Programming Paradigms CSI2120 – Winter 2019

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Review of Object-oriented Programming

- **Acknowledgement**
  - These slides are a barely modified version of the slides for Chapter 2, ***Object-Oriented Software Engineering: Practical Software Development using UML and Java*** by Tim Lethbridge and Robert Laganière

1. What is Object Orientation?

- **Procedural paradigm:**
  - Software is organized around the notion of procedures
  - Procedural abstraction
    - Works as long as the data is simple
  - Adding data abstractions
    - Groups together the pieces of data that describe some entity
    - Helps reduce the system's complexity.
      - Such as records and structures

- **Object oriented paradigm:**
  - Organizing procedural abstractions in the context of data abstractions

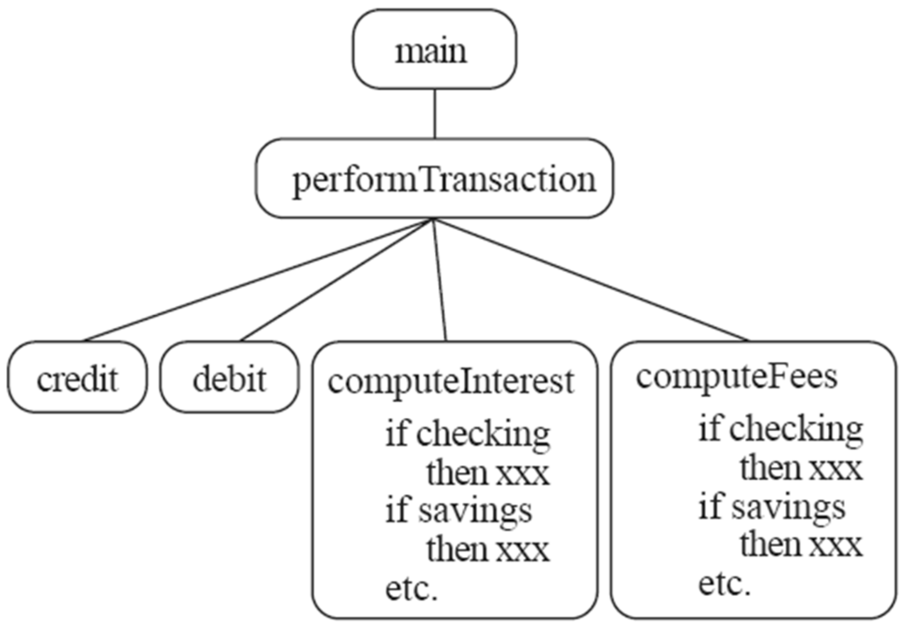
Object Oriented Paradigm

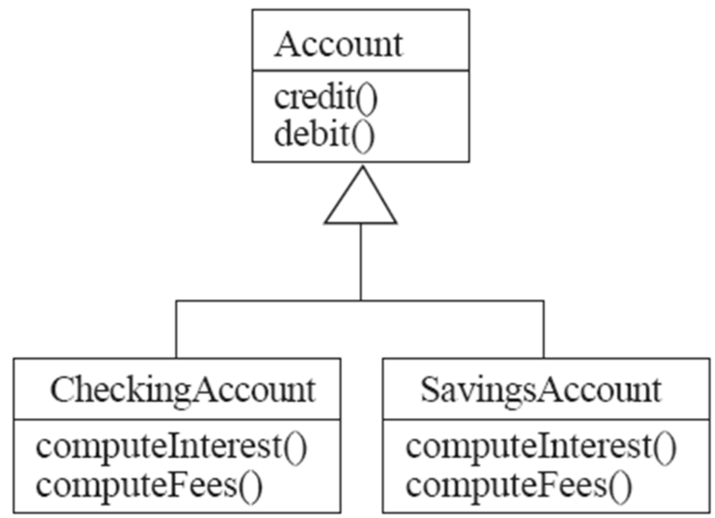
- **An approach to the solution of problems in which all computations are performed in the context of objects.**

  – The objects are instances of classes, which:
    - are data abstractions
    - contain procedural abstractions that operate on the objects

  – A running program can be seen as a collection of objects collaborating to perform a given task

A View of the Two Paradigms

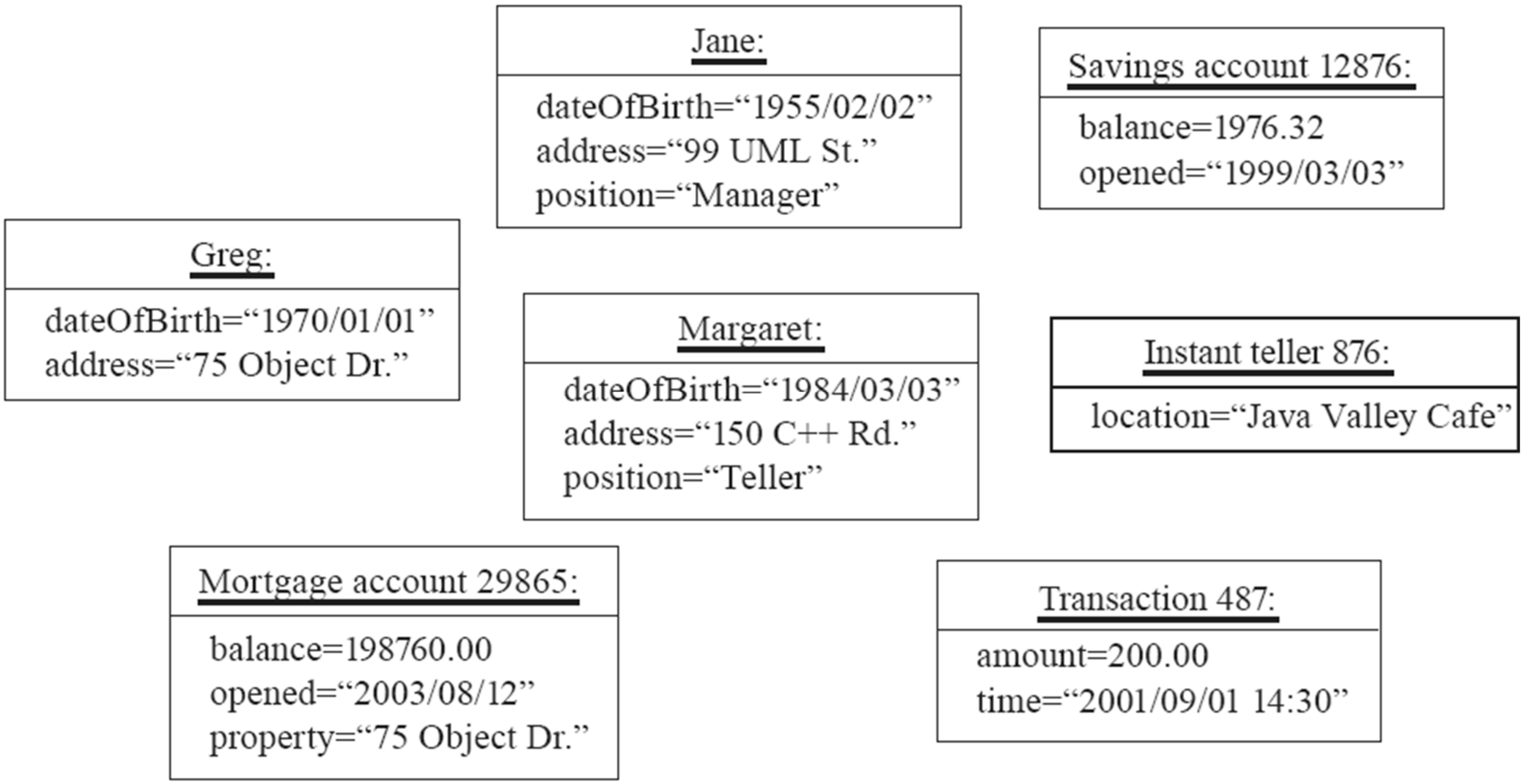




2 Classes and Objects

- **Object**
  - A chunk of structured data in a running software system
  - Has properties
    - Representing its state
  - Has behaviour
    - How it acts and reacts
    - May simulate the behaviour of an object in the real world

Objects


Jane:
dateOfBirth="1955/02/02"
address="99 UML St."
position="Manager"
Savings account 12876:
balance=1976.32
opened="1999/03/03"
Greg:
dateOfBirth="1970/01/01"
address="75 Object Dr."
Margaret:
dateOfBirth="1984/03/03"
address="150 C++ Rd."
position="Teller"
Instant teller 876:
location="Java Valley Cafe"
Mortgage account 29865:
balance=198760.00
opened="2003/08/12"
property="75 Object Dr."
Transaction 487:
amount=200.00
time="2001/09/01 14:30"

Classes

- **A class:**
  – A unit of abstraction in an object oriented (OO) program

  – Represents similar objects
    - Its instances

  – A kind of software module
    - Describes its instances’ structure (properties)
    - Contains methods to implement their behaviour

Is Something a Class or an Instance?

  - Something should be a class if it could have instances
  - Something should be an instance if it is clearly a single member of the set defined by a class
- **Film**
  - Class; instances are individual films.
- **Reel of Film:**
  - Class; instances are physical reels
- **Film reel with serial number SW19876**
  - Instance of ReelOfFilm
- **Science Fiction**
  - Instance of the class Genre.
- **Science Fiction Film**
  - Class; instances include ‘Star Wars’
- **Showing of ‘Star Wars’ in the Phoenix Cinema at 7 p.m.:**
  - Instance of ShowingOfFilm

Common Approach to Naming Classes

- Use capital letters
  - E.g. BankAccount not bankAccount

- Use singular nouns

- Use the right level of generality
  - E.g. Municipality, not City

- Make sure the name has only one meaning
  - E.g. ‘bus’ has several meanings

Bjarne Stroustrup: What is so great about classes?

- ***"Classes are there to help you organize your code and to reason about your programs"*.**
- ***"A class is the representation of an idea, a concept, in the code. An object of a class represents a particular example of the idea in the code"*.**
  - *"Without classes, a reader of the code would have to guess about the relationships among data items and functions - classes make such relationships explicit and "understood" by compilers. With classes, more of the high-level structure of your program is reflected in the **code**, **not** just in the **comments**".* [emphasis added]

Source: http://www.stroustrup.com/bs_faq.html#class, accesed Jan. 2019

3 Instance Variables

- **Variables defined inside a class corresponding to data present in each instance**
  - Also called fields or member variables
  - Attributes
    - Simple data
    - E.g. name, dateOfBirth
  - Associations
    - Relationships to other important classes
    - E.g. supervisor, coursesTaken

Variables vs. Objects

- **A variable**
  - Refers to an object
  - May refer to different objects at different points in time
- **An object can be *referred* to by several different variables at the same time**
- **Type of a variable**
  - Determines what classes of objects it may contain

Class variables

- **A class variable's value is shared by all instances of a class.**
  - Also called a static variable
  - If one instance sets the value of a class variable, then all the other instances see the same changed value.
  - Class variables are useful for:
    - Default or 'constant' values (e.g. PI)
    - Lookup tables and similar structures
  - Caution: do not over-use class variables

4 Methods, Operations and Polymorphism

- **Operation**
  - A higher-level procedural abstraction that specifies a type of behaviour
  - Independent of any code which implements that behaviour
    - E.g. calculating area (in general)

Methods, Operations and Polymorphism

- **Method**
  - A procedural abstraction used to implement the behaviour of a class
  - Several different classes can have methods with the same name
    - They implement the same abstract operation in ways suitable to each class
    - E.g. calculating area in a rectangle is done differently from in a circle

Polymorphism

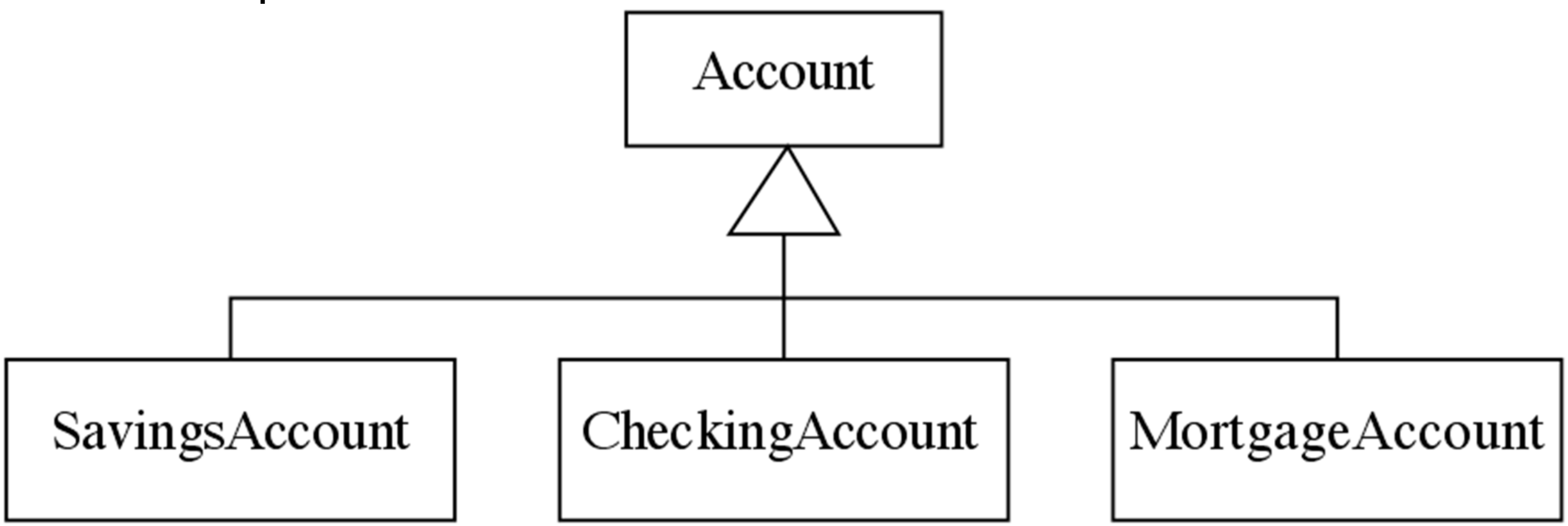
- **A property of object oriented software by which an abstract operation may be performed in different ways in different classes.**
  - Requires that there be multiple methods of the same name
  - The choice of which one to execute depends on the object that is in a variable
  - Reduces the need for programmers to code many if-else or switch statements

5 Organizing Classes into Inheritance Hierarchies

- **Superclasses**
  - Contain features common to a set of subclasses
- **Inheritance hierarchies**
  - Show the relationships among superclasses and subclasses
  - A triangle shows a generalization in UML 
- **Inheritance**
  - The implicit possession by all subclasses of features defined in its superclasses

An Example Inheritance Hierarchy

- **Inheritance**
  - The implicit possession by all subclasses of features defined in its superclasses

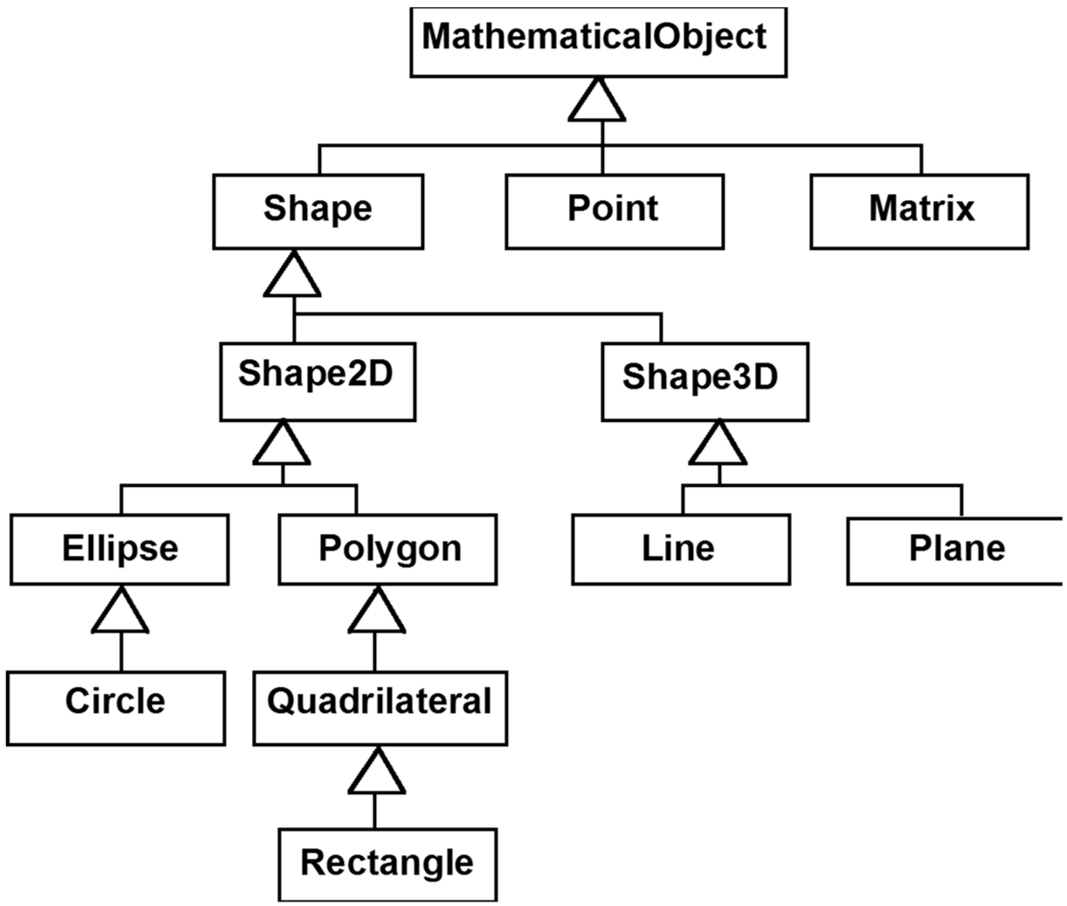


See in Umple

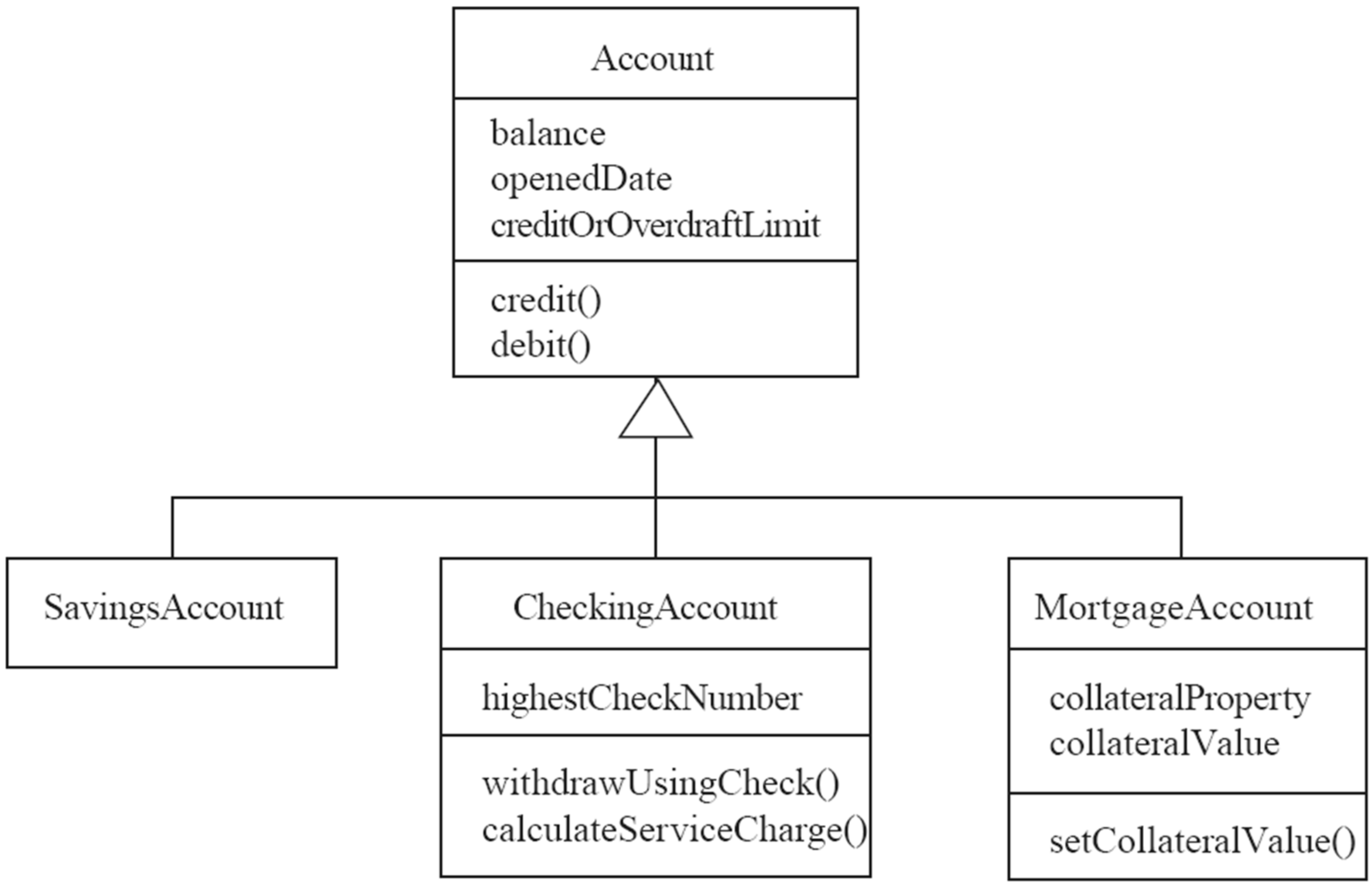
The Isa Rule

- **Always check generalizations to ensure they obey the isa rule**
  - “A checking account is an account”
  - “A village is a municipality”
- **Should ‘Province’ be a subclass of ‘Country’?**
  - No, it violates the isa rule
    - “A province is a country” is invalid!

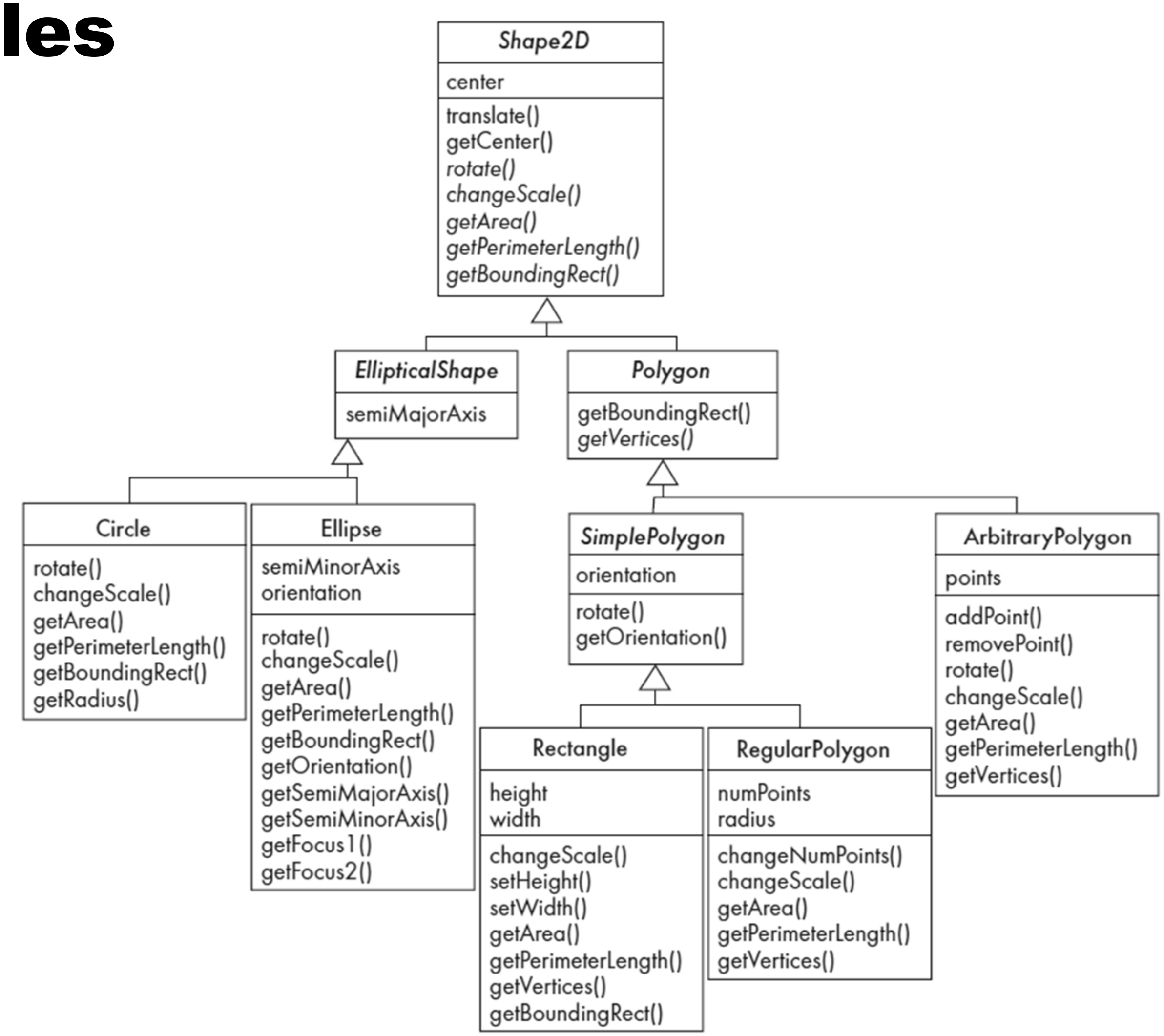
A Possible Inheritance Hierarchy of Mathematical Objects



Make Sure all Inherited Features Make Sense in Subclasses



6 Inheritance, Polymorphism and Variables



Some Operations in the Shape Example

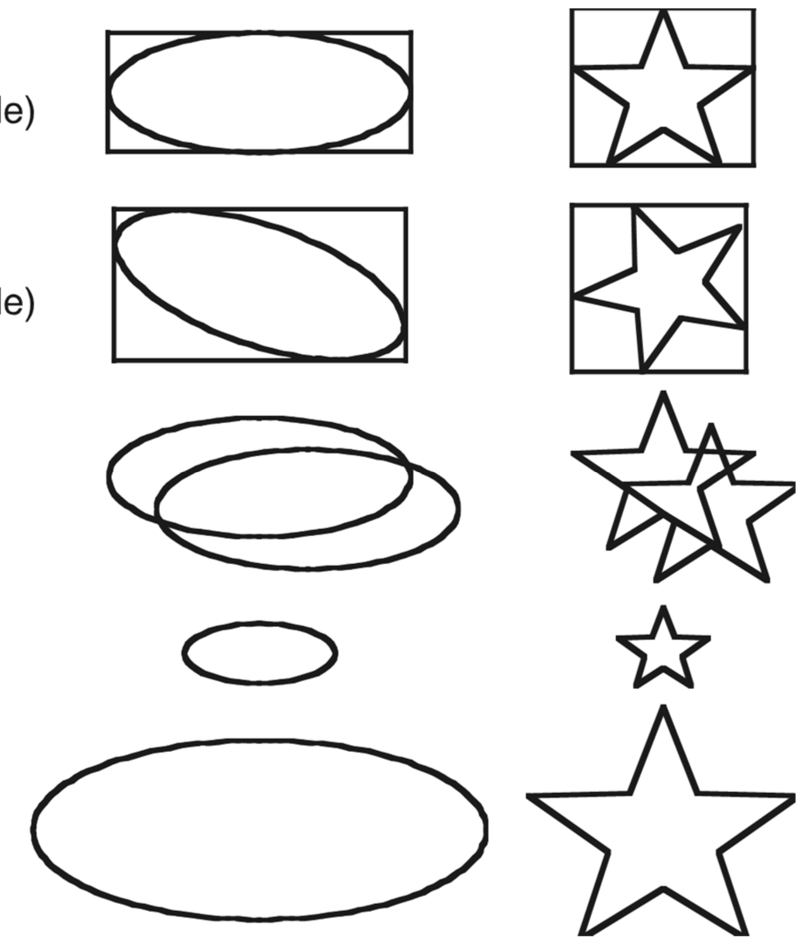
Original objects
(showing bounding rectangle)

Rotated objects
(showing bounding rectangle)

Translated objects
(showing original)

Scaled objects
(50%)

Scaled objects
(150%)



Abstract Classes and Methods

- **An operation should be declared to exist at the highest class in the hierarchy where it makes sense**
  - The operation may be abstract (lacking implementation) at that level
  - If so, the class also must be abstract
    - No instances can be created
    - The opposite of an abstract class is a concrete class
  - If a superclass has an abstract operation then its subclasses at some level must have a concrete method for the operation
    - Leaf classes must have or inherit concrete methods for all operations
    - Leaf classes must be concrete

Overriding

- **A method would be inherited, but a subclass contains a new version instead**
  - For restriction
    - E.g. scale(x,y) would not work in Circle
  - For extension
    - E.g. SavingsAccount might charge an extra fee following every debit
  - For optimization
    - E.g. The getPerimeterLength method in Circle is much simpler than the one in Ellipse

Methods and Inheritance

- **How a decision is made about which method to run**
  1. If there is a concrete method for the operation in the current class, run that method.
  2. Otherwise, check in the immediate superclass to see if there is a method there; if so, run it.
  3. Repeat step 2, looking in successively higher superclasses until a concrete method is found and run.
  4. If no method is found, then there is an error
     - In Java and C++ the program would not have compiled

Dynamic Binding

- **Occurs when decision about which method to run can only be made at run time**
  – Needed when:
    - A variable is declared to have a superclass as its type, and
    - There is more than one possible polymorphic method that could be run among the type of the variable and its subclasses

7 Concepts that Define Object Orientation

- **The following are necessary for a system or language to be OO**
  - Identity
    - Each object is distinct from each other object, and can be referred to
    - Two objects are distinct even if they have the same data
  - Classes
    - The code is organized using classes, each of which describes a set of objects
  - Inheritance
    - The mechanism where features in a hierarchy inherit from superclasses to subclasses
  - Polymorphism
    - The mechanism by which several methods can have the same name and implement the same abstract operation.

Other Key Concepts

- **Abstraction**
  - Object -> something in the world
  - Class -> objects
  - Superclass -> subclasses
  - Operation -> methods
  - Attributes and associations -> instance variables
- **Modularity**
  - Code can be constructed entirely of classes
- **Encapsulation**
  - Details can be hidden in classes
  - This gives rise to information hiding:
    - Programmers do not need to know all the details of a class

Bjarne Stroustrup: What is "OOP" and what's so great about it?

- *"Object-oriented programming is a style of programming originating with Simula (…) relying of encapsulation, inheritance, and polymorphism."*
- *"It means programming using class hierarchies and virtual functions to allow manipulation of objects of a variety of types through well-defined interfaces and to allow a program to be extended incrementally through derivation."*

Source: http://www.stroustrup.com/bs_faq.html#class, accesed Jan. 2019

The Origins of Java

- **Origin**
  - The first object oriented programming language was Simula-67
    - designed to allow programmers to write simulation programs
- **1980s**
  - Smalltalk was developed at Xerox PARC
    - New syntax, large open-source library of reusable code, bytecode, platform independence, garbage collection.
  - C++ was developed by B. Stroustrup at ATT Labs
    - Started in 1979. The initial version was called "C with Classes".
- **1990s**
  - Sun Microsystems started a project to design a language that could be used in consumer ‘smart devices’: Oak
    - When the Internet gained popularity, Sun seized the opportunity and renamed the new language Java. It was first presented at the SunWorld ’95 conference.

Appendix

- **Review of Java in a Few Slides**

Java documentation

- **Looking up classes and methods is an essential skill**
  - Looking up unknown classes and methods will get you a long way towards understanding code
- **Java documentation can be automatically generated by a program called Javadoc**
  - Documentation is generated from the code and its comments
  - You should format your comments as shown in some of the book's examples
    - These may include embeded html

Characters and Strings

- **Character is a class representing Unicode characters**
  - More than a byte each
  - Represent any world language
- **char is a primitive data type containing a Unicode character**
- **String is a class containing collections of characters**
  - + is the operator used to concatenate strings

Arrays and Collections

- **Native arrays are of fixed size and lack methods to manipulate them**
- **`ArrayList` is part of the collection framework and is a growable array to hold a collection of other objects**
- **Iterators can be used to access members**

```
ArrayList<Integer> numbers = new ArrayList<Integer>();
numbers.addAll(Arrays.asList(1, 2, 3, 4, 5, 6, 7, 8));
Iterator<Integer> i = numbers.iterator();
while(i.hasNext())
{
   System.out.println(i.next());
}
```

Casting

- **Java is very strict about types**
  - If variable v is declared to have type X, you can only invoke operations on v that are defined in X or its superclasses
    - Even though an instance of a subclass of X may be actually stored in the variable
  - If you know an instance of a subclass is stored, then you can cast the variable to the subclass

    E.g. if I know a Vector contains instances of String, I can get the next element of its Iterator using:

    ```
    (String)i.next();
    ```

    To avoid casting you should use generics as in the previous slide:

    ```
    ArrayList<String> a; i=a.iterator(); i.next()
    ```

Exceptions

- **Anything that can go wrong should result in the raising of an Exception in Java**
  - Exception is a class with many subclasses for specific things that can go wrong
- **Use a try - catch block to trap an exception**

```
try
{
   // some code
}
catch (ArithmeticException e)
{
  // code to handle division by zero
}
```

Interfaces

- **Like abstract classes, but cannot have executable statements**
  - Define a set of operations that make sense in several classes
  - Abstract Data Types
- **A class can implement any number of interfaces**
  - It must have concrete methods for the operations
- **You can declare the type of a variable to be an interface**
  - This is just like declaring the type to be an abstract class
- **Important interfaces in Java's library include**
  - Runnable, Collection, Iterator, Comparable, Cloneable

Packages and importing

- **A package combines related classes into subsystems**
  – All the classes in a particular directory

- **Classes in different packages can have the same name**
  – Although not recommended

- **Importing a package is done as follows:**
  – import finance.banking.accounts.*;

Access control

- **Applies to methods and variables**
  - public
    - Any class can access
  - protected
    - Only code in the package, or subclasses can access
  - no modifier (blank)
    - Only code in the package can access but not sub-classes outside package
  - private
    - Only code written in the class can access
    - Inheritance still occurs!

Threads and concurrency

- **Thread:**
  - Sequence of executing statements that can be running concurrently with other threads
- **To create a thread in Java:**
  1. Create a class implementing Runnable or create a class extending Thread
  2. Implement the run method as a loop that does something for a period of time
  3. Create an instance of this class
  4. Invoke the start operation, which calls run

Programming Style Guidelines

- **Remember that programs are for people to read**
  – Always choose the simpler alternative
  – Reject clever code that is hard to understand
    - Stroustrup: *“Don't be clever”*.
  – Shorter code is not necessarily better
- **Choose good names**
  – Make them highly descriptive
  – Lethbridge/Laganière: “Do not worry about using long names”
  – Stroustrup: *“Don't use overly long names; they are hard to type, make lines so long that they don't fit on a screen, and are hard to read quickly.”*

Programming style ...

- **Comment extensively**
  - Comment whatever is non-obvious
  - Do not comment the obvious
  - Comments should be 25-50% of the code
  - Stroustrup: *“If the comment and code disagree, both are probably wrong”*.
- **Organize class elements consistently**
  - Variables, constructors, public methods then private methods
- **Be consistent regarding layout of code**
  - Stroustrup: *“Such style issues are a matter of personal taste. Often, opinions about code layout are strongly held, but probably consistency matters more than any particular style”*

Programming style ...

- **Avoid duplication of code**
  - Do not ‘clone’ if possible
    - Create a new method and call it
    - Cloning results in two copies that may both have bugs
      - When one copy of the bug is fixed, the other may be forgotten

Programming style ...

- **Adhere to good object oriented principles**
  - E.g. the ‘isa rule’

- **Prefer private as opposed to public**

- **Do not mix user interface code with non-user interface code**
  - Interact with the user in separate classes
    - This makes non-UI classes more reusable

10 Difficulties and Risks in Object-Oriented Programming

- **Language evolution and deprecated features:**
  - Java is evolving, so some features are ‘deprecated’ at every release
  - But the same thing is true of most other languages
- **Efficiency can be a concern in some object oriented systems**
  - Java can be less efficient than other languages
    - VM-based
    - Dynamic binding
- **Stroustrup [HOPL-III, 2007]**
  - *“Another problem was that Java encouraged a limited “pure object-oriented” view of programming with a heavy emphasis on run-time resolution and a de-emphasis of the static type system”*