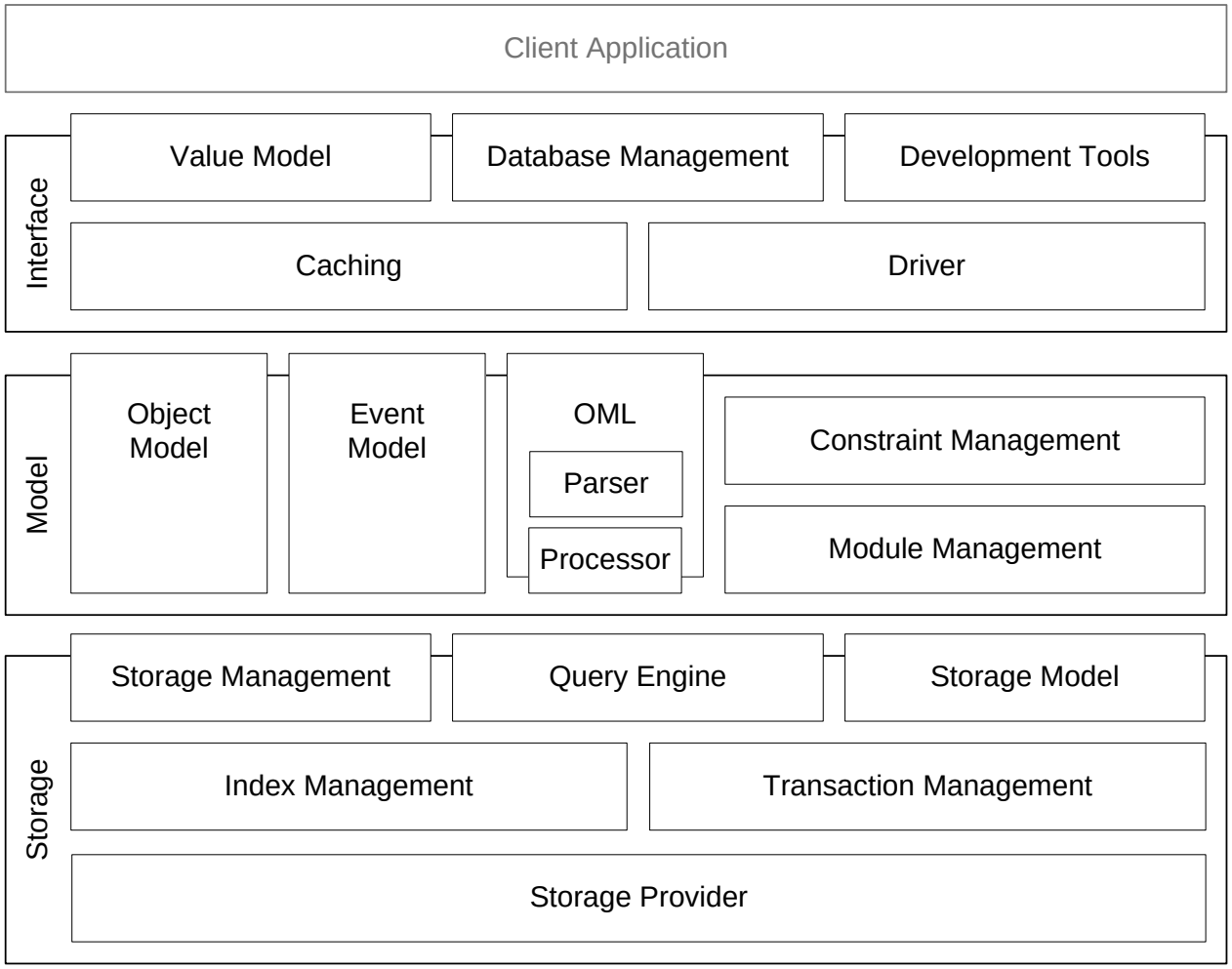
Object-Oriented Databases
Design and Implementation: OMS Avon

- Architecture
- Storage, Model and Interface Layer
- Database Modules

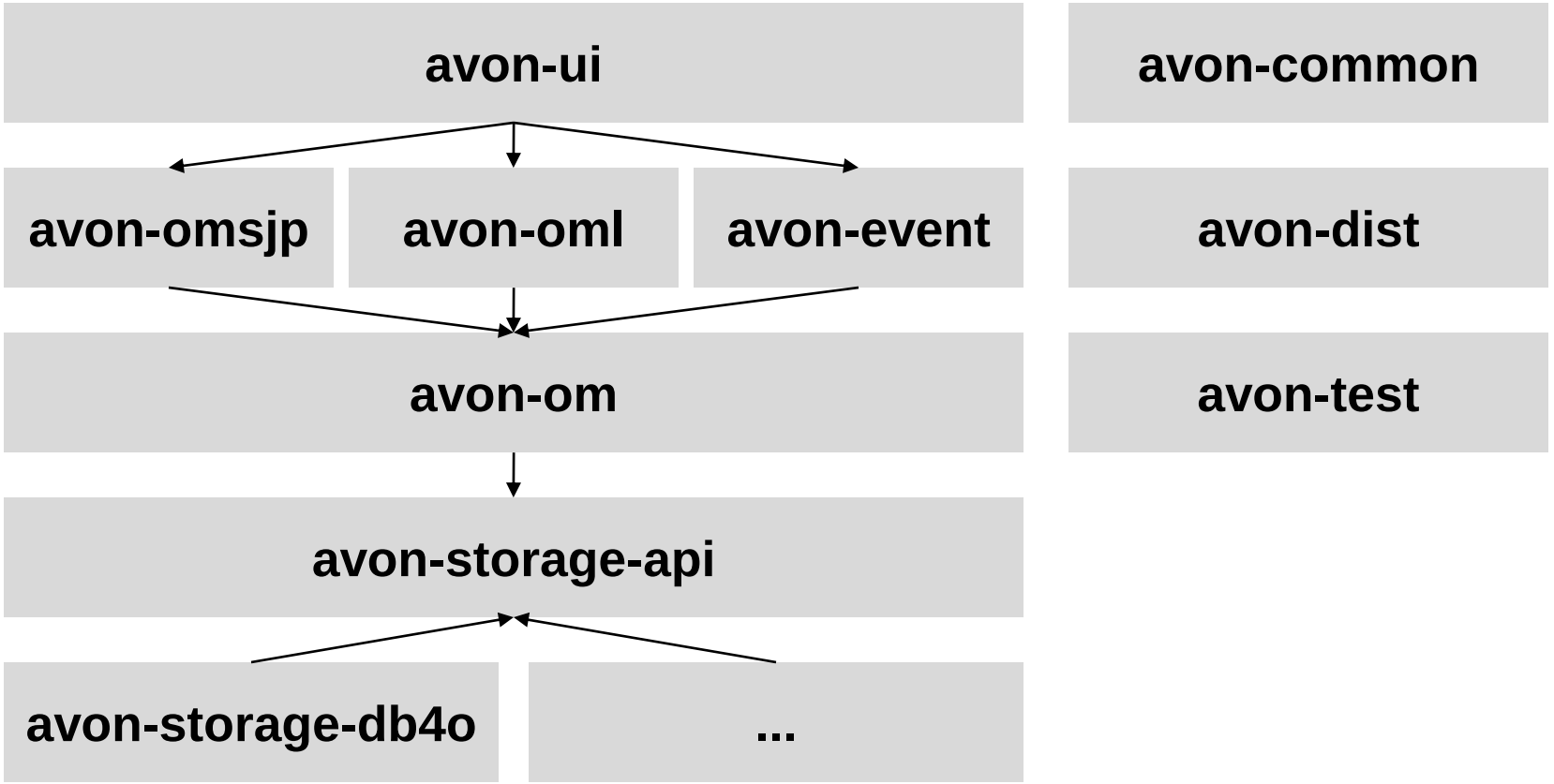
OMS Avon

- Java implementation of the OM data model and OML
- Storage layer
  - manages low-level storage
  - package **`ch.ethz.globis.avon.storage`**
- Model layer
  - implements functionality associated with the OM data model
  - package **`ch.ethz.globis.avon.om`**
  - package **`ch.ethz.globis.avon.oml`**
- Interface layer
  - provides a high-level application programming interface
  - package **`ch.ethz.globis.avon.omsjp`**

OMS Avon Architecture



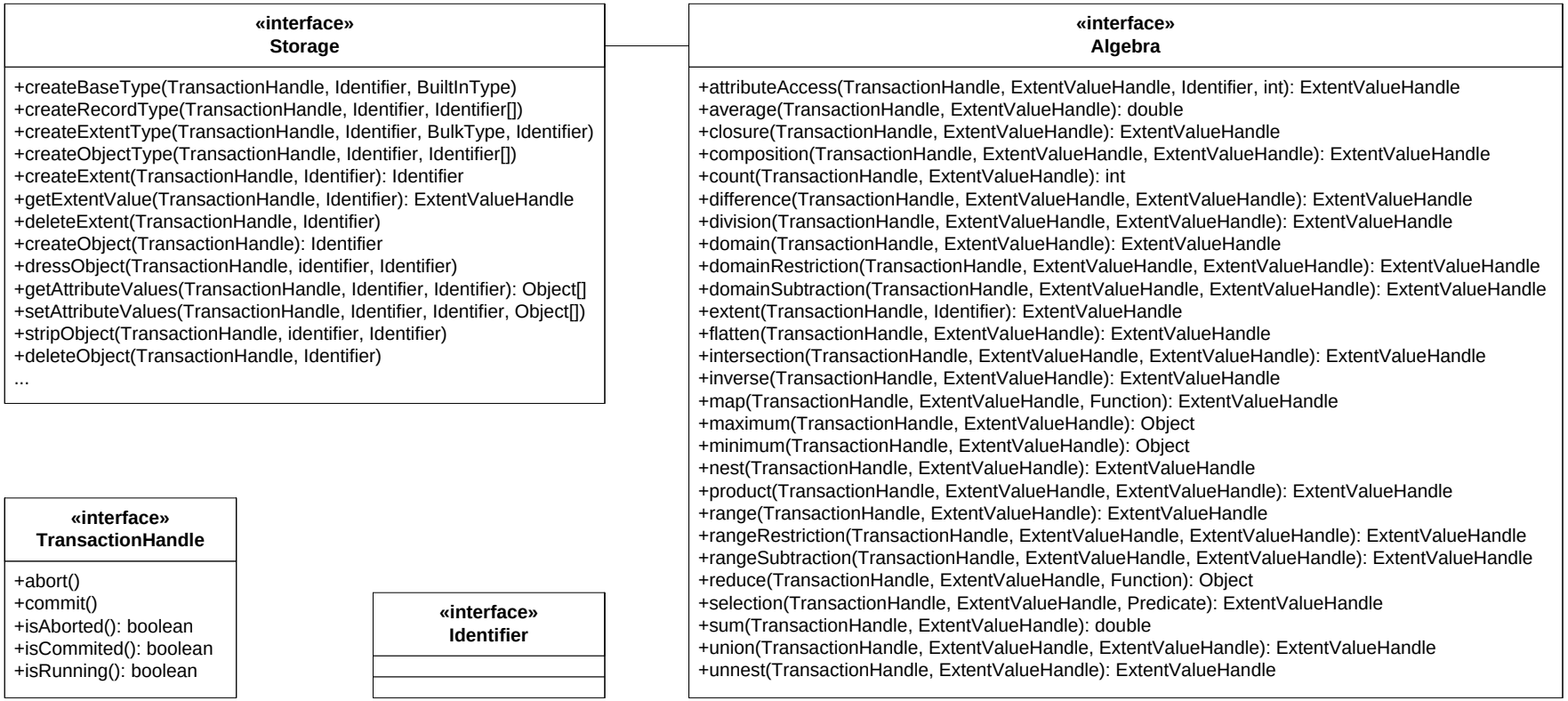
OMS Avon Project Modules



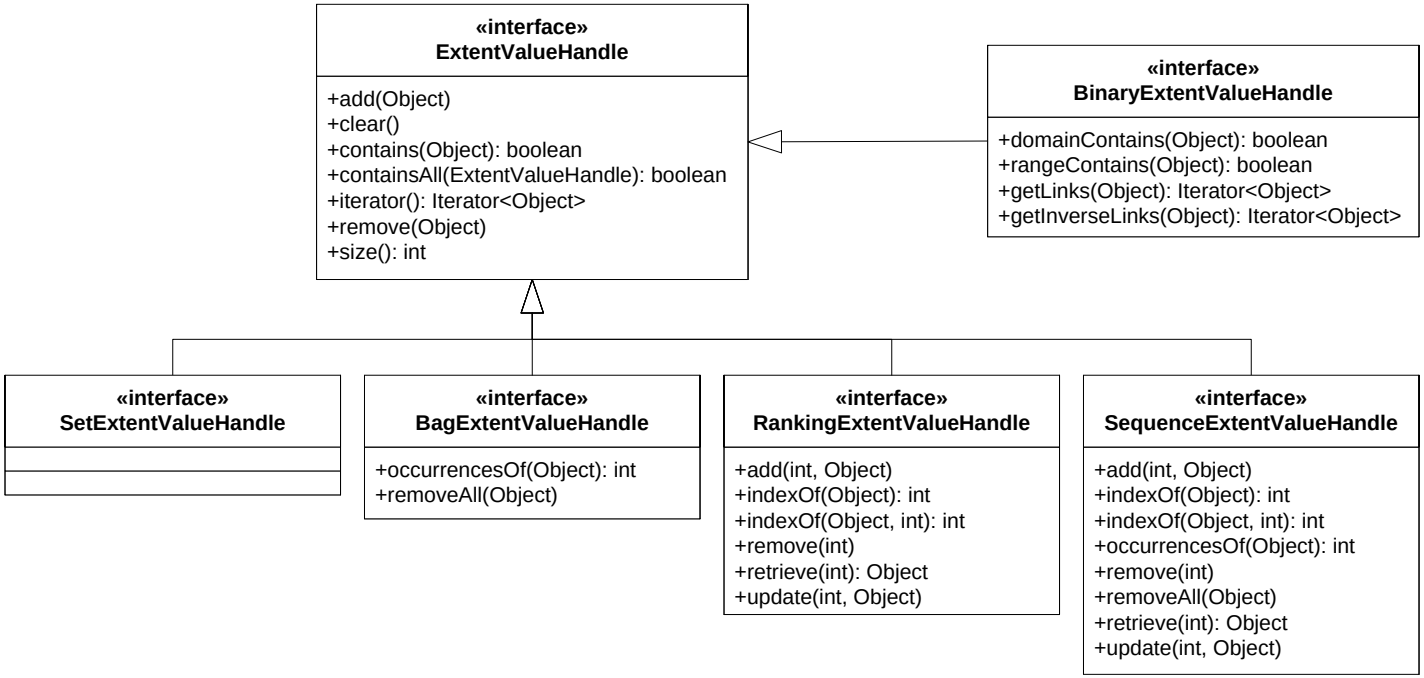
OMS Avon Storage Layer

- Storage interface based on type and information units
  - type units provide metadata
  - information units store data
- Application programming interfaces for
  - create, retrieve, update and delete operations
  - schema evolution
  - creating and managing indexes
  - low-level query operators
  - transactions, concurrency control and recovery
- Extent value handles manage bulk values
- Various storage providers

Storage Layer Concepts



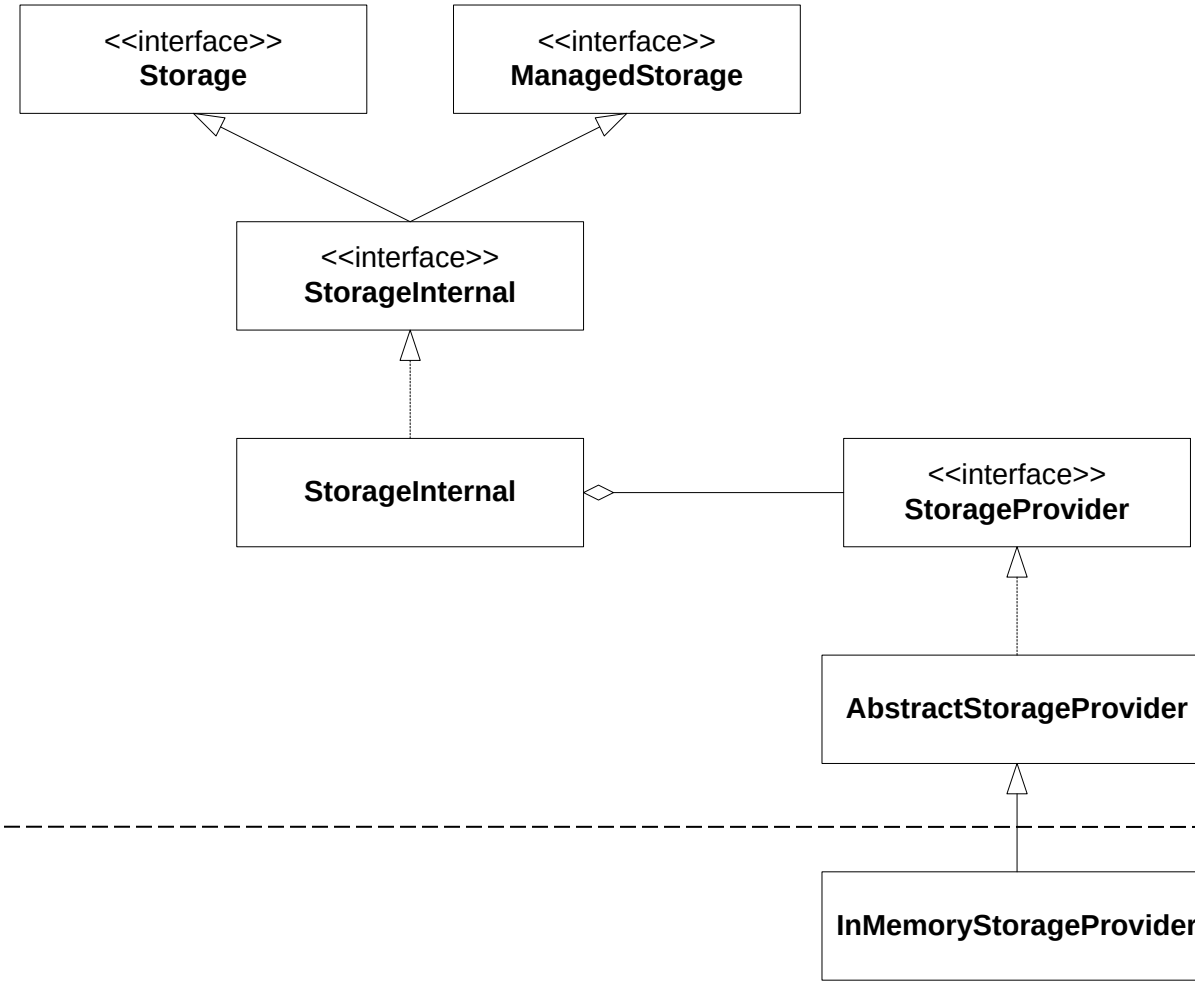
Storage Layer Concepts



Storage Layer

- Consists of three main parts
- Application Programming Interface
  - used by the model layer
  - encapsulates high-level functionality and concepts
- Internal
  - internal functionality
  - common and managed functionality
- Service Provider Interface
  - interface for storage providers that provide low-level functionality
  - db4o, Berkeley DB, in-memory

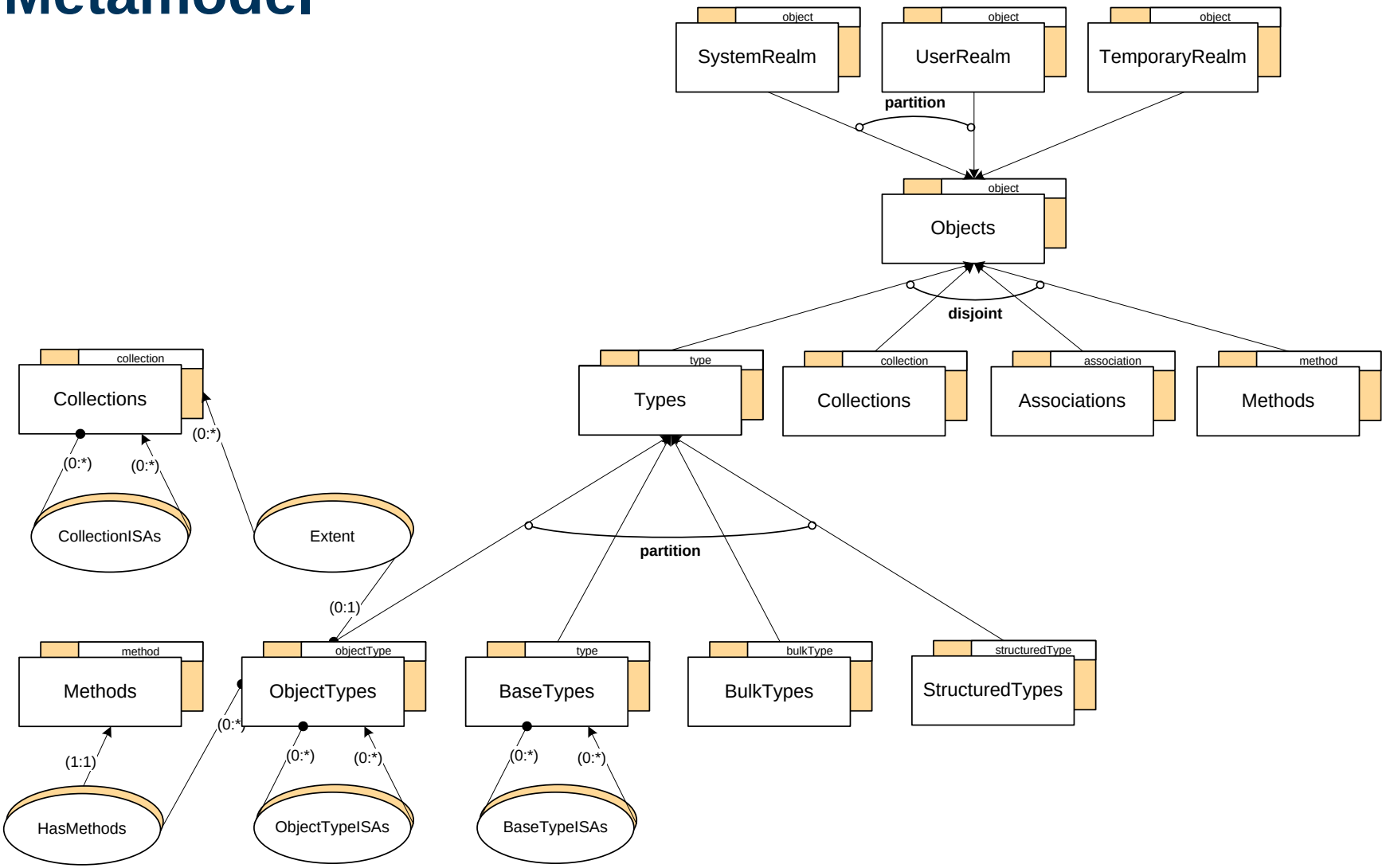
Storage Layer Design



OMS Avon Model Layer

- One generic Java abstraction to represent OM objects
  - single point of extensibility
  - flexibility for database evolution
  - central control for transactions and recovery
- Classes for managing generic objects
  - create, retrieve, update and delete operations
- Utility classes to access and interpret generic objects
  - cache metadata and access data from the storage layer
- Entire OM metamodel is bootstrapped
  - metamodel is expressed using OM (metacircularity)
  - different flavours of the metamodel
  - metamodel extensibility

Metamodel


object
SystemRealm
object
UserRealm
object
TemporaryRealm
partition
object
Objects
disjoint
collection
Collections
type
Types
collection
Collections
association
Associations
method
Methods
(0:*)
(0:*)
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CollectionISAs
Extent
partition
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method
Methods
objectType
ObjectTypes
type
BaseTypes
bulkType
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structuredType
StructuredTypes
(0:*)
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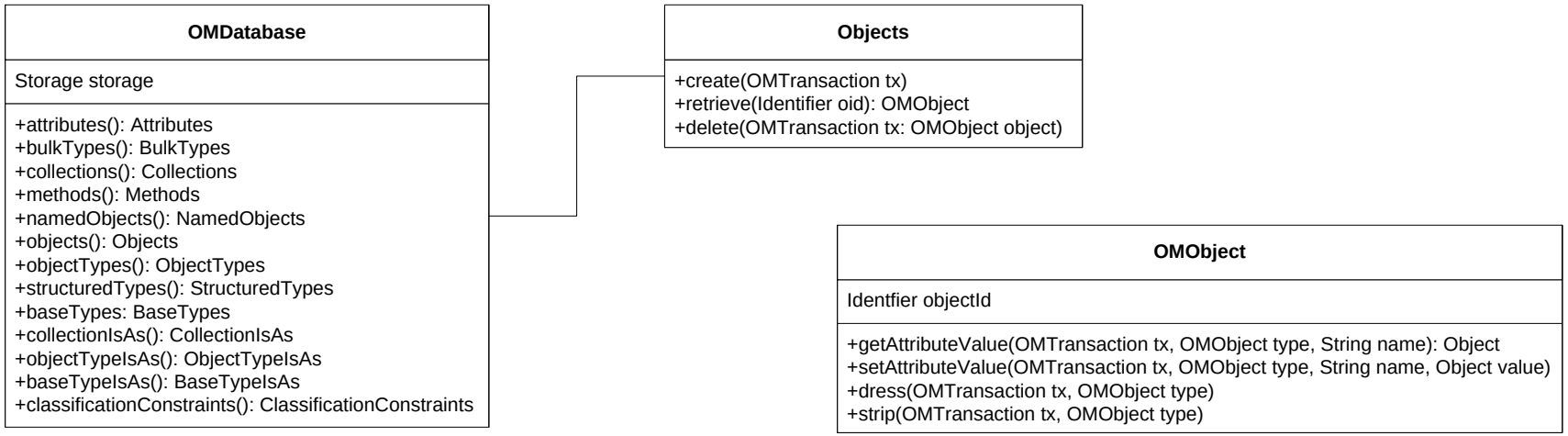
HasMethods
ObjectTypeISAs
BaseTypeISAs

Application Programming Interface

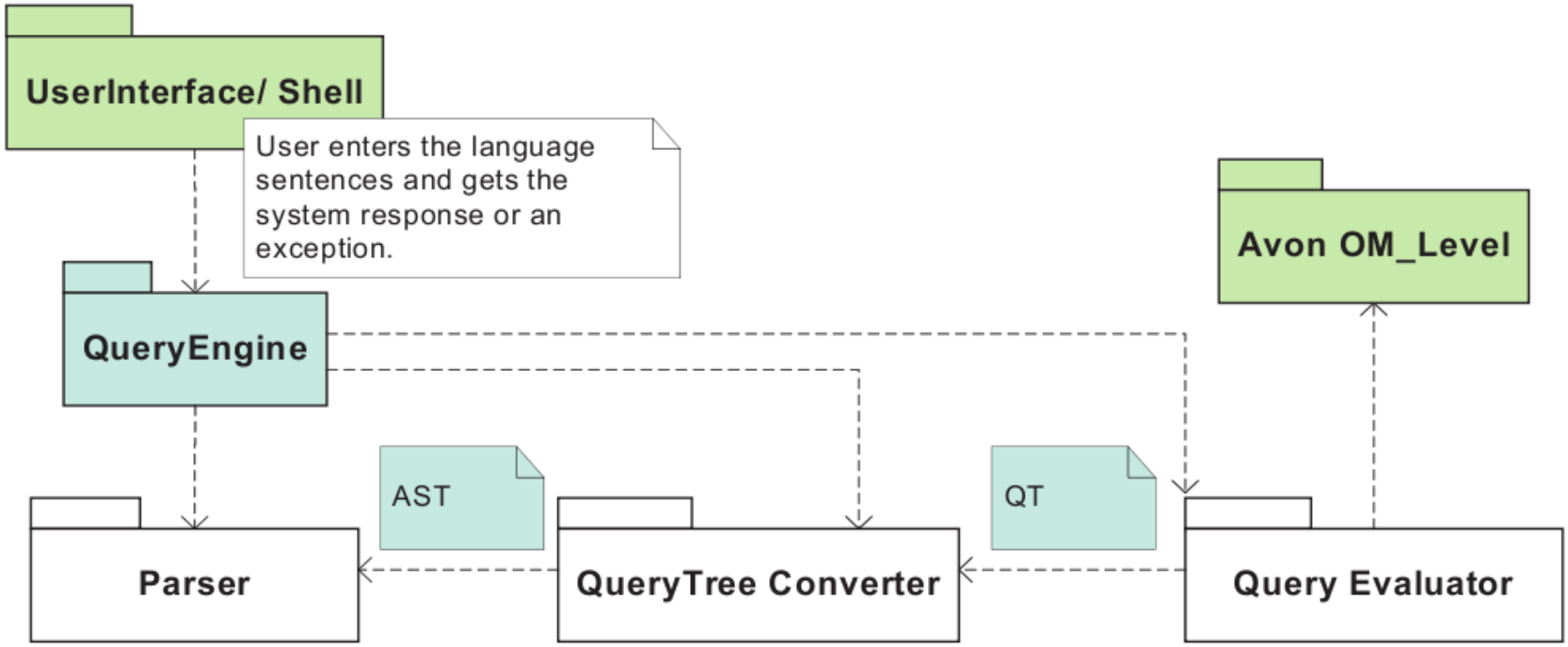



```
OMDatabase database = OMDatabaseManager.openDatabase("contacts.oms");
OMTransaction tx = database.beginTransaction();
OMObject object = database.objects().create(tx);
OMObject tPerson = database.namedObjects().retrieve(tx, "person");
object.dress(tx, tPerson);
OMObject tContact = database.namedObjects().retrieve(tx, "contact");
object.setAttributeValue(tx, tContact, "name", "Moira C. Norrie");
tx.commit();
```

Database Modules

- OMS Avon supports database modules that can extend or adapt the system for special application domains
- A database module consists of
  - metamodel extension to define new concepts
  - functionality that manages the new concepts
  - query language extension to interact with new concepts
- Existing database modules
  - main system
  - event system
  - peer-to-peer data sharing
  - personal information management
  - Web content management
  - ...

OML Query Engine

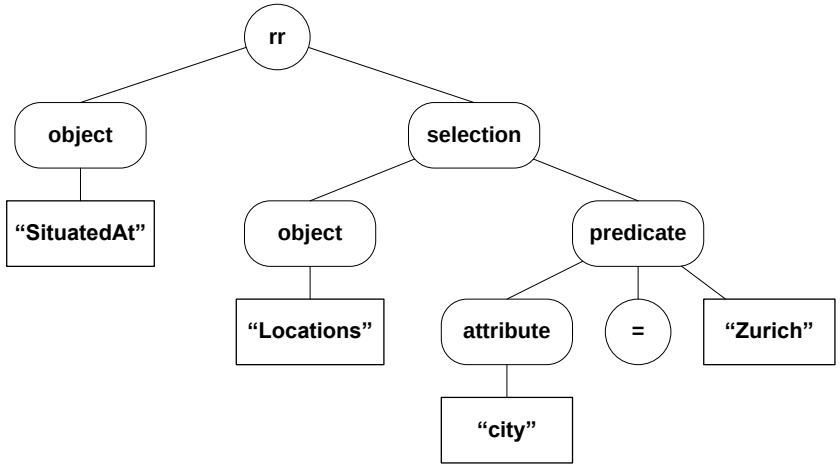


OML Query Evaluation

- Parser
  - used JavaCC to generate parser and lexer
  - returns an abstract syntax tree (AST)
- Query Tree Converter
  - uses the visitor design pattern to process AST in post-order
  - transforms the AST into a query tree (QT)
- Query Tree Evaluator
  - uses the visitor design patter to process QT in post-order
  - returns only the last result from the OML script
  - stores intermediated results in the node structure

Query Tree

```
SituatedAt
    rr(
        all $l in Locations
        having
         ($l.city = "Zurich")
)
```



- QT nodes are atomic construct
- Used to build different database operations
  - selection, domain, range, iteration, object access

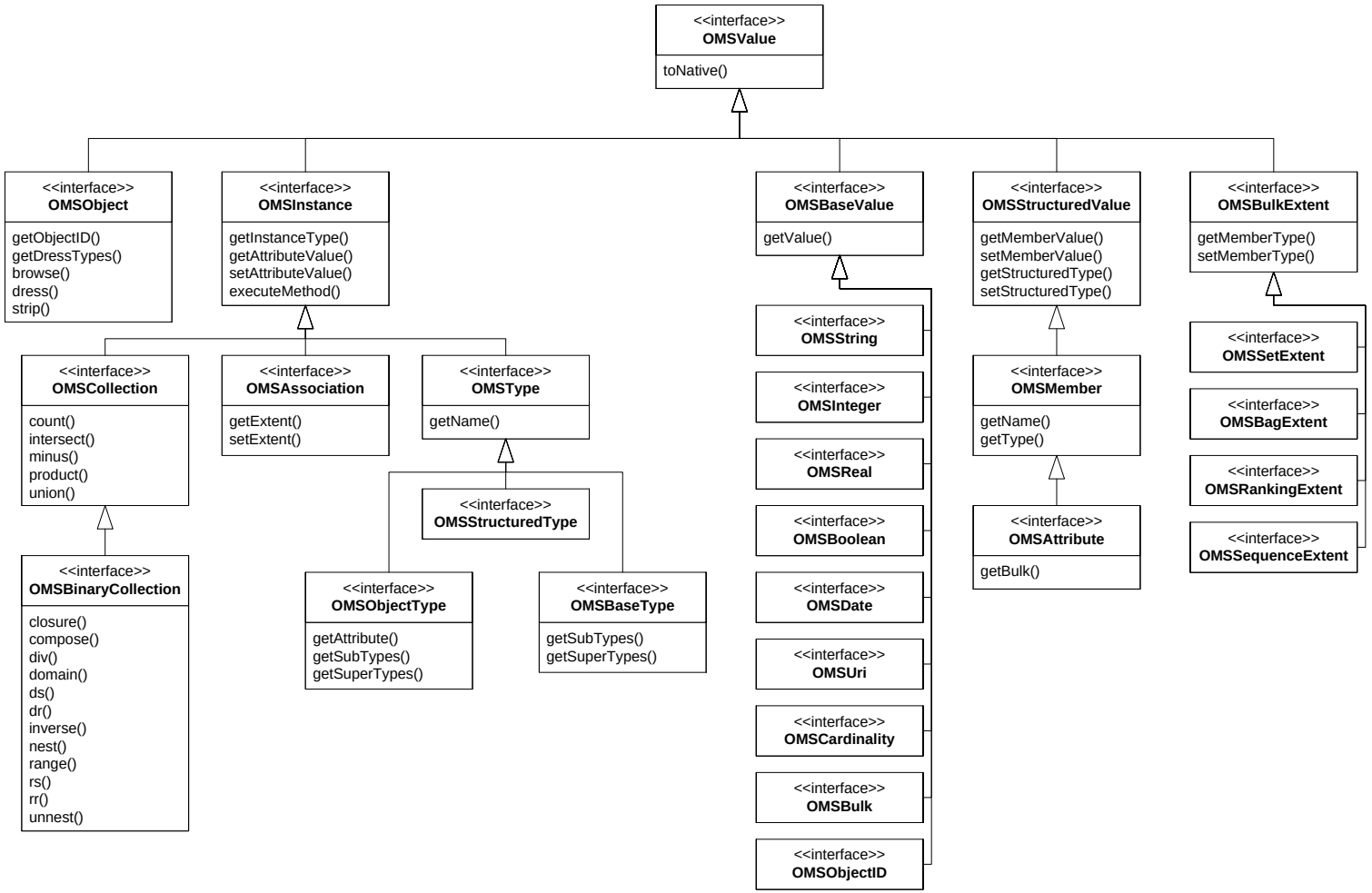
OMS Avon Interface Layer

- OMS Avon provides alternative interfaces for application development
- OMSjp
  - uniform access to heterogeneous OMS databases
  - programmatic interface based on Java
  - equivalent to JDBC in the OMS world
  - maps Java types to OM types
  - provides Java abstractions for OM system concepts
- Object Model Language (OML)
- Graphical User Interface
  - OMSjp Eclipse plug-in with graphical schema editor
  - OMSjp Browser

OMSDriver and OMSDatabase

- OMSDriver
  - provides database management functionality
  - abstraction of underlying implementation
  - one driver per supported platform
  - driver manager loads drivers based on configuration file
  - driver is configured via URL
  - **`omsjp:platform://user/password@host:port/database`**
- OMSDatabase
  - provides database functionality
  - create, update and delete object
  - query interface
  - schema management
  - import and export of databases

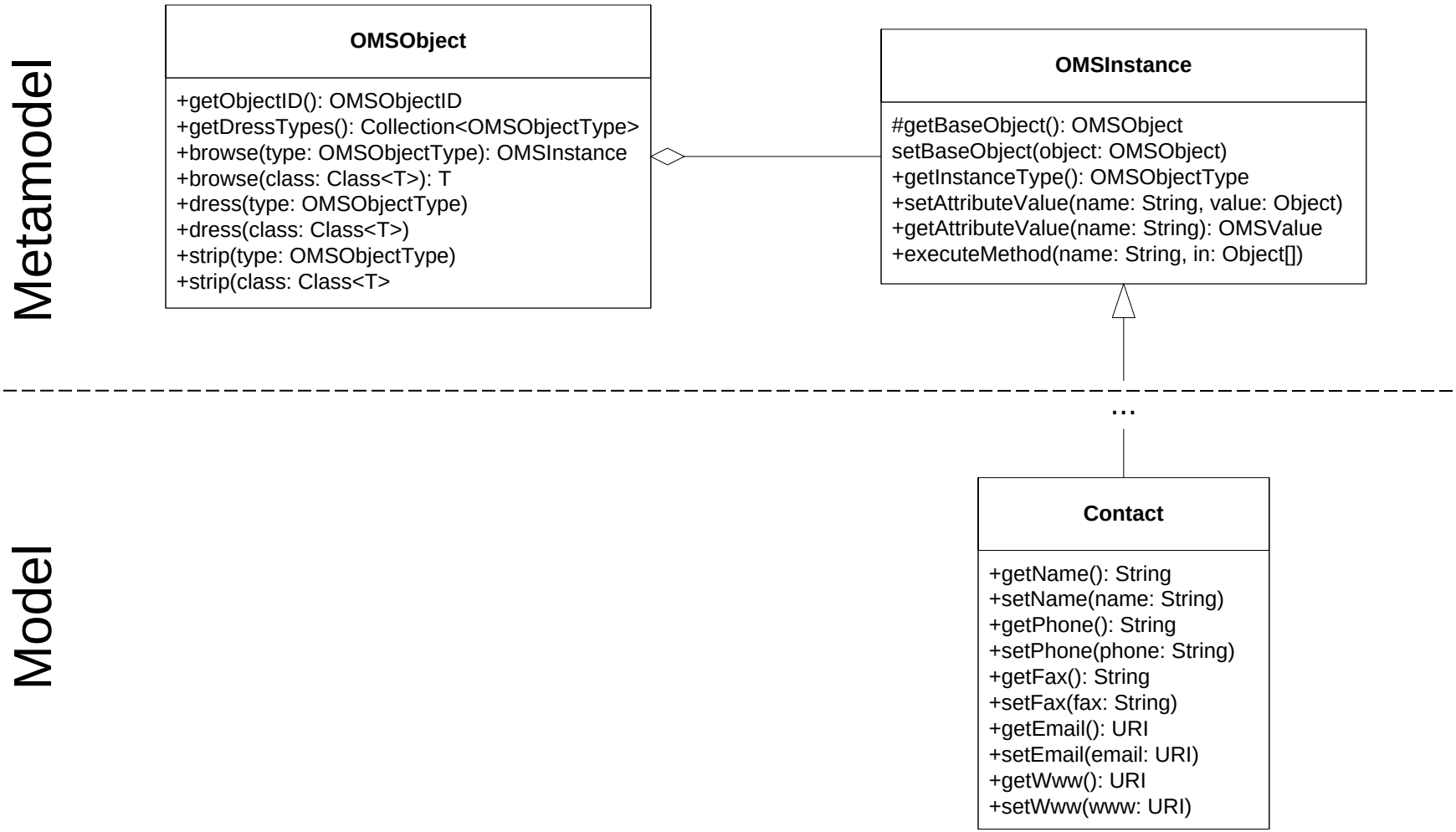
OMSjp Value Framework



Impedance Mismatch

- Mapping the OM object-model to the Java object-model creates a new impedance mismatch
  - multiple instantiation
  - multiple inheritance
- A single object is represented by multiple classes
  - a metamodel class of type **`OMSObject`**
  - several model classes of type **`OMSInstance`**
- Application-specific instance classes can be used instead of generic instance classes
  - if data model does not multiple inheritance, Java inheritance can be used to implement application-specific model classes
  - if data model does use multiple inheritance, application-specific model classes cannot use Java inheritance

OMSObject and OMSInstance



Using Application-Specific Instances

```
public class Contact extends AbstractInstance {
   public void setName(final String name) throws OMSException {
      this.setAttributeValue("name", name);
   }
   public String getName() throws OMSException {
      OMSString s = (OMSString) this.getAttributeValue("name");
      return s.getString();
   }
   ...
}
```

- Façade design pattern
- Access
  - method browse() of class OMSObject
  - automatically if context defines a type, e.g. in a query
- Mapping file defines instance type registrations
  - contact = ch.ethz.globis.demo.contacts.Contact

OMSjp in Action

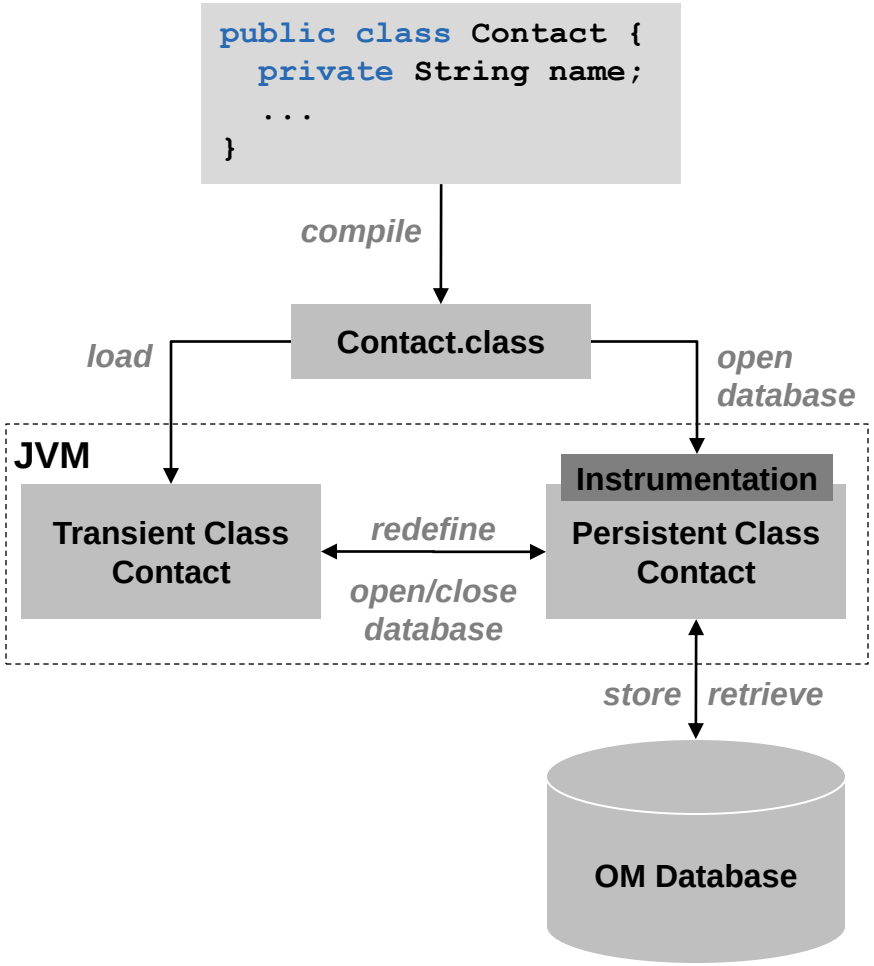
```
// connect driver and open database
OMSDriver driver =
      OMSDriverManager.getDriver("omsjp:avon:local://localhost");
OMSDatabase db = driver.openDatabase("contacts.oms");

// retrieve and access an object
Contact contact = db.getObject(Contact.class, "name", "Moira C. Norrie");
URI www = contact.getWww();

// dress an object and set new attribute value
Person person = contact.getBaseObject().dress(Person.class);
person.setTitle("Prof");

// retrieve a collection and perform a query
OMSBinaryCollection worksFor =
      (OMSBinaryCollection) db.getCollection("WorksFor");
Organisation organisation =
      (Organisation) worksFor.dr(contact).range().first();

// close database and disconnect driver
driver.closeDatabase();
driver.disconnect();
```

Using OML in OMSjp

```
// query for a single object
OMSValue result = db.evaluateQuery(
   "first(all $p in Persons having ($p.name = 'Moira Norrie')");
Person moira = (Person) result;
moira.setName("Moira C. Norrie");

// query for a collection of object
OMSValue result = db.evaluateQuery("dom(SituatedAt rr(all $l in Locations
                                    having ($l.city = 'Zurich')");
OMSCollection collection = (OMSCollection) result;
OMSBulkValue< ? > extent = collection.getExtent();
for (Object o: extent) {
   Contact contact = (Contact) o;
   System.out.println(contact.getName());
}
```

Dynamic Bytecode Instrumentation

- Avoid impedance mismatch to provide transparent persistence
- Code injected at run-time
  - persistence agent is registered in JVM when database is opened
  - agent transforms all classes that are loaded by the JVM
  - when database is closed, transient agent is registered
- Instrumentation supports
  - OMSjp façade pattern
  - type generation and hierarchies
  - multi-valued attributes
  - associations



Instance Instrumentation

```
public class Person implements OMSInstance {
  private String name;
  private OMSObject baseObject;
  public Person(OMSObject object) {
    this.baseObject = object;
  }
  public void setName(String name) {
    this.name = name;
    this.setAttributeValue("name", this.name);
  }
  public String getName() {
    this.name = (String) this.getAttributeValue("name");
    return this.name;
  }
  public void setAttributeValue(String name, Object object) {
    baseObject.setAttributeValue(this.getClass(), name, object);
  }
   Object getAttributeValue(String name) {
    return baseObject.getAttributeValue(this.getClass(), name);
  }
}
```

Class Hierarchy Instrumentation

Java Object Model

Static

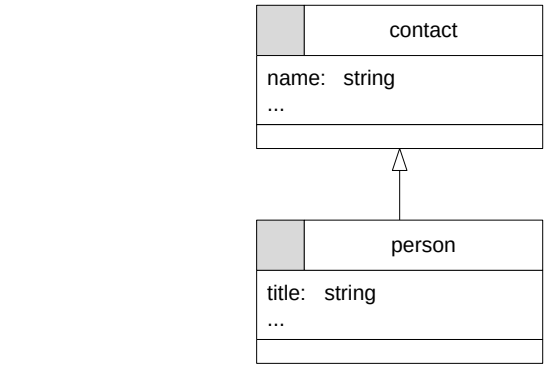
```
public class Contact {
  private String name;
  ...
}
```

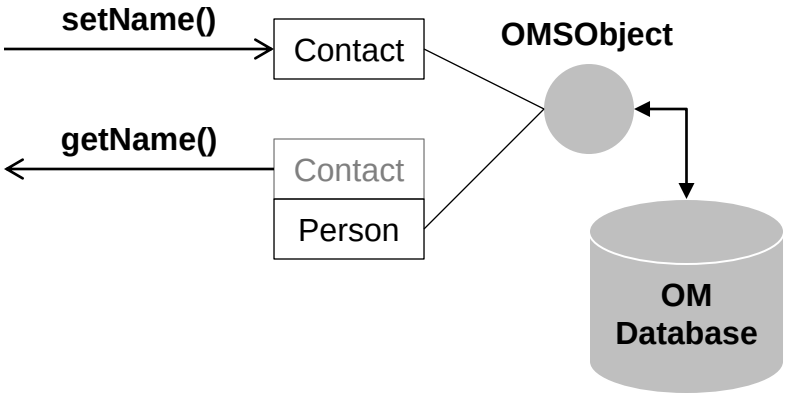
```
public class Person extends Contact {
  private String title;
  ...
}
```

Dynamic

```
Person christoph = new Person();
christoph.setName("Christop Lins");
christoph.setTitle("MSc");
```

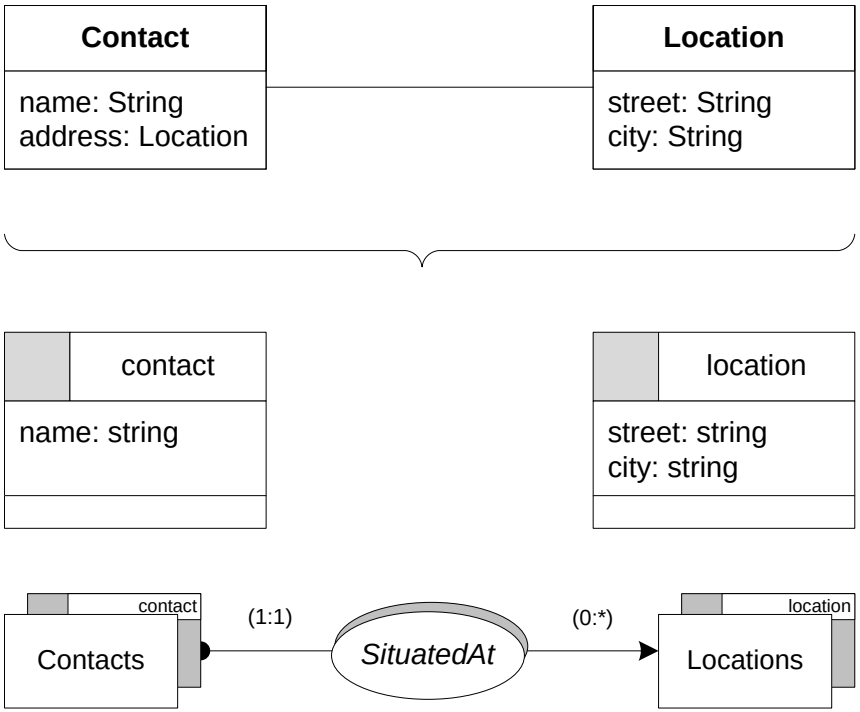
OM Data Model





Type and Association Instrumentation

- Type creation
  - existence of OM type is checked using the fully qualified Java type name
  - Java class analysed using reflection
  - Java types mapped to OM types
  - every type gets an extent collection
- Object references
  - OM types are created for properties that reference non-basic and non-collection types
  - persistence by reachability
  - agent can be configured to create associations instead of references to raise semantic expressiveness



Collection Instrumentation

- Multi-valued properties are represented using OM extents
  - **`Set<T>`** is mapped to **`OMSSet<T>`**
  - **`List<T>`** is mapped to **`OMSSequence<T>`**
  - other collection types are currently not supported by the agent
- OM extents provide support for
  - collection behaviour
  - collection algebra
  - management of large collections

```
public class Person implements OMSInstance {

  private final Set<String> topics;
  private final List<String> tasks;

  public Person() {
    this.topic = new OMSSet<String>();
    this.tasks = new OMSSequence<String>();
  }

  public void addTopic(String topic) {
    topic.add(topic);
  }

  ...

}
```

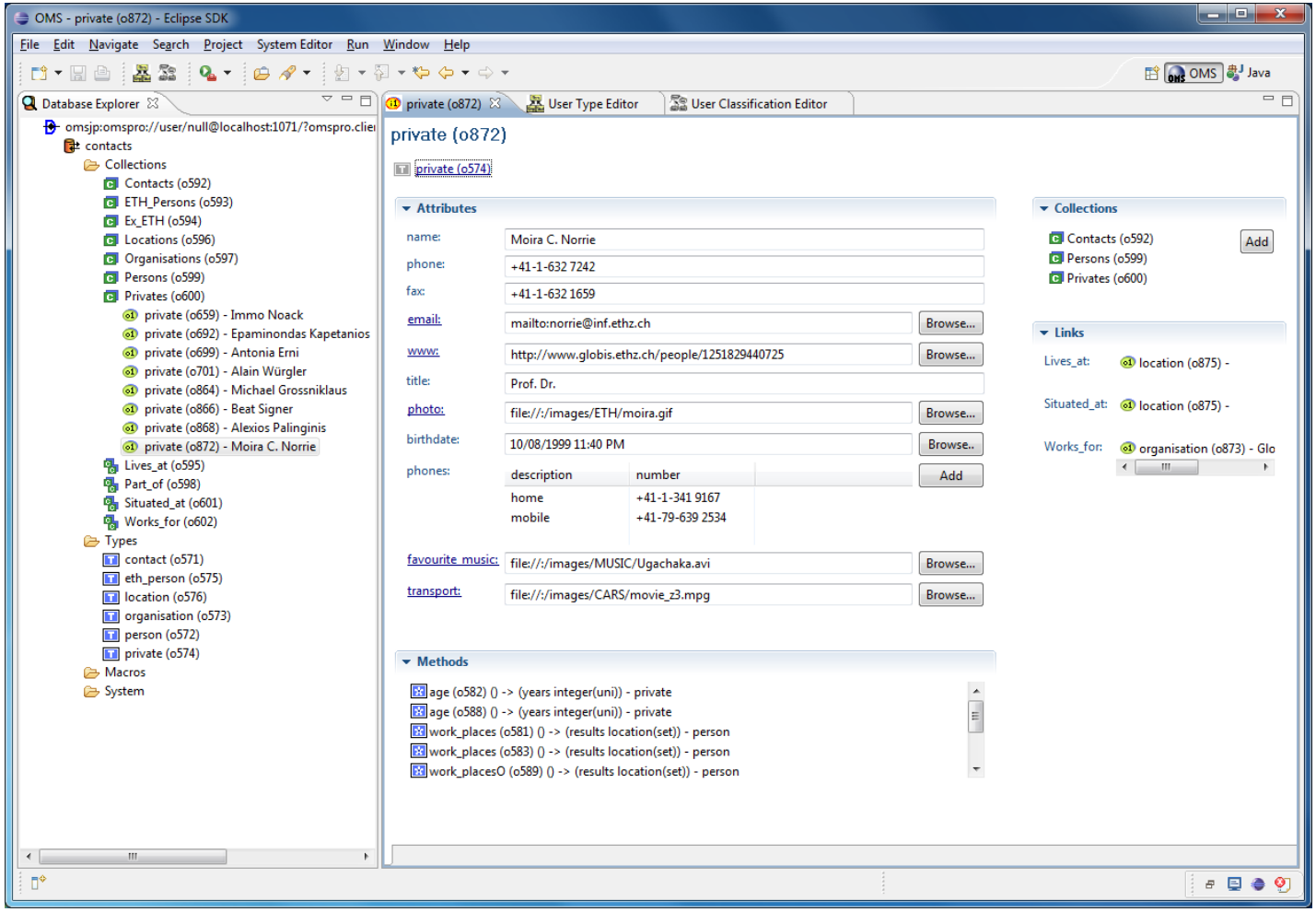
Conventions

- Classes
  - must not be abstract
  - must have a public default constructor
- Properties
  - must be accessible through getter and setter accessor methods that follow the Java Beans convention
    - `public Type getProperty()`
    - `public void setProperty(Type)`
  - all other method names must not contain the **`get`** and **`set`** prefixes
  - keyword **`transient`** can be used for non-persistent properties
  - Arrays are not supported as class members
  - List and Set are supported, all other Java Collections are forbidden.
  - direct initialisation of class members as part of their declaration is not supported

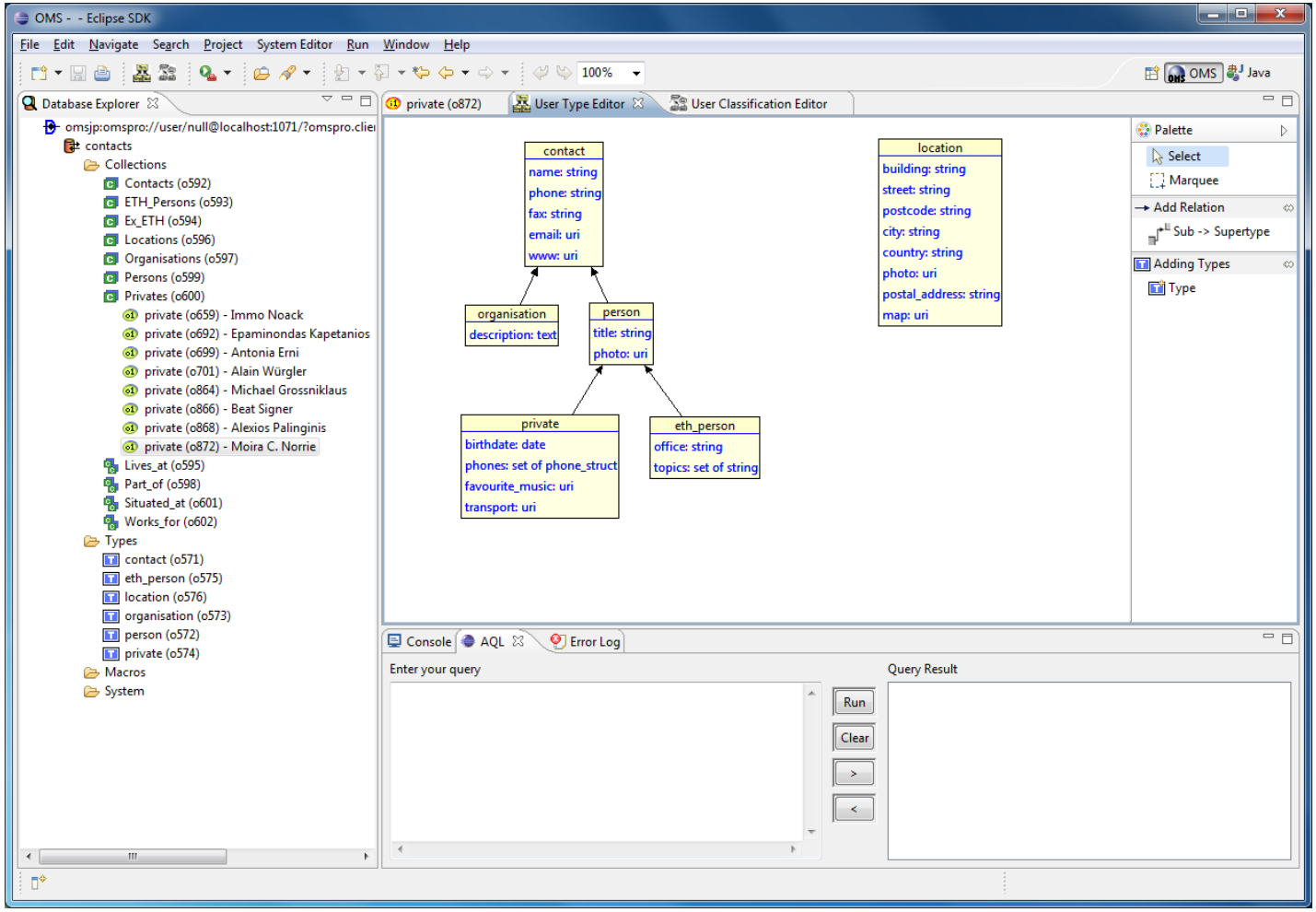
Seamless Access to OM Functionality

```
// connect driver and open database
OMSDriver driver =
      OMSDriverManager.getDriver("omsjp:avon:local://localhost");
OMSDatabase db = driver.openDatabase("contacts.oms");

// create a persistent person object
Person person = new Person();
person.setName("Christoph Lins");

// evolve person to a private contact
OMSObject object = ((OMSInstance) person).getBaseObject();
Private private = object.dress(Private.class);
private.setMusic("http://www.youtube.com/watch?v=kwKWYuZvmhc");

// create a transient person object
driver.closeDatabase();
person = new Person();
person.setName("Barney Stinson");

// disconnect driver
driver.disconnect();
```

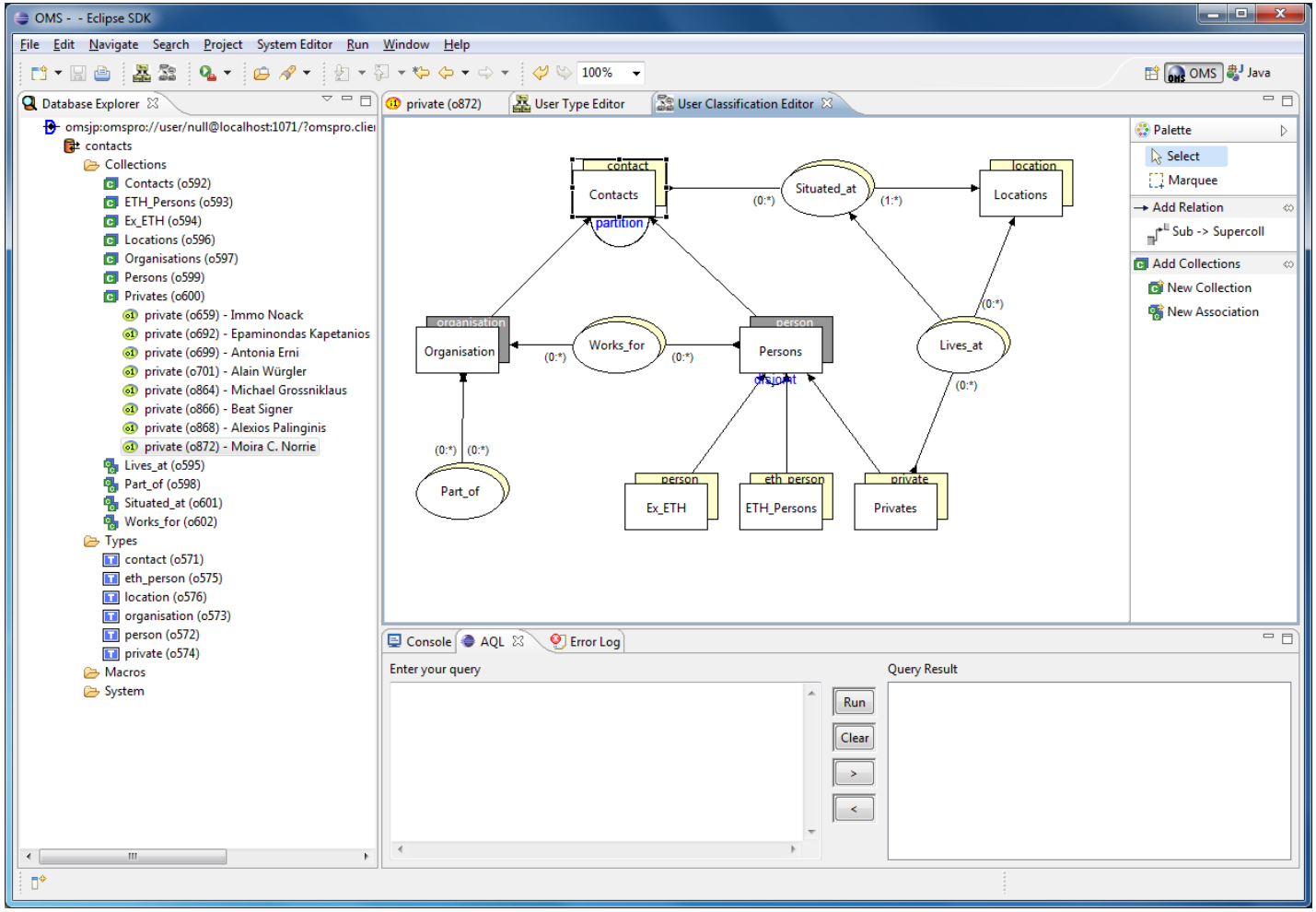
OMSjp Eclipse Plug-in: Object Browser



OMSjp Eclipse Plug-in: Type Editor



OMSjp Eclipse Plug-in: Classification Editor



References

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- B. Aeppli: **Eclipse-Based Front-End for OMSjp**, *Diploma Thesis, 2005*
- C. Schmid: **Design and Development of an Eclipse Schema Editor for OMSjp**, *Diploma Thesis, 2005*
- C. Lins: **Exploiting Dynamic Bytecode Instrumentation to Support Transparent Persistence**, *Semester Thesis, 2009*

Next Week
Course Review

- Exam Information
- Summary
- OODBMS Architectures