The Story of a Framework

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Purpose/Approach of Tutorial

- Purpose: Tutorial
  - to review and extend our vocabulary for designing and implementing object-oriented frameworks so that we become more effective in developing them
- Approach: Tutorial
  - shows the design and implementation of a framework using a running and evolving real-world example

Tutorial: Structure

- Part I: Programming (30 min.)
- Part II: Design (90 min.)
- Part III: Frameworks (60 min.)

Part I: Programming

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Part I: Topics

- Classes and interfaces
- Inheritance and code reuse
- Method types
- Unit testing

Part I: Outline

- Step 1: A simple class
- Step 2: An interface and two classes
- Step 3: A class hierarchy with a reusable superclass

Step 1: Topics

- GenericName class
  - a simple class for handling generic names
- Method types
  - query methods
  - mutation methods
  - helper methods
- Unit testing
  - simple unit testing of individual classes using JUnit

Homogeneous Generic Names

- Definition: Homogeneous Generic Name
  - a name that consists of an arbitrary number of components
  - homogeneous, because components are strings and not interpreted further
  - usually has a string representation with designated delimiter char
- Examples
  - "/usr/local/bin", "~riehle/java", "C:\WINNT\system"
  - "java.lang.util", "org.jvalue.Name"
- Counterexamples (heterogeneous names)
  - URL's like "http://developer.java.sun.com/developer/TechTips/index.html"

GenericName Class

- The GenericName class provides one field
  - a Vector, holding the name components
- It defines default delimiter and escape characters

GenericName: Fields

```
public class GenericName {
    public static final char DELIMITER_CHAR= '#';
    public static final String DELIMITER_STRING= "#";
    public static final char ESCAPE_CHAR= '\\';
    public static final String ESCAPE_STRING= "\\";

    private Vector fComponents;
}
```

GenericName: Behavior

- GenericName provides methods for
  - creating a name
  - querying, comparing, and representing the name
  - changing the name

GenericName: Methods

```
public class GenericName {
    public GenericName(String name) { ... }
    public GenericName(Vector components) { ... }

    public String asString() { ... }
    public String asDataString() { ... }

    public boolean isEmpty() { ... }

    public String getFirstComponent() { ... }
    public void setFirstComponent(String nc) { ... }
    public String getLastComponent() { ... }
    public void setLastComponent(String nc) { ... }
    public String getComponent(int index) { ... ]
    public void setComponent(int index, String nc) { ... }

    ...
}
```

Method Types

- Definition: Method Type
  - describes purpose of a method
  - describes what a client is to expect from a method
- Three main categories
  - query methods
  - mutation methods
  - helper methods

Query Methods

- Definition: Query Method (a.k.a. Assessing Method)
  - returns information about this object
  - does not change the state of this object
- Method types in this category
  - get methods (getters); prefix: get (if any)
  - boolean query methods; prefix: is, has, may, or can
  - comparison methods; prefix: is
  - conversion methods; prefix: as, to
- Standard Java examples
  - Object::hashCode(), Object::getClass(), Object::equals()

Mutation Methods

- Definition: Mutation Method
  - changes the state of this object
  - usually does not return any information
- Method types in this category
  - set methods (setter); prefix: set (if any)
  - command methods; prefix: handle, execute
  - initialization methods; prefix: init, initialize
- Standard Java examples
  - Vector::addElement(), Vector::insertElementAt(), Vector::removeElementAt()
  - JComponent::repaint(), JComponent::setVisible(), JComponent::add*Listener

Helper Methods

- Definition: Helper Method
  - performs some support task for this object
  - does not change state of this object, but only of argument objects
  - frequently a static method put into a separate helper class
- Method types in this category
  - general helper methods; prefix: no specific
  - factory methods; prefix: new, create, make
  - assertion methods; prefix: assert, ensure, check
- Standard Java examples
  - String::valueOf()

Unit Testing 1/2

- What is unit testing?
  - unit testing tests quality of an implementation unit
  - unit may be individual class, component, package
  - unit testing is a form of regression testing
- Goals of unit testing
  - gain confidence in quality of implementation
  - increase design through second streamlined view
  - communicate expected behavior (specification)
  - discover and isolate bugs quickly and early on
  - automate testing itself and make it repeatable

Unit Testing 2/2

- Process of unit testing
  - write regular code and test code in parallel
  - evolve regular code and test code in parallel
  - run tests after every non-trivial change

GenericName: Test Case Setup

```
import junit.framework.*;
import org.jvalue.value.name.*;

public class GenericNameTest extends TestCase {
   protected GenericName fGN0; // ("")
   protected GenericName fGN1; // ("##Eliot")
   protected GenericName fGN2; // ("T.##Eliot")
   protected GenericName fGN3; // ("T.#S.#Eliot")

   protected void setUp() {
        fGN0= createGenericName("");
        fGN1= createGenericName("##Eliot");
        fGN2= createGenericName("T.##Eliot");
        fGN3= createGenericName("T.#S.#Eliot");
   }

   ...
}
```


GenericName: Example Test Cases

```
public void testAsString() {
    assertEquals("", fGN0.asString());
    assertEquals("Eliot", fGN1.asString());
}

public void testAsDataString() {
    assertEquals("##", fGN0.asDataString());
    assertEquals("##Eliot", fGN1.asDataString());
}

public void testSetLastComponent() {
    fGN0.setLastComponent("Thoreau");
    assertEquals(createGenericName("##Thoreau"), fGN0);
    fGN1.setLastComponent("Thoreau");
    assertEquals(createGenericName("##Thoreau"), fGN1);
}
```

GenericName: Example Test Run

- The output is simple and reassuring

```
java org.jvalue.value.name.test.GenericNameTest

..........
Time: 0.525

OK (11 tests)
```


Step 2: Topics

- GenericName interface
  - an interface for generic name objects
  - two implementation classes StringName and VectorName
- Interface concept
  - separating interfaces from implementations
  - interface design (method types, design by contract)
- Unit Testing
  - testing an interface
  - test case and test setup inheritance

Implementing Generic Names

- StringName
  - represents a generic name as a single string
  - example: "java.lang.Object" represented as "java#lang#Object"
  - advantage: efficient memory use
  - disadvantage: slow access to individual components
- VectorName
  - represents a generic string as a Vector of strings
  - example: "java.lang.Object" represented as { "java", "lang", "Object" }
  - advantage: fast access to individual components
  - disadvantage: inefficient memory use
- Which class to choose? What if you need both?

GenericName Interface

- GenericName interface
  - defines the generic name abstraction
  - hides different implementation classes behind shared definition
- StringName and VectorName
  - implement the GenericName interface
  - provide behavior within the limits of the GenericName definition
- How to abstract from StringName and VectorName?
- How to make GenericName concrete as implementations?

GenericName: Interface

```
public interface GenericName {
    public String asString();
    public String[] asStringArray();
    public boolean isEmpty();

    public String getComponent(int i);
    public String getFirstComponent();
    public String getLastComponent();
    public NameEnumeration getComponents();
    public int getNoComponents();

    public void append(String component);
    public void insert(int index, String component);
    public void prepend(String component);
    public void remove(int index);

    ...
}
```


StringName: Fields and Methods

```
public class StringName implements GenericName {
    protected String fName;
    protected int fNoComponents;

    // implementation of GenericName interface
    public int getNoComponents() {
        if (fNoComponents == -1) {
            if (!isEmpty()) {
                fNoComponents= getNoChars(fName, getDelChar(), getEscChar())+1;
            } else {
                fNoComponents= 0;
            }
        }
        return fNoComponents;
    }
    ...

}
```

VectorName: Fields and Methods

```
public class VectorName implements GenericName {
    protected Vector fComponents;

    // implementation of GenericName interface
    public int getNoComponents() {
        return fComponents.size();
    }

    ...
}
```


Interfaces

- Definition: Interface
  - a contract between a client and a service object that provides the interface
  - acts as the coupling link between anonymous client and service object
- Contracts are mutual: two perspectives result
  - client perspective: external view
  - implementation perspective: internal view
- Java provides explicit interface concept
  - statically type-checked and guaranteed by the compiler
  - interface specification only on the level of method signatures
  - please note: used for many purposes, we focus on one use

Client and Implementation Perspectives

- Clients ...
  - make use of the interface only
  - must observe contract specified by interface
  - must stick to the interface and ignore implementations
  - are unknown to implementations
- Implementations ...
  - provide behavior defined by the interface
  - may only vary within the limits set up by the interface
  - are unknown to clients that work with interfaces only

Technical Benefits of Interfaces

- Implementations can be evolved without affecting clients
  - improved behavior (smaller, faster)
  - bug fixes behind the scenes
- New implementations can be introduced easily
  - an interface defines no superfluous baggage
  - supports incremental system evolution/delivery
- Implementations can be selected dynamically
  - client gets best service available upon request
  - allows for dynamic loading of services

Organizational Benefits of Interfaces

- Supports teamwork
  - systems are subdivided along interfaces into subsystems
  - teams decouple their work through interfaces
- Supports incremental delivery
  - provide standard implementations first
  - later introduce implementations with higher quality-of-service

Disadvantages of Interfaces

- Increased Complexity
- More typing

Use of the Word "Interface"

- Explicit interfaces (a Java interface)
  - defined using keyword interface
  - example: GenericName
- Implicit interfaces (interface of a Java class)
  - defined by the available methods of a class
  - usually refered to as "class interface"
  - example: interface of GenericName class

Interface Design

- Design by Contract
  - define state space
  - define possible transitions in state space
  - define expected client behavior
- Method design
  - make a method serve one and only one purpose
  - define preconditions/exceptions

Method Design

- Methods serve exactly one purpose
  - query methods
  - mutation methods
  - helper methods
- Mixing purposes spells trouble
  - unless you follow well-established idioms/patterns
  - unless your interface is very simple
  - unless you want to ensure atomicity of operation

StringName: getComponent(int index)

```
public String getComponent(int i) {
    assertIsValidIndex(i);
    return doGetComponent(i);
}

protected String doGetComponent(int i) {
    int startPos= getStartPosOfComponent(i);
    int endPos= getEndPosOfComponent(i);
    String component= fName.substring(startPos, endPos);
    return asUnmaskedString(component);
}
```

VectorName: getComponent(int index)

```
public String getComponent(int i) {
    assertIsValidIndex(i);
    return doGetComponent(i);
}

protected String doGetComponent(int i) {
    return (String) fComponents.elementAt(i);
}
```


Design by Primitives

- Definition: Primitive Method
  - do exactly one specific "primitive" thing
  - encapsulate access to object's state
- Primitive methods ...
  - can be readily composed
  - are typically protected and not accessed from the outside
  - rely on context to make sure preconditions of operation are met
- Definition: Design by Primitives
  - base a class implementation on primitive methods
  - compose client-oriented methods using primitive methods

StringName: Primitive Methods

```
public StringName implements GenericName {
    ...

    protected String doGetComponent(int i);
    protected void doSetComponent(int i, String c);
    protected void doInsert(int i, String c);
    protected void doRemove(int i);
    ...
}
```


Unit Testing of Interfaces

- Testing interfaces or implementations?
  - the quality of an implementation
  - the compliance of an implementation to an interface
- How to test implementations behind interfaces
  - write test code against the interface
  - supply objects of different implementations
  - set up test cases in which different implementations are matched

GenericName: Test Case Setup

```
public abstract class AbstractGenericNameTest extends TestCase {
    protected GenericName fN0; // ("")
    protected GenericName fN1; // ("org", '.')
    protected GenericName fN2; // ("lang.Object", '.')
    protected GenericName fN3; // ("java.lang.Object", '.')

    protected void setUp() {
        fN0= createGenericName("");
        fN1= createGenericName("org", '.');
        fN2= createGenericName("lang.Object", '.');
        fN3= createGenericName("java.lang.Object", '.');
    }

    protected abstract GenericName createGenericName(String name);
    protected abstract GenericName createGenericName(String name, char delChar);
    protected abstract GenericName createGenericName(Vector components);
    ...

}
```


GenericName: Example Test Cases

```
// from AbstractGenericNameTest
public void testAsString() {
    assertEquals("", fN0.asString());
    assertEquals("Object", fN1.asString());
    assertEquals("lang Object", fN2.asString());
    assertEquals("java lang Object", fN3.asString());
}


// from AbstractGenericNameTest
public void testIsEqual() {
    assertEquals(fN0, createGenericName(""));
    assertEquals(fN1, createGenericName("Object"));
    assertEquals(fN2, createGenericName("lang#Object"));
    assertEquals(fN3, createGenericName("java#lang#Object"));
}
```

Step 3: Topics

- AbstractGenericName superclass
  - sharing code through an abstract superclass
  - providing convenient standard implementations
  - moving common helper methods into helper classes
- Abstract superclasses
  - inheritance interface
  - design by primitives
  - narrow inheritance interface principle

Example Method Implementations

```
public String getFirstComponent() {
    return getComponent(0);
}

public void append(String component) {
    insert(getNoComponents(), component);
}

public String asString(char delimiter, char escape) {
    if (isEmpty()) { return ""; }
    StringBuffer sb= new StringBuffer();
    for (int i= 0; i<getNoComponents(); i++) {
        sb.append(doGetComponent(i));
        sb.append(String.valueOf(delimiter));
    }
    sb.setLength(sb.length()-1);
    return sb.toString();
}
```

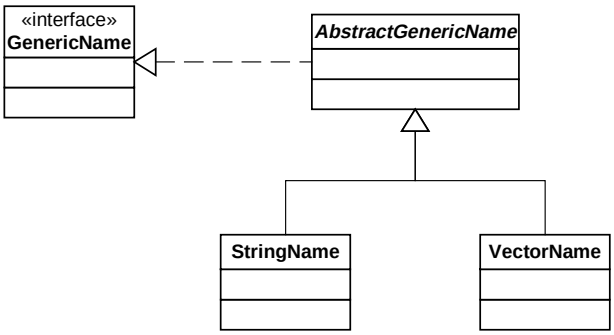
Analysis of Method Implementations

- Similarities between StringName and VectorName methods
  - many similar method implementations
  - all method implementations based on small set of primitive methods
- Only these primitive methods use implementation state

AbstractGenericName Superclass

- AbstractGenericName superclass
  - implements GenericName interface
  - implements all methods except for primitive ones
  - declares primitive methods as abstract
- StringName and VectorName
  - are subclasses of AbstractGenericName
  - implement primitive methods

GenericName: Class Model



AbstractGenericName: Class Definition

```
public abstract class AbstractGenericName implements GenericName {
    public String asString() { ... }
    public int getNoComponents() { ... };
    public String getComponent(int i) { ... };
    public void setComponent(int i, String c) { ... };
    public NameEnumeration getComponents() { ... }
    public void append(String component) { ... }
    public void prepend(String component) { ... }
    public void insert(int i, String c) { ... };
    public void remove(int index) { ... };
    ...
}
```

StringName: doGetComponent(int index)

```
class AbstractGenericName implements GenericName {
    public String getComponent(int i) {
        assertIsValidIndex(i);
        return doGetComponent(i);
    }
    ...

    protected abstract String doGetComponent(int i);
    ...
}

class StringName extends AbstractGenericName {
    protected String doGetComponent(int i) {
        int startPos= getStartPosOfComponent(i);
        int endPos= getEndPosOfComponent(i);
        String component= fName.substring(startPos, endPos);
        return asUnmaskedString(component);
    }
    ...
}
```


VectorName: doGetComponent(int index)

```
class AbstractGenericName implements GenericName {
    public String getComponent(int i) {
        assertIsValidIndex(i);
        return doGetComponent(i);
    }
    ...

    protected abstract String doGetComponent(int i);
    ...
}

class VectorName extends GenericName {
    protected String doGetComponent(int i) {
        return (String) fComponents.elementAt(i);
    }
    ...
}
```

Abstract Superclasses

- Definition: Abstract Class
  - an abstract class cannot be instantiated (= is abstract)
  - in Java, abstract classes are marked by keyword abstract
  - an abstract class is always meant to be a superclass
- Purpose of abstract superclasses
  - to be reused by subclasses
  - to provide common code for subclasses
  - to define a skeleton of control flow for subclasses

Inheritance Interface

- Definition: Inheritance Interface
  - set of abstract methods defined by an abstract superclass
  - inheritance interface serves abstract superclass
  - to be implemented by concrete subclasses
- Design of the inheritance interface
  - should consist of simple methods (design by primitives)
  - should be minimal (narrow inheritance interface principle)

AbstractGenericName: Inheritance Interface

```
public abstract class AbstractGenericName implements GenericName {
    ...

    protected abstract String doGetComponent(int i);
    protected abstract void doGetComponent(int i, String c);
    protected abstract void doInsert(int i, String c);
    protected abstract void doRemove(int i);
    protected abstract GenericName createGenericName(String n);
    ...
}
```


Default vs. Specific Implementation

```
// from AbstractGenericName (default implementation)
public String asDataString() {
    if (isEmpty()) {
        return "";
    }
    StringBuffer sb= new StringBuffer();
    for (NameEnumeration i= getComponents(); i.hasMoreElements();) {
        String s= i.nextComponent();
        s= maskString(s);
        sb.append(s);
        sb.append(DELIMITER_CHAR);
    }
    sb.setLength(sb.length() - 1);
    return sb.toString();
}
```

Specific Implementation

```
// from StringName (fast implementation)
public String asDataString() {
    return fName.toString();
}
```


Part I: Summary

- Classes and interfaces
- Inheritance and code reuse
- Method types
- Unit testing

Part II: Design

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Part II: Topics

- Value objects
- Design aspects
- Design patterns
- Role modeling
- UML collaborations

Part II: Outline

- Step 4: Value Objects
- Step 5: Design Patterns
- Step 6: Role Modeling

Step 4: Topics

- Value objects
  - values and objects
  - working with value objects
- Value object design
  - values as shared immutable objects
  - first take at a value framework design

Object vs. Value Types

- Object types
  - object identity
  - reference semantics
  - referential integrity
- Value types (think ints and floats)
  - no identity, only "occurrences of representations"
  - value semantics ("copy semantics")
  - no integrity constraints on value level
- Programming languages should provide value concept
  - please note the "efficient classes proposal" for Java by James Gosling

Programming with BigInteger

```
// helper method: sums up list of BigInteger objects
public static BigInteger sum(Vector biList) {
    BigInteger result= BigInteger.valueOf(0);
    Enumeration i= biList.elements();
    while(i.hasMoreElements()) {
        BigInteger element= (BigInteger) i.nextElement();
        result= result.add(element);
    }
    return result;
}
```

Programming with Point

```
// how it should be with Point objects... but isn't.
public void move(Point delta) {
    fOrigin= fOrigin.add(delta);
    // rather than: fOrigin.x+= delta.x, fOrigin.y+= delta.y
}
```


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Categories of Value Types

- Primitive value types
  - Character, Integer, String, etc.
- Business domain value types
  - GenericName, Address, Currency, Money, etc.
- Technical domain value types
  - FileName, URL, IPAddress, SecurityTicket, etc.

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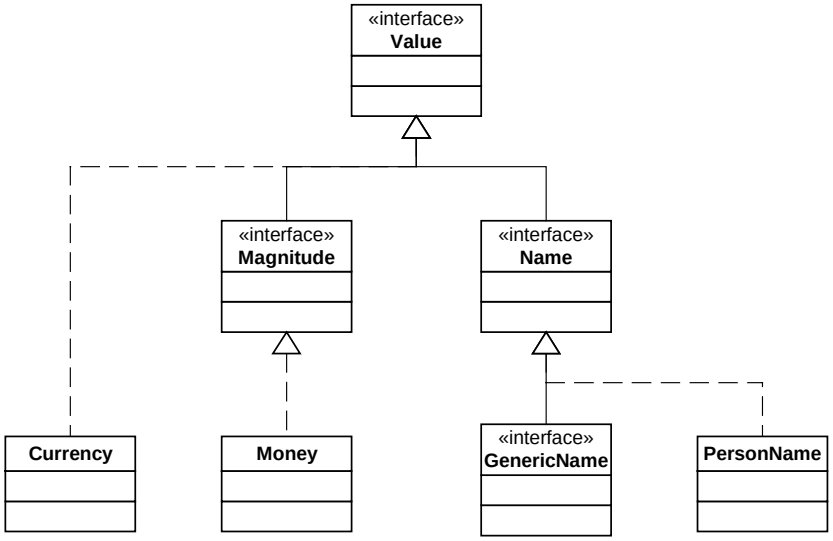
How to Implement Value Objects

- Immutable objects
  - no mutation methods
  - only query and helper (factory) methods
- Shared objects
  - use manager object to control instances
  - protect constructors

Why Use Value Objects?

- Less programming errors
  - no side-effects!!
- Better in-memory performance
  - sharing objects (heap allocated)
  - copying objects (stack allocated, see efficient classes proposal)
  - concurrency: no locking overhead
- Better performance across process boundaries
  - serialization: always copy, no need to check references
  - persistence: no need to maintain referential integrity
  - distribution: always copy, no need to worry about references

Value Interface Hierarchy



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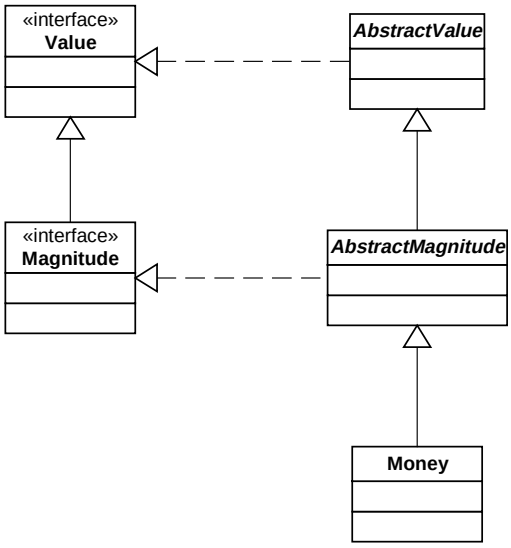
Value Class Hierarchy Implementation



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Value: Interface

```
public interface Value {
    public String asDataString();
    public String asString();
    public boolean isEqual(Value value);
    public boolean isValid();
    public String getTypeName();
    ...
}
```


Magnitude: Interface

```
public interface Magnitude extends Value {
    public boolean isGreater(Magnitude value);
    public boolean isGreaterOrEqual(Magnitude value);
    public boolean isLess(Magnitude value);
    public boolean isLessOrEqual(Magnitude value);
}
```

Money: Class Definition

```
public class Money extends AbstractMagnitude {
   protected Currency fCurrency;
   protected double fAmount;

   protected Money() { ... }

   public double getAmount() { ... }
   public Currency getCurrency() { ... }

   public Money add(Money m) { ... }
   public Money subtract(Money money) { ... }
   public Money multiply(double multiplier) { ... }
   public Money divide(double divisor) { ... }
   public Money negate() { ... }
}
```

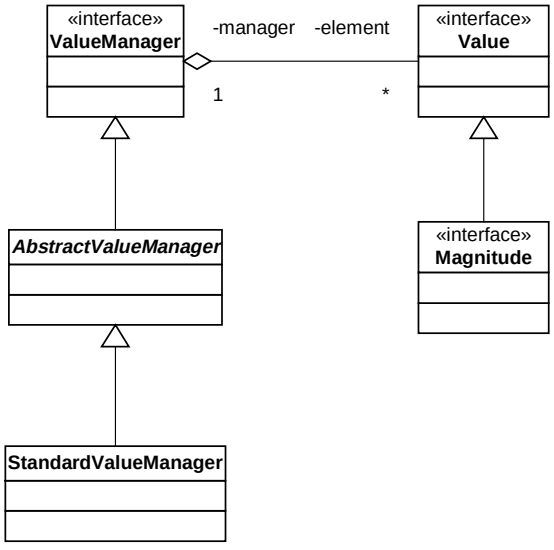

Programming with Money

```
public class Account {
    public Money getBalance() {
        return fBalance;
    }

    public void deposit(Money deposit) {
        // checking, logging, ...
        doSetbalance(getBalance().add(deposit));
    }

    protected void doSetBalance(Money balance) {
        fBalance= balance;
    }

    ...
}
```

ValueManager

- A value manager...
  - maintains list of value object for given type
  - returns value object upon request
  - registers new value objects
- A "proto-" value...
  - serves as a placeholder until new value object is requested
  - is returned as new value object

ValueManager: Class Model



ValueManager: Interface

```
public interface ValueManager {
    public int getNoDistinctValues();
    public int getNoTotalValues();

    public Value getProtoValue();
    public void setProtoValue(Value pv);

    public Value getValue(Value value);

    ...
}
```


Value Object Retrieval/Creation

- Client requests new value object
- Value initializes proto-value
- Value calls on value manager for real value object
- Value manager returns new/matching value object or null
- If null, proto-value is returned

Step 5: Topics

- Design aspects
  - sharing type information: *Type Object*
  - managing objects of same type: *Manager*
  - providing convenient access: *Singleton*
  - reading/writing value objects: *Serializer*
- Design patterns
  - concept of design patterns
  - pattern examples

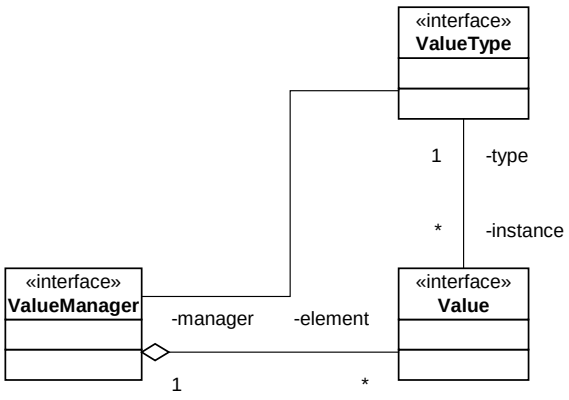
Design Aspect: Value Type Information

- Need to provide type information
  - name of value type
  - cardinality finite/infinite
  - default comparison algorithm
- One possible solution
  - implement type information as static methods
  - but: you program where you should just provide information
  - also: programming is more error-prone

ValueType

- ValueType instance
  - represents value type (class)
  - provides type information for one value type
  - centralizes all type information common to that specific value type
  - is configured at runtime
- ValueType provides operations
  - to access the type name
  - to determine whether value type is of finite cardinality
  - to access and change the current value implementation status
  - and more, as the values are used in more contexts (GUI, etc.)

ValueType: Class Model



ValueType: Interface

```
public interface ValueType {
    public String getName();

    public boolean hasFiniteCardinality();
    public boolean hasInfiniteCardinality();

    ...
}
```


AbstractValue: Type Object Access

```
public AbstractValue implements Value {
    public String getTypeName() {
        return getTypeObject().getName();
    }

    public ValueType getTypeObject() {
        return getValueManager().getValueType();
    }

    ...
}
```

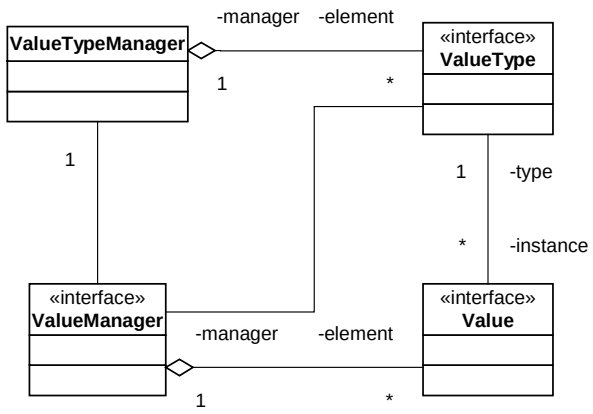
Design Aspect: Managing Objects

- How to learn about value types?
  - need convenient access to value types by string (type name)
- How to learn about available value types?
  - need to iterate over all value types
- Used in GUI's, for serialization, etc.

ValueTypeManager

- ValueTypeManager
  - maintaines ValueType objects
  - serves as convenient access point (by type name)
  - lets you iterate over available value types
- Not an interface, but a single class
  - because it is so simple
  - because it is unlikely to be extended any time soon

ValueTypeManager: Class Model



ValueTypeManager: Class Definition

```
public final class ValueTypeManager {
    protected Hashtable fValueTypes;
    protected static ValueTypeManager sInstance= null;

    public ValueTypeManager() { ... }

    public boolean hasValueType(String name) { ... }
    public ValueType setValueType(String name) { ... }
    public synchronized void addValueType(ValueType vt) { ... }

    public Enumeration getValueTypes() { ... }

    public static final ValueTypeManager getInstance() { ... }
}
```

Design Aspect: Convenient Access

- How to access ValueTypeManager object?
  - you want only one instance that must be shared by all clients
  - passing it as an operation parameter to every client bloats method signatures
- Provide global access point to single instance
  - access points ensures that there is only one instance
  - multithreading may require one instance per thread/operational context
- Single instance is called a Singleton

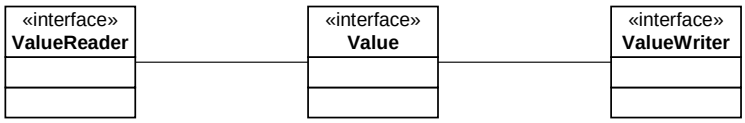
ValueTypeManager: Access

```
public final class ValueTypeManager {
    protected static ValueTypeManager sInstance= null;

    // see Double-Checked Locking pattern by Schmidt et al.
    public static final ValueTypeManager getInstance() {
        if (sInstance == null) {
            synchronized(ValueTypeManager.class) {
                if (sInstance == null) {
                    sInstance= new ValueTypeManager();
                }
            }
        }
        return sInstance;
    }

    ...
}
```

Design Aspect: Serialization of Values

- How to read and write value objects?
  - you need different formats for different purposes/backends
  - you don't want to change value type implementations for a new backend
  - you don't want clients to depend on specific value types

ValueReader/ValueWriter: Class Model



ValueWriter: Interface

```
public interface ValueWriter {
    public void writeBoolean(String fieldName, boolean value) throws IOException;
    public void writeBoolean(String fieldName, Boolean value) throws IOException;
    ...

    public void writeString(String fieldName, String value) throws IOException;
    public void writeVector(String fieldName, Vector value) throws IOException;
    ...

    public void writeInitialValue(Value value) throws IOException;
    public void writeValue(String fieldName, Value value) throws IOException;
    ...
}
```


Money: writeOn(ValueWriter)

```
public void writeOn(ValueWriter writer) throws IOException {
    writer.writeValue("currency", fCurrency);
    writer.writeDouble("amount", fAmount);
}
```

Serialization: Writing a Value Object

- Client retrieves/creates ValueWriter object
- Client calls writeInitialValue on writer with value as argument
- Writer calls writeOn on value with itself as argument
- Value calls write* methods of writer object

- Recursive descent is ended by primitive value types

Design Patterns

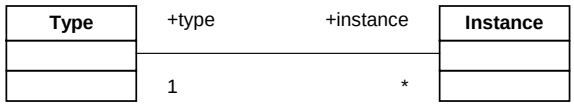
- Definition: Design Pattern
  - the abstraction from a recurring form in a specific context
  - form is frequently a problem solution (but not always!)
  - grow out of experience with designing and implementing systems
  - are documented in a structured form (see *Design Patterns* book)

- Experience and design patterns
  - you need experience to understand and apply a design pattern
  - design patterns are seldom helpful to novices (or as teaching devices)

Type Object: Explanation

- Intent: Type Object
  - represent type as object to decouple instances from their classes
  - be able to change type and create new types at runtime
- Definition: Type Object
  - is an object that represents a given type
  - is independent of the implementing class
- Examples
  - ValueType
  - (Class, Method, etc.)

Type Object Pattern: Structure Diagram



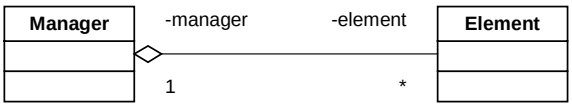
Type Object: Applicability

- Applicability (when to use)
  - if you need to flexibly provide type information
  - if you have a proliferation of subclasses
  - if you need to create new types dynamically
  - ...
- Consequences
  - you configure types rather than program them
  - you avoid subclass proliferation
  - you can change types dynamically
  - you increase design complexity
  - ...

Manager: Explanation

- Intent: Manager
  - encapsulate the management of instances of a class in a manager object
  - be able to vary management behavior independently of managed objects
- Definition: Manager
  - is an object that centralises management of set of managed objects
  - may comprise full life-cycle: creation, access, deletion
- Examples
  - ValueManager, ValueTypeManager
  - (java.awt.Container, java.rmi.Registry)

Manager: Structure Diagram



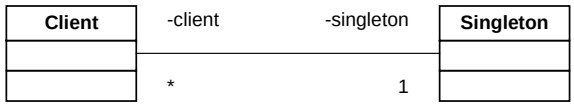
Manager: Applicability

- Applicability (when to use)
  - if elements of set of objects need to be managed properly
  - if you want to separate management from managed objects
  - ...
- Consequences
  - management is handled explicitly rather than buried in code
  - management can be changed without affecting managed objects
  - ...

Singleton: Explanation

- Intent: Singleton
  - ensure that a class has only one instance
  - provide a global point of access to it
- Definition: Singleton
  - is a globally accessible one-of-a-kind object
  - in multithreaded systems, there may be singletons-per-thread, etc.
- Examples
  - ValueTypeManager

Singleton: Structure Diagram



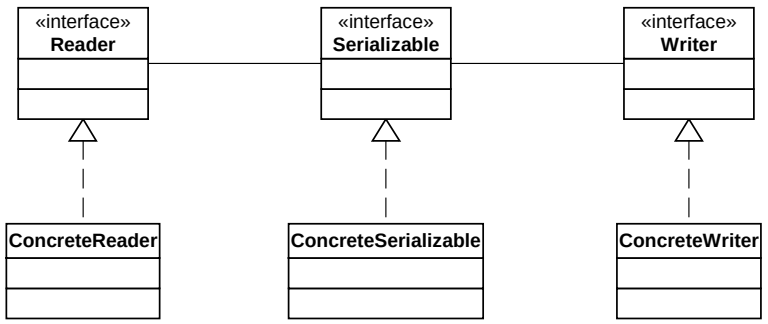
Singleton: Applicability

- Applicability (when to use)
  - if there must be exactly one instance of a class (in a given context)
  - if you want to change implementations without affecting clients
- Consequences
  - you get controlled access to the singleton
  - you can change implementations without affecting clients
  - the singleton is globally accessible
  - ...

Serializer: Explanation

- Intent: Serializer
  - encapsulate reading/writing algorithm of object structures in dedicated objects
  - thereby, efficiently read and write object structures from varying backends
  - backends may be flat files, relational databases, all kinds of buffers, etc.
- Definition: Serializer
  - is an object that either reads (Reader) or writes (Writer) an object structure
- Examples
  - Value/ValueReader/ValueWriter
  - Serializable/ObjectInputStream/ObjectOutputStream

Serializer: Structure Diagram



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Serializer: Applicability

- Applicability (when to use)
  - if you need to read/write objects in varying formats
  - if you need to add new formats without affecting the objects to be read/written
  - ...
- Consequences
  - it is easy to add new/change existing formats and backends
  - makes primary objects simpler to implement
  - requires implementation of a Serializable interface
  - weakens encapsulation due to generic field access protocol
  - ...

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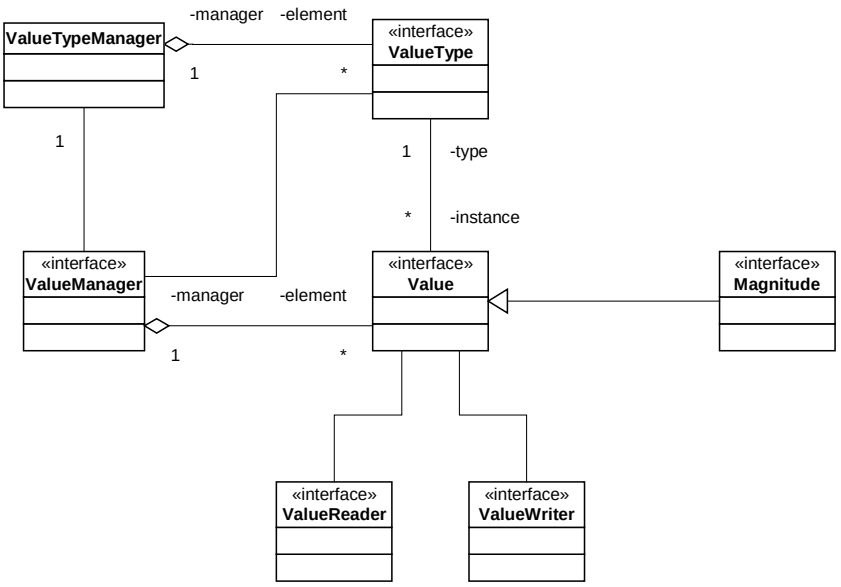
Value: Overall Class Model



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Value Class Model: High Pattern Density

- Sharing type information: *Type Object*
- Managing objects of same type: *Manager*
- Providing convenient access: *Singleton*
- Reading/writing value objects: *Serializer*
- And others more...

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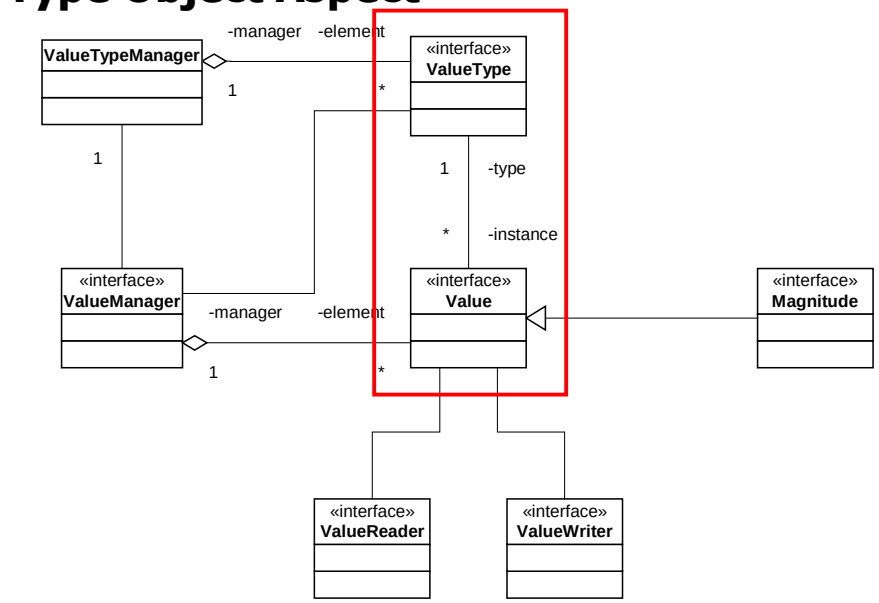
Type Object Aspect



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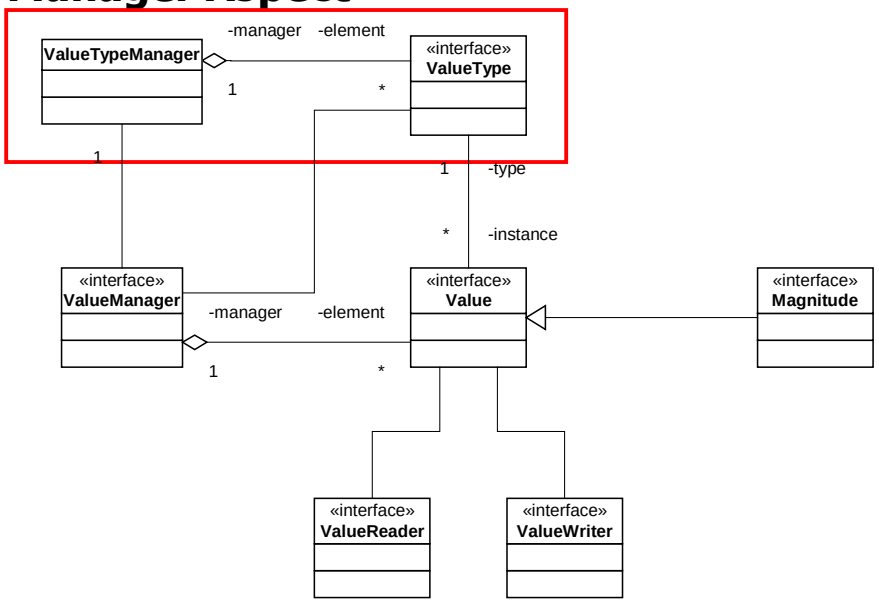
Manager Aspect



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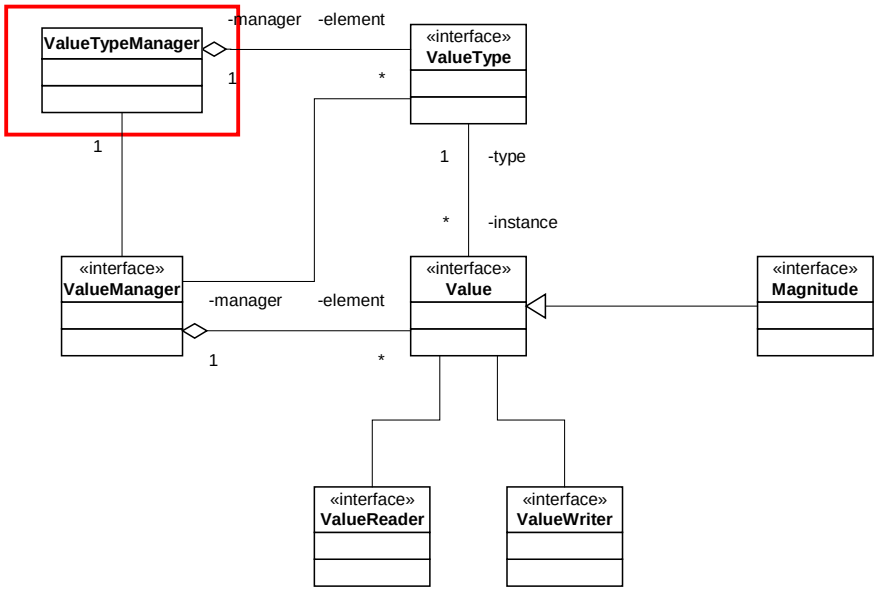
Singleton Aspect



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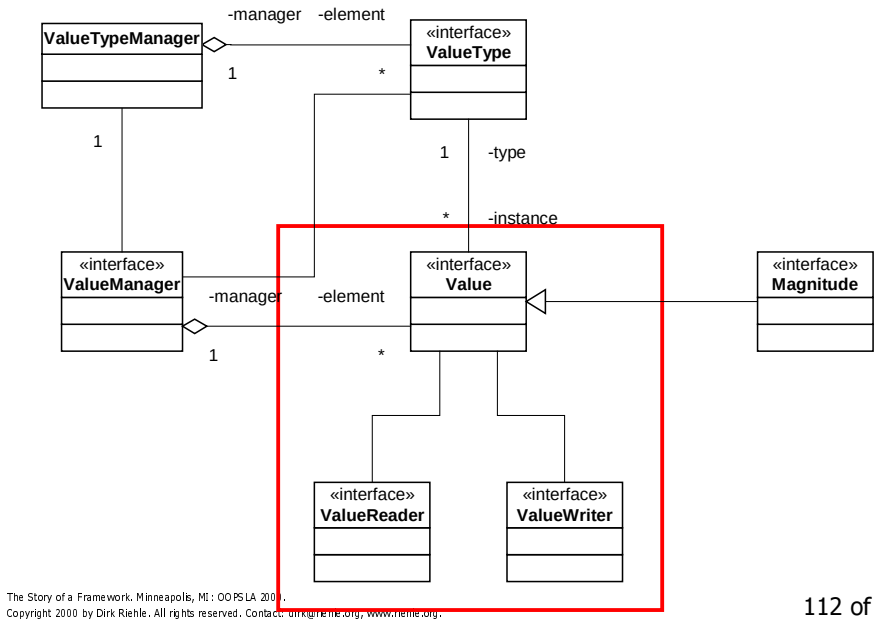
Serialization Aspect



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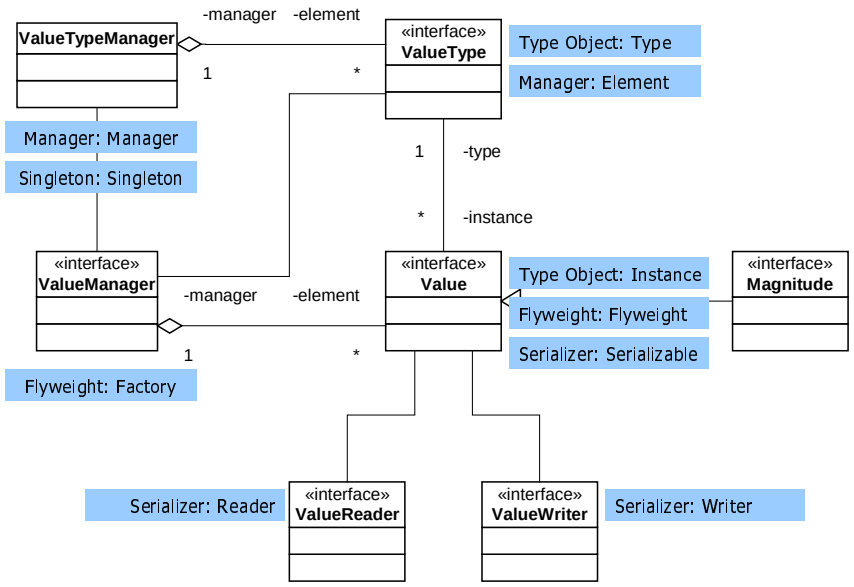
Value Objects: Pattern Annotation



Step 6: Topics

- Role modeling
  - object role play
  - object collaboration
- UML collaborations
  - collaboration specifications
  - describing design patterns

Money: Design Aspects

- Design patterns, as discussed:
  - Flyweight, Type Object, Manager, Singleton, Serializer
- Design aspects, not discussed:
  - Value implements java.io.Serializable
- Design aspects, inherited from Object:
  - keyable, comparable, printable, multi-threaded
- Hidden design aspects, without methods:
  - immutable

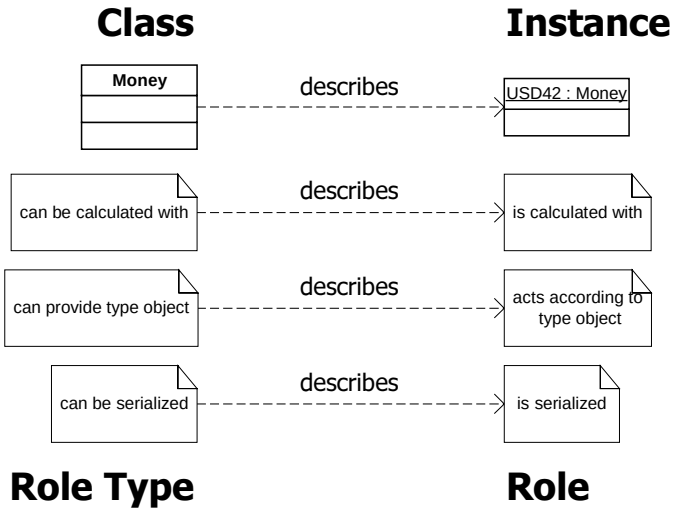
Complexity: Aspects Interact

- Value
  - createValue (ProtoValue aspect) and hashCode (keyable aspect)
  - initializing a Value with new data changes the hashcode
- Object
  - hashCode (keyable aspect) and equals (comparable aspect)
  - equal objects must provide same hashcode
- Still, aspects can be separated!

Roles: Aspects of a Specific Kind

- Definition: Role
  - an observable behavioral aspect of an object in a specific context
- Definition: Role type
  - a type that defines the behavior of a role an object may play
  - may or may not have methods
- Objects and roles: m-to-n relationship
  - objects play roles to act in different contexts
  - a role may be played by different objects over time (think call center)

Roles: Type/Instance Distinction



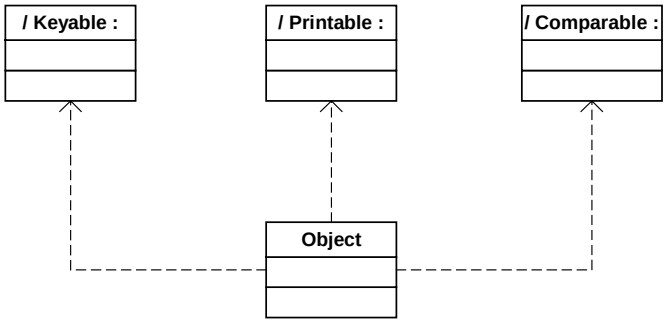
UML and Role Modeling

- UML provides support for role modeling...
  - but it is not complete
  - syntax and semantics document contradict each other
  - semantics document is much more precise than syntax document
- Heated debates about what constitutes role modeling
  - even after 1.3 release (or, perhaps, just then)
- Major influences on role concept in UML
  - Trygve Reenskaug: OOram

UML: ClassifierRoles

- UML concept for role: none
  - no instance level concept for roles
  - objects interact, but this is not filtered through roles
- UML concept for role type: ClassifierRole
  - a ClassifierRole is a Classifier
  - a ClassifierRole is attached to a Classifier
  - a Classifier may have several ClassifierRoles
  - ClassifierRoles are used in collaborations (discussed later)
- Notation: Object / ClassifierRole : Classifier
  - reminder: a Classifier may be a class or an interface or a datatype or ...

java.lang.Object: ClassifierRoles



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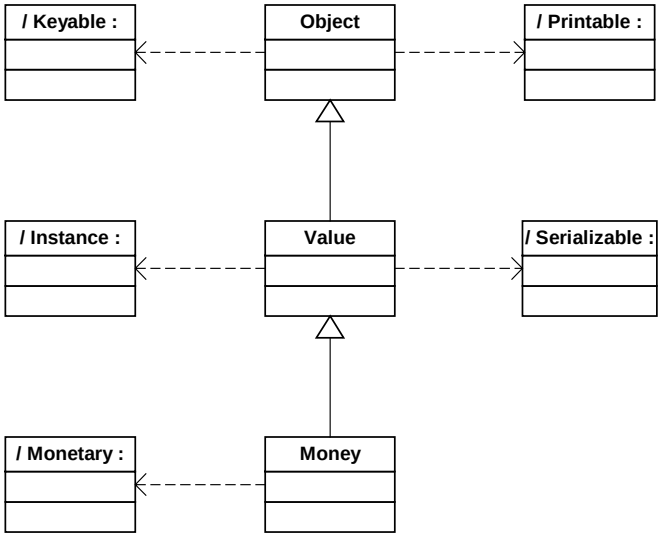
Money: ClassifierRoles



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Benefits of Modeling with Roles

- Reduces complexity
  - by breaking up complex (class) interfaces into parts
- Increases reuse
  - by separating roles from classes, we can reuse them

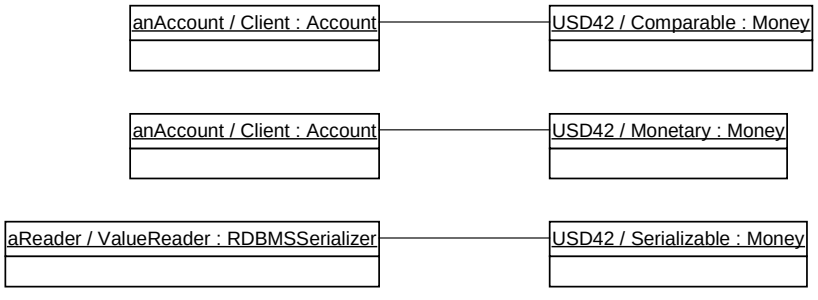
Implementing Roles

- Variant 1: as a set of methods in a class
  - simple but efficient implementation
  - accounts for about 80% of all cases
- Variant 2: as a dedicated interface
  - lets you reuse role for different classes
  - accounts for about 18% of all cases
- Variant 3: as a role object class
  - lets you dynamically attach roles at runtime
  - accounts for about 1% of all cases

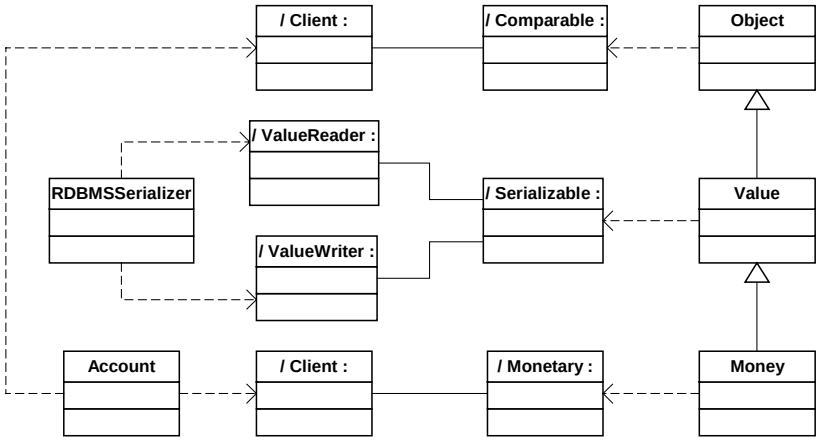
Implementation Dependencies

- Roles of one object interact
  - otherwise, there would be no synergy
  - a class is more than the sum of its roles
- Dependencies example
  - keyable: hashCode() provides hash code
  - equality: equals() must match hashcode for lookup in hashtables
  - shared immutable: equals() can be reduced to checking object identities

Money: Collaboration Instances



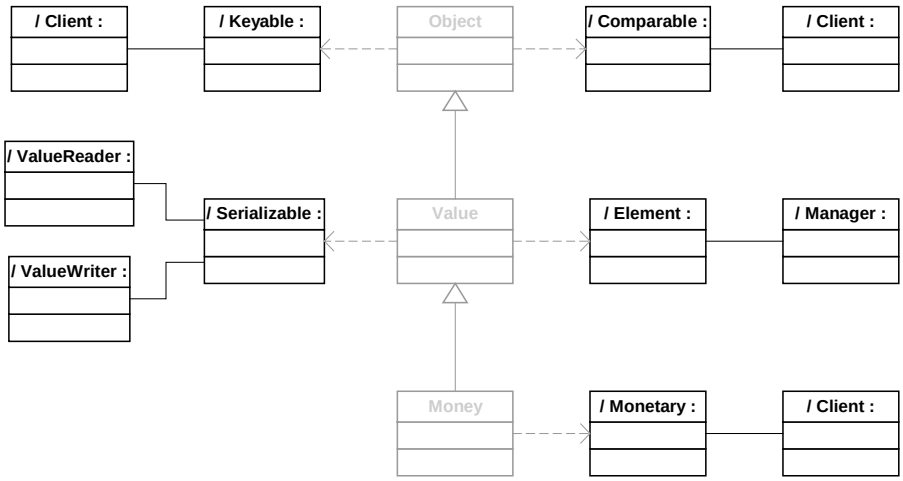
Money: Collaboration Specifications



UML: Collaborations

- Definition: Collaboration Instance
  - set of objects that collaborate by playing roles
  - Booch: "behavioral part of a collaboration"
  - UML 1.3: "collaboration on an instance level"
- Definition: Collaboration Specification
  - set of classifiers that relate to each other through classifier roles
  - Booch: "structural part of a collaboration"
  - UML 1.3: "collaboration on a specification level"
- Please note type/instance distinction again

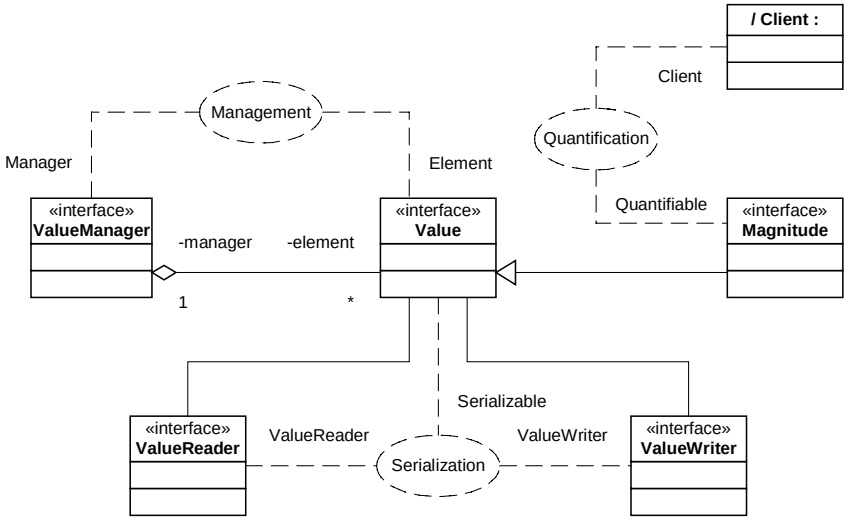
Money: Collaboration Specifications



Benefits of Collaboration Specifications

- Reduces complexity
  - by breaking up complex collaborations into parts
- Increases reuse
  - by separating collaborations from class relationships, we can reuse them

UML: Ellipse Shorthand



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Design Patterns and Collaboration Specifications

- Design pattern
  - an idea of a problem solution
  - infinite and unconstrained variation in implementation
- Design template
  - a template for a specific design solution
  - infinite but constrained variation in implementation
- Design fragment
  - a specific design solution applied in the context of a larger system
  - exactly one implementation

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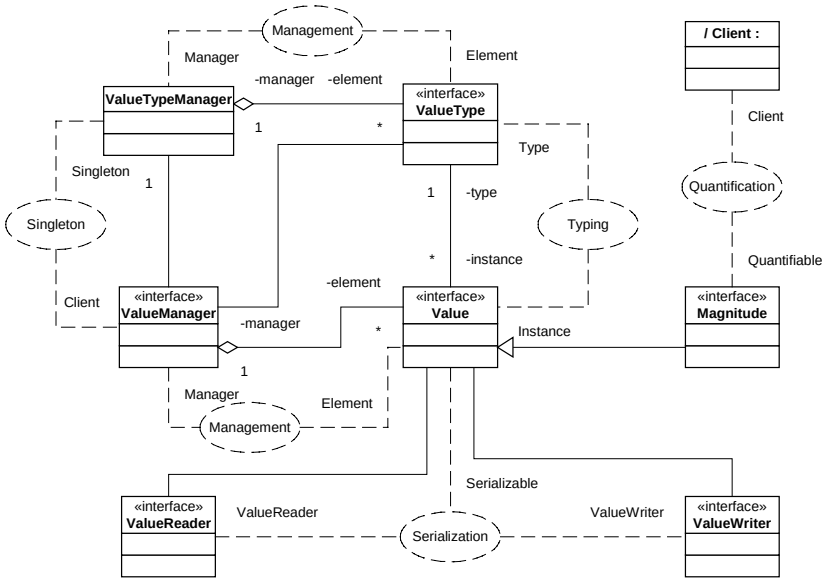
Value: Overall Class Model



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Part II: Summary

- Value objects
- Design aspects
- Design patterns
- Role modeling
- UML collaborations

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Part III: Frameworks

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Step 7: Topics

- Value framework
  - interface architecture
  - implementation architecture
- Framework types
  - black-box frameworks
  - white-box frameworks
- Framework clients
  - inheritance clients
  - use-clients

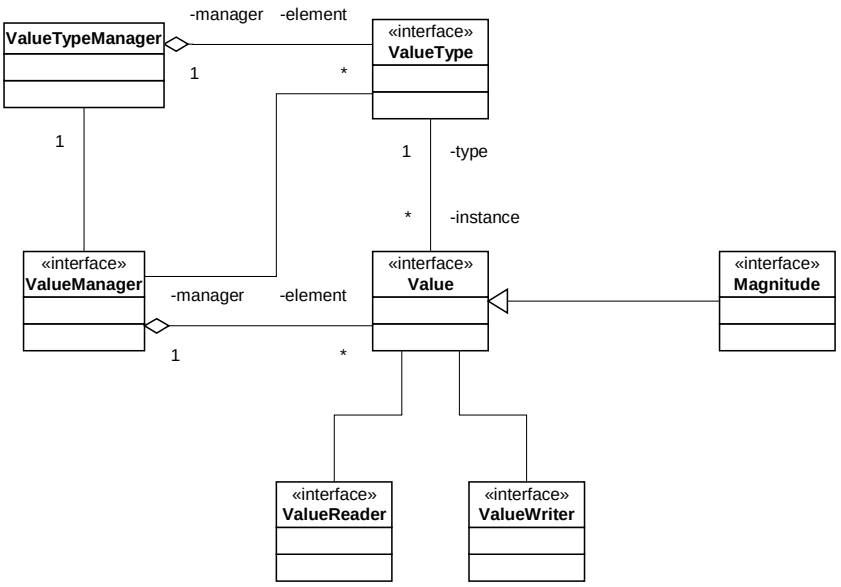
Framework (Traditional Definition)

- Definition: Framework
  - a reusable design and implementation that covers a particular domain
  - consists of an interface architecture and a (partial) implementation
- Purpose of frameworks
  - higher productivity
  - shorter time-to-market
  - less bugs
  - more homogeneous application suite
- Because of improved design and code reuse

Interface Architecture

- Definition: Interface Architecture
  - set of interfaces that determines overall structure and behavior
  - prescribes architecture for given domain or aspect thereof
- A.k.a. abstract design

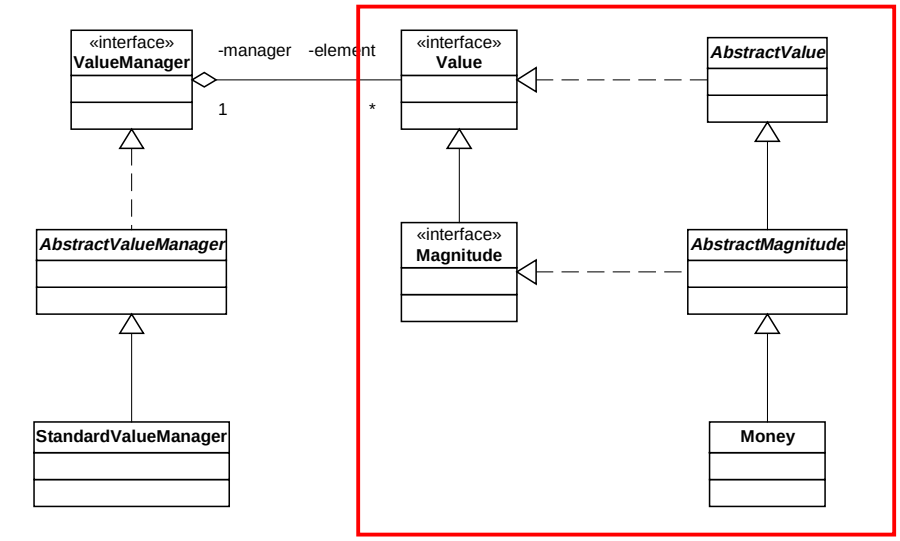
Value Framework: Interface Architecture



Implementation Architecture

- Definition: Implementation Architecture
  - set of abstract and concrete classes that implement an interface architecture
  - provides readily usable classes as well as half-fabricated customizable classes
- A.k.a. concrete design, implementation

Value Class Hierarchy Implementation



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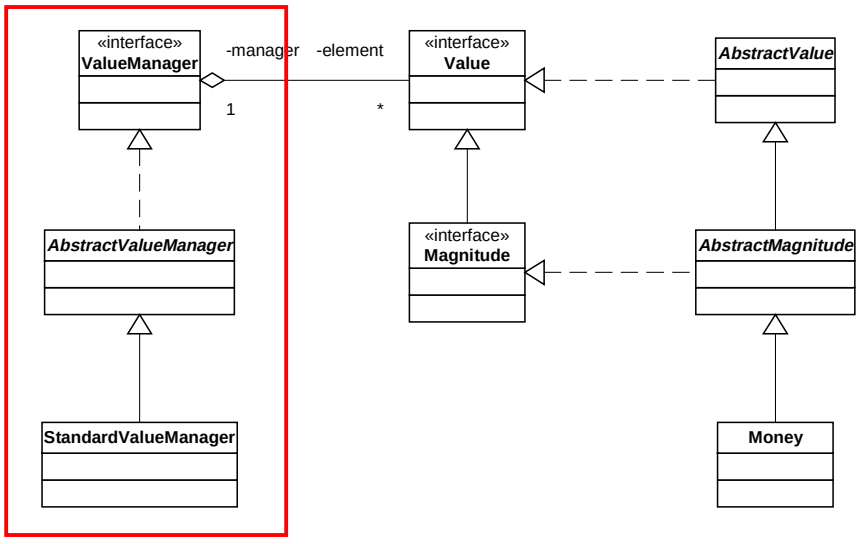
ValueManager Implementation



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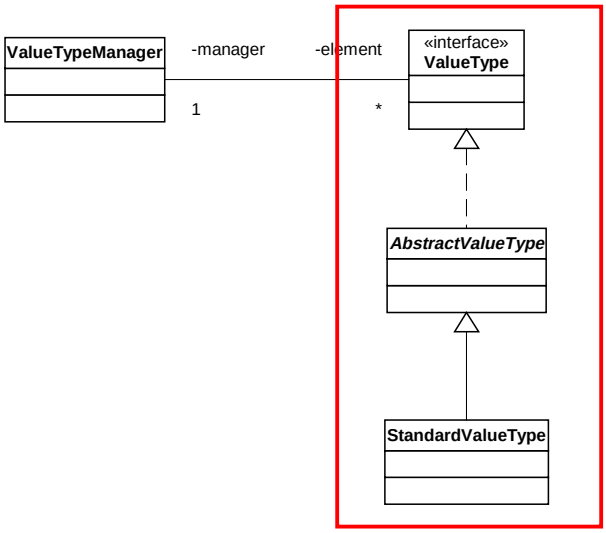
ValueTypeManager Implementation



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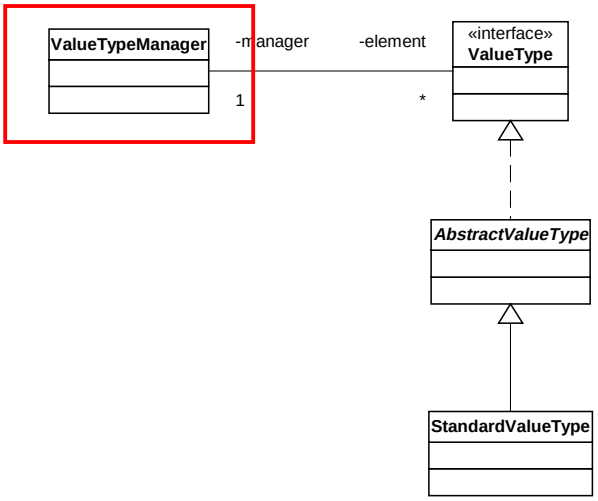
ValueType Implementation



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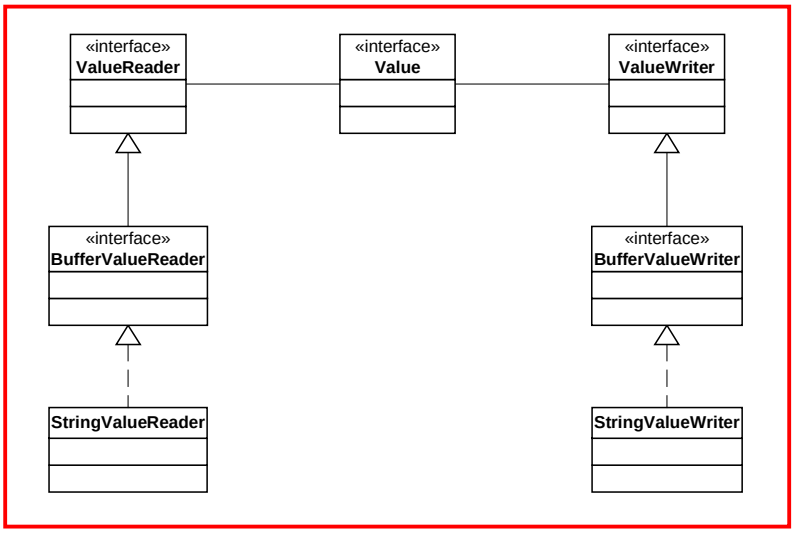
Serialization Implementation



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Implementation Variants

- Single class
  - ValueTypeManager
- Single interface + concrete class
  - *Reader, *Writer
- Single interface + abstract class + concrete classes
  - Value
  - ValueType
  - ValueManager

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Framework Types

- White-box frameworks
- Black-box frameworks
- Gray-box frameworks

White-Box Frameworks

- Definition: White-Box Framework
  - a framework that provides abstract superclasses for subclassing
  - extension clients first use inheritance to customize framework
  - use-clients then compose objects to apply framework
- Examples
  - Java Object framework

Black-Box Frameworks

- Definition: Black-Box Framework
  - a framework that provides readily usable classes
  - use-clients use object composition to apply the framework
- Examples
  - Swing (most mature GUI frameworks)

Gray-Box Frameworks

- Definition: Gray-Box Framework
  - a framework that is both a black-box and a white-box framework
  - most frameworks are gray-box frameworks (except for very mature ones)
- Examples
  - Value framework
  - Swing
- Classification is not so important
- More important is how to use a framework

Using Frameworks

- Inheritance clients
  - use inheritance interface
- Use-clients
  - use collaboration specifications

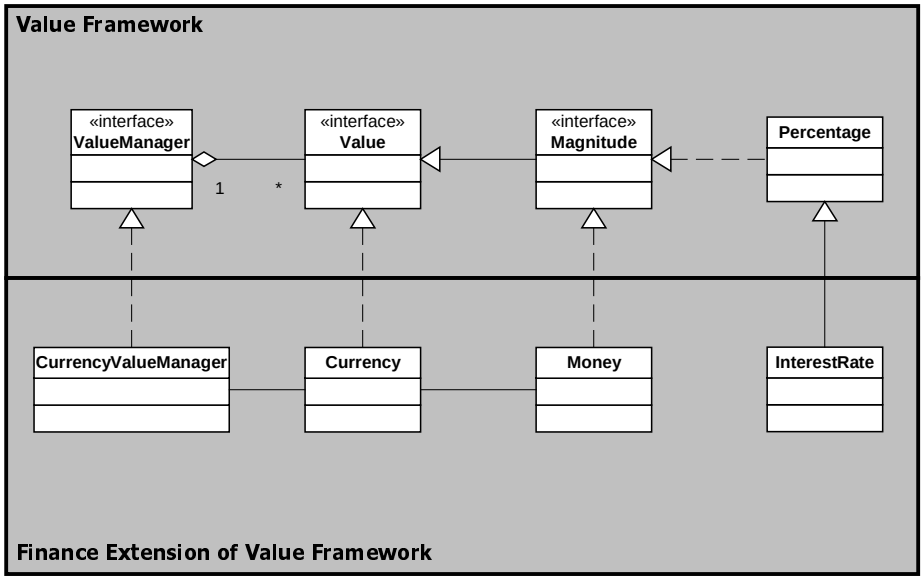
Framework (Extended Definition)

- Definition: Framework (traditional)
  - a reusable design and implementation that covers a particular domain
  - consists of an interface architecture and a (partial) implementation
- Definition: Framework (extended)
  - the class model of the framework provides
    - an extension point class set
    - a free classifier role set
    - a built-on class set

Framework Extension

- Definition: Framework Extension
  - a set of interfaces and classes that subclass a framework
  - consists of an interface architecture and a (partial) implementation
  - may be an application-specific extension or a framework itself
- Examples
  - Value framework extension for banking domain
  - Value framework for internet naming domain
- A.k.a. framework application
  - bad naming though, bears risk of confusion

Framework Extension: Finance/Currency



Extension Point (Classes)

- Definition: Extension Point (Class)
  - a framework class that may be subclassed by framework-external classes
  - define inheritance interface to framework extensions
- Definition: Extension Point Class Set
  - set of extension point classes of a framework
- Definition: Extension Class
  - class of a framework extension that subclasses an extension point class
  - make use of a framework's inheritance interface

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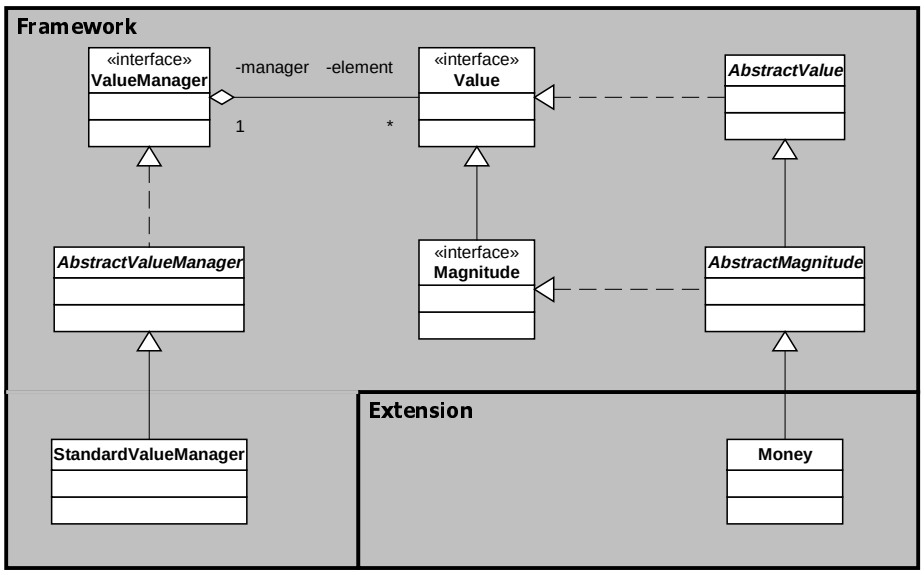
Value Framework: Extension Points



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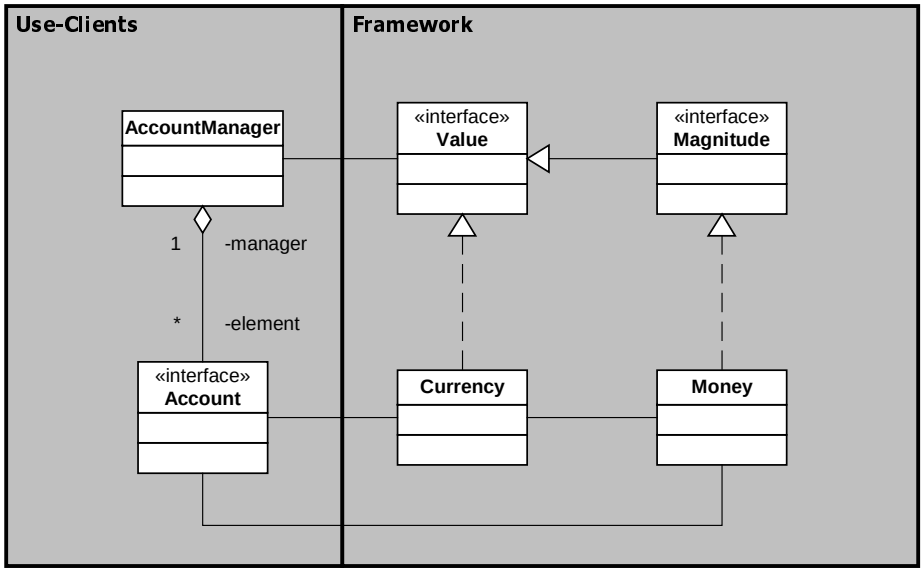
Framework Use by Use-Clients

- Use-clients create framework objects
  - from framework classes
  - from framework extension classes
- Use-clients compose framework objects

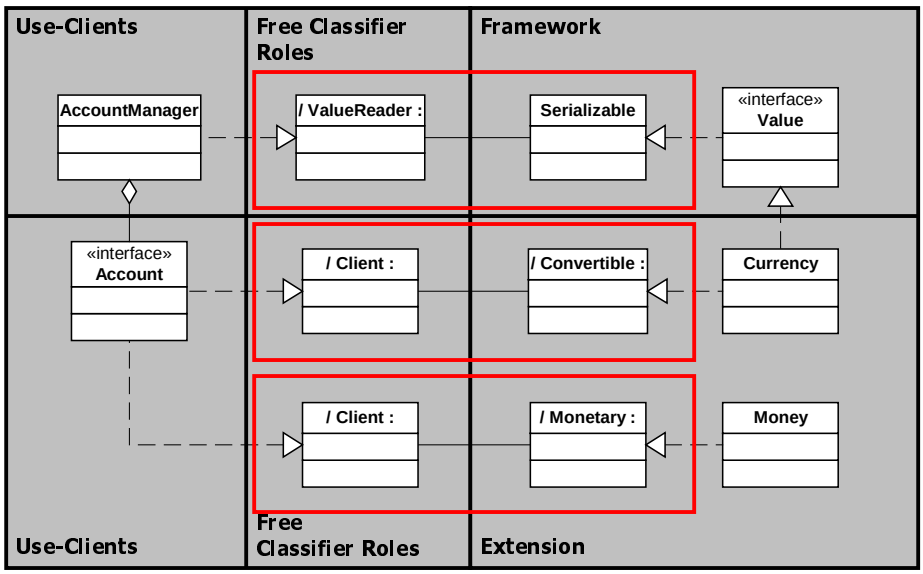
Framework Use-Clients: Finance/Account



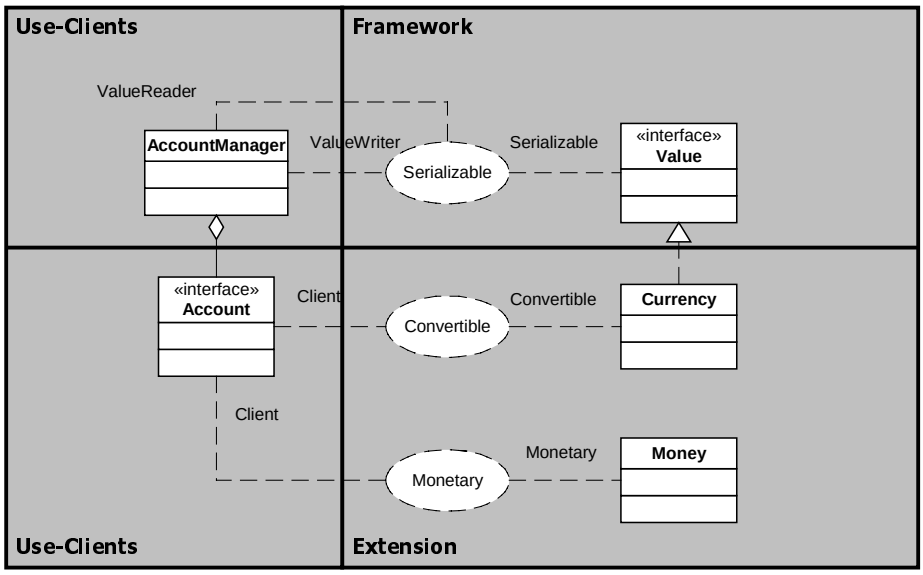
Definition: Free ClassifierRole

- Definition: Free Classifier Role (of a Framework)
  - a classifier role (ClassifierRole) that is available to use-clients
  - use-client classes pick up free classifier roles to make use of a framework
- Definition: Free Collaboration Specification (of a Framework)
  - a collaboration specification that provides free classifier roles

Use-Clients with Free Classifier Roles



Use-Clients with Ellipse Shorthand



How to Document a Framework

- Specify the use-client interface
  - determine and publish only free classifier roles to clients
  - document collaboration with free collaboration specifications
- Specify inheritance interface
  - determine extension point class set and
  - document inheritance interfaces of extension point classes
- Specify dependencies
  - determine classes a framework itself builds on
  - document relationship with built-on classes using collaboration specifications

Part III: Summary

- Value framework
  - interface architecture
  - implementation architecture
- Framework types
  - black-box frameworks
  - white-box frameworks
- Framework clients
  - inheritance clients
  - use-clients

JValue: A Java Value Object Framework

- The Value Object framework exists: JValue
  - available using the LGPL 2.0
  - contributions welcome!
- Please see: http://www.jvalue.org

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