- Given
 - Initial position and velocity of a solid body as 3-dimensional vectors
 - Acceleration of the body as a 3-dimensional vector **(assume this doesn't change with time)**
 - Granularity of simulation time (Δ)
 - Total elapsed time (T)
- Find the positions (as 3-dimensional vectors) every Δ units of time for the entire elapsed time (T)

Augmenting V3

Let's add a member function to print out the x, y and z co-ordinates of a V3 object

```
struct V3 {  
    double x, y, z;  
    ... Member functions "sum", "scale" and "length" ...  
    void print() {  
        cout << "x: " << x << " y: " << y << " z: " << z << endl;  
        return;  
    }  
};
```


A Motion Simulator Program

```
int main()
{ V3 vel, acc, pos; // initial velocity, acceleration, initial position
  V3 currDispl, currPos; // current displacement & position
  double t = 0.0, deltaT, totalT; // t: time elapsed so far
  cout << "Give x, y and z components of initial velocity: ";
  cin >> vel.x >> vel.y >> vel.z;
  cout << "Give x, y and z components of acceleration: ";
  cin >> acc.x >> acc.y >> acc.z;
  cout << "Give x, y and z components of initial position: ";
  cin >> pos.x >> pos.y >> pos.z;
  cout << "Give total simulation time: "; cin >> totalT;
  cout << "Given simulation time granularity: "; cin >> deltaT;
  ... Rest of code ...
}
```

A Motion Simulator Program

```
int main()
{ V3 vel, acc, pos; // initial velocity, acceleration, initial position
  V3 currDispl, currPos; // current displacement & position
  double t = 0.0, deltaT, totalT; // t: time elapsed so far
  ... Reading in values ...
  if ((totalT < 0) || (deltaT <= 0)) {
    cout << "Invalid input!" << endl; return -1;
  }
  ... Rest of code ...
}
```

A Motion Simulator Program

```
int main()
{ V3 vel, acc, pos; // initial velocity, acceleration, initial position
  V3 currDispl, currPos; // current displacement & position
  double t = 0.0, deltaT, totalT; // t: time elapsed so far
  ... Reading in and validating values ...
  while (t <= totalT) {
    // Calculate current displacement using  $vel*t + (0.5)*acc*t^2$ 
    currDispl = (vel.scale(t)).sum(acc.scale(0.5*t*t));
    currPos = currDispl.sum(pos);
    cout << "Time " << t << " "; currPos.print(); t = t + deltaT;
  }
  return 0;
}
```

An Alternative Implementation

Define a MotionSimulator Object

```
struct MotionSimulator {  
    V3 initPos, initVel, acc;  
    V3 currPos, currVel;  
    double deltaT;  
    void initializeSimulator() {  
        currPos = initPos; currVel = initVel; return;  
    }  
    ... Rest of member functions ...  
};
```

An Alternative Implementation

Define a MotionSimulator Object

```
struct MotionSimulator {  
    ... Member declarations ...  
    void initializeSimulator() { ... }  
    void simulateAStep() {  
        // Calculate updated position as currPos + currVel*deltaT  
        // Calculate updated velocity as currVel + acc*deltaT  
        currPos = currPos.sum(currVel.scale(deltaT));  
        currVel = currVel.sum(acc.scale(deltaT));  
        return;  
    }  
    ... Rest of member functions ...  
};
```

An Alternative (Not Equivalent) Implementation



Define a MotionSimulator Object

```
struct MotionSimulator {  
    ... Member declarations ...  
    void initializeSimulator() { ... }  
    void simulateAStep() { ... }  
    void printPosition() {  
        currPos.print();  
        return;  
    }  
};
```

A Motion Simulator Program

```
int main()
{ MotionSimulator mSim;
  double t = 0.0, deltaT, totalT; // t: time elapsed so far
  cout << "Give x, y and z components of initial velocity: ";
  cin >> (mSim.initVel).x >> (mSim.initVel).y >> (mSim.initVel).z;
  cout << "Give x, y and z components of acceleration: ";
  cin >> (mSim.acc).x >> (mSim.acc).y >> (mSim.acc).z;
  cout << "Give x, y and z components of initial position: ";
  cin >> (mSim.initPos).x >> (mSim.initPos).y >> (mSim.initPos).z;
  cout << "Give total simulation time: "; cin >> totalT;
  cout << "Given simulation time granularity: "; cin >> deltaT;
  mSim.deltaT = deltaT;
  ... Rest of code ...
}
```

A Motion Simulator Program

```
int main()
{
    MotionSimulator mSim;
    double t = 0.0, deltaT, totalT; // t: time elapsed so far
    ... Reading in and validating values ...
    mSim.initializeSimulator();
    while (t <= totalT) {
        mSim.simulateAStep();
        cout << "Time " << t << " "; mSim.printPosition();
        t = t + deltaT;
    }
    return 0;
}
```


An Interesting Question



- Are the results computed by the two simulations the same?
- If not, why?
 - Try with various values of simulation time granularity
 - For what values of simulation time granularity, do the results computed by the two simulations agree (by and large)?
- Implementation choices are important when solving a problem

Summary



- A simple motion simulator program using object-oriented programming
- Use of member functions
- Glimpse of data hiding, and effect of simulation time granularity