OO Theory: ADT, Object and Class

서울대학교 컴퓨터공학부
Internet Data Base LAB
교수 김 형 주

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Forget Java & C++ at the moment!!!

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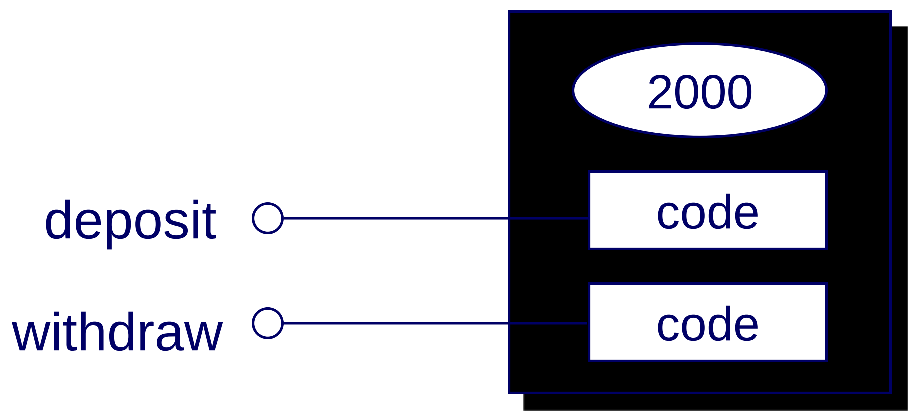
Object

An encapsulated software structure which usually models an application domain entity

Object = **Data + Operations**



Bank Account object

Related Terms

Instance variables

The variables(data) contained in an object are called *instance variables.*

Method

An operations of an object is called *method*.

Message

A request to invoke an operation is called *message.*

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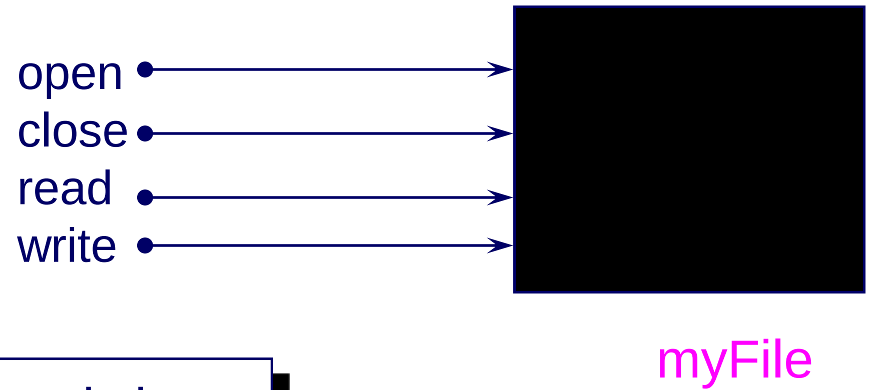
Example: File Object



Object-oriented view

myFile open() : myFile, please open yourself.

myFile read(ch) : myFile, please give me the next char.

myFile close() : myFile, close yourself.

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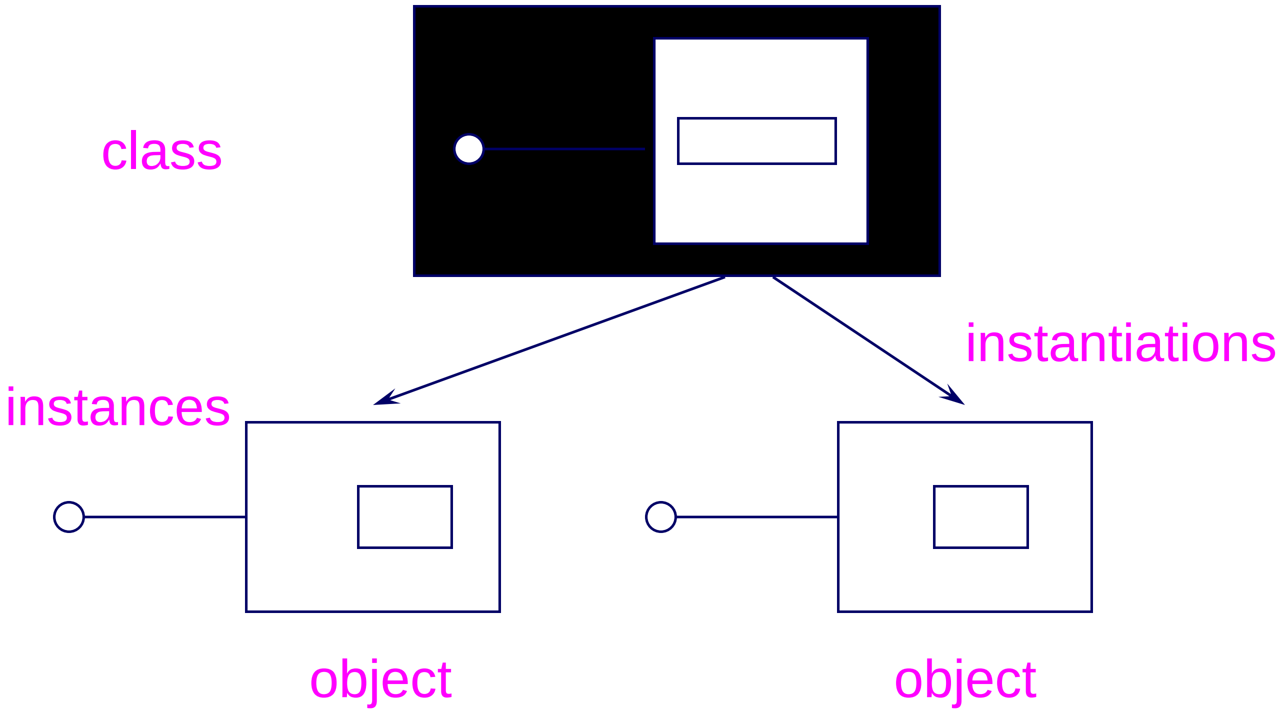
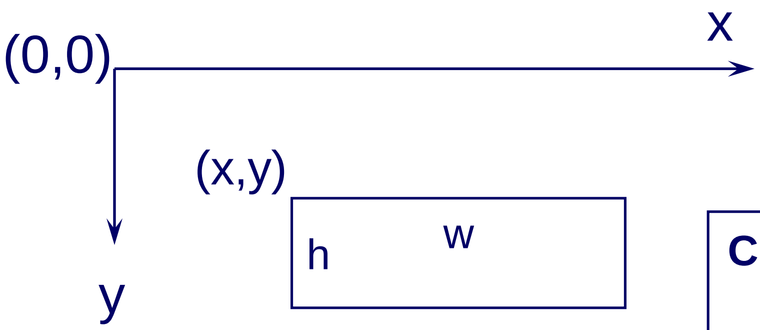
Class

An abstract data type which define
the representation and behavior of objects.



Example: Rectangle

Define a Rectangle Class.




```
Class Rectangle
   data
            int x, y, h, w;
   method
            create (int x1, y1, h1, w1)
              { x=x1;   y=y1;   h=h1;   w=w1; }

            moveTo (int x1, y1)
              { x=x1;   y=y1;   self.display(); }

            display ()
              { drawRectangle(x, y, h, w); }
End Class
```

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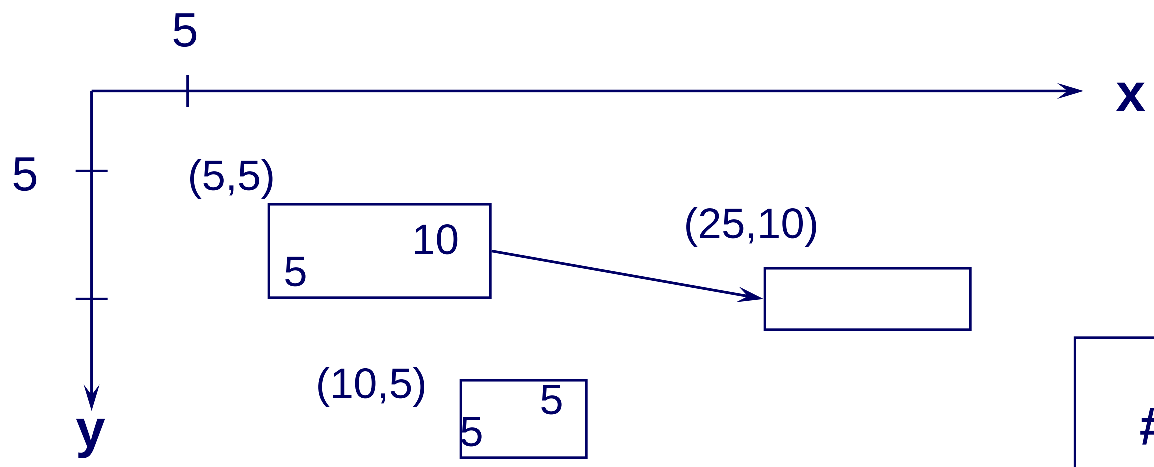
Interface of Rectangle

```
class Rectangle {
   operations
         create(int x1, y1, h1, w1);

         moveTo(int x1, y1);

         display();
}
```

Example: Using Rectangle




```
#Import Rectangle

Rectangle  r1, r2;
r1.create(5, 5, 10, 5);
r1.display();
r1.moveTo(25,10);

r2.create(10, 15, 5, 5);
r2.display();
```

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Related Terms

Behavior

The set of methods exported by an object is called its *behavior* or *interface*.

Encapsulation

The data of an object can only be accessed via the methods of the object.

Data Abstraction

Definition of an abstract type.
Encapsulation is need.

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1. Introduction

- ADT(Abstract Data Types)
  - represented and implemented through classes
- Class
  - basic implementation and representation unit
  - a class is basically a type

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1.1 Data Types

- Informal Definition
  - representation + operations
    - representation = attributes or the structure of the type
    - operations = constructor operations + base operations

    - type construct operators: generic extraction operations
      - e.g.) field selection, arrays, lists, sets and sequences

      - e.g.) ITM.Cost := ITM.Cost * 1.1;

constructor operation base operation

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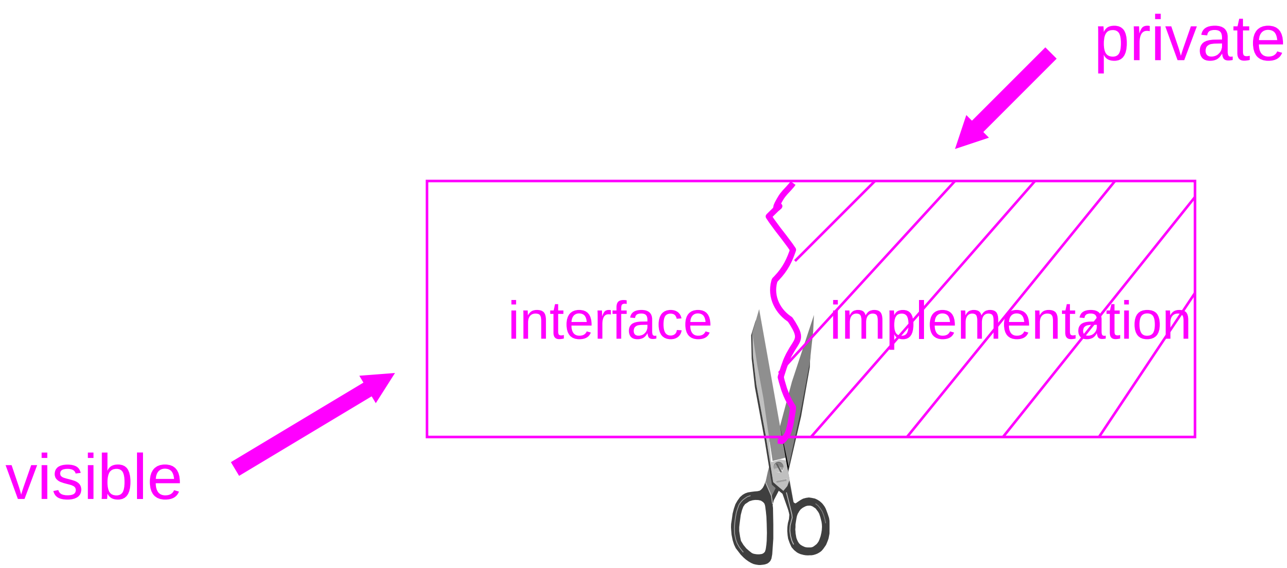
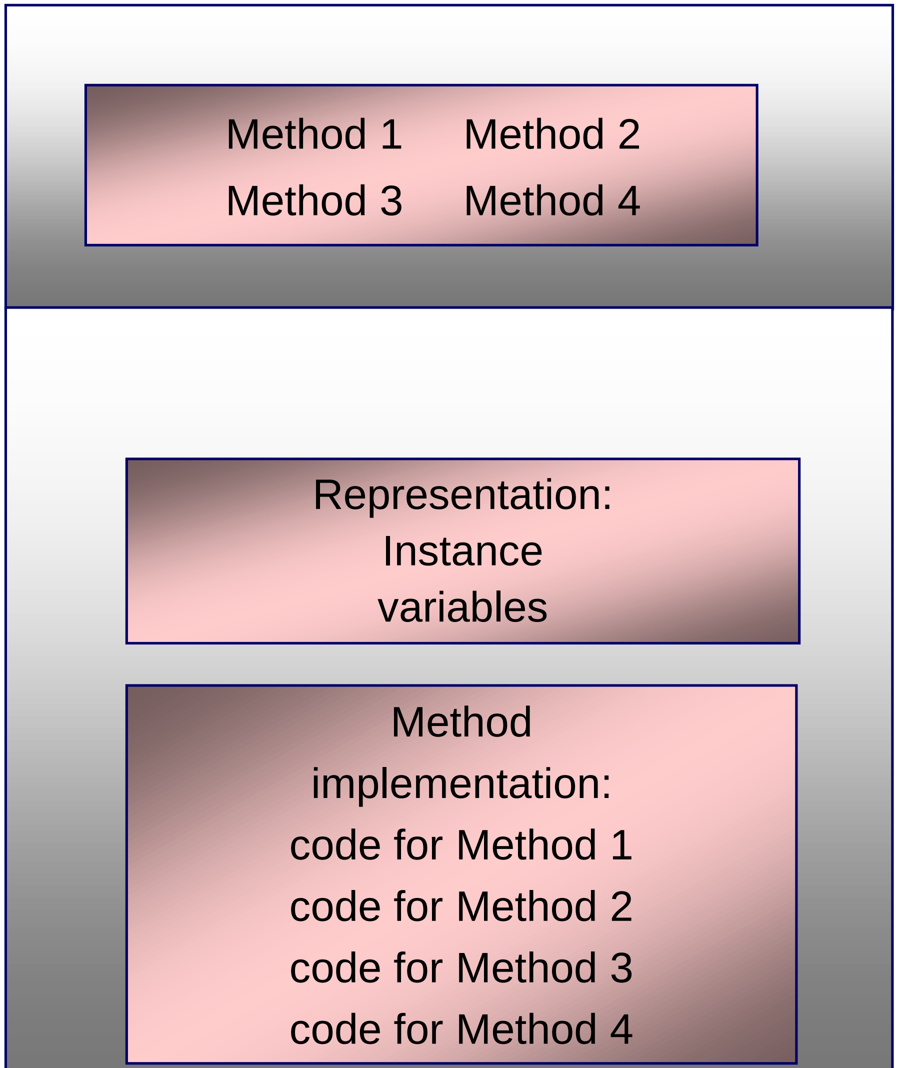
1.2 From Data Types to ADTs

- Clear distinction between implementation and interface
  - interfaces are *public*
  - representations and implementations of interfaces are *private*
  - "encapsulation"



The overall structure of an abstract data type (Class)



Interface
Public

Implementation
Private

From Data Types to ADTs

- Suppose we have ADT: a set of integers
  - A linked list of records vs. An array of integers
  - The interfaces of two implementations are same to users' view
  - The implementation of associated operations like "Find an element" would be different

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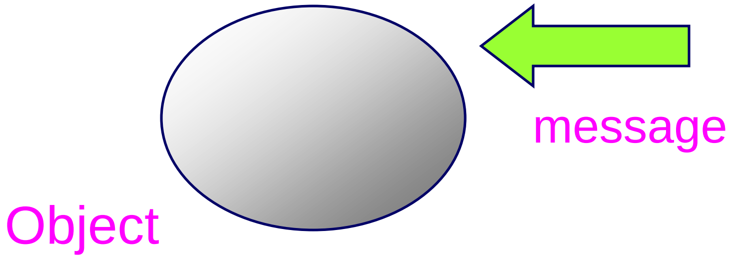
1.3 The Object / Message Paradigm (1)

- The data is active computational entity
  - Messages comprise the object's *interfaces*
  - Messages can change/retrieve the object's internal states



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1.3 The Object / Message Paradigm (2)

- Procedural Model
  - function call to return data values
  - function call to update input data parameter
- Object / Message model
  - send messages to perform computation and return a value
  - send messages to ask an object to change the object's content
- In terms of computational power
  - The procedural model and the object/message model are same
- In terms of modeling, software development, software extensibility, reusability
  - The object/message model is far superior

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1.4 Modularization

- Naturally provide a divide-and-conquer strategy
- In procedural model → through procedures
- In OO model → through *abstract data typing*
  - advantages
    - models the real world
    - autonomous
    - generates correct applications
    - reusable

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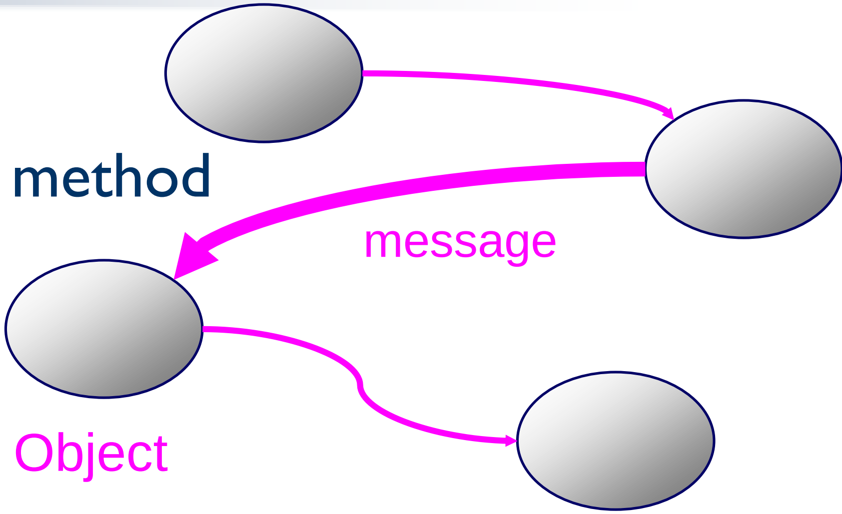
1.4.1 Modeling of the Real World

- Data-based vs. Procedure-based
- OO → Data-based
  - more direct representation of the real world
  - improved clarity, robustness, debugging and maintenance of programs
  - encapsulation

1.4.2 Autonomy

- Object is an autonomous agent
  - messages are the only interacting method



- Nodes: Mail service, Secretary, Salesperson, Salesmanager
- Procedural Abstraction: spanning many nodes and many things
- ADT Abstraction: autonomous
  - define messages
  - code correpondant method locally

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1.4.3 Generation of Correct Applications

- OO Modularization Can develop more robust code bases
  - Encapsulated ADT can easily be *stubbed*
    - actual code that implements an operation is commented out and replaced by a diagnostic message.
  - Helps isolate errors within ADT
    - Exception-checking and error-handling mechanism can be incorporated easily

1.4.4 Reusability

- Conventional library mechanism has several drawbacks
  - no parametric polymorphism and overloading
    - replications of function and excessive use of case statement
- ADT and OO provide overloading and polymorphism
  - Naturally guarantee reusability

1.5 Benefits of ADT (Summary)

- Provides better conceptualization and modeling
- Enhances robustness
- Enhances performance
- Better captures the semantics of the type
- Separates between implementation and specification
- Allows extensibility of the system

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- **Classes**
- Overloading
- Dynamic binding
- Parametric polymorphism
- Constraints
- Summary

2.2 Classes

- Language construct to define ADT in OO PLs
- Class definition includes
  - name of the class
  - external operations (interfaces)
  - internal representation
  - internal implementation of the interface

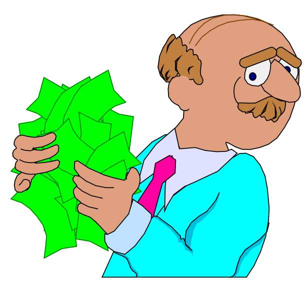
2.1 Instance Variables

- Internal representation of a class
  - hold the state of objects that are instances of a class
  - take on different values for each instance
  - may specify type constraints

- Strongly typed OO languages: Eiffel
  - successful compilation guarantees no return errors
- Weakly types OO languages: JavaScript, Python
- Typeless OO languages: Smalltalk
  - flxibility, rapid prototyping

Instance variables

Instance John



Name: “John Chan”
Age: 32
Salary: $35,000

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2.2 Methods and Messages

- Methods define the behavior of instances of a class
- Sending messages (or invoking methods) involves
  - target object
  - *selector* (name of the method)
  - arguments of the operator
- Example
  - *C initializeReal : 3 Imaginary : 2*
    - C : target object
    - initializeReal, Imaginary : selector
    - 3, 2 : arguments
- Protocol
  - set of messages that the object can respond

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2.2.1 The Method Body

- Code that implements the method
- Possibly several method bodies: Dynamic Binding
  - actual code of the method will be determined at run time

- Smalltalk: A method (within the method body) can access the instance variables of the class and its superclasses

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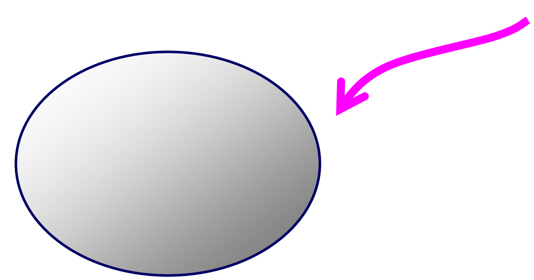
2.2.2 Implicit Parameters and The Pseudovariable "Self"

- How is the target object identified in the method body
  - Implicitly by the pseudovariable "self" or "this"
- Smalltalk "self" and C++ "this"
- Inside the method body: "self"
  - "self" is an implicit formal parameter
- "Super" indicates its superclass



2.2.2 The implicit pseudovariable

- Purpose of pseudovariable
  - As a return variable of a method
  - To invoke other methods on the target object
  - To distinguish between the object as an instance of the class and the object as an instance of a superclass

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2.2.3 Accessor and Update Methods

- Generic operations
- Accessor methods: Retrieve operations of instance variables (rather than perform complex computations)
- Update methods: Update operations of instance variables (rather than perform complex computations)

- Automatically generated in some OO languages because they are so common
  - get_real, get_imaginary
  - put_real, put_imaginary

2.3.1 Creating Objects (1)

- In conventional languages (Pascal, C)
  1. Explicit declaration and definition
  2. Allocate space from the memory heap and declare pointer to it

```
Type
ComplexPtr = ^Complex

Complex = RECORD
    Real: real;
    Imaginary: real;
END;
```

```
VAR
  C1, C2: Complex;

C1.Real := 1.0;
C1.Imaginary := 2.0;
```

```
VAR
  pC1, pC2; ComplexPtr;

new(pC1);
pC1^.Real := 1.0;
pC1^.Imaginary := 2.0;
```

2.3.1 Creating Objects (2)

- In OO languages: Ask the class to stamp out an instance
  - Suppose we have "Complex" class
  - Use special object-creation class method to initialize instance variables
    - new Complex Real: Imaginary:
    - new Complex Real: 3 Imaginary: 2
  - Use generic new method with uninitialized instance variables
    - C := new Complex
    - C initializeReal: 3   initializeImaginary: 2

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2.3.2 Destroying Objects and Garbage Collection

- Two strategies
  - Explicit "dispose" or "delete" operation (Pascal,C)
    - little overhead
    - problem of "dangling" references
  - Implicit disposal or reclamation of the object when it is no longer reachable (Smalltalk, Lisp)
    - garbage collection
    - no dangling reference
    - run-time overhead

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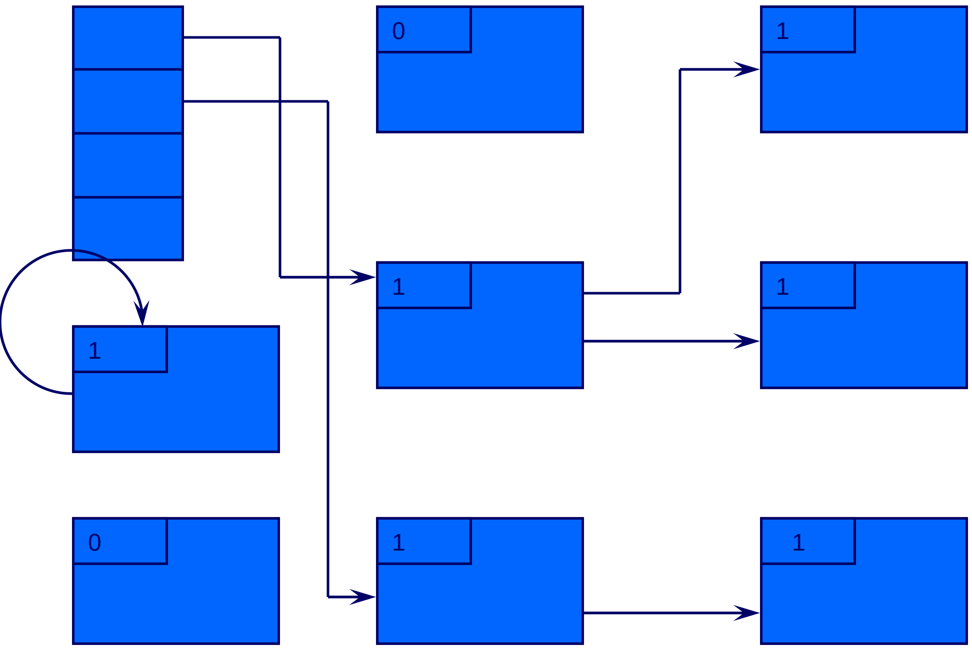
2.3.2.1 Garbage Collection (1)

- Reference counting



- no stop-and-reclaim phase
- dangling reference finding
- space utilization is enhanced
- "circular reference" problem
- overhead of incrementing and decrementing the reference

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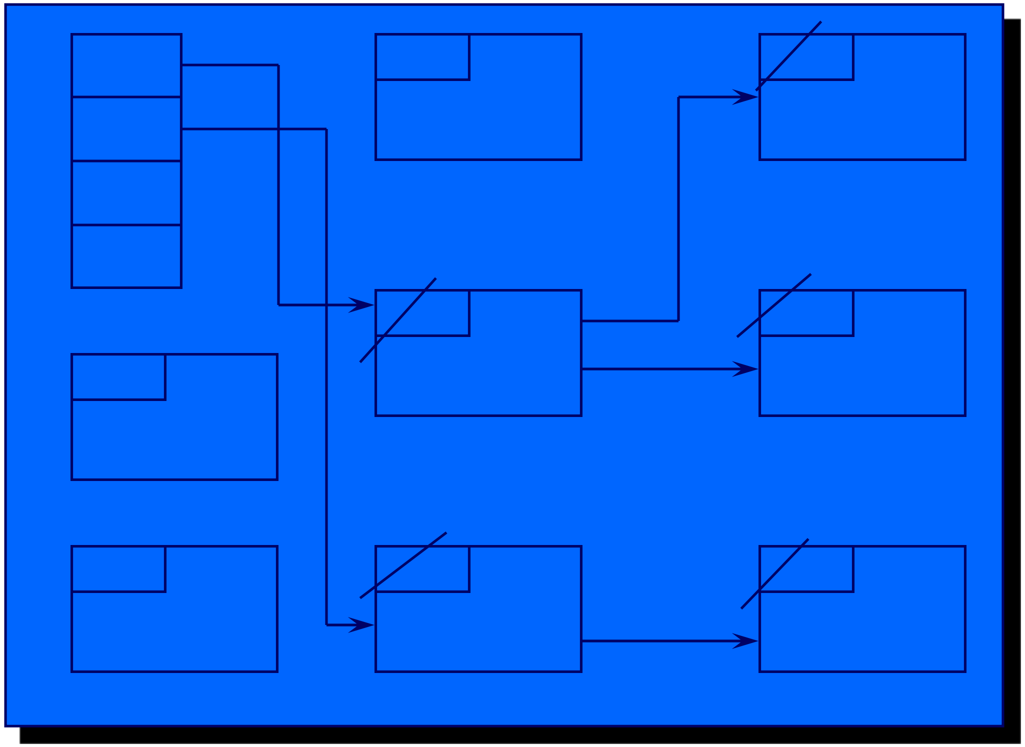
2.3.2.1 Garbage Collection (2)

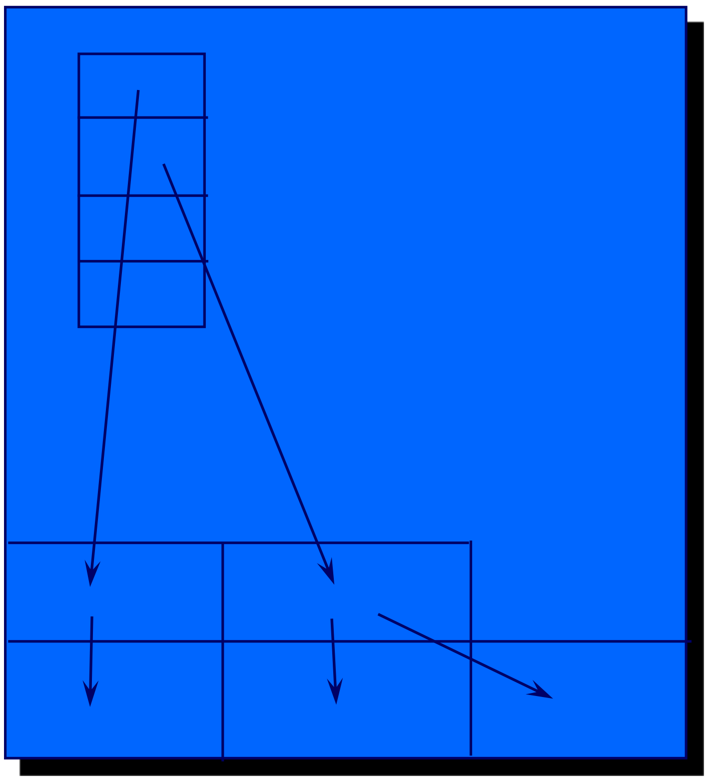
- Mark-and-sweep



- mark phase

2.3.2.1 Garbage Collection (3)

- Mark-and-sweep (cont'd)



-sweep phase

The mark-and-sweep scheme
-- use global information to reclaim storage stop-and-sweep overhead
-- no "circular reference" problem
-- memory compaction is possible
-- system-stop overhead

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2.3.2.1 Garbage Collection (4)

- Reference counting: circular reference problem and counting overhead
- Mark and sweep: stop-and-sweep overhead when memory runs out
- Copy and Swap algorithm
  - Half the space H1 and H2
  - Allocate objects from H1
  - If H1 is filled up, copy the live objects of H1 into H2
  - H1 and H2 are reverse

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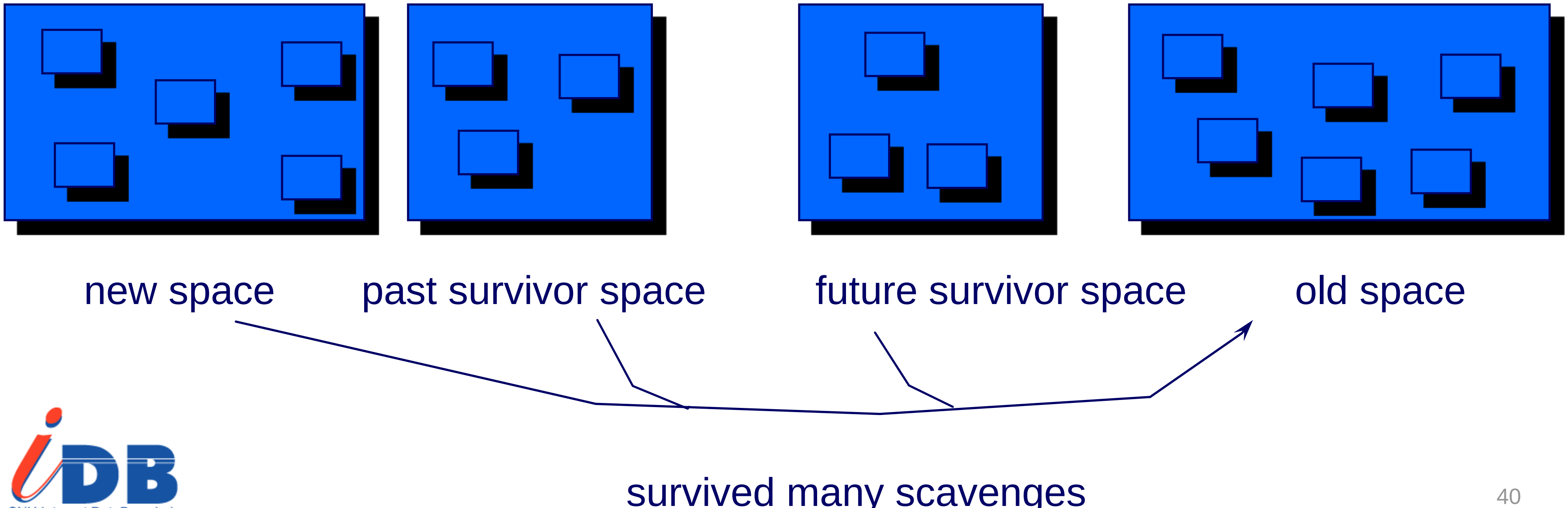
2.3.2.1 Garbage Collection (5)

- Copy and swap: space overhead
- Generation Scavenging (scavenge: 청소하다, 배기하다)
- Assumption: 새로이 생성된 객체일수록 삭제되기가 쉽다



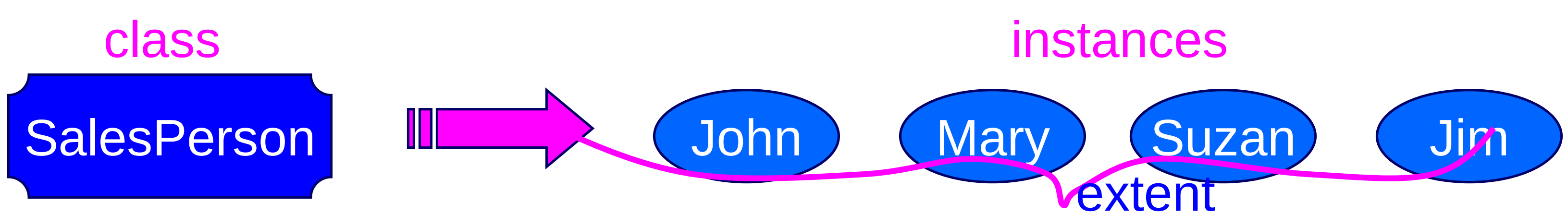
2.3.2.1 Garbage Collection (6)

- Generation Scavenging
  - new space: creating new objects
  - past survivor space: survivors from the previous round
  - future survivor space: space for scavenging
  - old space: “die-hard” area for old objects

- past s-space and future s-space are reversed after scavenging
- reduces the overhead of the stop-and-copy
- there can be copying and age-tracking and space overhead

2.4 Class Extensions (1)

- Meaning: actual, existing instances of a class
- How can we facilitate processing large numbers of objects of the same type?
- Conventional PL (Pascal): A type represents the set of all possible objects
- DBMS: A table type represents the set of all records
- In OOPLs, we already used the name of class when we want to create an instance of a class, then How?



In conventional PLs : Pascal

```
TYPE
   Complex =
         RECORD
            Real : real;
            Imaginary : real;
         END;
```

denotes

{ (Real, Imaginary) |
Real is real;
Imaginary is real }

Set of all complex numbers

Complex type ← like template

OO Concepts

Class

extent

Set of objects

Extent : It is useful in DBMS

Process <u>large numbers of objects of the same type</u>

```
CREATE TABLE SalesPerson
   (Name          CHAR(20),
    Address       CHAR(20),
    Tel_No        INTEGER,
    Salary        FLOAT,
    …)
```

extent

instances

John Mary Suzan Jim

extent

```
Query : SELECT Name, Address
        FROM SalesPerson
        WHERE Salary > 50000
```

<u>** SQL has the language construct for EXTENT: relation name</u>

2.4 Class Extensions (2)

- Two strategies to access existing instances
  - Through the class extensions (if the language supports extension).
    - Keyword "extent" or "extension"
  - Through a collection object (almost all OOPLs support this)
    - keyword: "collection", "set", "bag", "array"

2.4.1 Collections

- Most OO PLs support "collection" class
- Similar effect to extensions
- Subclasses of collection class
  - Sets, Arrays, or Bags (Sets with duplicates)
- Smalltalk
  - SalesPeople := Set new
  - SalesPeople add: John
- Eiffel
  - SalesPeople: SET[SalesPerson]

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- <u>**Overloading**</u>
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3 Overloading

- Operations of the *same name* but *different semantics* can be invoked for objects of different type
- Conventional PLs support basic overloading on built-in basic types such as int, real and character
- OOPLs take one step further for any operation of any object type
  - If S1 and S2 are sets, S1 + S2 would be set union

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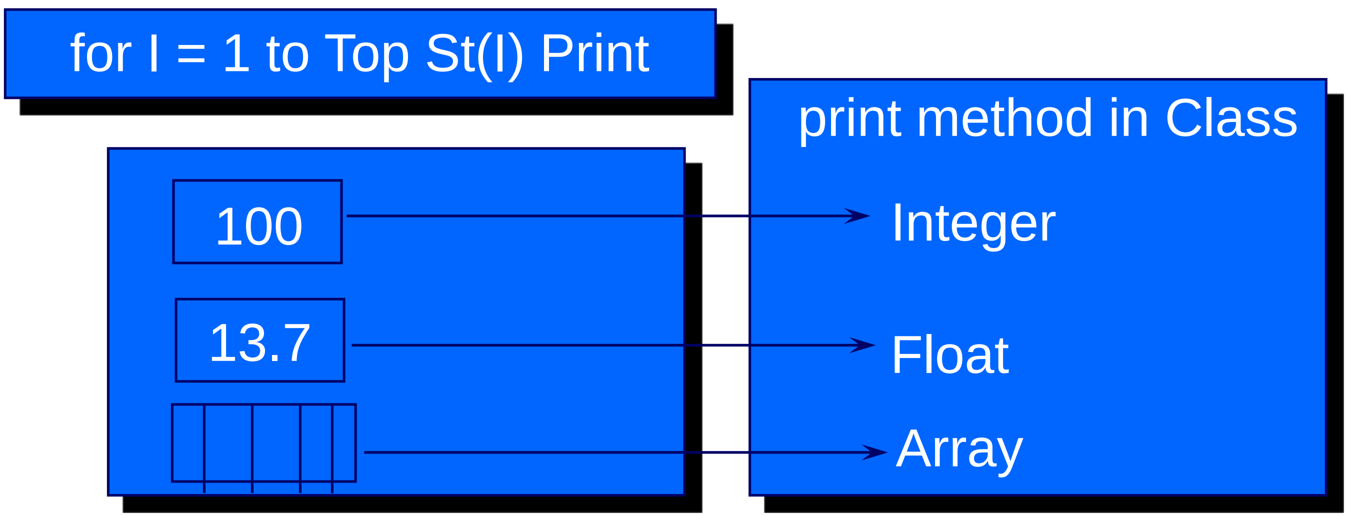
4 Dynamic Binding (1)

- Supports operator overloading
- In typeless language, variable's type will be known *at run time*
- Provide extensibility, compact code, clarity!



Dynamically binding "*Print*"

4 Dynamic Binding (2)

- Manipulation collections of objects of different types implies "not strongly typed"
- The power of overloading and dynamic binding is best utilized by typeless language
- Advantages
  - Extensibility
  - Development of more compact code
  - Clarity
- Disadvantages: slow

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5 Parametric Polymorphism

- *"Anything goes"* makes it a form of polymorphism
- *Uses types as parameters* in generic type declarations or classes
  - e.g.) template in C++, parameterized type in CLU
- Genericity
- flexibility & advantage of code sharing with power of strong typing

Parameterized polymorphic types in CLU

List-sum = proc[t: type] (a: list[t])
    returns(t)
    requires the type t has a binary operator
        + : proctype(t, t) returns(t) that "adds" two objects of type t.
    Effects it returns the sum of the elements
        in the list using the binary '+'

List-sum[int](IL)

List-sum[real](RL)

Integer list

List of real numbers

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6 Constraints

- ADT needs to be correct and complete
- Test the correctness or completeness
  - constraints on objects and instance variables
  - pre- and postconditions of methods
- Help the programmer express the semantics of ADT as directly as possible

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