Value Objects

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ADAP C07

Values

- Are timeless abstractions
  - No life-cycle, no birth or death, no change
  - No identity, cannot be counted, there is only one “copy”
- Consequences for programming
  - Often implemented as immutable objects
  - Program state changes by assigning values to fields
- Values are instances of value types
  - Also often called “data” and “data types”
  - We avoid the potential confusion

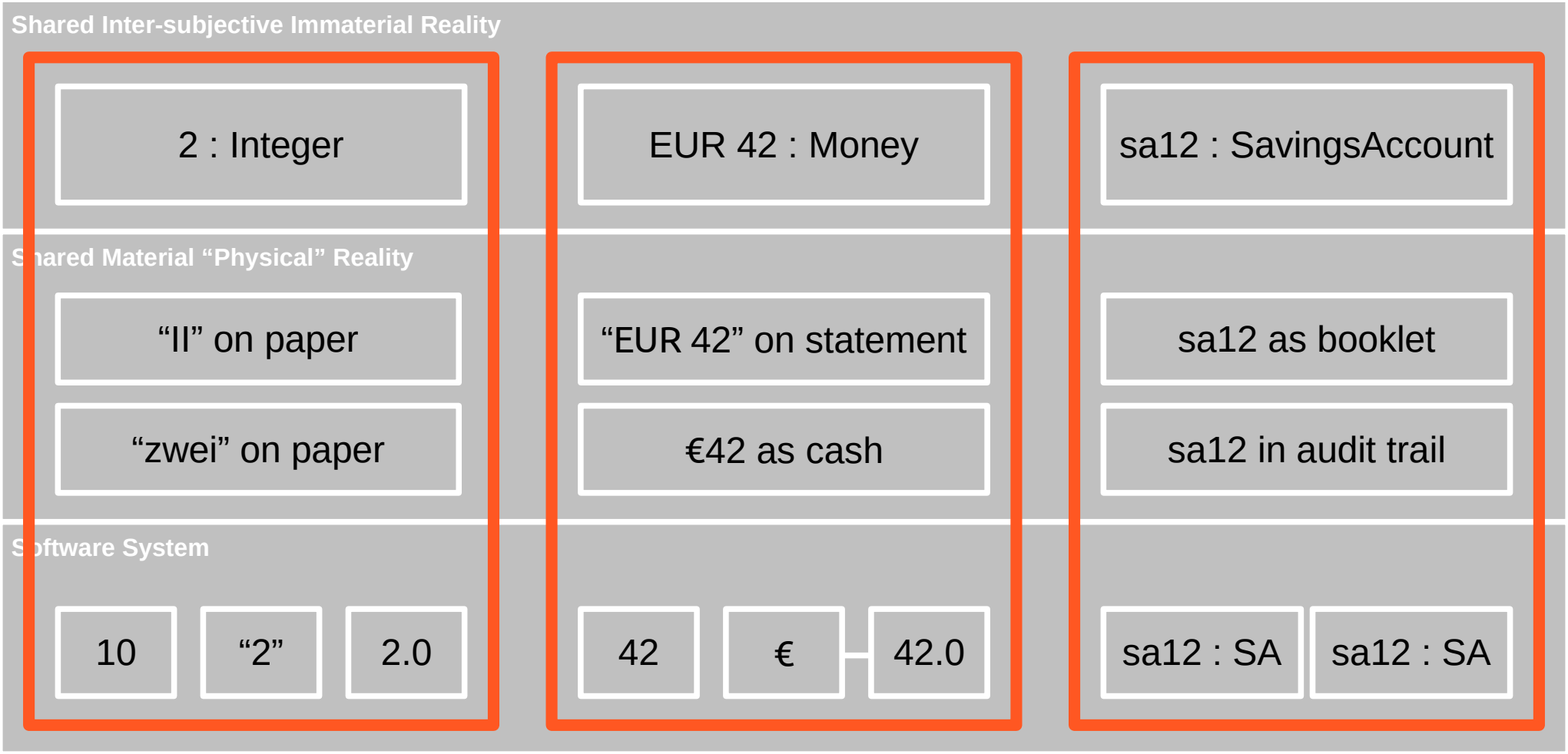
Objects

- Are virtual or physical entities from the modeled world
  - Exist in time, have a life-cycle
  - Can be created, changed, shared, destroyed
  - Have identity independent of internal structure
- Consequences for programming
  - Can be implemented as traditional classes with mutable state
  - Leads to side-effects a.k.a. aliasing and source of bugs
- Objects are instances of object types (classes)

Examples of Value Types

- So-called “primitive data types”
  - Numbers, strings, characters, …
- Common general value types
  - Names, coordinates, postal codes, …
- Domain-specific value types
  - SI unit (quantity units), ranges, restrictions, ...
  - Currency, monetary amount, interest rate, stock ticker symbol, …
  - Protocol names, URLs, HTTP return codes, …
  - …

Value and Object Representations



Objects and Values

- A software system consists of both objects and values
  - Object attributes have values
- The system is an object graph with values as leaves

Benefits of Domain-Specific Value Types

- Brings program closer to problem domain
- Restrains a major source of possible bugs (aliasing)
- May enhance system performance (see implementation)

Quiz: Modeling PostalAddress

- **How would you model a PostalAddress class?**
  - As a value type
  - As an object type
  - As something else

Answer: Modeling PostalAddress

- **How would you model a PostalAddress class?**
  - As a value type
    - **Conceptually: Yes. A postal address does not have a life-cycle and does not change.**
    - **Pragmatically: No. May be too heavyweight, with little sharing possible.**
  - As an object type
    - **Conceptually no, pragmatically yes. See above.**
  - As something else
    - **Tertium non datur.**

Implementation 1 / 4: General Semantics

- Implement java.lang.Object equality contract correctly

```
public boolean equals(Object o) {
  if ((o == null) || !(o instanceof Name)) return false;

  Name n = (Name) o;
  int noComponents = getNoComponents();
  if (n.getNoComponents() != noComponents) return false;

  for (int i = 0; i < noComponents; i++) {
    if (!getComponent(i).equals(n.getComponent(i))) return false;
  }

  return true;
}
```

```
public int hashCode() {
  return asString().hashCode();
}
```

Implementation 2 / 4: Immutability

- Value types as classes defining immutable objects
  - Do not change the state of the object; rather return a new one
    - Affects the interface; no mutation methods of return type void
    - Use Java's final fields to ensure immutability
    - Adjust client code to accept new object

```
public Name remove(int i) {
  assertIsValidIndex(i);
  ...
  Name result = doRemove(i);
  ...
}
```

```
protected Name doRemove(int index) {
  int newSize = getNoComponents() - 1;
  String[] newComponents = new String[newSize];
  ... // copy components skipping component at index
  return getName(newComponents);
}
```

Implementation 3 / 4: Sharing

- Value types as classes defining shared objects

```
public Name getName(String[] components) {
  return getStringArrayName(component);
}
```

```
public StringArrayName getStringArrayName(String[] components) {
  String  nameString = NameHelper.asNameString(components);
  StringArrayName result = allStringArrayNames.get(nameString);
  if (result == null) {
    synchronized (this) {
      result = allStringArrayNames.get(nameString);
      if (result == null) {
        result = new StringArrayName(components);
        allStringArrayNames.put(nameString, result);
      }
    }
  }
  return result;
}
```

Benefits of Sharing Value Objects

- Trivial equality contract implementation
- More difficult if you have different implementation classes

```
public boolean equals(Object o) {
  return this == o;
}
```

```
public int hashCode() {
  return super.hashCode();
}
```

Implementation 4 / 4: Handle / Body Idiom

- Handle / Body Idiom [C95]
  - Pass around only the handle, which holds the body
  - Forward all method calls from handle to body
- Copy-on-write (mutation method call)
  - Upon mutation method call to handle, copy body
  - This way, the client gets isolated from source context
- Benefits of handle / body idiom
  - Protects client from aliasing effects
  - Minimizes memory consumption

Implementation Benefits of Value Objects

- Immutable objects are
  - Safe for concurrency
  - Perform well (no need for synchronization)
- Shared objects
  - Make equality easy to implement
  - Minimize memory consumption
- No identity of value objects allows for free copying
  - Database benefit: No need for separate database table
  - Serialization benefit: Value object can be serialized in-line
  - Distributed systems benefit: No cross-process reference

Quiz: Implementing Base Contracts

- How to implement on java.lang.Object
  - For either a value or an object type
    - These comparison methods …
      - boolean isSame(Object o)
      - boolean equals(Object o)
    - These creation methods …
      - Object clone()
      - Constructor
    - These other methods …
      - int hashCode()
      - getId()

Answer: Implementing Base Contracts

- Value types
  - These comparison methods …
    - boolean isSame(Object o)
      - **N/A**
    - boolean equals(Object o)
      - **By attribute comparison**
  - These creation methods …
    - Object clone()
      - **return this;**
    - Constructor
      - **Is hidden when sharing values**
  - These other methods …
    - int hashCode()
      - **Calculate hash function**
    - getId()
      - **return ids.get(hashCode())**
- Object types
  - These comparison methods …
    - boolean isSame(Object o)
      - **return this == o;**
    - boolean equals(Object o)
      - **By attribute comparison**
  - These creation methods …
    - Object clone()
      - **Create shallow clone**
    - Constructor
      - **Whatever**
  - These other methods …
    - int hashCode()
      - **return super.hashCode()**
    - getId()
      - **Safe version of return (int) this**

Design Exercise

- Design a function that accepts a distance and a speed as input and returns the time it takes to go that distance at that speed

Missing Information

- Functional properties
  - Precision of calculation? (Assume double)
  - What types of units? (Assume metric system)
  - Handling of decimal multiples (Assume no)
  - …
- Non-functional properties
  - Speed of calculation? (Assume as fast as possible)
  - Concurrent computations? (Assume yes)
  - Behavior in boundary cases? (Assume ignore)
  - ...

Solution in Pseudo Code

```
function calculate_duration
    in: speed
    in: distance
    out: duration

begin
    duration = distance / speed
end
```

QuantityUnit

Base Units (of the Metric System)

Quantity	Base Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Thermodynamic Temperature	kelvin	K
Luminous Intensity	candela	cd
Amount of Substance	mole	mol

State Pattern vs. enum

```
public enum BaseUnit {
    m(0),
    kg(1),
    s(2),
    A(3),
    K(4),
    cd(5),
    mol(6);
}
```

Unit (of Measure)

```
public class Unit {
    // example: m/s = { 1.0, 0, -1.0, 0, 0, 0, 0 }
    protected double exponents[7];
    ...
}
```

Quantities with Units

```
public class QuantityUnit {
    protected double quantity;
    protected Unit unit;
    ...
}
```

Value Types in Java

- Not yet, but … probably never. Oh well, updated in 2019, but thing final yet

Value Type Constructors

- Arrays
- Enumerations
- Parameterized types
  - Quantity units (SI units)
  - Ranges and range bounds
  - Expressions, restrictions
  - ...

Enums as Value Type Constructors

- Enumerations provide shared values
  - Constructors can only be private
  - Fields can be mutable, however

Param. Types as Value Type Constructors

```
public class RangeRestriction<T extends Comparable<T>>
  extends Restriction<T> {

  protected Range<T> range;

  public RangeRestriction(T lowerBound, T upperBound) {
    this(new Range<T>(lowerBound, upperBound));
  }

  public RangeRestriction(Range<T> range) {
    this.range = range;
  }

  @Override
  public boolean isSatisfiedBy(T value) {
    return range.includes(value);
  }

}
```

Object Identifiers / References

- Plain main memory reference
- Handle (specialized pointers)
- External object identifiers
- Primary key to relation

Reality Check [B+97]

- Large financial system (1997)
  - More than 2500 (regular) C++ classes
- Utilization of value object (classes)
  - About 50 unique value types (implemented as classes)
  - About 20 unique value type constructors
  - More than 200 code (enum) like value types

The JValue Value Object Framework

- JValue, originally a framework for value objects in Java
  - Since 1998 but in its third (modern Java) incarnation
  - Only recently on http://github.com/jvalue/value-objects
- **Contributions are welcome! Final theses possible as well.**

Review / Summary of Session

- Value objects / types
  - Definition, charteristics, benefits
  - Values vs. objects
  - Implementation strategies
- Examples

Thank you! Questions?

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