CS345H: Programming Languages

Lecture 17: Introduction to Object-Oriented Languages

Thomas Dillig
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Overview

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- Not in the sense of how to use it, but to understand the fundamental aspects of this paradigm
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- Not in the sense of how to use it, but to understand the fundamental aspects of this paradigm

- We will also explore how to formalize some aspects of it
Subtyping

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Example: $\tau_1 = \text{Int} \to \text{Int}$ and $\tau_2 = \alpha \to \text{Int}$.

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Another Kind of Polymorphism

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    public int a;
};
class Y {
    public int a;
    public int b;
};
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- Here, anyone who expects something of type $X$ can work just as well with something of type $Y$

- **Why?** Because the fields of $Y$ are a superset of the fields of $X$
Subtyping Polymorphism

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- Observe that subtyping is really another kind of polymorphism as it allows us to write code that works with more than one type.
Structural Supertyping

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▶ This is also known as “duck typing”
Nominative Subtyping

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Next Key Idea using in object-oriented languages: Classes
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Classes

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- A **class** combines data with functions that operate on this data
- Crucially, the methods operating on data are bundled *together* with the data and can access the data
- You can view a class as a type that includes both data and functions to manipulate this data
- We create an **instance** of a class to use it
- Every instance has its own data
Classes Example

Consider the following program:

```c
struct point {
    int x;
    int y;
};
void inc_x(point* p) {
    p->x++;
}

point *p = new point;
inc_x(p);
```
Here is the same program rewritten with classes:

```cpp
class point {
    int x;
    int y;
    void inc_x() {
        this->x++;
    }
};

point *p = new point;
p->inc_x();
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Object = instantiated class
Terminology of OO

- Class: A kind of type that combines data and functions to operate on this data

- Important: There is one class X in a program (even before running it), but potentially many instances of X at run-time

- Functions in classes are called methods

- Data fields are (sometimes) called instance variables

- Important: Every instance of a class has its own set of instance variables!

- Constructor: A special method that is run on instance creation
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Here is a slightly extended version of the program:

```cpp
class point {
    int x;
    int y;
    point() { this->x = 0; this->y = 0; }
    void inc_x() {
        this->x++;
    }
};

point *p = new point();
point *q = new point();
p->inc_x();
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Classes Example Extended

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What is the value of y->x?
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What is the value of \( y \rightarrow x \)? 0
Objects and Subtyping

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- But subtyping now also needs to take methods into account!
- Specifically, any subtype must also have (at least) the same methods as the original type
- This way, we can use the subtype in any context that expects the original type
Virtual Methods and Subtyping

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- Allowing redefinition of methods is known as virtual methods.

- This is another key OO feature.
Virtual Method Example

Consider the following code:

class point {
    int x;
    int y;
    point() { this->x = 0; this->y = 0; }
    virtual void inc_x() {
        this->x++;
    }
};
class bigpoint:public point {
    int x;
    int y;
    virtual void inc_x() {
        this->x+=2;
    }
};
point *p = new bigpoint();
p->inc_x();
Static vs. Dynamic Types

- Allowing subtyping of classes means that every expression in a program has two kinds of types:

  1. Static Type: This is the type computed by the type checker at compile time. For example, the static type of \( p \) in the example is \( \text{point} \).
  2. Dynamic Type: This is the type of object a variable holds at run-time. For example, the dynamic type of \( p \) in the example is \( \text{bigpoint} \).

- The dynamic type decides which virtual method is called!
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- This is sometimes called the essence of OO
Relationship between Static and Dynamic Type

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▶ In OOP, we also use types at run-time to decide which method to invoke!

▶ You can think of this operationally as an implicit run-time check on a type tag that decides which version of a method is called.
Encapsulation

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- This means that class data can be made non-accessible to clients of the class
- Example: Declaring an instance variable `private`
- Fortunately, this only rejects some programs at compile time but does not change semantics
Why Encapsulation?

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Actually, old idea: This is also known as abstract data types (ADT) and predates OOP.
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Essential OOP Features

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  2. Classes
  3. Virtual Methods
  4. Encapsulation
Why OOP?

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▶ This often allows for much cleaner and more extensible code.

▶ If the problem you are solving fits into the OO model!
Uses of OOP

- OOP is a great fit for:
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- OOP is a great fit for:
  - GUI toolkits
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- In fact, many modern languages, such as Java, force an OOP style

- However, not every problem maps well into objects!
The idea of objects and subtyping originated at MIT in the 1950s and 1960s
History of OOP

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- Over the years, various features that we would call object-oriented today made their way into various LISP dialects
First object-oriented language: Simula 67
Object Orientation: History Cont.

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- Simula was designed as an special-purpose language for discrete event simulations

- But it as certainly not designed as a general-purpose programming language
Features Combined in Simula

▶ Subtyping
Features Combined in Simula

- Subtyping
- Classes
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- Garbage Collection
From Simula to Smalltalk

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- And lead to a huge wave of OO languages
- This was an huge fad in the late 90’s
OO in the Real World

This Reference Helps You Understand the Basics of OOP and Get Started Writing Programs Right Away!
Introduction to Object-Oriented Thinking in Music

MUSC 318

due Monday
Group work is encouraged for this assignment.
Other OO languages

- C++
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- C++
- Java

Pretty much any newer imperative language (and plenty functional ones as well)
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The OO paradigm in the wild

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The OO paradigm in the wild

- Object oriented programming is one of the very few techniques that actually seems to make it easier for humans to build software

- But it does not work well for every problem

- However, since it is so pervasive, this tends to be forgotten
Summay

- We have looked at the four aspects that define object-oriented programming
Summary

- We have looked at the four aspects that define object-oriented programming

- Next time: Some issues with semantics and typing in OO languages