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Java Data Objects
The Future for Java Object Persistence

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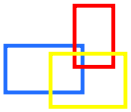
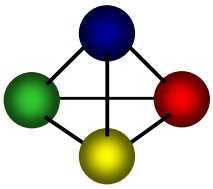


Overview



- What is JDO?
- JDO Goals
- How does JDO work?
- Using JDO
- JDO and EJB
- Looking forward…

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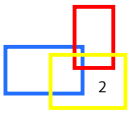

What is JDO?

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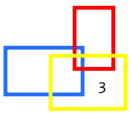

Java Data Objects (JDO)

- Standard for transparent Java object persistence
  - Provides developers with a Java-centric and object view of persistence and data store access
- Designed to allow pluggable vendor "drivers" for accessing any database/data store
- Designed to work in conjunction with Application Servers
  - "Connector Architecture" used to specify the contract between JDO Vendor and Application Server for instance, connection, and transaction management

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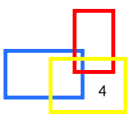
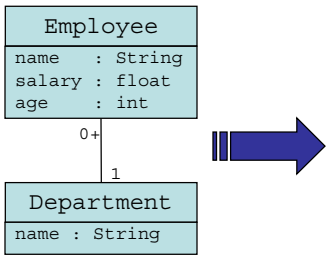


An Example - Creating the classes




```
public class Employee {
  private String     name;
  private int        age;
  private float      salary;
  private Department department;

  public Employee ( String name, int age ) {
    this.name = name;
    this.age  = age;
  }
  public String getName ( ) {
    return name;
  }
  public int getAge ( ) {
    return age;
  }
  ...
  public Department getDepartment ( ) {
    return department;
  }
  public void setDepartment ( Department d ) {
    department = d;
  }
}
```

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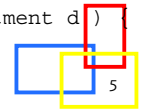

An Example - Adding persistence

```
static void main ( String[] args ) {

  // Need to get a database connection
  ...

  Department dept = new Department("R&D");

  Employee emp = new Employee("Joe Bloggs", 30);

  emp.setDepartment(dept);

  // Committing the transaction stores the
  // new instances in the database
  ...
}
```

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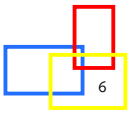

http://jcp.org/jsr/detail/012.jsp

Java Community Process

- Standard driven by the Java Community
- JDO is a Java Specification Request
  - JSR-000012
  - Specification "lead" heads expert group who propose formal specification
  - Participants & public review specification
  - Reference implementation and compatibility tests required prior to publication
  - Standard approved by JSR Executive Committee

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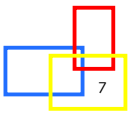

Expert Group Members

- Alagic
- Ericsson
- Forte Software
- IBM
- Informix Software
- Lawson Software
- LIBeLIS
- Object People
- Objectivity
- Oracle
- Poet Software
- Rational Software
- SAP AG
- Secant Technologies
- Silverstream Software
- Software AG
- Sun Microsystems
- Tech@spree
- **Versant**

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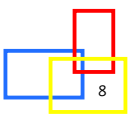

http://access1.sun.com/jdo/index.html

JDO Current Status

- JSR-000012 approved July-1999
- Specification lead selected July-1999
  - Craig Russell, SUN Microsystems
- Expert group formed August-1999
  - Expert group reviews specification before release
  - Versant is a member of the expert group
- First public review completed July-2000
- Second public review started June-2001
- Reference implementations and Technology Compatibility Kit (TCK) development underway

Approval Imminent

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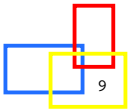

JDO Goals

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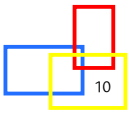

Goals of the JDO Architecture

- Transparent "object" persistence
  - Minimal to 0 constraints on building classes
  - No new data types or data access language
    - DDL & DML is Java
- Use in a range of implementations
  - J2ME - Embedded, device-oriented
  - J2SE - Client/server
  - J2EE - Enterprise Java Beans
- Data store independence
  - Relational, object, object-relational, hierarchical, file systems, ...

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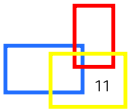

JDO Audience

- Java application developers
  - Transparent object persistence
  - Java-centric, no need to know how to access a database
- EJB application developers
  - Connection pooling & transaction management via Application Server
  - Transparent database access for non-CMP solutions (Session Beans & BMP)
    - No need to use JDBC directly
    - Object Queries to find instances

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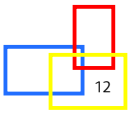

JDO versus JDBC

- Not meant to replace it!
  - Complimentary technology
  - Standardizes object access to data stores
  - Programmer just sees Java classes
- JDO for RDBs likely implemented on top of JDBC
  - JDBC useful for direct control over database access and connection management
  - JDBC is mature, widely accepted and understood
  - JDBC supported by major database vendors

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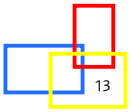

How does JDO work?

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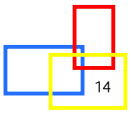

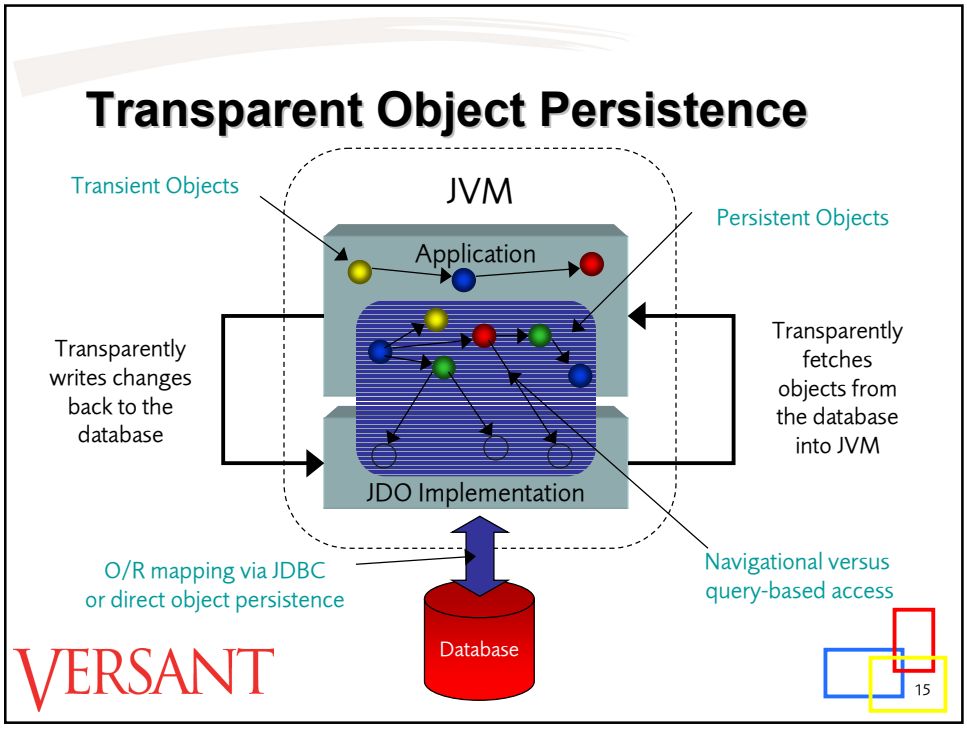
Transparent Object Persistence
Transient Objects
JVM
Persistent Objects
Application
Transparently writes changes back to the database
Transparently fetches objects from the database into JVM
JDO Implementation
O/R mapping via JDBC or direct object persistence
Navigational versus query-based access
Database
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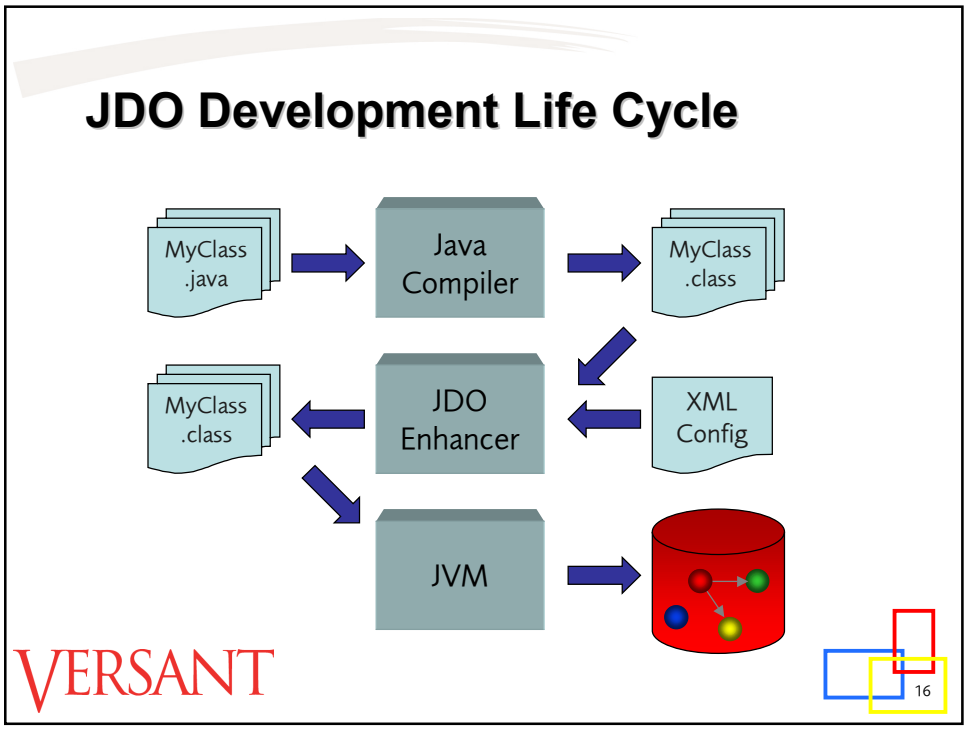
JDO Development Life Cycle
MyClass .java
Java Compiler
MyClass .class
MyClass .class
JDO Enhancer
XML Config
JVM
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JDO Enhancer - What does it do?

- Reads byte code and generates new byte code
  - Adds hooks to enable JDO implementation to transparently:
    - Retrieve objects
    - Track changes to object state
    - Write changes to data store on commit
- Developer doesn't have to explicitly fetch/store objects

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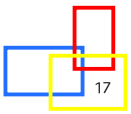

Non-managed versus Managed

- Two ways of developing JDO applications
- Non-managed Environments
  - Client/Server, 2-tier
  - Explicit connection and transaction management
- Managed Environments
  - Application Server (EJB), n-tier
  - Implicit connection and transaction management

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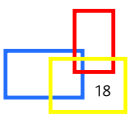

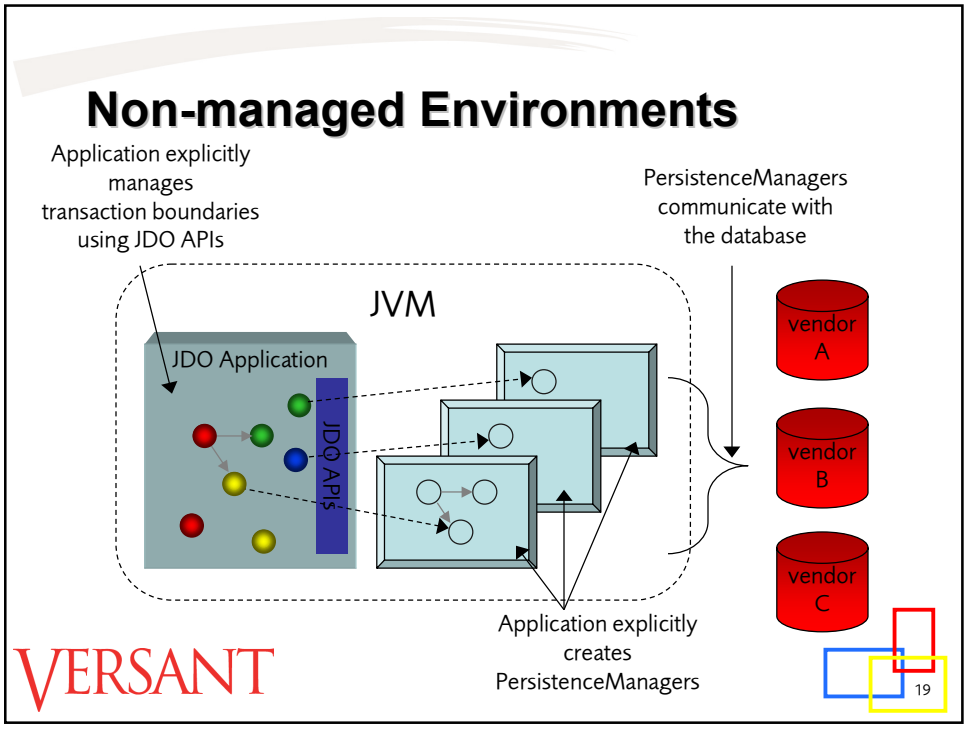
Non-managed Environments
Application explicitly manages transaction boundaries using JDO APIs
PersistenceManagers communicate with the database
JVM
JDO Application
JDO APIs
vendor A
vendor B
vendor C
Application explicitly creates PersistenceManagers
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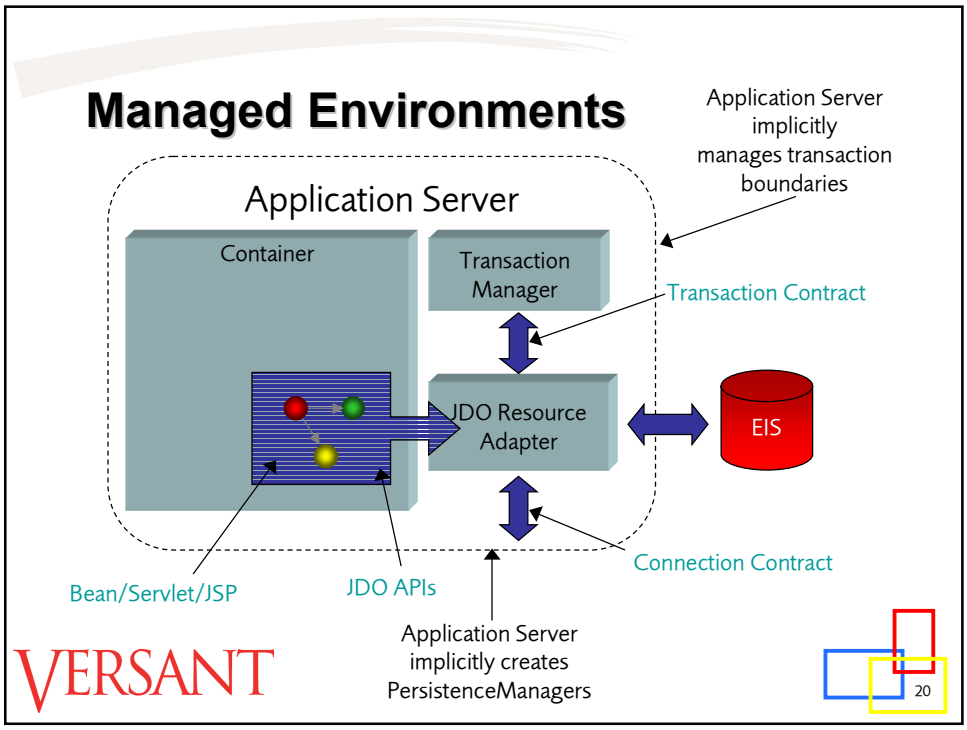
Managed Environments
Application Server implicitly manages transaction boundaries
Application Server
Container
Transaction Manager
Transaction Contract
JDO Resource Adapter
EIS
Connection Contract
Bean/Servlet/JSP
JDO APIs
Application Server implicitly creates PersistenceManagers
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Using JDO

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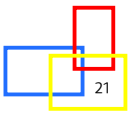

JDO Interfaces and Classes

- PersistenceManagerFactory (Interface)
- PersistenceManager (Interface)
- Transaction (Interface)
- Query (Interface)
- PersistenceCapable (Interface)
- InstanceCallbacks (Interface)
- JDOHelper
- JDO Exception Classes
  - …

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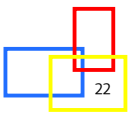

An Overview

- Use PersistenceManagerFactory to get a PersistenceManager
  - PersistenceManager embodies a database connection
- Use a PersistenceManager to create a Transaction or a Query
- Use a Transaction to control transaction boundaries
- Use a Query to find objects by value
- Enhanced classes implicitly implement PersistenceCapable
- PersistenceCapable classes can implement InstanceCallbacks

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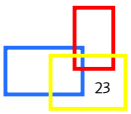

JDO Object Model

- Support for all Java field types
  - Primitives, object references, interfaces
  - Exception: References to system-defined classes
- Support for all Java class and field modifiers
  - Public, private, protected, static, transient, abstract, final, synchronized, volatile
- Support for all user-defined Java classes
  - Exception: any classes that depend on state of inaccessible or remote objects
    - java.net.SocketImpl
  - Exception: any classes that use native methods

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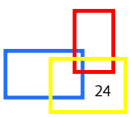

PersistenceManagerFactory (Interface)

- Standard mechanism to get PersistenceManager instances
  - May implement resource pooling and connection management
- Implements java.io.Serializable
  - Support for lookup via JNDI
- Uses JavaBeans pattern for get/set Properties
  - Standard properties
    - ConnectionUserName
    - ConnectionPassword
    - ConnectionURL
    - ...

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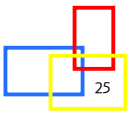

PersistenceManager (Interface)

- Primary interface to the "object cache"
  - Cache management methods
    - Refresh/release objects
- Provides management of PersistenceCapable objects
  - Identity management methods
  - Life-cycle management methods
- Acts as factory for other JDO classes
  - Query creation methods
  - Transaction creation methods
- Use to get Collection of all instances of a class
  - Class extent methods

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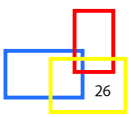

PersistenceManager Methods

- Identity Methods
  - Get the JDO Identity of a JDO Instance

```
Object getObjectId ( Object pc )
```

  - Get a JDO Instance given its JDO Identity

```
Object getObjectById ( Object oid )
```

- Lifecycle Methods

```
void makePersistent ( Object pc )
void deletePersistent ( Object pc )
void makeTransient ( Object pc )
void makeTransactional ( Object pc )
void makeNontransactional ( Object pc )
```

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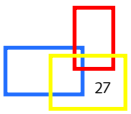

Class Extents

- Collection of all object instances of a given class managed by the data store
- Available for any PersistenceCapable class

```
Extent getExtent ( Class   pc,
                   boolean subclasses )
```

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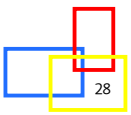

JDO Query Objectives

- Query language neutral
  - Optional support for SQL, OQL, etc.
  - Optimizations possible for specific query languages
- Multi-tier architecture
  - Entirely in-memory
  - Server-side (data store query engine) execution
- Support for Large result sets
- Support for "compiled" queries

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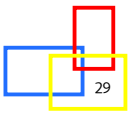

Query (Interface)

- PersistenceManager is the Query factory

```
Query newQuery ( Class      cls,
                 Collection cln,
                 String     filter )
```

- Queries filter Collections and return Collections
- Required elements in a query
  - Collection of candidate instances
    - May be a class extent
    - May be a Collection in the JVM
  - Class (type) of the result set
  - Filter (Java boolean expression)
- Optional elements in a query
  - Parameter & variable declarations; Imports; Ordering

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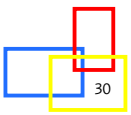

Query "Filters"

- Filters are Java boolean expressions
- Identifiers are class attributes
- Navigation via '.' notation
  - Support for single object navigation
  - Support for collections via "contains()" method
  - Support for wildcards via "startsWith()" & "endsWidth()"
- Support for parameter substitution and variables

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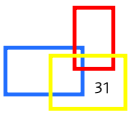
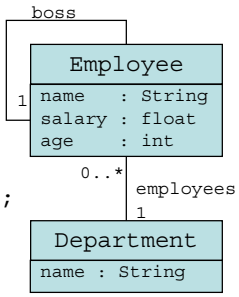


"Filters": Simple example

- Find well compensated employees

```
String filter = "salary > 100000";
```




```
Extent     employees = pm.getExtent(Employee.class);
Query      query     = pm.newQuery(employees, filter);
Collection results   = (Collection) query.execute();
```

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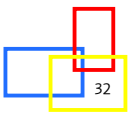
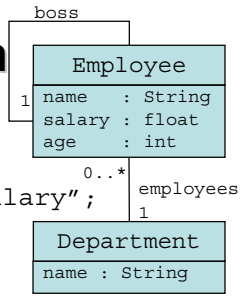


"Filters": Object Navigation



- Find over compensated employees

```
String filter = "salary > boss.salary";
```

```
Extent     employees = pm.getExtent(Employee.class);
Query      query     = pm.newQuery(employees, filter);
Collection results   = (Collection) query.execute();
```

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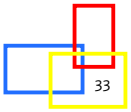

Using Parameters & Variables

- Support for parameterized queries
  - Parameters are substituted at execution time
  - Parameters are typed
  - Parameters specified using Java syntax
  - Multiple statements separated by semicolons

```
query.declareParameters ("float salary");
```

- Support for use of variables in queries
  - Variables are typed
  - Variables specified using Java syntax
  - Multiple statements separated by semicolons

```
query.declareVariables ("Employee emp");
```

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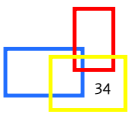
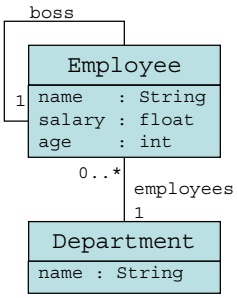


"Filters": Complex example



- Find all Departments with at least one well-compensated Employee

```
String filter = "
  employees.contains(emp) &&
  emp.salary > salary";
```

```
Extent     depts   = pm.getExtent(Department.class);
Query      query   = pm.newQuery(depts, filter);
query.declareParameters("float salary");
query.declareVariables("Employee emp");
Collection results =
    (Collection) query.execute(new Float(100000.0));
```

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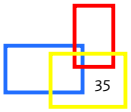

Imports & Ordering

- Imports
  - Imports specified using Java syntax
  - Multiple statements separated by semicolons

```
query.declareImports ("import example");
```

- Ordering
  - Ordering can be "ascending" or "descending"

```
query.setOrdering ("salary ascending");
```

  - Ordering can include navigation via '.' notation

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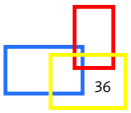

Transaction (Interface)

- PersistenceManager is the Transaction factory

```
Transaction currentTransaction ()
```

- Transactions can be "unmanaged" (local) or "managed" (distributed)
  - Explicit control versus implicit control
  - Designed to work in Embedded & Enterprise environments
- Support for data store (default) and optimistic (optional) concurrency models
- Methods for "unmanaged" transactions

```
isActive ()
begin ()
commit ()
rollback ()
```

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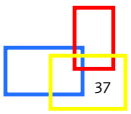

PersistenceCapable (Interface)

- Implemented by a "Persistence Capable" Class

```
PersistenceManager
  jdoGetPersistenceManager ( )
```

Get Persistence Manager for this instance

```
Object jdoGetObjectId ( )
```

JDO Object Identity

```
boolean jdoIsPersistent ( )
boolean jdoIsTransactional ( )
boolean jdoIsDirty ( )
boolean jdoIsNew ( )
boolean jdoIsDeleted ( )
```

Status Interrogation

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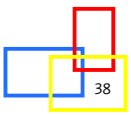

JDOHelper

- Static methods that mirror PersitenceManager & PersistentCapable interfaces
  - Delegates to appropriate interface
- Simplifies management of persistent objects

```
static Object getObjectId ( Object pc )

static boolean isPersistent ( Object pc )
static boolean isDirty ( Object pc )
static boolean isNew ( Object pc )
static boolean isDeleted ( Object pc )
…
```

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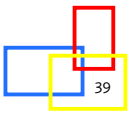

JDO Identity

- Object identity implemented by JVM
  - Is this the same object instance?

```
obj1 == obj2
```

- Object equality implemented by class developer
  - Is this the same object?

```
obj1.equals (obj2)
```

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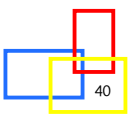

JDO Identity (cont'd)

- JDO identity implemented by JDO vendor
  - Can be based on primary key
    - Defined by application, enforced by database
  - Can be managed by the data store
    - Not related to any attribute value
  - Can be managed by JDO implementation
    - Guarantee uniqueness in the JVM but not datastore

```
obj1.jdoGetObjectId().equals(obj2.jdoGetObjectId())
```

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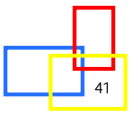

"Uniquing" in JDO

- JDO instances representing the same data store "object" exist only once per PersistenceManager
- Regardless of how the instance is obtained
  - Queries
  - Navigation
  - Other PersistenceManager methods

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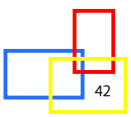

An Example

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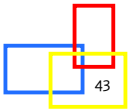
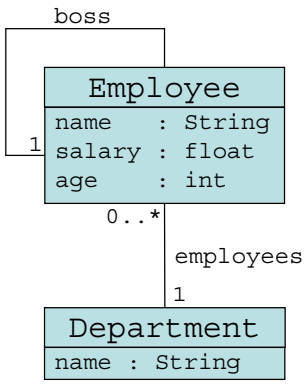


How does it work? An example...



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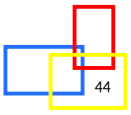

An Example: Employee Class

```
public class Employee {
  private String     name;
  private int        age;
  private float      salary;
  private Employee   boss;
  private Department department;

  public Employee ( String name, int age ) {
    this.name = name;
    this.age  = age;
  }
  public String getName ( ) {
    return name;
  }
  ...
  public Department getDepartment ( ) {
    return department;
  }
  public void setDepartment ( Department d ) {
    department = d;
  }
}
```

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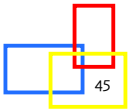

An Example: Department Class

```
public class Department {
  private String name;
  private Set    employees = new HashSet();

  public Department ( String name ) {
    this.name = name;
  }
  public String getName ( ) {
    return name;
  }
  ...
  public void addEmployee ( Employee emp ) {
    emp.setDeparment(this);
    employees.add(emp);
  }
}
```

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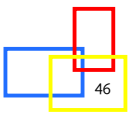

XML Metadata

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE jdo SYSTEM "jdo.dtd">
<jdo>
  <package name = "com.versant.jdoexample"/>
  <class name = "Employee"/>
  <class name = "Department">
    <field name = "employees">
      <collection element-type="Employee"/>
    </field>
  </class>
</jdo>
```

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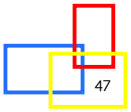

An Example: Connecting

```
static void main ( String[] args ) {

  // Create a Vendor specific factory
  PersistenceManagerFactory factory =
    new VersantPersistenceManagerFactory();

  // Set connection parameters
  factory.setConnectionURL(args[0]);

  // Get a PersistenceManager
  PersistenceManager pm =
    factory.getPersistenceManager();
```

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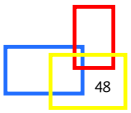

An Example: Find a Department

```
// Begin a Transaction
Transaction tx = pm.currentTransaction();
tx.begin();

// Construct the Query
Extent     depts   = pm.getExtent(Department.class);
String     filter  = "name = dept";
Query      query   = pm.newQuery(depts, filter);

// Execute the Query
query.declareParameters("String dept");

Collection results = pm.execute(args[1]);

// Extract the Department from the result set
Department dept =
  (Department) results.iterator().next();
```

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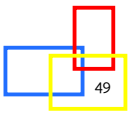

An Example: Create an Employee

```
// Create a new Employee
Employee emp =
  new Employee(args[2], Integer.parseInt(args[3]));

// Add Employee to Department
dept.addEmployee(emp);

// Commit transaction
tx.commit();
}
```

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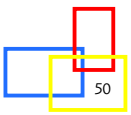

JDO and J2EE

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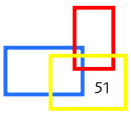

Java Connector Architecture

- Mandated as plug-in for non-JDBC data access
  - Deals with connection, transaction & security management
- Common Client Interface
  - Provides standard APIs to get a connection

```
javax.resource.cci.ConnectionFactory
javax.resource.cci.Connection
```

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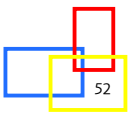

JDO & JCA

- PersistenceManagerFactory maps to ConnectionFactory
- PersistenceManager maps to Connection
  - Container-managed transactions
    - Management delegated to container
  - Bean-managed transactions
    - Explicit commit/rollback

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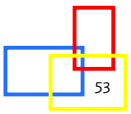

Getting a Connection

- First get a PersistenceManagerFactory
  - Done during setSessionContext()

```
// Obtain the initial JNDI Naming context
Context ctx = new InitialContext();
// perform JNDI lookup to obtain the connection factory
PersistenceManagerFactory pmf = (PersistenceManagerFactory)
  ctx.lookup("java:comp/env/jdo/VersantPersistenceManagerFactory");
```

- Then get a PersistenceManager

```
// Obtain a connection
PersistenceManager pm = pmf.getPersistenceManager();
```

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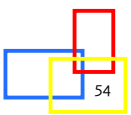

JDO & EJB

- Alternative to using CMP for data store access
  - Simpler & faster to develop
  - Still standard-based & database independent
- Can be used from JSP/Servlets, SessionBeans or BMP EntityBeans
  - Eliminates need to use JDBC directly
  - Simplifies development
- Facilitates an approach to development that compliments common J2EE design patterns
  - Session Façade
  - Value Object
  - Data Access Object

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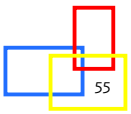

An Example: SessionBean

```
public void createEmployee (
  String name,
  int    age,
  String dept ) : throws RemoteException {

  // Get a PersistenceManager
  PersistenceManager pm = pmf.getPersistenceManager();

  try {
    // Construct the Query
    Extent     depts   = pm.getExtent(Department.class);
    String     filter  = "name = " + dept;
    Query      query   = pm.newQuery(depts, filter);

    Collection results = pm.execute();
```

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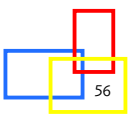

An Example: SessionBean

```
    // Extract the Department from the result set
    Department dept =
      (Department) results.iterator().next();

    // Create a new Employee
    Employee emp = new Employee(name, age);

    // Add Employee to Department
    dept.addEmployee(emp);
  }

  catch (Exception e) {

    throw new RemoteException(e);
  }
}
```

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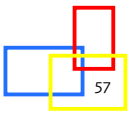

JDO & CMP

- EJB 2.0 addresses many of earlier CMP issues
  - Local interfaces
  - Container-managed relationships
  - EJBQL
- Development still order magnitude harder
  - Home & bean interfaces (local or remote)
  - Abstract bean class & dependent value classes
  - PrimaryKey class
  - Deployment descriptor
- Increasingly difficult to test

EJB 2.0 requires good tool support to make it useable!

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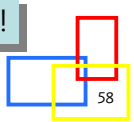

Summary

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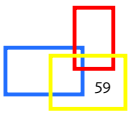

Looking forward...

- JDO accepted by Java Community
  - Needs your support
- JDO incorporated into Java platform
  - Standard mechanism for Java object persistence
  - Complimentary to JDBC
- JDO supported by Application Server vendors
  - Alternative to CMP
  - Disparity between JDO QL & EJB QL
    - Needs to be resolved

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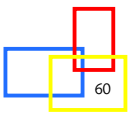

Vendor Support

O/R Mapping Tool Vendors

- Forte for Java – SUN
- TopLink - WebGain
- OpenFusion JDO – PrismTech
- Kodo JDO – TechTrader
- LiDO – LIBeLIS
- Rexip JDO – TCCybersoft

Consultants

- Object Identity
- Olgilivie Partners

Database/Middleware Vendors

- **enJin – Versant**
- FastObjects – Poet
- ObjectStore – eXcelon
- Orient ODBMS – Orient Technologies
- GemStone Facets – GemStone Systems

Others

- SAP

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