CS 635 Advanced Object-Oriented Design & Programming
Spring Semester, 2011
Doc 10 Cohesion
March 1, 2009

Copyright ©, All rights reserved. 2010 SDSU & Roger Whitney, 5500 Campanile Drive, San Diego, CA 92182-7700 USA. OpenContent (http://www.opencontent.org/pl.shtml) license defines the copyright on this document.
Reference

Object Coupling and Object Cohesion, chapter 7 of Essays on Object-Oriented Software Engineering, Vol 1, Berard, Prentice-Hall, 1993,
Some review
Question

Using your favorite OO programming language (Java, C++, Ruby, etc) in which class would you place the following method?

A reverse method that reverses the order of the characters in a string.
Cohesion

"Cohesion is the degree to which the tasks performed by a single module are functionally related."

IEEE, 1983

"Cohesion is the "glue" that holds a module together. It can be thought of as the type of association among the component elements of a module. Generally, one wants the highest level of cohesion possible."

Bergland, 1981

"A software component is said to exhibit a high degree of cohesion if the elements in that unit exhibit a high degree of functional relatedness. This means that each element in the program unit should be essential for that unit to achieve its purpose."

Sommerville, 1989
C - Version

Is this OO?

char* reverse(char *aString)
{
    int stringLength = strlen(aString);
    char reverse[stringLength + 1];
    for (k = 0; k < stringLength; k++)
        reverse[k] = aString[stringLength-k-1]
    return reverse;
}
class MyString
{
    public static char* reverse(char *aString);
}

char* MyString :: reverse(char *aString)
{
    int stringLength = strlen(aString);
    char reverse[stringLength + 1];
    for (k = 0; k < stringLength; k++)
        reverse[k] = aString[stringLength-k-1]
    return reverse;
}
Is this OO?

class MyString
{
    public static String reverse(String toReverse)
    {
        StringBuilder string = new StringBuilder(toReverse);
        StringBuilder reverse = string.reverse();
        return reverse.toString();
    }
}
Java

Is this OO?

class MyString
{
    public String reverse(String toReverse)
    {
        StringBuilder string = new StringBuilder(toReverse);
        StringBuilder reverse = string.reverse();
        return reverse.toString();
    }
}
Some Heuristics

A class should capture one and only one key abstraction

Keep related data and behavior in one place

Beware of classes that have many accessor method in their public interface
Cohesion
Types of Module Cohesion

Coincidental (worst)

Logical

Temporal

Procedural

Communication

Sequential

Functional (best)
Coincidental Cohesion

Little or no constructive relationship among the elements of the module

Common Object Occurrence

Object does not represent any single object-oriented concept

Collection of commonly used source code as a class inherited via multiple inheritance

class Rous{
    public static int findPattern( String text, String pattern) { // blah}

    public static int average( Vector numbers ) { // blah}

    public static OutputStream openFile( String fileName ){ // blah}
}

Tuesday, March 1, 2011
Logical Cohesion

Module performs a set of related functions, one of which is selected via function parameter when calling the module

Cure – Isolate each function into separate operations

```java
public void sample( int flag ){
    switch ( flag ){
    case ON:
        // bunch of on stuff
        break;
    case OFF:
        // bunch of off stuff
        break;
    case CLOSE:
        // bunch of close stuff
        break;
    case COLOR:
        // bunch of color stuff
        break;
    }
}
Temporal Cohesion

Elements are grouped into a module because they are all processed within the same limited time period

Common example

"Initialization" modules that provide default values for objects
"End of Job" modules that clean up

procedure initializeData() {
    font = "times";
    windowSize = "200,400";
    foo.name = "Not Set";
    foo.size = 12;
    foo.location = "/usr/local/lib/java";
}

Cure – Each object should have a constructor and destructor

How is this better?
Temporal Cohesion

Cure
Each object should have a constructor and destructor

How is this better?
Procedural Cohesion

Groups processing elements based on procedural or algorithmic relationships

Procedural modules are application specific

In context the module seems reasonable

Outside the context modules seem strange and very hard to understand

Can not understand module without understanding the program and the conditions existing when module is called

Makes module hard to modify, understand
Class Builder verse Program writer
Communication Cohesion

Operations of a module all operate upon the same input data set and/or produce the same output data

Cure - Isolate each element into separate modules

Rarely occurs in object-oriented systems due to polymorphism (overloading)
Sequential Cohesion

Sequential association the type in which the output data from one processing element serve as input data for the next processing element.

A module that performs multiple sequential functions where the sequential relationship among all of the functions is implied by the problems or application statement and where there is a data relationship among all of the functions.

Cure – Decompose into smaller modules.
Functional Cohesion

If the operations of a module can be collectively described as a single specific function in a coherent way, the module has functional cohesion.

If not, the module has lower type of cohesion.

In an object-oriented system:

Each operation in public interface of an object should be functional cohesive.

Each object should represent a single cohesive concept.
Informational Strength Cohesion

Myers states:

"The purpose of an informational-strength module is to hide some concept, data structure, or resource within a single module.

An informational-strength module has the following definition:

- It contains multiple entry points
- Each entry point performs a single specific function
- All of the functions are related by a concept, data structure, or resource that is hidden within the module"
Object Cohesion
Object Cohesion

The degree to which components of a class are tied together

Evaluating cohesion requires:

Technical knowledge of the application domain

Some experience in building, modifying, maintaining, testing and managing applications in the appropriate domain

Technical background in and experience with reusability
Questions to probe cohesiveness of an object

Does the object represent a complete and coherent concept or does it more closely resemble a partial concept, or a random collection of information?

Does the object directly correspond to a "real world entity," physical or logical?

Is the object characterized in very non-specific terms?
   Collection of data, statistics, etc.

Do each of the methods in the public interface for the object perform a single coherent function?

If the object (or system of objects) is removed from the context of the immediate application, does it still represent a coherent and complete object-oriented concept?
Questions to probe cohesiveness of system of objects

Does the system represent an object-oriented concept?

Do all the objects directly support, or directly contribute to the support of, the object-oriented concept that the system represents?

Are there missing objects?
Objects in Isolation

Isolation means without considering any hierarchy that may contain the object or class
Individual Objects

A primitive method is any method that cannot be implemented simply, efficiently, and reliably without knowledge of the underlying implementation of the object.

A composite method is any method constructed from two or more primitive methods – sometimes from different objects.

A sufficient set of primitive methods for an object is a minimum set of primitive methods to accomplish all necessary work with on the object.

A sufficient set of primitive methods has two major problems:

- Some tasks may be awkward and/or difficult with just a sufficient set of primitive methods.
- A sufficient set of primitive methods may not allow us to fully capture the abstraction represented by the object.

A complete set of primitive methods is a set of primitive methods that both allows us to easily work with the object, and fully captures the abstraction represented by the object.
To implement Java Collection

Subclass java.util.AbstractList and implement
add(int index, Object element)
get(int index)
remove(int index)
size()
set(int index, Object element)

Subclass java.util.AbstractCollection and implement
add(int index, Object element)
iterator()
size()

Iterator implements
hasNext()
next()
remove()

Is either of these a sufficient set of primitive methods?
### Java's ArrayList

<table>
<thead>
<tr>
<th>Method</th>
<th>Method</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>add(int index, Object element)</code></td>
<td><code>add(Object o)</code></td>
<td><code>addAll(Collection c)</code></td>
</tr>
<tr>
<td><code>addAll(int index, Collection c)</code></td>
<td><code>clear()</code></td>
<td><code>clone()</code></td>
</tr>
<tr>
<td><code>contains(Object elem)</code></td>
<td><code>containsAll</code></td>
<td><strong>ensureCapacity</strong> <em>(int minCapacity)</em></td>
</tr>
<tr>
<td><code>equals</code></td>
<td><code>get(int index)</code></td>
<td><code>hashCode</code></td>
</tr>
<tr>
<td><code>indexOf(Object elem)</code></td>
<td><code>isEmpty()</code></td>
<td><code>iterator</code></td>
</tr>
<tr>
<td><code>lastIndexOf(Object elem)</code></td>
<td><code>listIterator</code></td>
<td><code>remove(int index)</code></td>
</tr>
<tr>
<td><code>removeAll</code></td>
<td><code>retainAll</code></td>
<td><code>set(int index, Object element)</code></td>
</tr>
<tr>
<td><code>size()</code></td>
<td><code>subList</code></td>
<td><code>toArray()</code></td>
</tr>
<tr>
<td><code>toArray(Object[] a)</code></td>
<td><code>toArrayList</code></td>
<td><strong>trimToSize</strong></td>
</tr>
<tr>
<td><code>toString</code></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Is this a complete set of primitive methods?
Ruby Array
## Smalltalk OrderedCollection 2

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>increaseCapacity</td>
<td>Increases the capacity of the ordered collection</td>
</tr>
<tr>
<td>indexOf:</td>
<td>Finds the index of an element.</td>
</tr>
<tr>
<td>indexOf:ifAbsent:</td>
<td>Finds the index or returns nil if not found.</td>
</tr>
<tr>
<td>inject:into:</td>
<td>Inserts elements into the collection.</td>
</tr>
<tr>
<td>insert:before:</td>
<td>Inserts an element before another element.</td>
</tr>
<tr>
<td>inspectorClass</td>
<td>Returns the inspector class of the object.</td>
</tr>
<tr>
<td>inspectorClasses</td>
<td>Returns an array of inspector classes.</td>
</tr>
<tr>
<td>isEmpty</td>
<td>Checks if the collection is empty.</td>
</tr>
<tr>
<td>isNotEmpty</td>
<td>Checks if the collection is not empty.</td>
</tr>
<tr>
<td>isSameSequenceAs:</td>
<td>Checks if two ordered collections are the same.</td>
</tr>
<tr>
<td>isSequenceable</td>
<td>Checks if the object sequence is representable.</td>
</tr>
<tr>
<td>isWeakContainer</td>
<td>Checks if the collection is a weak container.</td>
</tr>
<tr>
<td>isWeakContainer:</td>
<td>Checks if an object is a weak container.</td>
</tr>
<tr>
<td>keysAndValuesDo:</td>
<td>Calls a block on each key-value pair.</td>
</tr>
<tr>
<td>last</td>
<td>Returns the last element.</td>
</tr>
<tr>
<td>lastIndexOf:</td>
<td>Finds the index of the last occurrence.</td>
</tr>
<tr>
<td>lastIndexOf:ifAbsent:</td>
<td>Finds the index or returns nil if not found.</td>
</tr>
<tr>
<td>lastObjectError</td>
<td>Returns an error if the collection is empty.</td>
</tr>
<tr>
<td>literalArrayEncoding</td>
<td>Converts the collection to a literal array.</td>
</tr>
<tr>
<td>makeRoomAtFirst</td>
<td>Makes room at the beginning of the collection.</td>
</tr>
<tr>
<td>makeRoomAtLast</td>
<td>Makes room at the end of the collection.</td>
</tr>
<tr>
<td>maxPrint</td>
<td>Returns the maximum printable element.</td>
</tr>
<tr>
<td>newReadWriteStream</td>
<td>Creates a new read/write stream.</td>
</tr>
<tr>
<td>nextIndexOf:from:to:</td>
<td>Finds the index of an element within a range.</td>
</tr>
<tr>
<td>noMatchError</td>
<td>Returns an error if no match is found.</td>
</tr>
<tr>
<td>noSuchElementError</td>
<td>Returns an error if no such element is found.</td>
</tr>
<tr>
<td>notEnoughElementsError</td>
<td>Returns an error if there are not enough elements.</td>
</tr>
<tr>
<td>notFoundError</td>
<td>Returns an error if the element is not found.</td>
</tr>
<tr>
<td>notKeyedError</td>
<td>Returns an error if the object is not keyable.</td>
</tr>
<tr>
<td>occurrencesOf:</td>
<td>Counts the occurrences of an element.</td>
</tr>
<tr>
<td>piecesCutWhere:</td>
<td>Splits the collection at a given condition.</td>
</tr>
<tr>
<td>piecesCutWhere:do:</td>
<td>Splits the collection and performs a block.</td>
</tr>
<tr>
<td>prevIndexOf:from:to:</td>
<td>Finds the index of the previous occurrence.</td>
</tr>
<tr>
<td>writeStream</td>
<td>Creates a write stream.</td>
</tr>
<tr>
<td>printOn:</td>
<td>Prints the object on a stream.</td>
</tr>
<tr>
<td>readStream</td>
<td>Creates a read stream.</td>
</tr>
<tr>
<td>readWriteStream</td>
<td>Creates a read/write stream.</td>
</tr>
<tr>
<td>reject:</td>
<td>Rejects elements that do not satisfy a condition.</td>
</tr>
<tr>
<td>remove:</td>
<td>Removes an element.</td>
</tr>
<tr>
<td>remove:ifAbsent:</td>
<td>Removes an element or returns nil if not found.</td>
</tr>
<tr>
<td>removeAll:</td>
<td>Removes all elements.</td>
</tr>
<tr>
<td>removeAllSuchThat:</td>
<td>Removes all elements that satisfy a condition.</td>
</tr>
<tr>
<td>removeAtIndex:</td>
<td>Removes an element at a given index.</td>
</tr>
<tr>
<td>removeFirst:</td>
<td>Removes the first element.</td>
</tr>
<tr>
<td>removeFirst:</td>
<td>Removes the first element at a given index.</td>
</tr>
<tr>
<td>removeIndex:</td>
<td>Removes an element at a given index.</td>
</tr>
<tr>
<td>removeLast:</td>
<td>Removes the last element.</td>
</tr>
<tr>
<td>removeLast:</td>
<td>Removes the last element at a given index.</td>
</tr>
<tr>
<td>replaceAll:with:</td>
<td>Replaces all elements with another.</td>
</tr>
<tr>
<td>replaceAll:with:from:to:</td>
<td>Replaces elements within a range.</td>
</tr>
<tr>
<td>replaceFrom:to:with:</td>
<td>Replaces elements from a start index.</td>
</tr>
<tr>
<td>replaceFrom:to:with:startingAt:</td>
<td>Replaces elements from a start index.</td>
</tr>
<tr>
<td>representBinaryOn:</td>
<td>Represents the object in binary format.</td>
</tr>
<tr>
<td>reverse</td>
<td>Reverses the elements of the collection.</td>
</tr>
<tr>
<td>reverseDo:</td>
<td>Reverses the elements and performs a block.</td>
</tr>
<tr>
<td>runsFailing:</td>
<td>Returns elements that fail a condition.</td>
</tr>
<tr>
<td>runsFailing:do:</td>
<td>Returns elements that fail a condition and performs a block.</td>
</tr>
<tr>
<td>runsSatisfying:</td>
<td>Returns elements that satisfy a condition.</td>
</tr>
<tr>
<td>runsSatisfying:do:</td>
<td>Returns elements that satisfy a condition and performs a block.</td>
</tr>
<tr>
<td>select:</td>
<td>Selects elements that satisfy a condition.</td>
</tr>
<tr>
<td>setIndices</td>
<td>Sets the indices of elements.</td>
</tr>
<tr>
<td>setIndicesFrom:</td>
<td>Sets the indices of elements from a start index.</td>
</tr>
<tr>
<td>size</td>
<td>Returns the number of elements.</td>
</tr>
<tr>
<td>storeOn:</td>
<td>Stores the object in a variable.</td>
</tr>
<tr>
<td>swap:with:</td>
<td>Swaps the elements with another.</td>
</tr>
<tr>
<td>tokensBasedOn:</td>
<td>Creates tokens based on a given string.</td>
</tr>
<tr>
<td>trim</td>
<td>Trims the elements.</td>
</tr>
<tr>
<td>with:do</td>
<td>Performs a block with each element.</td>
</tr>
</tbody>
</table>
Smalltalk OrderedCollection 3

decrementBy:boundedBy:highValue:wrapAround:
startingAt:replaceElementsIn:from:to:
replaceElementsFrom:to:withArray:startingAt:
replaceElementsFrom:to:withByteArray:startingAt:
replaceElementsFrom:to:withByteEncodedString:startingAt:
replaceElementsFrom:to:withCharacterArray:startingAt:
replaceElementsFrom:to:withIntegerArray:startingAt:
replaceElementsFrom:to:withLinkedList:startingAt:
replaceElementsFrom:to:withSequenceableCollection:startingAt:
replaceElementsFrom:to:withTwoByteString:startingAt:
replaceElementsFrom:to:withWordArray:startingAt:
indexOfSubCollection:startingAt:
indexOfSubCollection:startingAt:ifAbsent:
incrementBy:boundedBy:lowValue:wrapAround:
Levels of Cohesion

An object is not as cohesive as it could be if the public interface contains:

- Only primitive methods, but does not fully capture the abstraction represented by the object
- Primitive and composite methods, but does not fully capture the abstraction represented by the object
- A sufficient set of primitive methods with composite methods
- No primitive methods, just composite methods

Note

Objects with a sufficient set of primitive methods with composite methods is more cohesive than objects with out a sufficient set of primitive methods

All public methods must directly support the abstraction represented by the object. The methods must make sense when object is removed from the application
Composite Objects

A **composite object** is an object that is conceptually composed of two, or more, other objects, which are externally discernible.

**Component objects** are those that make up the composite object.

Component objects are **externally discernible** if

The externally discernible state of the object is directly affected by the presence or absence of one or more component objects

Component objects can be directly queried or changed via methods in the public interface of the composite object and/or
Ranking of Cohesion of Composite Objects
Increasing order of Goodness

Externally discernible component objects not related

Some externally discernible component objects are related, the group component objects does not make sense

The group component objects does not represent a single stable object-oriented concept, but are all bound together some how in an application

A majority of the externally discernible component objects support a single, coherent, object-oriented concept, but at least one does not

All of the externally discernible component objects support a single, coherent, object-oriented concept, but at least one needed is missing

All of the externally discernible component objects support a single, coherent, object-oriented concept, and none are missing
Accessing Cohesion of an Individual Object

Assessment of the public methods/public non-methods/component objects

Are all the items appropriate for the given object?

Do we have at least a minimally sufficient set of items?

Do we have extra or application-specific items?