Introduction

Object-Oriented Programming

236703

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Course Staff

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Slide Credits

• Original slides by Prof. Yossi Gil
  – Created in the late 20th century
• Retouched by Keren Lenz
  – ... and probably others over the years
• Latest retouches by Tal Cohen
  – Any mistakes, blame me.
This Course

• … is about abstraction mechanisms
  – not object oriented programming
  – not object oriented design

• A comparative approach
  – not about a specific language

• Learn language features that make writing high quality code easier
  • This course will make you better programmers!
Motivation

• Permanent software change principle
  – Software that does not change dies
  – Changes: bug fixes, feature additions, porting…
  – How can we make changes a little bit safer?

• Déjà vu principle
  – two similar code segments will lead to failure rising from unsynchronized changes

• The solution: Encapsulation and Abstraction to the rescue…
Encapsulation

• Rationale: If a program element, e, is accessible by many other elements, then changing e will affect all its dependents

• Encapsulation: A mechanism that limits the access to certain elements of the program
  – Representation of the data can be changed
  – Algorithms can be changed
Abstraction

• The process of:
  – identifying similarities between code fragments
  – eliminating these similarities by making a single instance of the repeated code
    • Possibly parameterized

• Allows a piece of code to ignore irrelevant details
The number 100 appears twice
What happens if we change the array size and forget to modify the array bound?
Abstracting constants: named constants

```
#define N 100

int a[N];
for (i = 0 ; i < N; i++)
    cout << a[i];
```
Abstracting constants: \texttt{enum} definition

\begin{verbatim}
enum {N = 100};

int a[N];
for (i = 0 ; i < N; i++)
    cout << a[i];
\end{verbatim}
Abstracting array size: macro definition

#define SIZEOF(array)
  (sizeof(array)/sizeof(array[0]))

int a[100];
for (i = 0 ; i < SIZEOF(a); i++)
  cout << a[i];
int[] a = new a[100];
for (int i = 0; i < a.length; i++)
    System.out.print(a[i]);
Abstracting array iteration: enhanced for loop

```java
int[] a = new int[100];
for (int ai : a)
    System.out.print(ai);
```
Abstraction mechanisms improve over time...

Generally speaking, levels of abstraction improved as programming languages evolved.

- First HLL: FORTRAN (1957)
- Types: Algol (1958)
- Modules: Algol 68 (1968)
- Classes: Simula (1965)
- Generics: ML (1973)
The OOP Manifesto

1. Everything is an object.
2. Computation is performed by objects communicating with each other by sending and receiving messages.
3. Each object has its own memory (state), which consists of other objects.
4. Every object is an instance of a class.
5. The class is the repository for behavior. All instances of the same class can perform the same actions.
6. Classes are organized into a singly rooted tree, called the inheritance hierarchy.
Additional Abstraction Mechanisms

• Types
  – Join fields and operations
  – Well defined instantiation process

• Methods
  – Allows the programmer to concentrate on *what* is being done, not *how* it is being performed
  – Syntactically (and semantically) bound to a certain type

• Encapsulation
  – Minimize dependencies
  – Allow consistent behavior
Additional Abstraction Mechanisms

• Inheritance and polymorphism
  – Avoid code duplication
  – Represent relations and allow substitution

• Dynamic Binding
  – A method call is not tied up with a specific method body
  – Provides polymorphism

• Genericity
  – Similarity between operations on different types (or other parameters)
What is a Type?

• A set of values
• A set of operations on those values

• Properties
  – Set of possible values
  – Set of operations (arithmetic? assignment? display?)
  – Relations with other types
  – Representation (location, stack, heap..)
  – Coercions to other types

• Classes in an object-oriented language are an elaboration of this notion to include relations among types and operations (class inheritance, method inheritance)
Types

• Often broken down into
  – Elementary (primitive, atomic types)
    • C types: int, char, double, float…
  – Compound : generated using type constructors – operators that accept types and generate a new type.
    • C constructs: struct, enum, union, arrays, pointers…
Types and Operations

• Certain operations are legal for values of each type

  – It *doesn’t* make sense to add a function pointer and an integer in C
  – It *does* make sense to add two integers
  – It *might* make sense to add an integer and a pointer (this is what an array reference might be in some languages)

  – But all have the same assembly language implementation!
Type Systems

• A language’s type system specifies which operations are valid for which types
• Type checking ensures that operations are used with the correct types

• Three kinds of languages:
  – *Untyped*: No type checking (machine code)
  – *Statically typed*: The compiler computes the type of each expression. All or almost all checking of types is done as part of compilation (C, Java)
  – *Dynamically typed*: Almost all checking of types is done as part of program execution (Python, Smalltalk).
The Type Wars

• Static Typing:
  – Catches many programming errors at compile time (safety)
  – Enforces the design decisions (clarity)
  – Avoids overhead of runtime type checks (performance).

• Dynamic Typing:
  – Flexible
  – Less code – no need to declare types
  – Rapid prototyping easier in a dynamic type system.
interface List { void add(Object o); }  
class ArrayList implements List { void add(Object o) { ... } }  
class LinkedList implements List {  
    void addFirst(Object o) { ... }  
    void add(Object o) { ... }  
}

LinkedList w = new LinkedList();
w.addFirst("1"); // DT ✔️ ST ✔️

List x = new LinkedList();
x.addFirst("1"); // DT ✔️ ST ☑️

List y = new ArrayList();
y.addFirst("1"); // DT ☑️ ST ☑️

LinkedList z = new ArrayList(); // ST ☑️
z.addFirst("1"); // DT ☑️
Typing Strength

• Strong typing:
  – An unbreakable association between a value and its type
  – An operation fails on arguments which have the wrong type

• Weak typing:
  – One can change the value-type association
  – Language implicitly converts types when used
Strong Typing -- What does it look like?

Strong typing prevents mixing abstractions.
Nominal vs. Structural Type Systems

- **Nominal equivalence**: two types are equivalent if they have the same name in the same context
- **Structural equivalence**: two types are equivalent if they have the same structure

```plaintext
struct {int x; int y;} a1;
struct {int x; int y;} b1;
a1 := b1;  // N   S

a: array[1..100] of Integer;
b: array[1..100] of Integer;
a := b;     // N   S
```

- a and b are equivalent in terms of **structure**, but not **nominal** as they have different names.
- a and b are equivalent in terms of **nominal** as they have the same name.
- a1 and b1 are equivalent in terms of **nominal** as they have the same name.
- a1 and b1 are equivalent in terms of **structural** as they have the same structure.
Nominal vs. Structural Type Systems

• Pascal’s type system is almost purely nominal

• C
  – struct, union – nominal equivalence
  – All other type constructors (e.g., arrays, function pointers) – structural

• C++
  – Just as C (class types: nominal equivalence)
  – Templates – structural

• Java
  – class – nominal equivalence
  – Arrays, templates – structural
C as a Hybrid Language

• structs (and unions) are nominal...

```c
typedef struct { int i; } S1;
typedef struct { int i; } S2;

S1 s1;
S2 *p = &s1; //error!
```

• All other type constructors create structural types

```c
typedef int A1[100];
typedef int A2[100];

A1 a1;
A2 *p = &a1; //OK
```
Intra-program Communication in C

• It is possible to declare the same type in different modules
  – Either by including a common header file
  – Or by manually defining the type twice
• The compiler views these definitions as the same type
  – Even if they are different.
  – The reason: C’s type system is weakly typed.