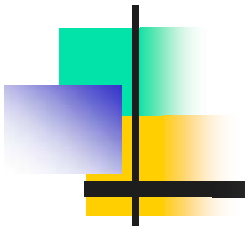
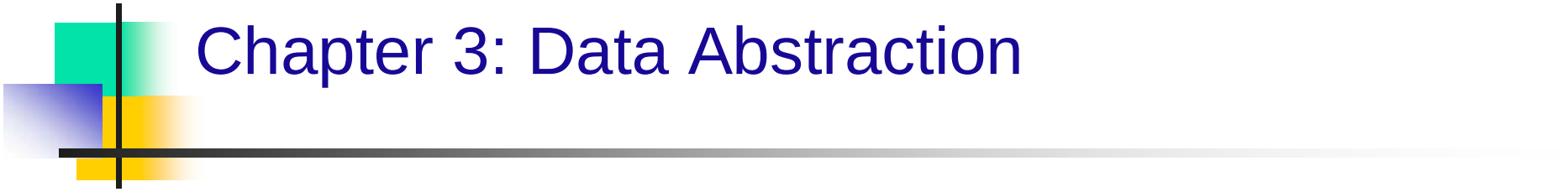


Algorithms and Data Structures: Overview

- Algorithms and data structures
  - Data Abstraction, Ch. 3
  - Linked lists, Ch. 4
  - Recursion, Ch. 5
  - Stacks, Ch. 6
  - Queues, Ch. 7
  - Algorithm Efficiency and Sorting, Ch. 9
  - Trees, Ch. 10
  - Tables and Priority Queues, Ch. 11
  - Advanced Tables, Ch. 12
- 1-1/2 weeks per chapter (keep up on the reading)

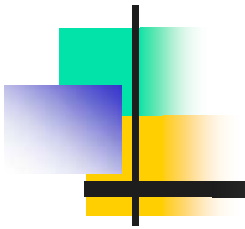


Chapter 3: Data Abstraction

Data Abstraction and Problem Solving with Java: Walls and Mirrors

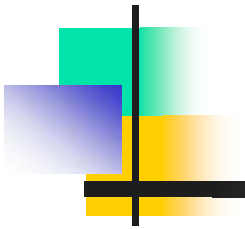
By

Carrano and Pritchard



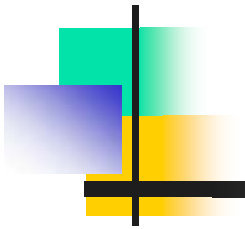
Modularity

- Modularity is:
  - Well-defined components, with
  - Well-defined interfaces
- Technique: *split each object/procedure into simpler objects/procedures until you have trivial objects/procedures that are easy to design and implement*
  - A technique for managing complexity
- Design and implementation focuses on one component at a time
  - Easier to write, read, and modify
  - Isolates errors and eliminates redundancy



Modular Design

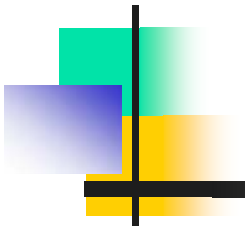
- Interface:
  - **What** each component does
  - **How** you communicate with it (inputs and outputs)
- Design:
  - **How** a component does what it does, using other components
  - Build up complex components from simple ones
- Top-down design
  - Start with a high-level design, then refine until each component until you get to trivial ones
- Bottom-up Implementation
  - Build simple modules and put them together to get complex functionality



Data Abstraction

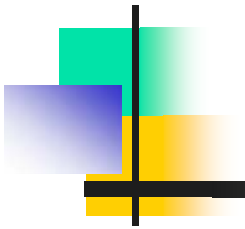
1. Decide what data elements you will be operating on
2. Decide what operations you will be doing to each data element
3. Define a clean interface to these operations
   - That is independent of the implementation
4. Implement the objects
   - Data and data structures
   - Interfaces
   - Procedures

- Now you have an Abstract Data Type (ADT)



ADTs vs. Data Structures

- An ADT is a description of some type of data (or a collection of data) and the operations on that data
  - Example: A Bank
    - It stores money
    - You can deposit, withdraw, write checks, check balance
- A data structure is a way of structuring some collection of data
  - Example: A pile of money, a safe full of money, etc.
- ADTs have clean interfaces, and the implementation details are hidden
- Data structures are often used to implement ADTs

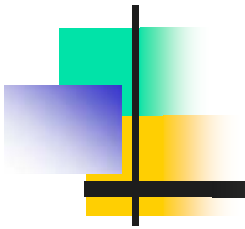


ADT Examples

- Student record
- Class List
- A Student's Transcript
- A complex number
- Graphical elements (e.g., shapes)
- Formatted documents
- A GUI button
- Notice that each of these is a collection of objects
  - Sometimes the objects in the collection are of the same type, and sometimes different types
  - Basic objects vs. container objects
- Let's specify these in more detail

Example: A List

- Think of a list of words:
  - A shopping list
  - A todo list
  - A schedule
  - A list of people in this class
  - Etc.
- In some order
- All of the items are of the same type
- Operations: <discuss>
- Variations: order, type, common operations, size, …



ADT List Operations

1. Create an empty list
2. Determine whether a list is empty
3. Determine the number of items on a list
4. Add an item at a given position in a list
5. Remove the item at a given position in a list
6. Remove all the items from a list
7. Get the item at a given position in a list
8. Other operations?

Specifications: createList()

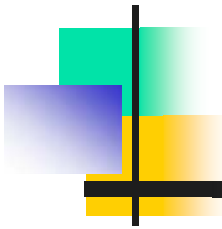
- Description:
  - Creates a new, empty list
- Inputs:
  - Nothing or Type of items in list
- Outputs:
  - None
- Result:
  - A new empty list is created
- What haven't we specified?
  - Size
  - Maybe type
  - Anything else?

Specifications: isEmpty()

- Description:
  - Checks to see if a list is empty
- Inputs:
  - None
- Outputs:
  - *true* if the list is empty
  - *false* if the list is not empty
- Result:
  - The list is unchanged

Specifications: add(index, item)

- Description:
  - Adds an item to a list
- Inputs:
  - index: where in the list to add the item
  - item: the item to add to the list
- Outputs:
  - Throws an exception if the index is out of range, or if the list is full
  - Otherwise, the list now contains item
- Result:
  - If index is valid, item is now in the list and all items after index have moved up one position



Specifications: remove(index)

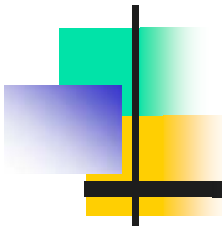
- Description:
  - Removes an item from a list
- Inputs:
  - index: which item to remove
- Outputs:
  - Throws an exception if the index is out of range, or if the list is empty
- Result:
  - If index is valid, the item has been removed from the list and all items above index have been moved down one position

Specifications: removeAll()

- Description:
  - Removes all items from a list
- Inputs:
  - None
- Outputs:
  - None
- Results:
  - The list is now empty

Specifications: get(index)

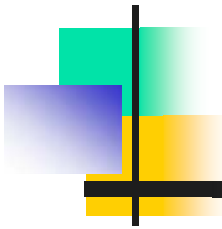
- Description:
  - Gets an item from a list
- Inputs:
  - index: the item to get
- Outputs:
  - Returns the item at the specified index
  - Throws an exception if index is out of range
- Results:
  - The list is unchanged



Example Usage

- Assume lists contains strings

new List aList; **aList**



Example Usage

- Assume lists contains strings

New List aList;

aList.createList();

aList =

Example Usage

- Assume lists contains strings

New List aList;

aList.createList();

aList.add(1, “Milk”);

Example Usage

- Assume lists contains strings

New List aList;

aList.createList();

aList.add(1, “Milk”);

aList.add(2, “Eggs”);

aList

Milk

Eggs

Example Usage

- Assume lists contains strings

New List aList;

aList.createList();

aList.add(1, “Milk”);

aList.add(2, “Eggs”);

aList.add(3, “Butter”);

aList

Milk

Eggs

Butter

Example Usage

- Assume lists contains strings

```
New List aList;
aList.createList();
aList.add(1, “Milk”);
aList.add(2, “Eggs”);
aList.add(3, “Butter”);
aList.add(4, “Apple”);
```

aList
Milk
Eggs
Butter
Apple

Example Usage

- Assume lists contains strings

```
New List aList;
aList.createList();
aList.add(1, “Milk”);
aList.add(2, “Eggs”);
aList.add(3, “Butter”);
aList.add(4, “Apple”);
aList.add(5, “Bread”);
```

aList

Milk

Eggs

Butter

Apple

Bread

Example Usage

- Assume lists contains strings

```
New List aList;
aList.createList();
aList.add(1, “Milk”);
aList.add(2, “Eggs”);
aList.add(3, “Butter”);
aList.add(4, “Apple”);
aList.add(5, “Bread”);
aList.add(6, “Chicken”);
```

aList

Milk

Eggs

Butter

Apple

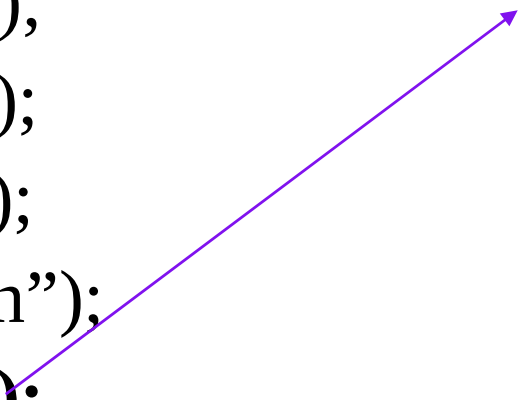
Bread

Chicken

Example Usage

- Assume lists contains strings

```
New List aList;
aList.createList();
aList.add(1, “Milk”);
aList.add(2, “Eggs”);
aList.add(3, “Butter”);
aList.add(4, “Apple”);
aList.add(5, “Bread”);
aList.add(6, “Chicken”);
aList.add(4, “Nuts”);
```

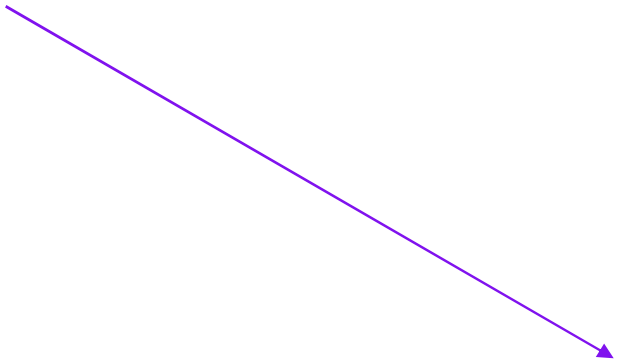


Example Usage

- Assume lists contains strings

New List aList;

aList.remove(5);



aList

Milk

Eggs

Butter

Nuts

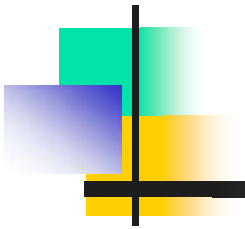
Apple

Bread

Chicken

ADTs Revisited

- ADTS specify
  - What is stored
  - What operations can be performed on that data
  - How to request the operations
  - What is returned
  - The state of the data after the operations
- They **do not** specify
  - How the data is stored
    - Or even that it is stored at all
      - Think of the Bank analogy again
  - How the operations are performed



Our List Operations

- add() adds data to a data collection
- remove() and removeAll() remove data from a data collection
- isEmpty(), size(), and get() ask questions about the data in a data collection

- Other operations
  - displayList()
  - replace()
  - List operations or external operations?

Using a List: displayList(List aList)

```
// Display the items in a List
// Note: independent of List implementation
void displayList(List list) {
    for(int index = 1; index < aList.size(); index++) {
        String dataItem = aList.get(index);
        System.out.println("item "
                + index + ": " + dataItem);
    }
}
```

Using a List: replace(List a, int i, String item)

```
// Replace the list element at index i with item
// Note: independent of List implementation
void replace(List a, int i, String item) {
    if(i >= 1 && i <= a.size()) {
        a.remove(i);
        a.add(i, item);
    }
}
```

Alternate replace(List a, int i, String item)

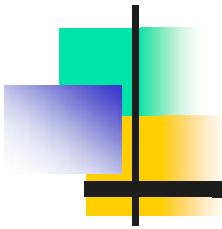
```
// Replace the list element at index i with item
// returns true if the operation succeeded
boolean replace(List a, int i, String item) {
    try {
        a.remove(i);
    } catch(ListException e) {
        return false;
    }
    a.add(i, item);
    return true;
}
```

Example

- See List code

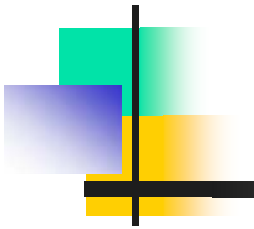
Example: A Sorted List

- Often data is kept in a specified order
  - We call this *sorted data*
- Static lists can be sorted once
- Dynamic lists (with things being added and deleted) require that either
  - The modifications maintain the sorted order, or
  - The data be resorted before certain operations.
- Operations: create(), isEmpty(),size(), add(item), remove(index), removeAll(), get(index), find(item).
- How is this different from a List?



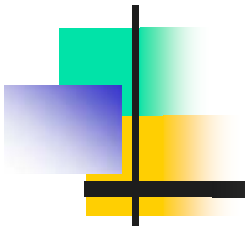
Example: A Phone Book

- Data:
  - Phone records
- Operations:
  - Add an entry
  - Remove an entry
  - Look up someone's phone number (by name)
  - View all entries
  - View one entry at a time, in order
  - Get the number of entries
- Details:
  - Stored in alphabetical order



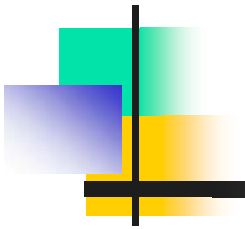
Phone Book Data and Operations

1. void add(String firstName, String lastName, String Number);
2. boolean remove(int index);
3. int find(String firstName, String lastName);
4. String get(index); // returns the number
5. int size();



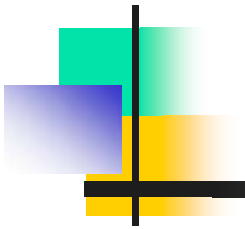
Implementing an ADT

- Once you have clearly defined data and operation, you can implement your ADT
- The implementation must respect the interface that you have defined
- The implementation should be flexible
  - *Don't* arbitrarily limit the size
  - *Don't* make assumptions about how it will be used
- The implementation should be efficient
  - Flexibility and efficiency are sometimes at odds



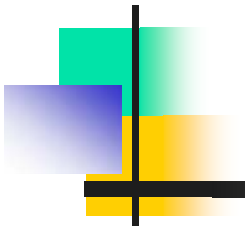
Encapsulation

- Encapsulation: Placing the data and all of the operations together in one well-defined place
- Java supports encapsulation with Classes
- Classes define a new data type (an ADT, in fact)
- Classes contain both the data and the code for the type
  - Called the member data and member functions (or methods) of that type
- How about C?
- How about C++?



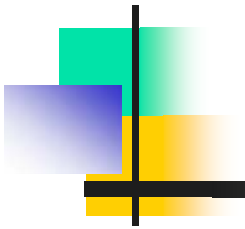
Public vs. Private

- Members (data and methods) can be **public** or **private**
- Private members are accessible only to methods in that class
  - Private members support data hiding
  - By default, everything is private
- Public members are accessible to any method, inside or outside the class
  - These are the interface methods
- In general, the member data should always be private, and all data access should be through methods.



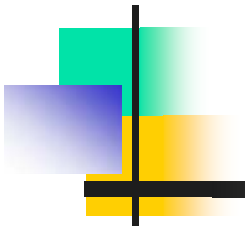
Member Data vs. Local Variables

- Member variables are part of the class
  - They last as long as the object lasts
  - They are accessible by any method in the class
- Local variables are part of a method
  - They last as long as the method is running
  - The are accessible only within the method that they are defined in



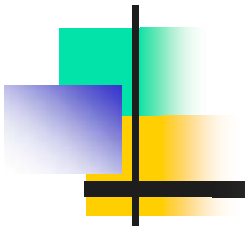
Constructors

- Constructors are special methods
- They are called exactly once, when an object is created using new
- They initialize member variables, and do anything else necessary at object creation
- Constructors always have the same name as the class
- Constructors can take parameters
- Constructors never return anything
- There can be more than one constructor, with different numbers and/or types of parameters



Example

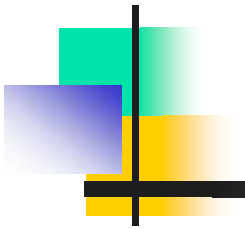
- See Phone Book code



Inheritance

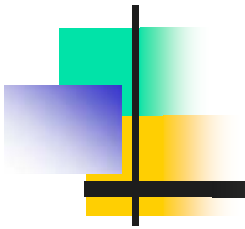
- Inheritance creates new classes as subclasses of existing classes
  - Anywhere the base class would work, but subclass also works (is-a relationship)
  - Example:

```
Class SortedList extends List {
   // Adds in sorted order
   public void add(item) {
         <the new add code>
   }
}
```



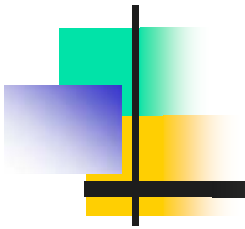
Object Equality

- Be careful when comparing objects
- Be default every object inherits from Object
- Object supports equals()
- But, equals() tests whether or not two objects are the same object
- If you want to be able to compare two objects, write your own equals() method to replace the equals() method in the Object base class
  - Your method should compare the data members for equality



Java Interfaces

- An Interface is a specification of the methods that an object supports
- A class may *implement* an interface
  - It must support all of the methods in the interface, exactly as they are defined in the interface
- A class that implements an interface may be used anywhere that the interface is expected



Java Exceptions

- Exceptions allow objects to signal exceptional conditions to the objects that called them
- They typically indicate run-time errors that are serious, but not fatal
  - Array index out of bounds, invalid parameter, etc.
- In C you would return an error code
- In Java you *throw an exception*
- The exception must be specified in the definition of the method that may throw it
- The calling method must use *try* and *catch*
- *See examples*