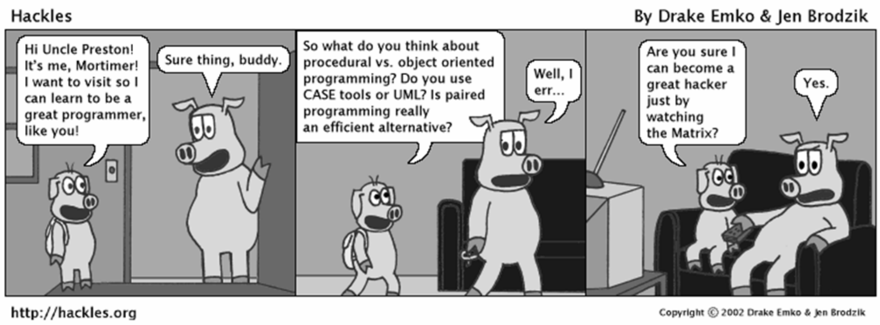
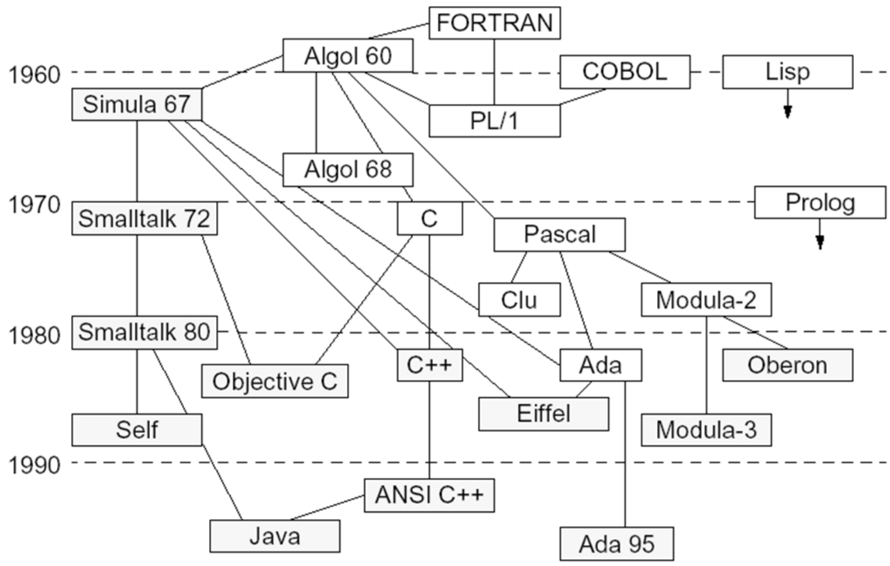
Introduction:
Programming Languages & Paradigms



Programming Language Timeline

- **FlowMatic**
  - 1955 Grace Hopper UNIVAC
- **ForTran**
  - 1956 John Backus IBM
- **AlgOL**
  - 1958 ACM Language Committee
- **LISP**
  - 1958 John McCarthy MIT
- **CoBOL**
  - 1960 Committee on Data Systems Languages
- **BASIC**
  - 1964 John Kemeny & Thomas Kurtz Dartmouth
- **PL/I**
  - 1964 IBM Committee
- **Simula**
  - 1967 Norwegian Computing Center Kristen Nygaard & Ole-Johan Dahl
- **Logo**
  - 1968 Seymour Papert MIT
- **Pascal**
  - 1970 Nicklaus Wirth Switzerland
- **C**
  - 1972 Dennis Ritchie & Kenneth Thompson Bell Labs
- **Smalltalk**
  - 1972 Alan Kay Xerox PARC
- **ADA**
  - 1981 DOD
- **Objective C**
  - 1985 Brad Cox Stepstone Systems
- **C++**
  - 1986 Bjarne Stroustrup Bell Labs
- **Eiffel**
  - 1989 Bertrand Meyer France
- **Visual BASIC**
  - 1990 Microsoft
- **Delphi**
  - 1995 Borland
- **Object CoBOL**
  - 1995 MicroFocus
- **Java**
  - 1995 Sun Microsystems

Programming Language History



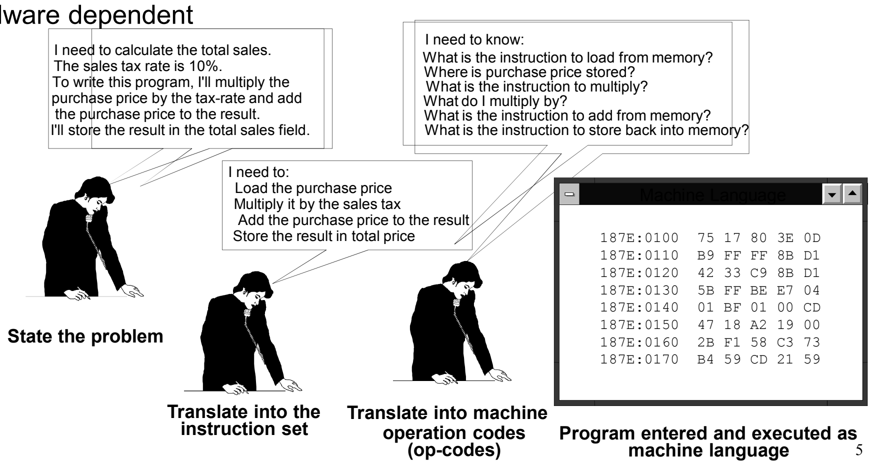
Five Generations of Programming Languages

- First Machine Languages
  - machine codes
- Second Assembly Languages
  - symbolic assemblers
- Third High Level Procedural Languages
  - (machine independent) imperative languages
- Fourth Non-procedural Languages
  - domain specific application generators
- Fifth Natural Languages

- Each generation is at a higher level of abstraction

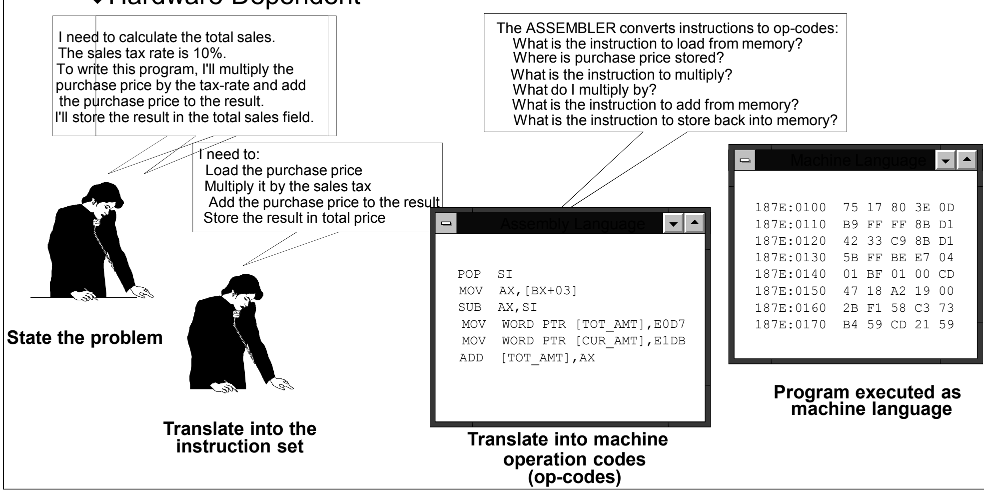
The First Generation (1940s)

- In the beginning … was the Stone Age: Machine Languages
  - Binary instruction strings
  - Introduced with the first programmable computer
  - Hardware dependent



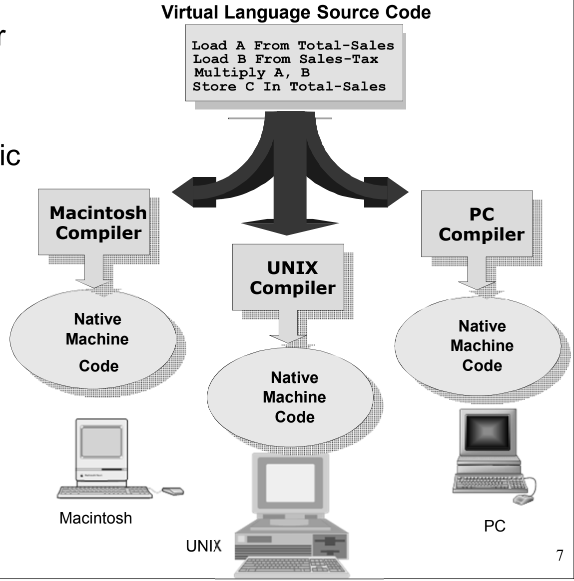
The Second Generation (Early 1950s)

- Then we begin to study improvements: Assembly Languages
  - 1-to-1 substitution of mnemonics for machine language commands
  - Hardware Dependent



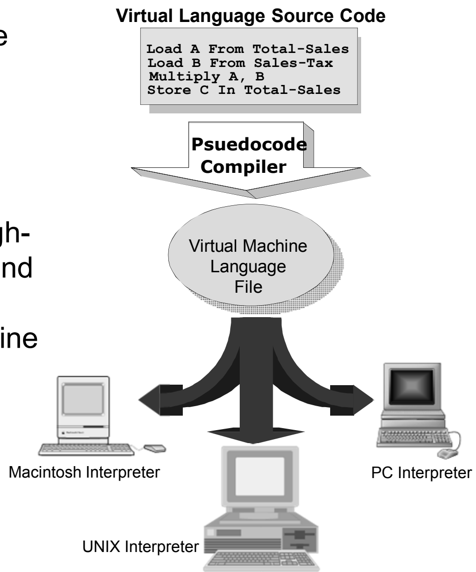
The Second Generation (1950s)

- The invention of the Compiler
  - ◆Grace Murray Hopper (Flowmatic)
- Each CPU has its own specific machine language
  - ◆A program must be translated into machine language before it can be executed on a particular type of CPU



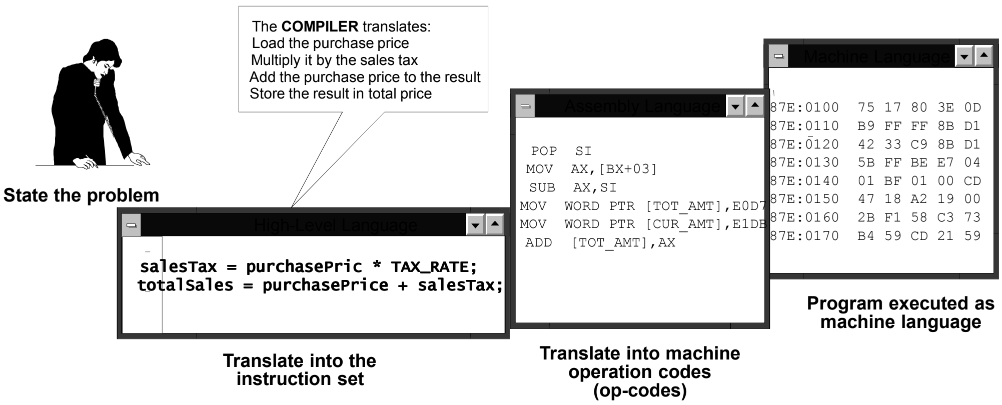
The Second Generation (1950s)

- Interpreters and Virtual Machine Languages
  - ◆Speedcoding
  - ◆UNCOL
- Intermediaries between the statements and operators of high-level programming languages and the register numbers and operation codes of native machine programming languages

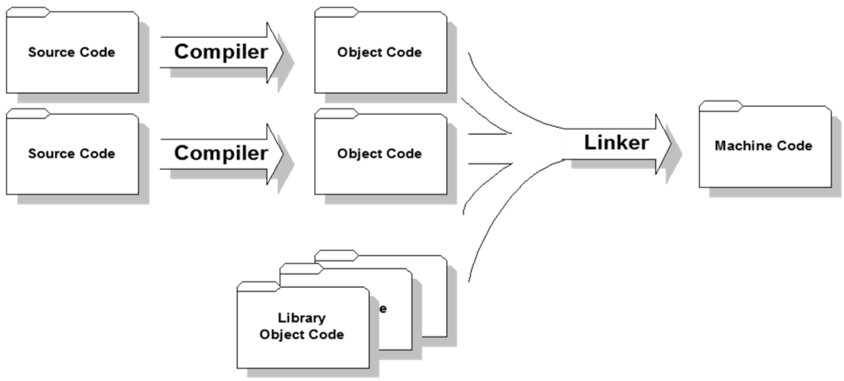


The Third Generation (1955-65)

- *High-level Procedural Languages* make programming easier
  - FORTRAN, ALGOL, LISP, COBOL, BASIC, PL/I



The Conventional Programming Process



- A compiler is a software tool which translates source code into a specific target language for a particular CPU type
- A linker combines several object programs eventually developed independently

Fourth Generation Languages (1980)

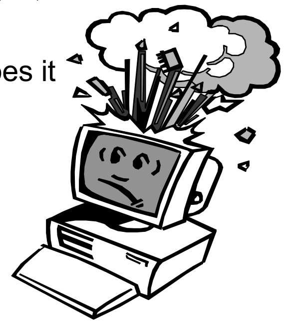
- Non-procedural Languages (problem-oriented)
  - User specifies what is to be done not how it is to be accomplished
  - Less user training is required
  - Designed to solve specific problems
- Diverse Types of 4GLs
  - Spreadsheet Languages
  - Database Query Languages
  - Decision Support Systems
  - Statistics
  - Simulation
  - Optimization
  - Decision Analysis
  - Presentation Graphics Systems

How do Programming Languages Differ?

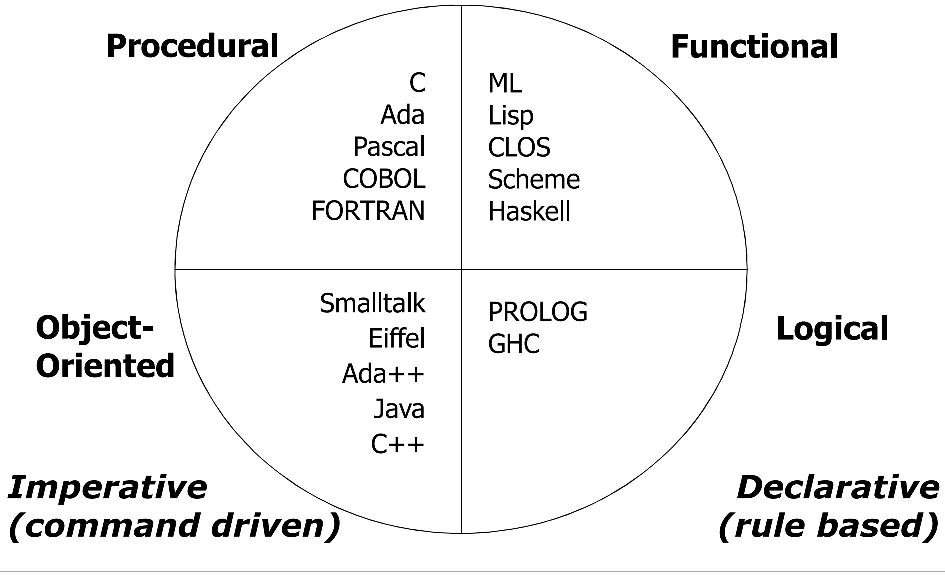
- Common Constructs:
  - basic data types (numbers,etc.);
  - variables;
  - expressions;
  - statements;
  - keywords;
  - control constructs;
  - procedures;
  - comments;
  - errors ...
- Uncommon Constructs:
  - type declarations;
  - special types (strings, arrays, matrices,...);
  - sequential execution;
  - concurrency constructs;
  - packages/modules;
  - objects;
  - general functions;
  - generics;
  - modifiable state;...

Language Styles …

- Procedural Languages
  - ◆Individual statements
  - ◆FORTRAN, ALGOL60, ALGOL68, Cobol, Pascal, C, Ada
- Functional Languages
  - ◆When you tell the computer to do something it does it
  - ◆LISP, Scheme, CLOS, ML, Haskell
- Logic Languages
  - ◆Inference engine that drives things
  - ◆Prolog, GHC
- Object-oriented Languages
  - ◆Bring together data and operations
  - ◆Smalltalk, C++, Eiffel, Sather, Python, Ada95, Java, OCAML



… and Programming Paradigms



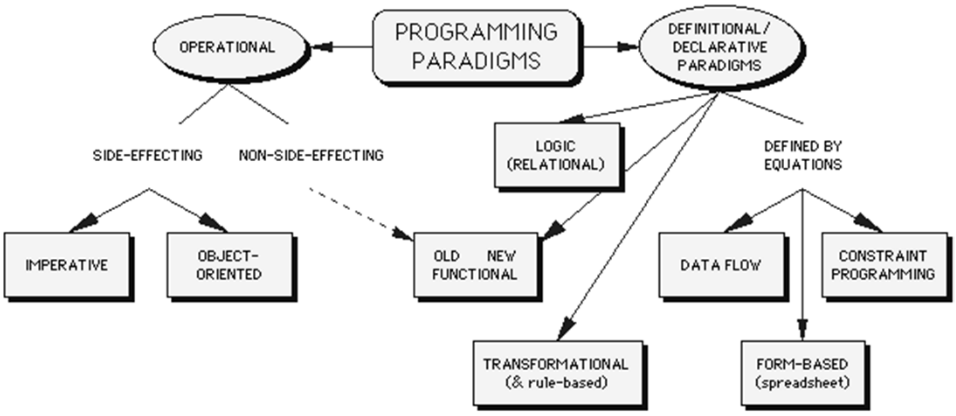
Programming Paradigms

- A programming language is a problem-solving tool

Procedural:	program =algorithms + data good for decomposition
Functional:	program =functions ∘ functions good for reasoning
Logic programming:	program =facts + rules good for searching
Object-oriented:	program =objects + messages good for encapsulation

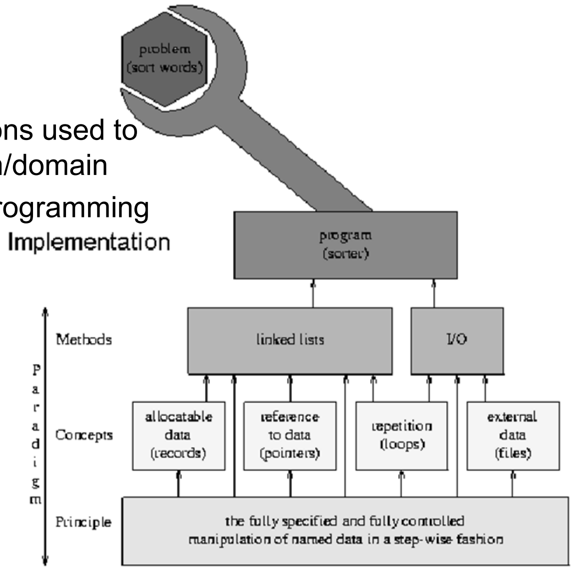
- Other styles and paradigms: blackboard, pipes and filters, constraints, lists,...

Programming Paradigms



What is a Programming Paradigm ?

- A set of coherent abstractions used to effectively model a problem/domain
- A mode of thinking aka a programming methodology



What about Abstractions?

- The intellectual tool that allows us to deal with concepts apart from particular instances of those concepts (Fairley, 1985)
- An abstraction denotes the essential characteristics of an object that distinguish it from all other objects and thus provide crisply defined conceptual boundaries, relative to the perspective of the viewer. (Booch, 1991)
- Abstraction, as a process, denotes the extracting of the essential details about an item, or a group of items, while ignoring the inessential details
- Abstraction, as an entity, denotes a model, a view or some other focused representation for an actual item (Berard, 1993)
- The separation of the logical properties of data or function from their implementation (Dale and Lily, 1995)

What about Abstractions?

- In summary, abstraction allows us access to the relevant information regarding a problem/domain, and ignores the remainder
- Abstraction is a technique to manage, and cope with, the complexity of the tasks we perform
  - The ability to model at the right level a problem/domain, while ignore the rest
- The use of abstraction, both as a noun and a verb, allows us to
  - control the level and amount of detail,
  - communicate effectively with customers and users

Mechanisms of Abstraction

- Abstraction by parameterization abstracts from the identity of the data by replacing them with parameters
  - Example: a function to square an integer
- Abstraction by specification abstracts from the implementation details to the behavior users can depend on.
  - Related terms: contract, interface
- The history of PLs is a long road towards richer abstraction forms

Examples of Abstractions in PLs

- Procedural (abstraction of a statement) allows us to introduce new operations
  - Using the name of a sequence of instructions in place of the sequence of instructions
  - Parameterization allows high level of flexibility in the performance of operations
- Data (abstraction of a data type) allows us to introduce new types of data
  - A named collection that describes a data object
  - Provides a logical reference to the data object without concern for the underlying memory representation
- Control (abstraction of access details) allows us e.g., to iterate over items without knowing how the items are stored or obtained
  - A way of indicating the desired effect without establishing the actual control mechanism
  - Allows designers to model iteration (e.g., Iterator), concurrency, and synchronization

Examples of Abstractions

- Procedural

```
int function search(ListTYPE inList; int item)
double function square(int x)
void function sort(ListTYPE ioList)
```

- Data

```
public abstract class Employee implements Serializable
{ private Name name;
  private Address address;
  private String ssn="999999999";
  private String gender="female";
  private String maritalStatus="single";}
```

- Control

```
#('name' 32 (1/2)) do: [:value|value printOn: Transcript]
#(9 12 6 14 35 67 18) select: [:value|value even]
Iterator y= x.iterator();
while (y.hasNext()) examine(y.next());
```

Programming Methodologies & Abstraction Concepts

Programming Methodologies	**Abstraction Concepts**	**Programming Languages Constructs**
Structured Programming	Explicit Control Structures	Do-while and other loops Blocks and so forth
Modular Programming	Information Hiding	Modules with well-defined interfaces
Abstract Data Types Programming	Data Representation Hiding	User-defined Data Types
Object-Oriented Programming	Reusing Software Artifacts	Classes, Inheritance, Polymorphism

Conversional Programming (1950s)

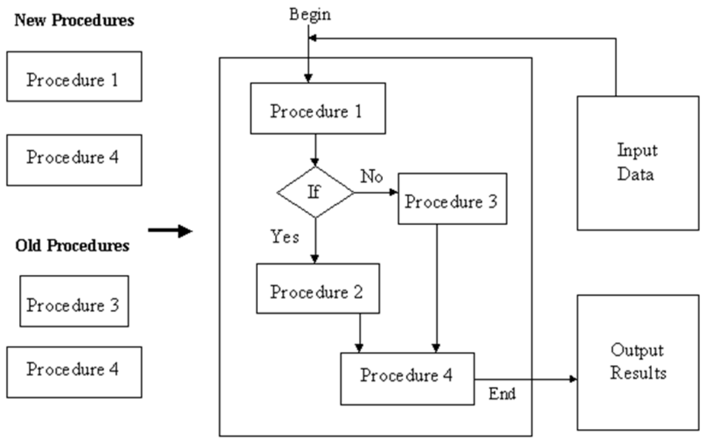
- Execute one statement after the other
- Uses GOTO to jump
- Single Entrance, Single Exit

- Subroutine (GOSUB)
  - Provided a natural division of labor
  - Could be reused in other programs
  - Elimination of Spaghetti-code

```
100   GOTO 500
110   PRINT I;
120   GOTO 400
150   PRINT I * 12;
160   GOTO 450
200   PRINT " = ";
210   GOTO 150
300   PRINT " 12 ";
310   GOTO 200
400   PRINT " * ";
410   GOTO 300
450   I = I + 1
460   IF I > 12 THEN STOP
460   GOTO 110
500   PRINT "The Twelves Table"
510   I = 1
520   GOTO 110
```

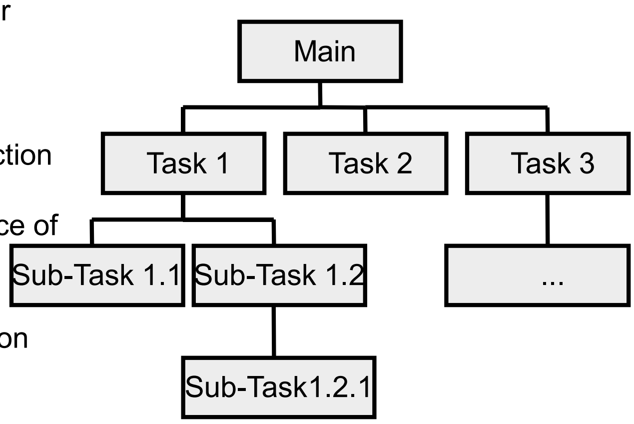
Procedure-Based Programming

- Only 4 programming constructs
  - Sequence
  - Selection
  - Iteration
  - Recursion
- Modularization



Structured Programming (1965)

- Divide and Conquer
  - Break large-scale problems into smaller components that are constructed independently
  - A program is a collection of procedures, each containing a sequence of instructions
- Functional Decomposition

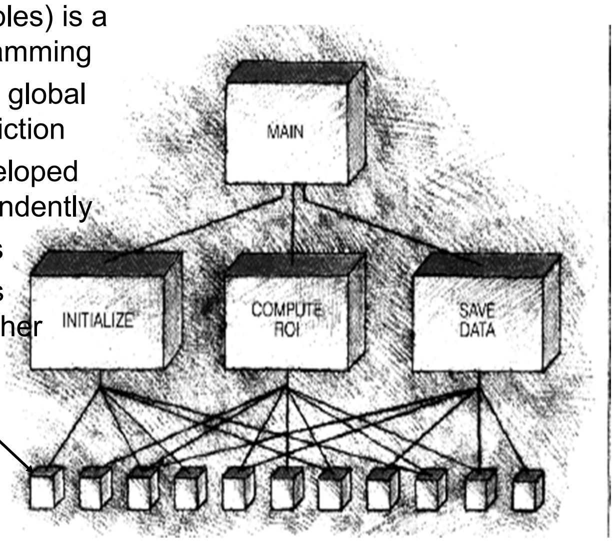


Structured Programming Problems

- Structured programming has a serious limitation:
  - It's rarely possible to anticipate the design of a completed system before it's implemented
  - The larger the system, the more restructuring takes place
- Software development had focused on the modularization of code
  - data moved around
    - argument/parameter associations
  - or data was global
    - works okay for tiny programs
    - Not so good when variables number in the hundreds

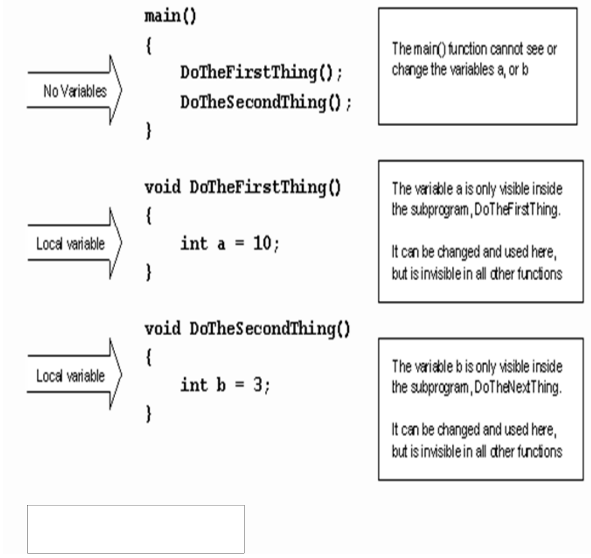
Don't use Global Variables

- Sharing data (global variables) is a violation of modular programming
- All modules can access all global variables without any restriction
  - No module can be developed and understood independently
- Global data are dangerous
  - This makes all modules dependent on one another



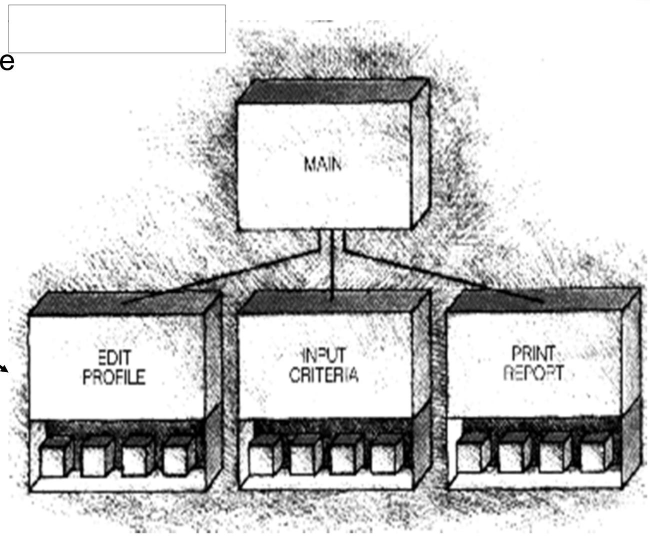
Information Hiding

- An improvement:
  - Give each procedure (module) it's own local data
  - This data can only be "touched" by that single subroutine
  - Subroutines can be designed, implemented, and maintained more easily
- Other necessary data is passed amongst the procedures via argument/parameter associations



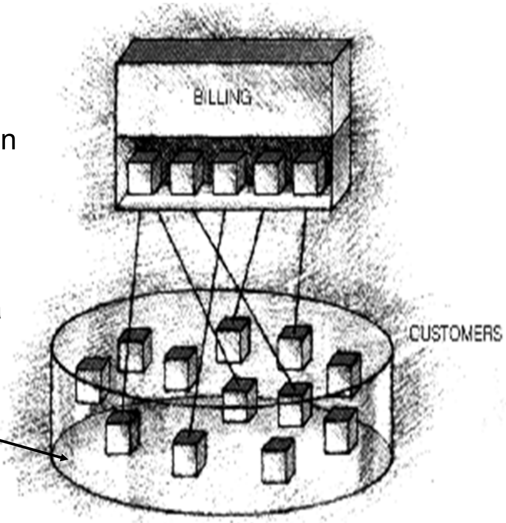
Modularized Data

- Localize data inside the modules
- This makes modules more independent of one another
  - Local Data



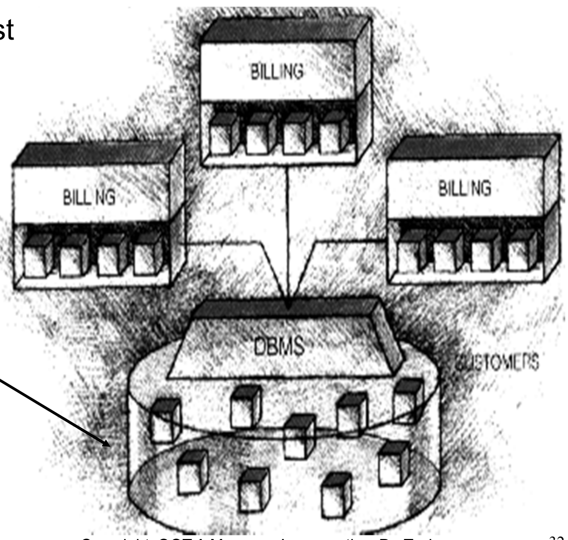
Data Outside of Programs

- Small programs require little input and output
- Large programs work with the same data over and over again
  - Inventory control systems
  - accounting systems
  - engineering design tools
- A program that accesses data store outside of the program
  - Store data in external files



Sharing Data

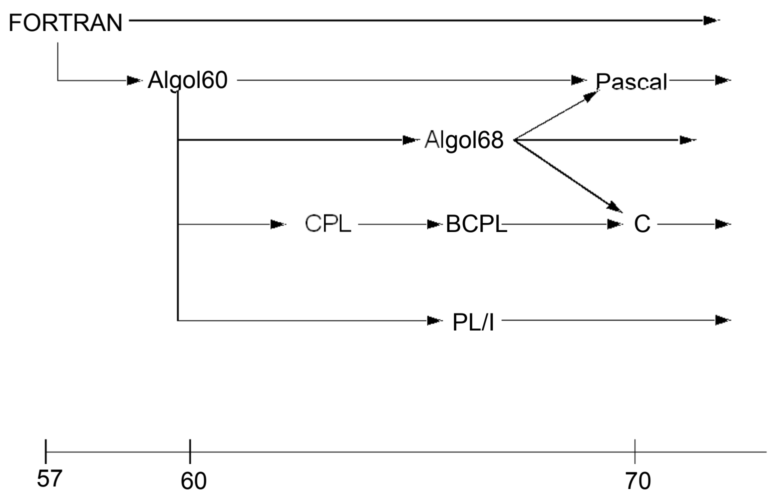
- Many people or programs must access the same file data
  - Requires a data base management system (DBMS)
- Data protected by a DBMS



The Procedural Programming Style

- Defines the world as 'procedures' operating on 'data'
  - procedures have clearly defined interfaces
- This approach doesn't work well in large systems
  - The result is defective software that is difficult to maintain
  - Code reuse limited
- There is a better way !!!

Procedural Programming: History



Imperative Programming

- It is the oldest but still the dominant paradigm
  - It is based on commands that update variables held in storage
  - Variables and assignment commands constitute a simple but useful abstraction from the memory fetch and update of machine instruction sets
  - Imperative programming languages can be implemented very efficiently
- Why imperative paradigm still dominant?
  - It is related to the nature and purpose of programming
- What is a program?
  - Programs are written to model real-world processes affecting real-world objects
  - Imperative programs model such processes
  - Variables model such objects

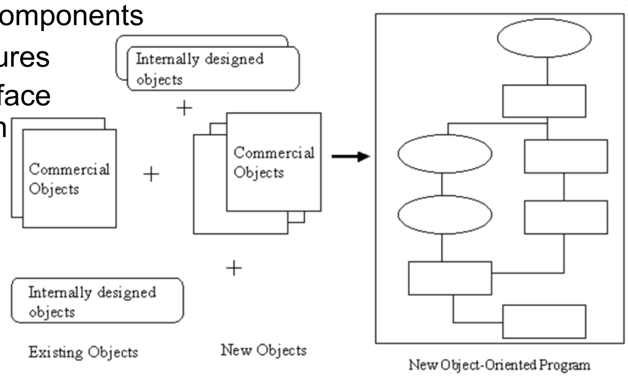
Object-Oriented Programming

The Roots of Object-Oriented Programming

Programming	*sequencing of instructions for the computer*
Procedural Programming	*functional decomposition: functions are building blocks, data is global.*
Modular Programming	*data organized into modules for functions which operate on them*
Object-Based Programming	*models of objects which encapsulate data and functions together: abstraction and info hiding*
Object-Oriented Programming	*modeling of objects also support of inheritance and polymorphism.*

Object-Oriented Programming

- Software Objects: software packet abstracting the salient behavior and attributes of a real object into a software package that simulates the real object
- Well-constructed programs are built on a solid foundation using previously-tested components
  - ◆Link data with procedures
  - ◆If object function/interface is clearly defined, then object implementation may change at will
- OOP key concepts:
  - ◆Object Classes
  - ◆Encapsulation
  - ◆Inheritance
  - ◆Polymorphism



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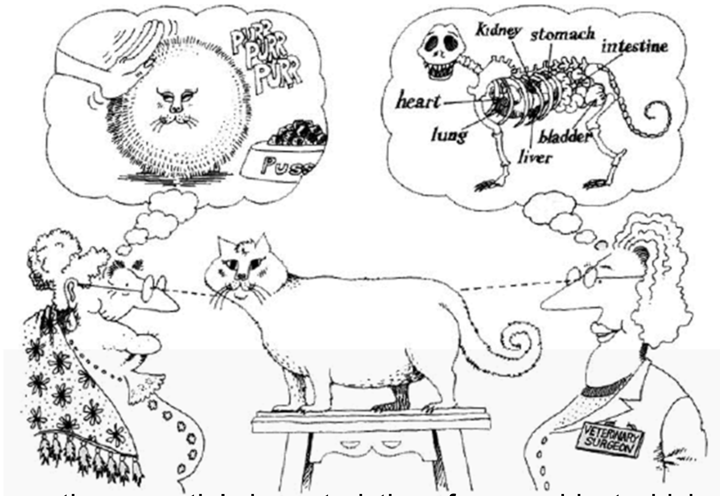
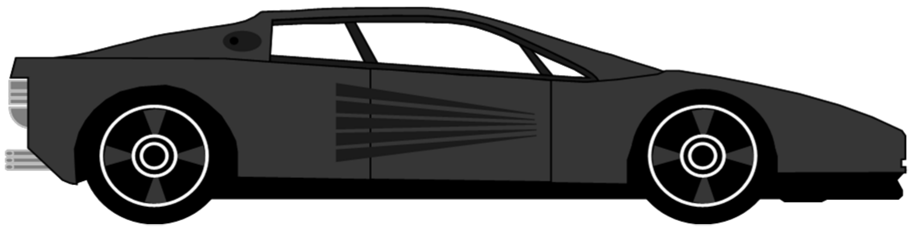
What is Data Abstraction?



- focuses on the essential characteristics of some object which yields clearly defined boundaries
- It is relative to the perspective of the viewer

What are Objects ?

- Real objects are such things as: Ferrari



What are Objects ?

- Real objects are such things as: Greece

What are Objects ?

- Real objects are such things as: Professor

What are Objects ?

- Real objects are such things as: Versateller

What are Objects ?

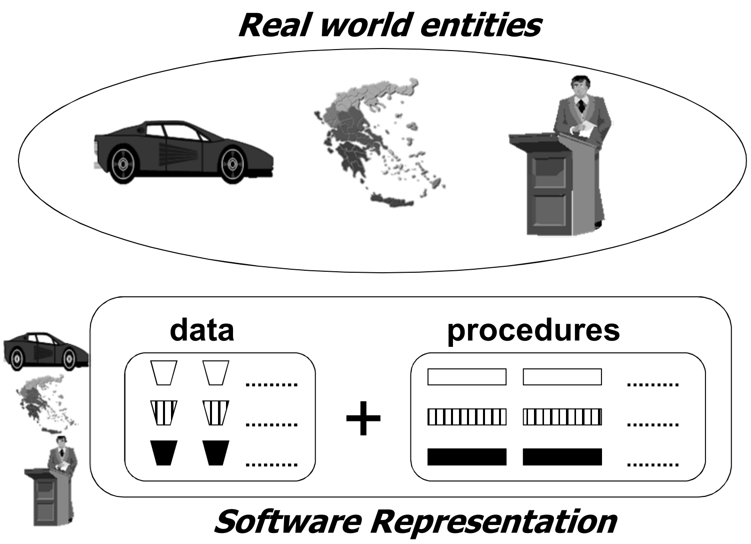
- Real objects are such things as:
  - ❶ Things Ferrari
  - ❷ Places Greece
  - ❸ Persons Professor
  - ❹ Systems Versateller

What are Objects ?

- Real objects have attributes:
  - ❶ Ferrari — Top Speed
  - ❷ Greece — Population
  - ❸ Professor — Courses
  - ❹ Versatellers — Amount on Hand
- Real objects also have behavior:
  - ❶ Ferrari — Accelerate
  - ❷ Greece — Tax
  - ❸ Professor — Teaches
  - ❹ Versatellers — Dispense Cash

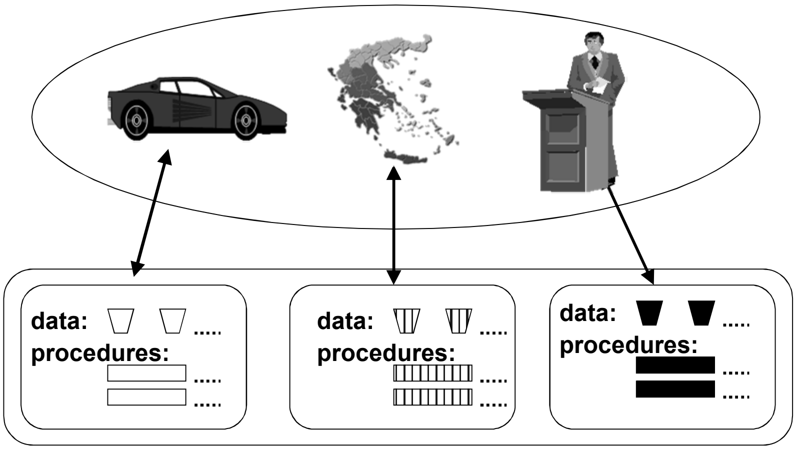
❶ Ferrari	Top Speed	**Accelerate**
❷ Greece	Population	**Tax**
❸ Professors	Courses	**Teaches**
❹ Versatellers	Amount on Hand	**Dispense Cash**

Traditional Representation



Object-Oriented Representation

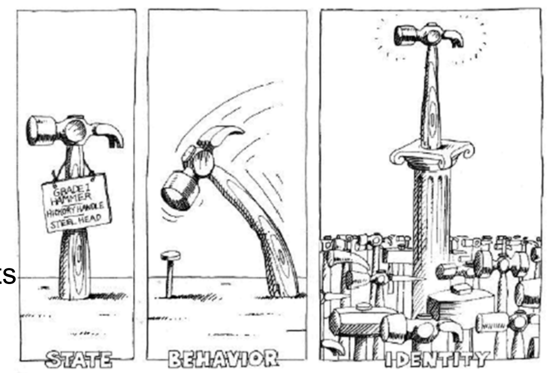
Real world entities



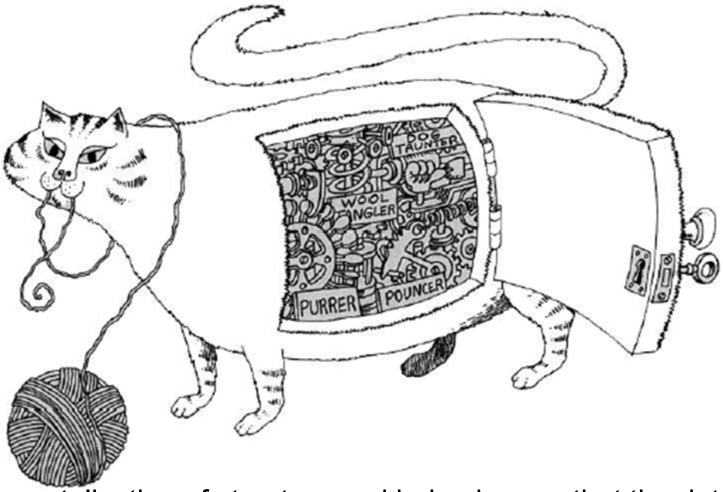
Software Representation

A More Formal Definition

- An object is a concept, abstraction, or thing with sharp boundaries and meaning for an application
- An object is something that has
  - State
    - one of the possible conditions in which an object may exist
    - represents over time the cumulative results of its behaviour
  - Behavior
    - determines how an object acts and reacts to requests from other objects
  - Identity
    - distinguishes it from other similar objects, even if its state is identical to that of another object



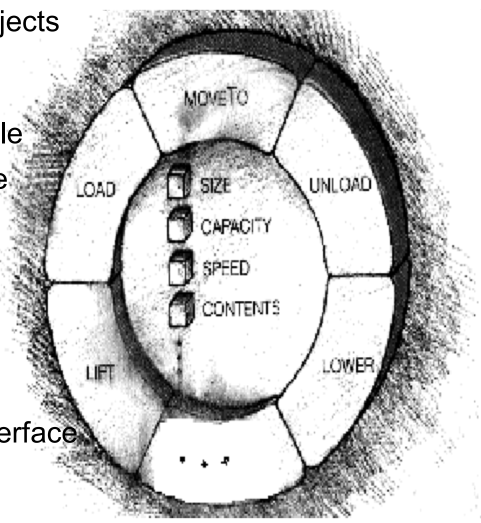
What is Encapsulation?



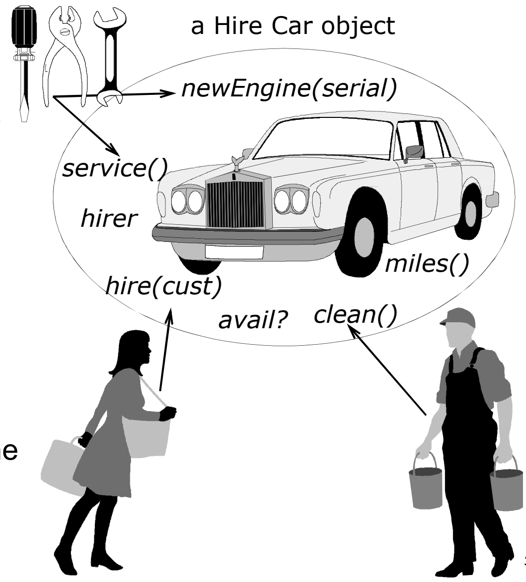
- compartmentalisation of structure and behaviour so that the details of an object's implementation are hidden

OOP Key Concepts: Encapsulation

- Attributes are encapsulated by the objects behavior
  - You don't need to know how the engine works to drive an automobile
- A great deal of functionality is invisible
  - Turn a switch - radio comes on
  - Press a pedal - car accelerates
- The better the design and the tighter the integration with the state of an object makes the object work better
  - separates implementation from interface
  - controlled access to data
  - extends the built-in types
  - allows for greater modularity

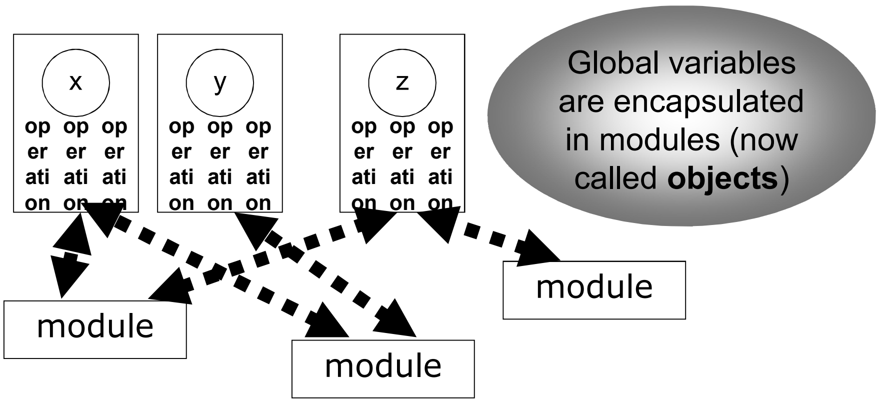


Separation of Responsibilities



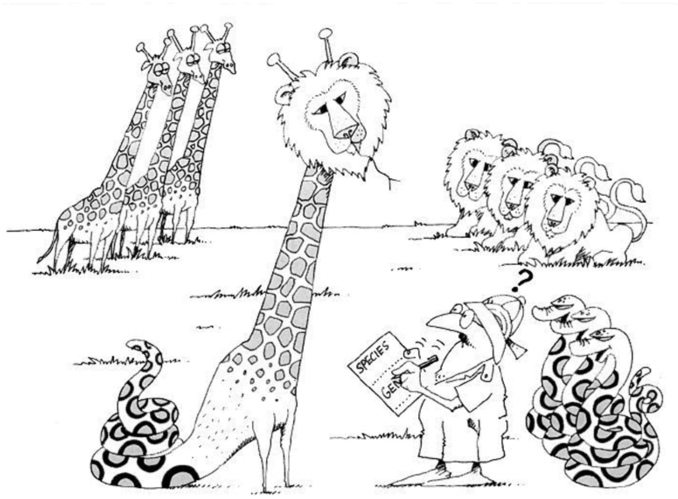
- We give an object responsibility
- We can provide two types of operations:
  - ◆Accessors
    - Methods which return (state) information
  - ◆Transformers
    - Methods which change the object (state) information

More on Encapsulation



- OOP is a discipline that relies on objects to impose a modular structure on programs
- OOP is more securely founded in an imperative language that supports the concept of encapsulation

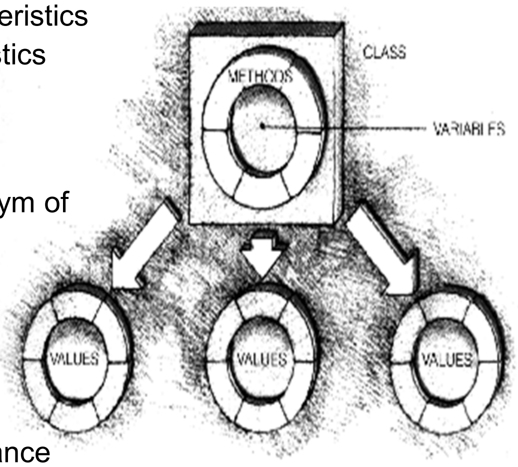
What is a Class?



- a set of objects that share a common structure and behaviour
- every class has zero or more instances

Object Classes

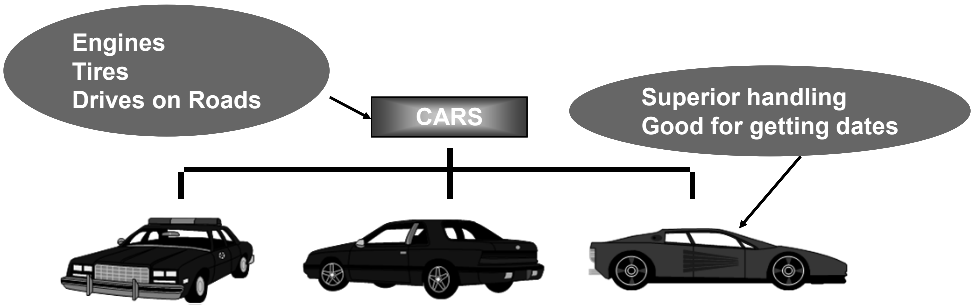
- A class is an abstraction in that it:
  - Emphasizes relevant characteristics
  - Suppresses other characteristics
- Classes are templates used to manufacture objects (instances)
  - Note that instance is a synonym of object
- Objects are similar
  - all cars are similar (belong to class *Car*)
  - difference between a generic concept and a particular instance (*a Ferrari*)



Copyright: OOT A Managers' perspective, Dr. Taylor

A More Formal Definition

- A class is a description of a group of objects with common properties (attributes), behavior (operations), relationships, and semantics
  - Related to others by characteristics



Interpretation/Representation of Objects & Classes

	Interpretation in the real world	Representation in the computer program
Object	An object represents anything in the real world that can be distinctly identified	An object has a unique identity, a state, and behaviors
Class	A class represents a set of objects with similar characteristics and behaviors. These objects are called instance of the class	A class characterizes the structure of states and behaviors that are shared by all its instances

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Object Classes for C Programmers

- A class is similar to a C `struct`

```
typedef struct {
   char* name;
   int age;
} Person;
Person alice;
```

  - **`alice`** is an instance of `struct` **`Person`**
  - In object-oriented programming **`alice`** is an object of class **`Person`**
- Unlike scripting languages and Java, all C data objects have a fixed size over their lifetime
  - except dynamically created objects
- Every data object in C has
  - a name and data type (specified in definition)
  - an address (its relative location in memory)
  - a size (number of bytes of memory it occupies)
  - visibility (which parts of program can refer to it)
  - lifetime (period during which it exists)

What is Inheritance?

- the ordering or ranking of class abstractions
  - important traits are built in at high levels (engine, lights)
  - similar things, work in a similar way (gas pedal on the right)

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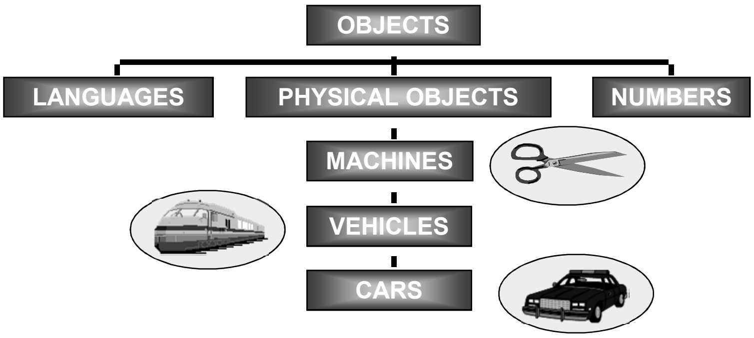
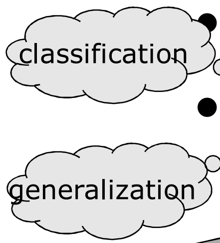
OOP Key Concepts: Inheritance

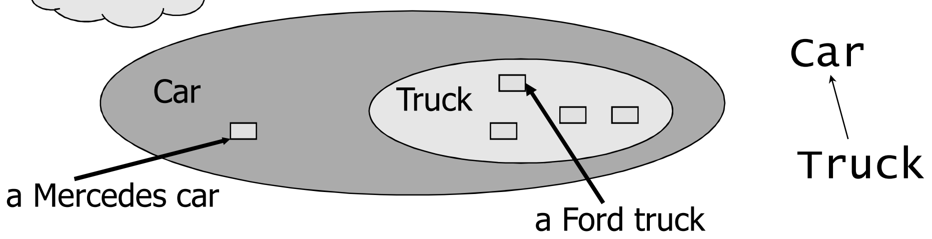


- Inheritance allow classes to use parent classes behavior and structure
  - improves reliability and manageability
  - allows code reusability
  - enforces consistency of interfaces
  - supports rapid software prototyping

The Concept of Generalization

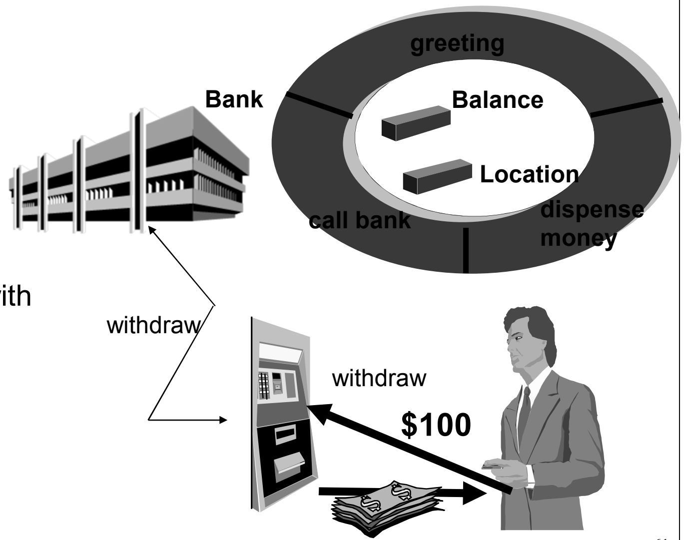


- Class: Implicitly defines a set of objects
  - aCar $\in$ Car = Set of all cars
- Generalization: Subset relation
  - Truck $\subseteq$ Car



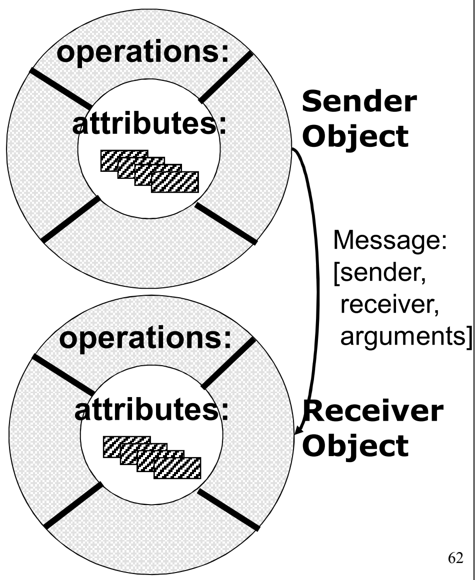
Object Messages

- An object-oriented program consists of objects interacting with other by sending messages



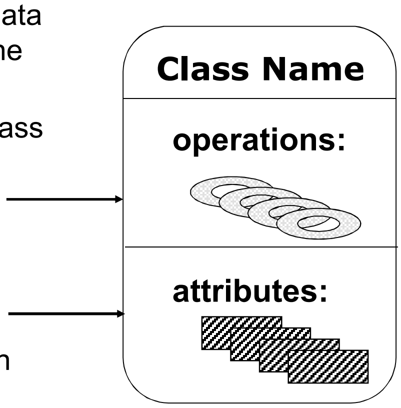
Object Messages

- A message has these three parts:
  - sender: the initiator of the message
  - receiver: the recipient of the message
  - arguments: data required by the receiver
- Receiver determines the code to be executed
  - *Procedural languages*: function name + scope
    ⇨ code
  - *OO languages*: message name + receiving object
    ⇨ code



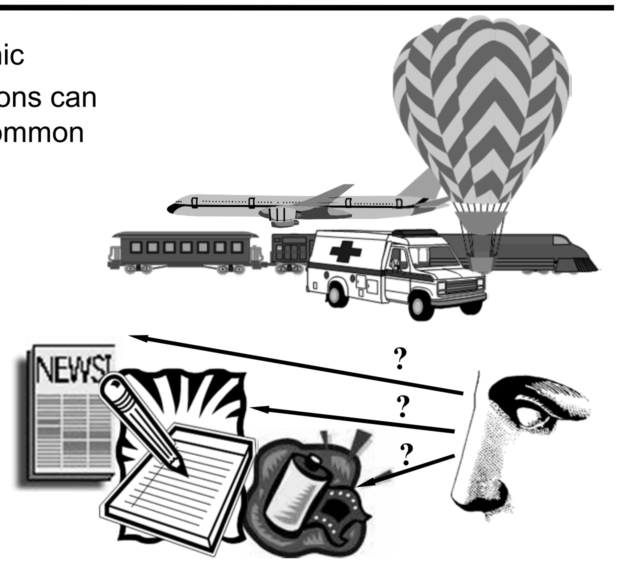
Object Messages and Class Methods

- Methods represent an executable code that is encapsulated in a class and is designed to operate on one or more data attributes that are defined as part of the class
- Methods implement the behavior of class objects
  - ◆Users invoke the methods of a class through messages
  - ◆A class specifies the actual implementation of its methods
- Messages can adapt themselves to an appropriate environment
  - ◆mean different things to different objects



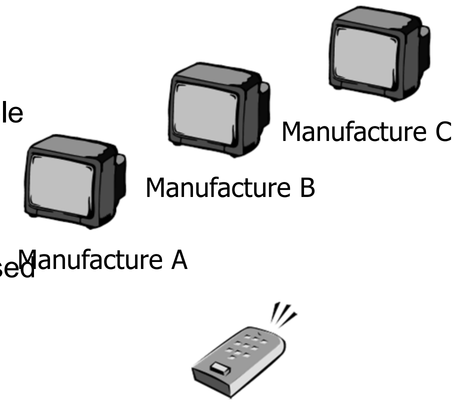
OOP Key Concepts: Polymorphism

- Messages are polymorphic
  - ◆different implementations can be hidden behind a common interface
- Accelerate command
  - ◆automobile
  - ◆train
  - ◆airplane
- Show command
  - ◆video clip
  - ◆newspaper article
  - ◆program source code



What is an Interface?

- Interface formalize polymorphism
- Proper combination of polymorphism and information hiding enables us to design objects that are interchangeable (plug and play compatible)
  - Exact meaning of the command is packaged with the object
  - Allows a simple command to be used to get what we want with different (and future) objects



- Interface support “plug-and-play” functionality

Procedural Programming vs. Using Polymorphism

```
For each Item in List
  if (Item.type is video)
      ShowVideo(Item);
  else if (Item.type is news)
      ShowNews(Item);
  else if (Item.type is code)
      ShowCode(Item);
```

```
For each Item in List
   Show(Item);
```

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What is Modularity?

- packages the abstractions into nice discrete units (components) which are loosely coupled and cohesive

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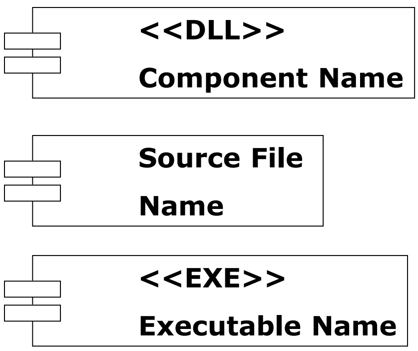
What is a Component?

- A non-trivial, nearly independent, and replaceable part of a system that fulfills a clear function in the context of a well-defined architecture
- A component may be
  - A source code component
  - A run time component or
  - An executable component
- Interfaces can be realized by components



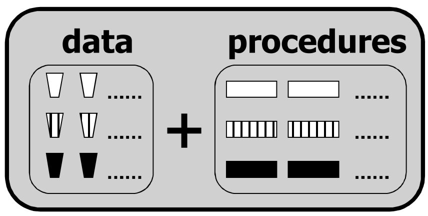
Why Reusable Components Design?

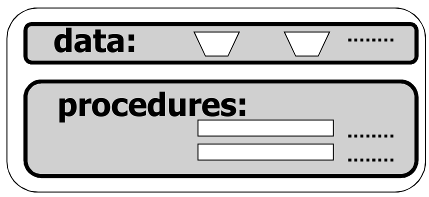
- Autonomy
  - a component/module should be an autonomous entity, so it could work anywhere
- Abstraction
  - it should have a clear abstraction, so others can easily understand it's behavior (know what to expect from it)
- Clear interfacing
  - it should have a clear interface so it will be easy to work with, and to maintain
- Documentation & Naming
  - without documentation and good naming for interface methods, no one will understand how to use it

Object-Oriented Style of Design & Programming

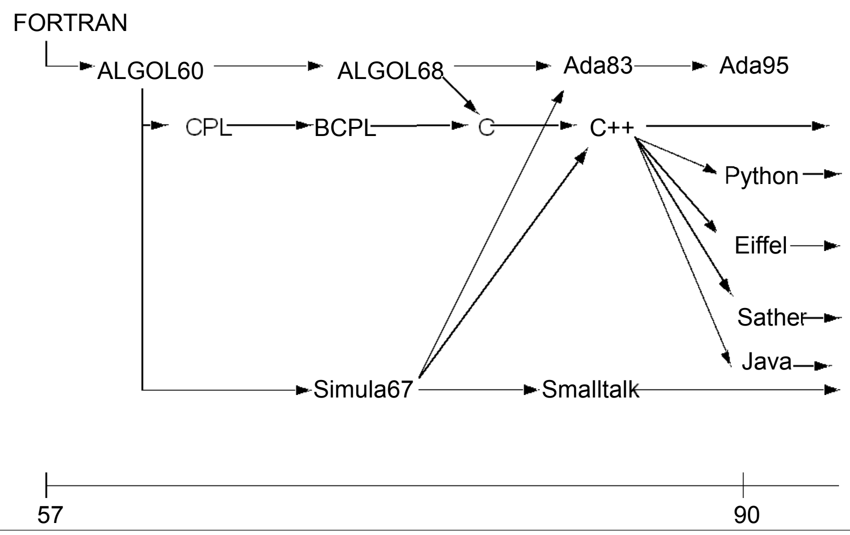
- Three Keys to Object-Oriented Technology
  - Objects
  - Messages
  - Classes

- Translation for structured programmers
  - Variables
  - Function Calls
  - Data Types



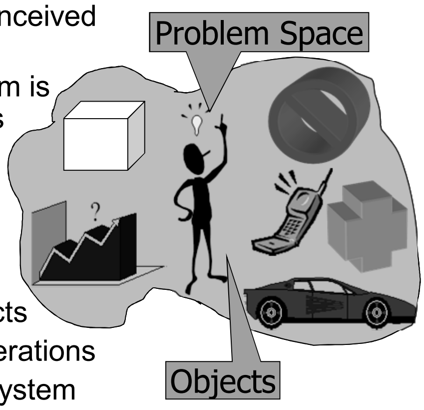


Object-Oriented Programming: History

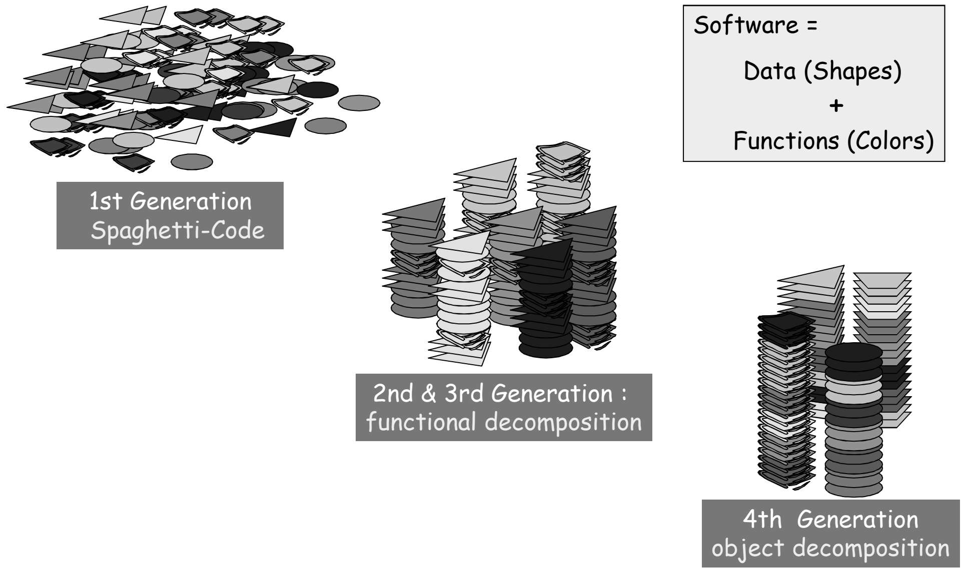


Procedural vs. Object Oriented Programming

- Procedural: Emphasizes Processes
  - ◆Data structures are designed to fit processes
  - ◆Processes and data structures are conceived in solution space
  - ◆In procedural programming, the system is modeled as a collection of procedures
- Object-Oriented: Emphasizes Objects
  - ◆Objects are from the problem space
  - ◆They survive changes in functionality
  - ◆Interpretation of messages is by objects
  - ◆Objects are easier to classify than operations
  - ◆In object-oriented programming, the system is modeled as a collection of interacting objects

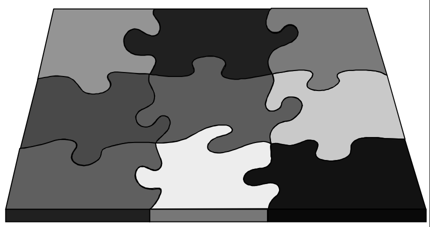


The Evolution of Software Design Methods



The Object Oriented Technology Mindset

- Traditionally, software was developed to satisfy a specific requirements specification
  - A billing system could not be made into something else even if were similar
    - Let the billing system handle mailings or ticklers
- Object Oriented Technology (OOT) has a different mindset
  - Instead of beginning with the task to be performed, OO design deals with the aspects of the real world that need to modeled in order to perform the task



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A Wish for Reuse

- Traditional software started from scratch
  - easier than converting old code--specific task
- Object Oriented Technology stresses reuse
  - objects are the building blocks
  - majority of time spent assembling proven components: e.g,. Graphical User Interface (GUI)
    - Borland's OWL, MS's MFC, or Java Swing
  - But reuse is hard to obtain!
    - Extreme programmers don't strive for it, they just do what they are getting paid to do

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The Promise of the Approach

- Object Oriented Technology offers
  - techniques for creating flexible, natural software modules
  - systems that are much easier to adapt to new demands
  - reuse shortens the development life cycle
  - systems are more understandable and maintainable
    - easier to remember 50 real world classes rather than 500 functions!
- Basic corporate operations change more slowly than the information needs
  - software based on corporate models have a longer life span
- Do you believe it has been easy for corporations to switch to this new technology?

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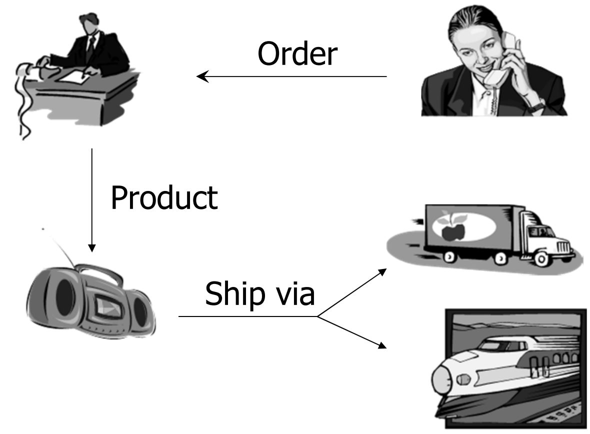
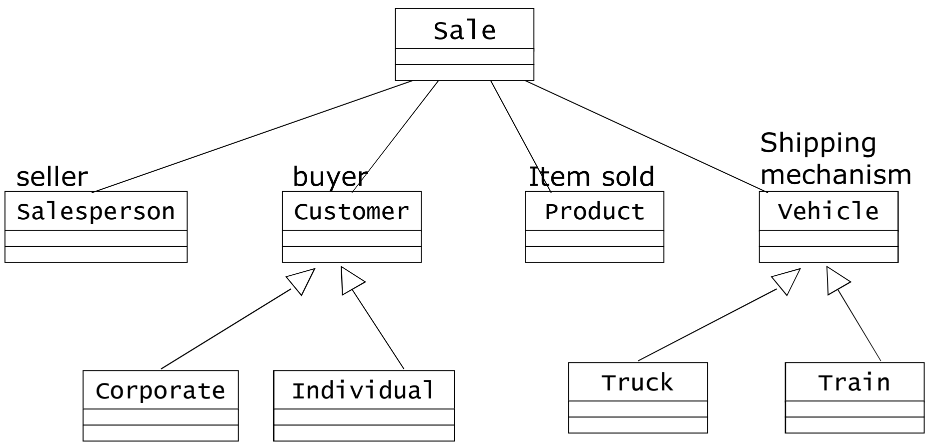
A Simple Sales Order Example

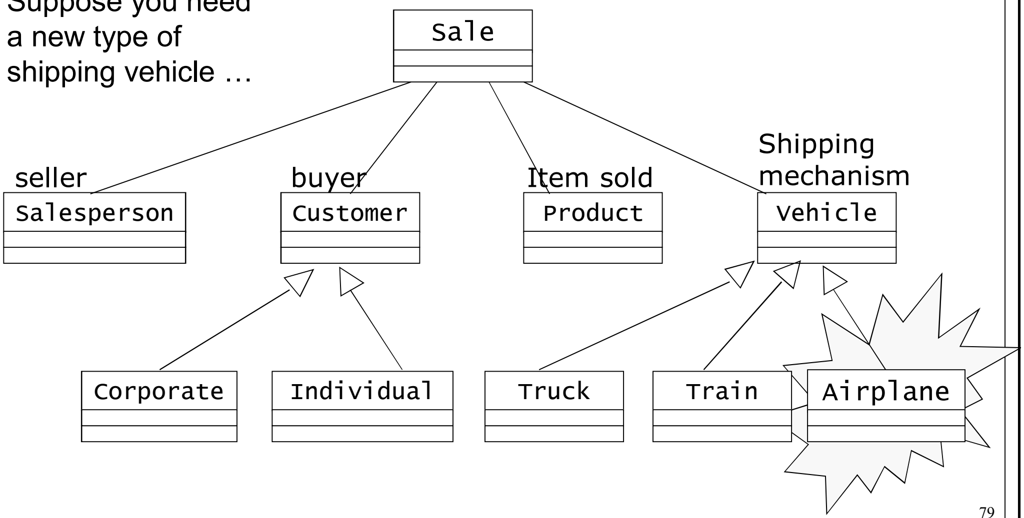


Class Diagram for the Sales Example



Effect of Requirements Change

Suppose you need a new type of shipping vehicle …



Benefits of OOP in Software Development

- We should always strive to engineer our software to make it reliable and maintainable
  - ◆Develop programs incrementally
  - ◆Don't need to understand everything up front (including things you will never use)
  - ◆Avoids spaghetti code
  - ◆No need to start from scratch every time
- As the complexity of a program increases, its cost to develop and revise grows exponentially
  - ◆OOP speeds development time