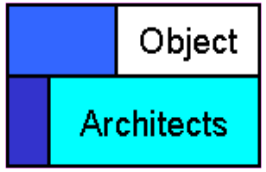


Persistence Options for Object-Oriented Programs

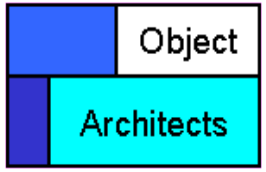
JAOO 2003

Wolfgang Keller, wk@objectarchitects.de

Monday September 22nd, 2003. (15:15h - 16:00h)

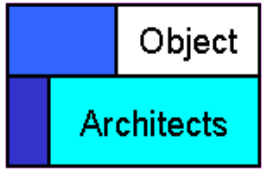
Your Charter of Rights

If you invest the next 45 Minutes



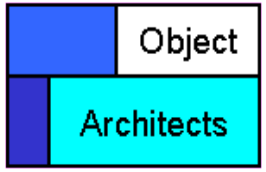
- you have the right to know **WHAT** you are told and **HOW YOU PROFIT** from it
- you have the right to know **WHO** you spend 45 minutes with
- and you have the right to know **HOW** this is done and **WHERE** you are at each moment

WHAT
The 4 Key Messages for „normal“ developers and architects



- know you application style before you decide for a certain way to implement persistence
- know the concept of transparent persistence
- don‘t develop your own green-field persistence layer unless you do it for fun. That made sense 10 years ago but in the presence of plenty of commercial and open source software for the area it is nowadays too expensive in most cases
- In case you run into problems, know where to find the patterns and explanations on the mechanics of persistence

HOW YOU PROFIT



- you might be prevented from making a few expensive mistakes, like
  - using a persistence mechanism that doesn‘t perform or doesn‘t fit the problem
  - getting project delay because of writing your own instead of using some product
- and you know where you find more information if you need help with persistence issues

WHO

Object Architects

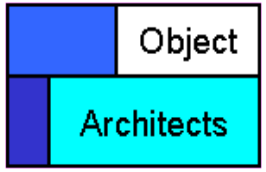
read at home

- a guy who has written persistence stuff for a bank in 1994-95, when the field was young and products were scarce.
- who has mined the field for patters, first in a research project in 1996 and later just for fun
- and who is now observing the field more or less as a technical hobby. See http://www.objectarchitects.de/

- no Generali Group Logo today on these slides as this has not got much to do with my daily job as a tech manager at

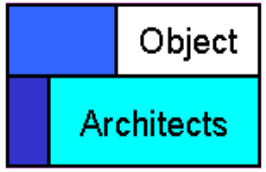
AMB GENERALI Informatik Services

HOW
Overview



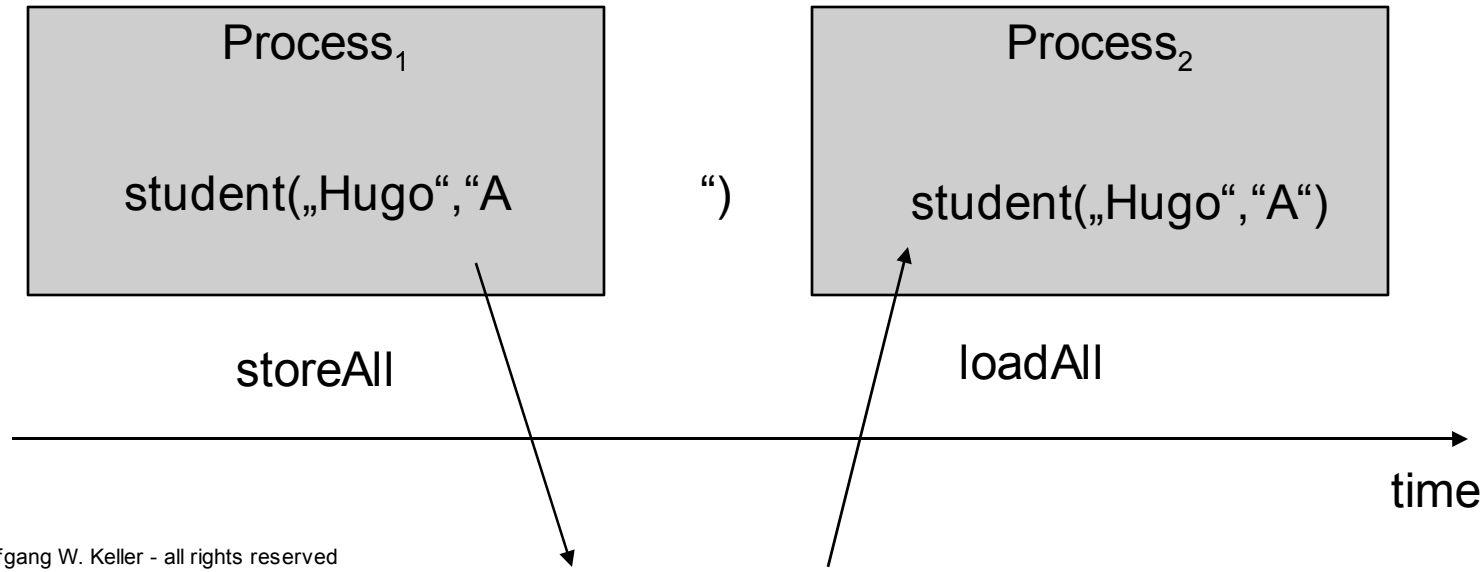
- what is persistence anyway?
  - persistence defined
  - the concept of transparent persistence
  - persistence interfaces
- application styles
  - when to use o/r mapping and when to use other options
- o/r mappers explained (how to …) from the primitive to the complex
  - the basics of mapping
  - the basics of implementing o/r mapper features
    - oid, inheritance, relations, transactions,
    - persistence in EJBs
- summary

What is Persistence anyway?
Persistence defined

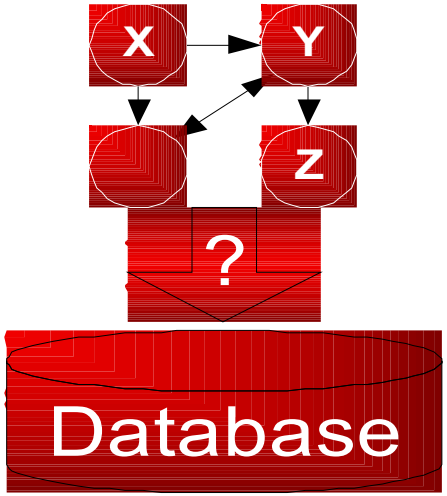


fast

- persistence is the ability of an object to survive the lifecycle of the project in which it resides
- objects that „die“ with the end of a process are called transient

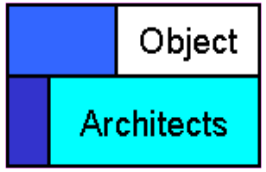


What are the Options to Implement Persistence?



Stream Persistence	Object Database		Object/ Relational Coupling	
	Object Server	Page Server	ORDBMS	O/R Access Layer

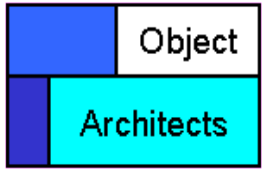
Generations of Database Technology (1)
How Databases evolved



read later

- flat files
  - no efficient key based access
- ISAM/VSAM files
  - efficient access via a key but no concurrency, recovery, logging ...
- hierarchical DBMS (IMS-DB)
  - very efficient as long a access paths are used as planned. Still fastest existing „real“ databases
- network model
  - CODASYL and the like: multiple access paths but also problem as soon as you leave the pre-designed access paths

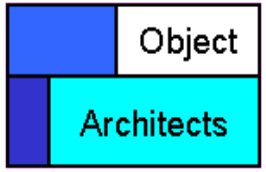
Generations of Database Technology (2)
How Databases evolved



read later

- relational DBMS
  - very flexible in terms of access - but watch out for performance
  - avoid for graphs, trees, ...
- OODBMS
  - very good performance for pointer based navigation
  - weaknesses in query processing and also data manipulation languages
  - low market share
- Object/Relational Addendums
  - offered by big DB vendors on top of RDBMS
  - but no broad production experiences

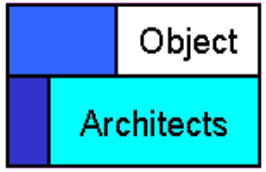
What is Persistence anyway?
The Concept of Transparent Persistence



- a persistence mechanism is called „transparent“ or also „orthogonal“ if persistent objects are treated no other in the programming environment than transient (non-persistent) objects

fast

Little Q&A session



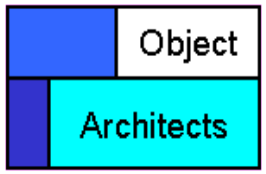
read later

Q: Is an object-oriented language with a persistence mechanism (be it transparent or non-transparent) automatically an object database?

A: No - there‘s a set of features that distinguishes a „database“ from an arbitrary file system or „low profile“ persistence mechanism. The features are:

- Concurrency (Locking, Units of Work (Transactions))
- Recovery, Logging
- Security
- Query Facilities
- Secondary Storage Management

Little Q&A session

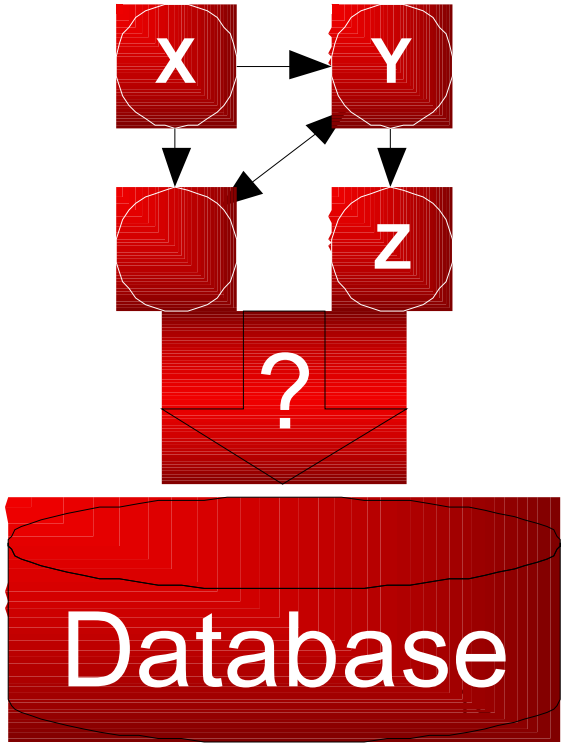


read later

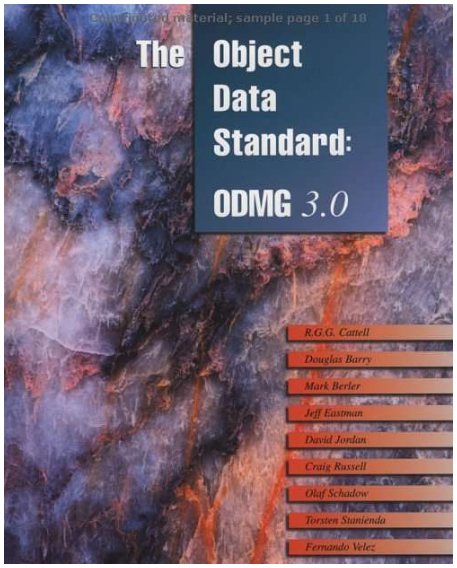
Q: What distinguishes making objects persistent from straight use of a relational database?

A: o-o languages have a rich set of features not present in relational databases or flat files, like:

- Complex objects
- Object identity
- Encapsulation
- Types and Classes
- Class or Type Hierarchies
- Overriding, overloading and late binding

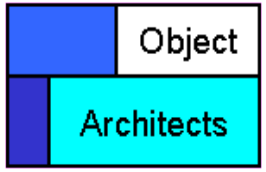


The ODMG Standard and Interface What's that?



- ODMG = Object Data Management Group (www.odmg.org)
- has published a standard for object databases in three editions
  - last edition from 2001
  - **the came JDO**
- ISBN 1-55860-647-5
- the standard is often used as a persistence extension to O-O languages.
- there are „language bindings" for Java, C++, Smalltalk, ...
- **JDO is a follow up standard – only Java => no language bindings**

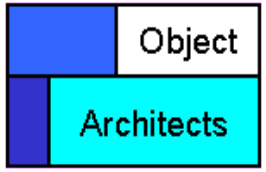
The ODMG standard and interface
Code is better than long explanations :-)




```
public void apply()
    {
        String in = readLineWithMessage("Edit Product with id:'
        int id = Integer.parseInt(in);

        // We don't have a reference to the selected Product.
        // So first we have to lookup the object.

        // 1. build oql query to select product by id:
        String oqlQuery = "select del from " +
                          Product.class.getName() +
                          " where _id = " + id;

        Database db = odmg.getDatabase(null); // the current DB
        Transaction tx = null;
        try
        {
            // 2. start transaction
            tx = odmg.newTransaction();
            tx.begin();

            // 3. lookup the product specified by query
            OQLQuery query = odmg.newOQLQuery();
            query.create(oqlQuery);
            DList result = (DList) query.execute();
            Product toBeEdited = (Product) result.get(0);

            // 4. lock the product for write access
            tx.lock(toBeEdited, Transaction.WRITE);
```


Source from: OJB ODMG API Tutorial
see http://db.apache.org/ojb/tutorial2.html

The ODMG standard and interface
Code is better than long explanations :-)

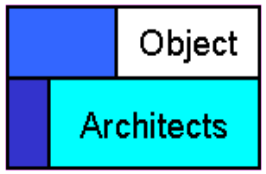



```
            // 5. Edit the product entry
               System.out.println("please edit existing product");
               in = readLineWithMessage(
                   "enter name (was " + toBeEdited.getName() + "):");
               toBeEdited.setName(in);
               in = readLineWithMessage(
                   "enter price (was " + toBeEdited.getPrice() + "):");
               toBeEdited.setPrice(Double.parseDouble(in));
               in = readLineWithMessage(
                   "enter available stock (was "+toBeEdited.getStock() + "):
");
               toBeEdited.setStock(Integer.parseInt(in));

               // 6. commit transaction
               tx.commit();
           }
           catch (Throwable t)
           {
               // rollback in case of e
               tx.abort();
               t.printStackTrace();
           }
       }
```

This is transparent enough but not really what was envisioned when transparent persistence was defined and „invented“

Source from: OJB ODMG API Tutorial
see http://db.apache.org/ojb/tutorial2.html

The Object-Oriented Database System Manifesto – Mandatory Features (1)



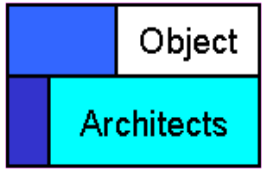
fast …

We have seen this list a few slides ago

- Complex objects
- Object identity
- Encapsulation
- Types and Classes
- Class or Type Hierarchies
- Overriding, overloading and late binding
- Computational completeness

feature list compiled from: [Atk+89] Malcolm P. Atkinson, François Bancilhon, David J. DeWitt, Klaus R. Dittrich, David Maier, Stanley B. Zdonik: The Object-Oriented Database System Manifesto. in "Deductive and Object-Oriented Databases", Proceedings of the First International Conference on Deductive and Object-Oriented Databases (DOOD'89), pp. 223-240

The Object-Oriented Database System Manifesto – Mandatory Features (2)

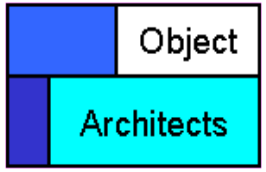


- Extensibility (of the Type System)
- Persistence
- Secondary storage management
- Concurrency
- Recovery
- Ad Hoc Query Facility

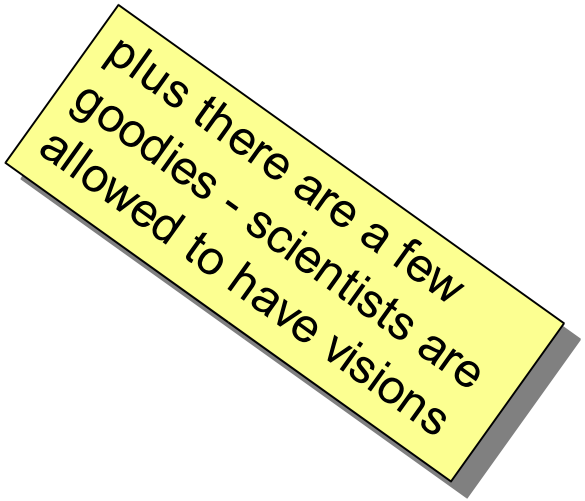
We have seen a similar list as the „database distinctive features“

feature list compiled from: [Atk+89] Malcolm P. Atkinson, François Bancilhon, David J. DeWitt, Klaus R. Dittrich, David Maier, Stanley B. Zdonik: The Object-Oriented Database System Manifesto. in "Deductive and Object-Oriented Databases", Proceedings of the First International Conference on Deductive and Object-Oriented Databases (DOOD'89), pp. 223-240

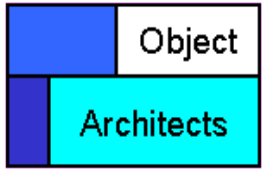
The Object-Oriented Database System Manifesto – Goodies



- Multiple inheritance
- Type checking and type inferencing
- Distribution
- Design transactions (Nested, Parallel)
- Versions (Schema Evolution)



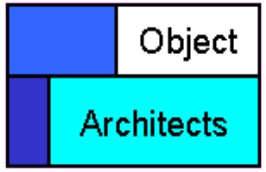
feature list compiled from: [Atk+89] Malcolm P. Atkinson, François Bancilhon, David J. DeWitt, Klaus R. Dittrich, David Maier, Stanley B. Zdonik: The Object-Oriented Database System Manifesto. in "Deductive and Object-Oriented Databases", Proceedings of the First International Conference on Deductive and Object-Oriented Databases (DOOD'89), pp. 223-240



Application Styles

when to use o/r mapping and when to use other tools

Chapter Overview
Application Styles

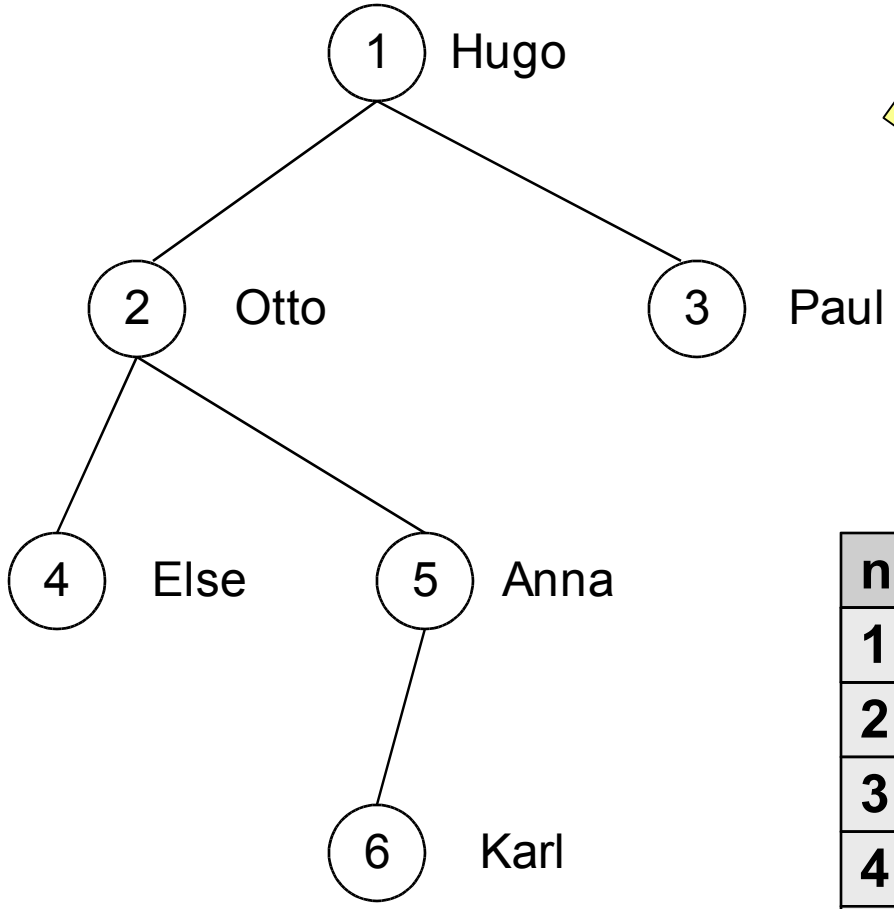


- key messages
- a few very important attributes for starters
  - single user systems
    - serialization and flat file persistence
  - multi user systems with check-in // check-out persistence
    - again serialization and flat file persistence
  - number of objects - database size
  - access patterns
    - object navigation versus record querying
- the list of forces a.k.a. nonfunctional requirements

Application Styles
Key Messages

- avoid using relational databases for tree like and graph like data structures
- avoid using flat files or OODBs for business systems that would be normally implemented using a relational database
  - systems with a high level of concurrency
  - and with a large number of short transactions

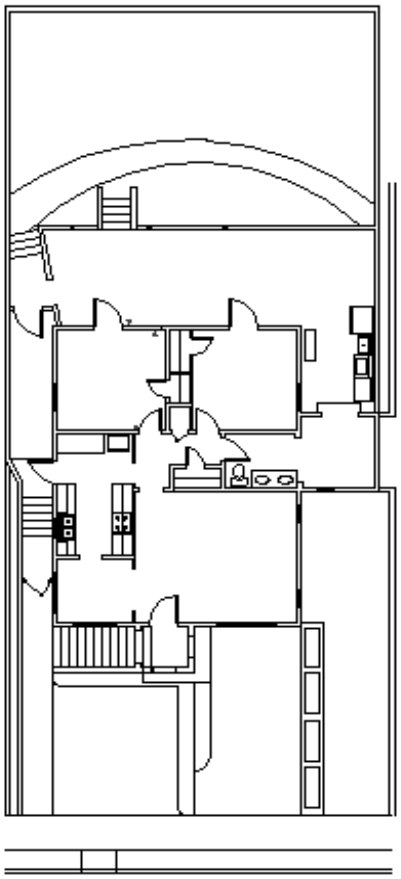
Please!
No Tree Structures in a Relational Database!



navigating from Hugo to Otto costs 3 select statements

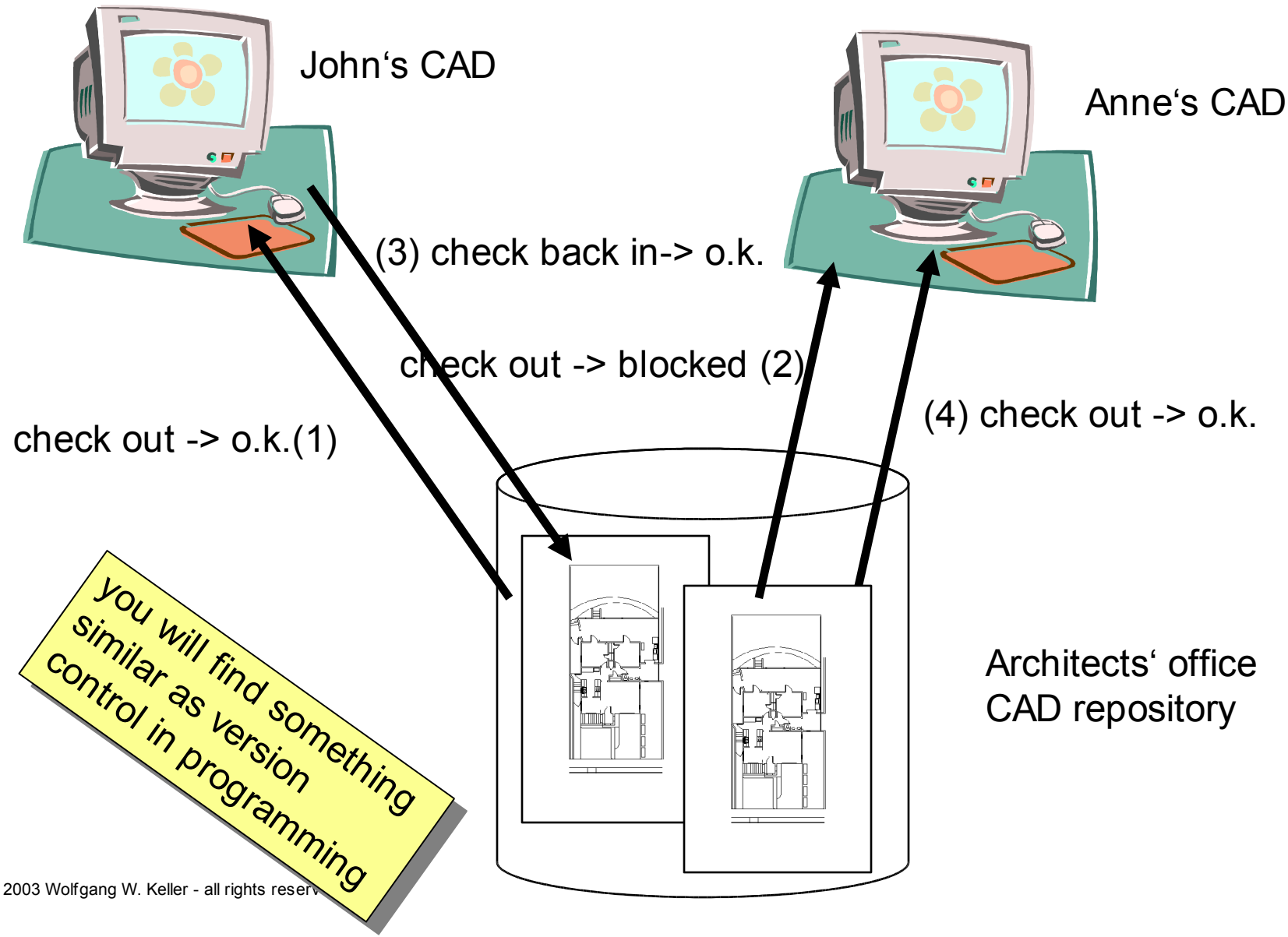
node id	parent	value
1	null	Hugo
2	1	Otto
3	1	Paul
4	2	Else
5	2	Anna
6	5	Karl

Single User System: Typical Example for a „Single User System“ - A User is editing a CAD Model of a Family Home

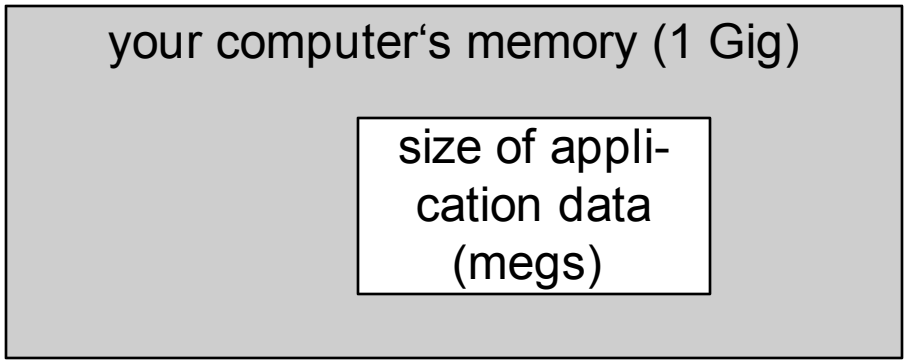


- CAD models and the like are typically represented by complex object models
- the size of low profile CAD models is in the mega bytes range
- it does not make too much sense if two people edit the same „small“ model at the same time
- serializing such a model into a flat file can do the job - often better than putting the model in a RDB

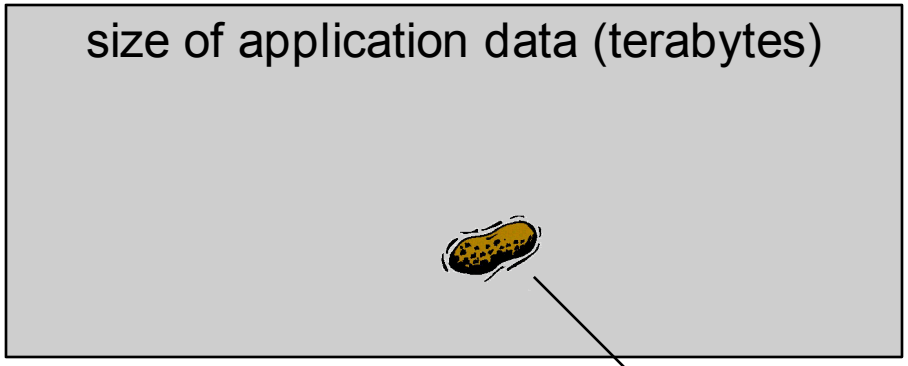
Now assume there are 7 Architects who do each a Piece of the Job



Size matters :-)



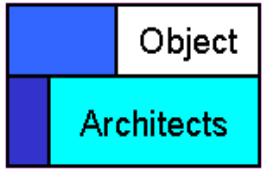
- flat file and check in / check out feasible



- PLEASE use a database

the memory size of your PC is peanuts compared to this

A few Rules of Thumb

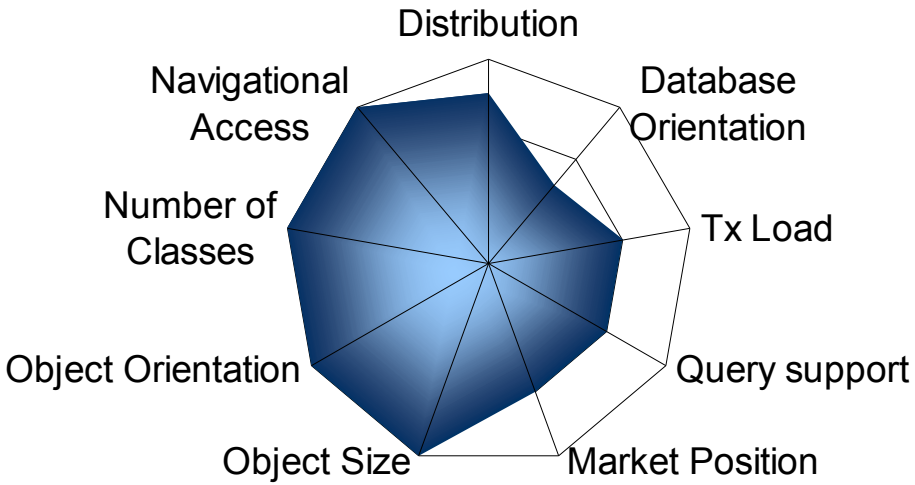


- You have high concurrency - many users working the same data
  - use a „real“ database like an RDBMS or an OODBMS
- You need „true“ database features like recovery, logging, concurrency
  - use a relational or object database :-)
- Your amount of user data is several times larger than the working storage of you computer
  - use a relational or object database
- Your amount of user data is small compared to your computer size, concurrency is low to non existent, the problem is a check in / check out problem
  - consider using stream persistence
- You build an Enterprise Information System like order entry, bookkeeping and the like
  - do what everybody does - use a RDBMS

For a more educated Decision have a look at Jens Coldewey's Tutorial on "Choosing Database Technology" - it's free!

Object Architects

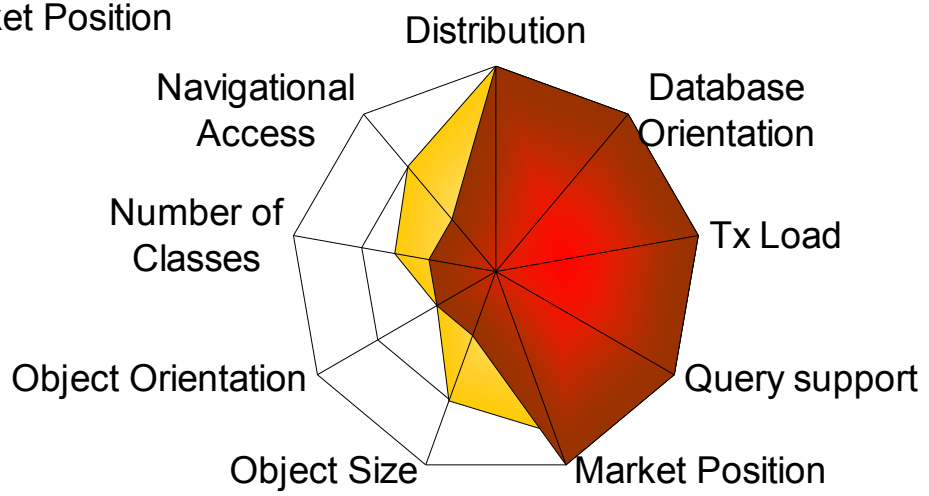
Backup



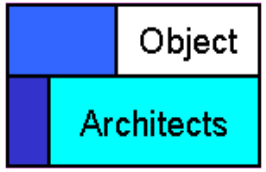
ODBMS

ORDBMS

RDBMS



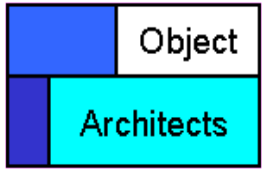
Available at: http://www.coldewey.com/publikationen/ChoosingDatabaseTech.pdf



O/R Mappers

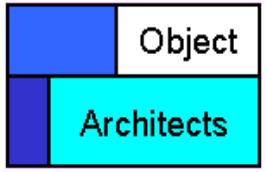
from the primitive to the complex

Chapter Overview (1/2)
O/R Mappers ... from the Primitive to the Complex



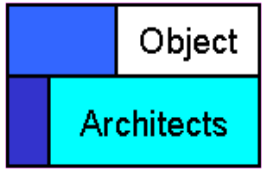
- mapping „straight“ objects
  - 1 class => 1 table
- the CRUD pattern
  - create, read, update, write
- object identity and the identity cache
- 1:n relations and lazy loading
- persistence „without programming“: exploiting meta information

Chapter Overview (2/2)
O/R Mappers ... from the Primitive to the Complex



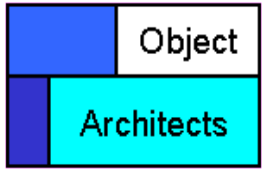
- mapping inheritance, polymorphism
- transactions

Key Messages



- even if I tell you ho to build one ☺
  don‘t build o/r mappers - buy them
  - unless you are a open source or commercial developer of such layers or in the research business
- avoid using implementation inheritance, multiple inheritance, polymorphic queries and other O-O gadgets for plain old domain objects in business systems.
  - This is only rarely needed and it only costs
  - O/R mappers get over complicated

Mapping „straight“ Objects



fast

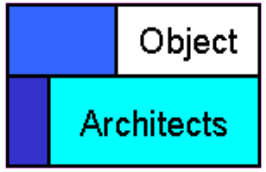
class Gangster
string name string nick_name int badness

Each field is mapped to a database column
this looks simple, but ....

```
SQL> desc gangster
 Name                                      Null?    Type
 ----------------------------------------- -------- ----------------------------
 NAME                                      NOT NULL VARCHAR2(255)
 NICK_NAME                                          VARCHAR2(64)
 BADNESS                                   NOT NULL NUMBER(10)
```

Source: Idea from the JBoss Crime Portal Tutorial
http://rzm-hamy-wsx.rz.uni-karlsruhe.de/Training/JBoss-3.0/html-generated/crimeportal.html

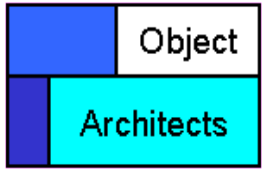
Mapping „straight“ Objects but ... The Devil is in the Details



Backup

- How do you map variable length data types like e.g. strings?
  - lots of VARCHARS do not speed up a database
- enums need special treatment
- SQL data types are not semantically identical with e.g. Java data types
- how do you deal with aggregated complex types like e.g. records?
  - Put them in an extra table (slower)
  - unfold them into various tables (tougher to maintain)
- Different mapper vendors have different answers

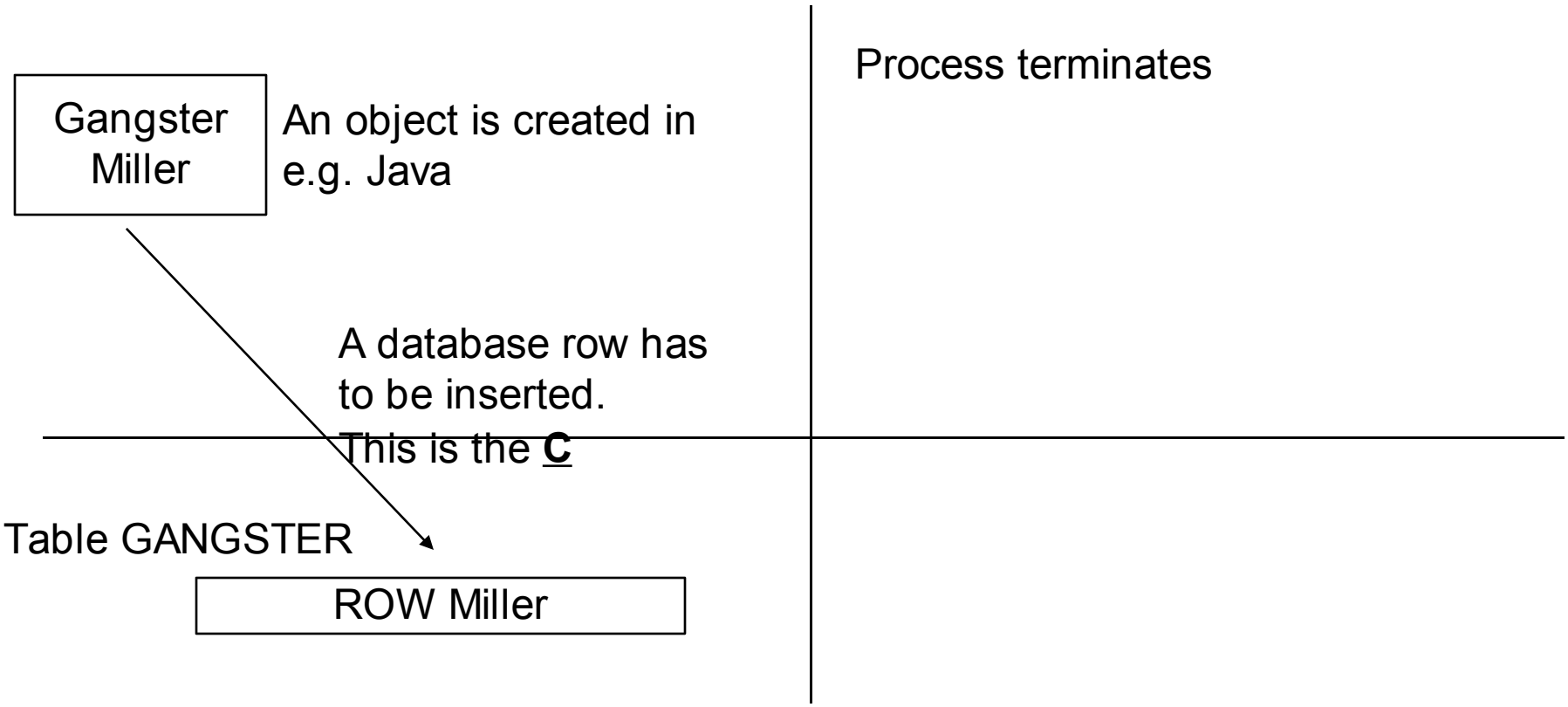
Mapping Straight Objects
You need an Identifier (id, a.k.a. oid)




```
Gangster bigBoss;
Gangster capo;
Gangster arrestHim;

capo = new Gangster(„Miller“,“the Killer“,9);
bigBoss = new Gangster(„Miller“,„the Smart“,13);

arrestHim = Gangster.getByName(„Miller“); // ????
```

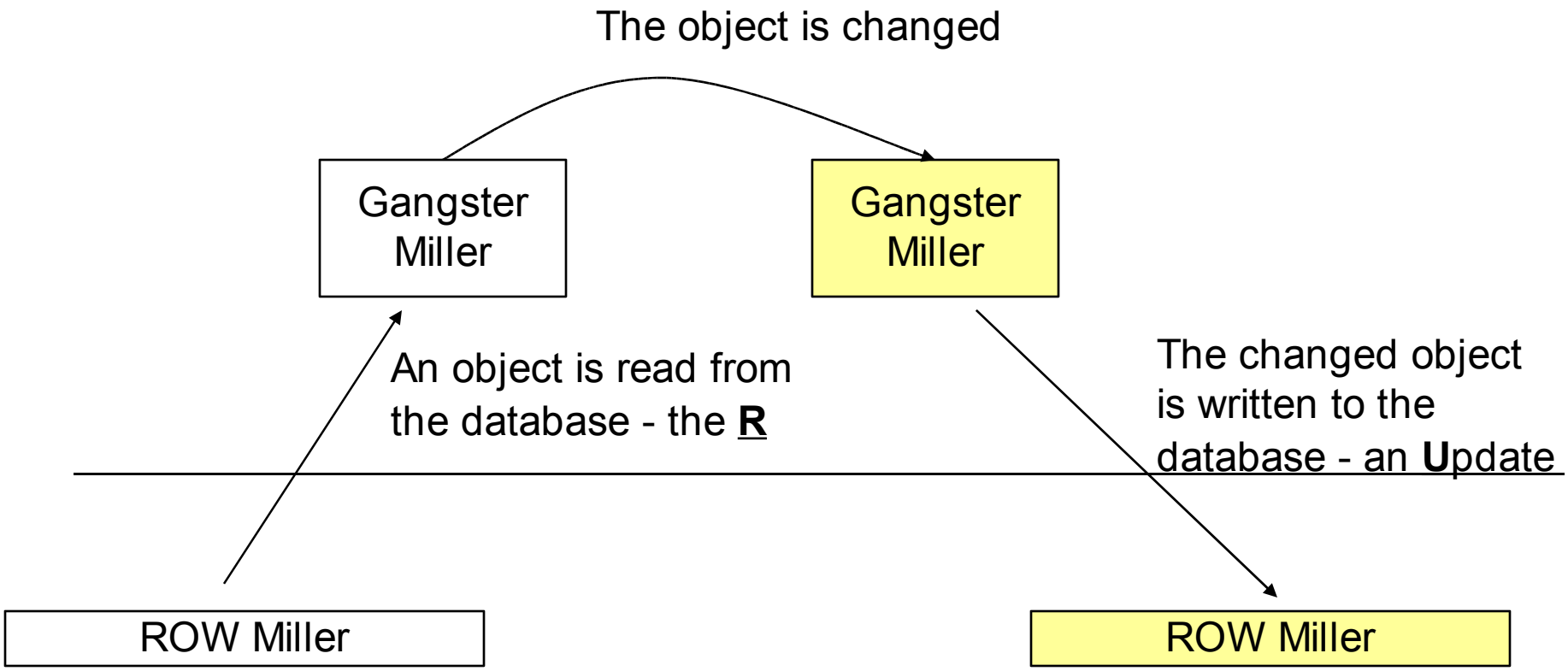
- In O-O languages instances are implicitly identified
  - duplicate „keys“ are no problems
- if you want to find something in a database you need a unique key
- therefore in most cases a synthetic object id (OID) is added to the „pure“ domain model

The CRUD pattern (1)
Or how are objects moved up and down between the database and object space



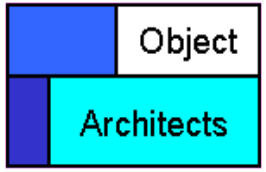
Create

The CRUD pattern (2)
Or how are objects moved up and down between the database and object space



Read, Update (Write) Pattern

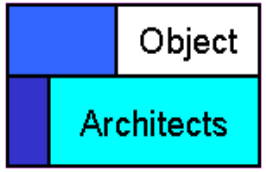
Sample:
The code that updates a Gangster EJB using Bean Managed Persistence (BMP)



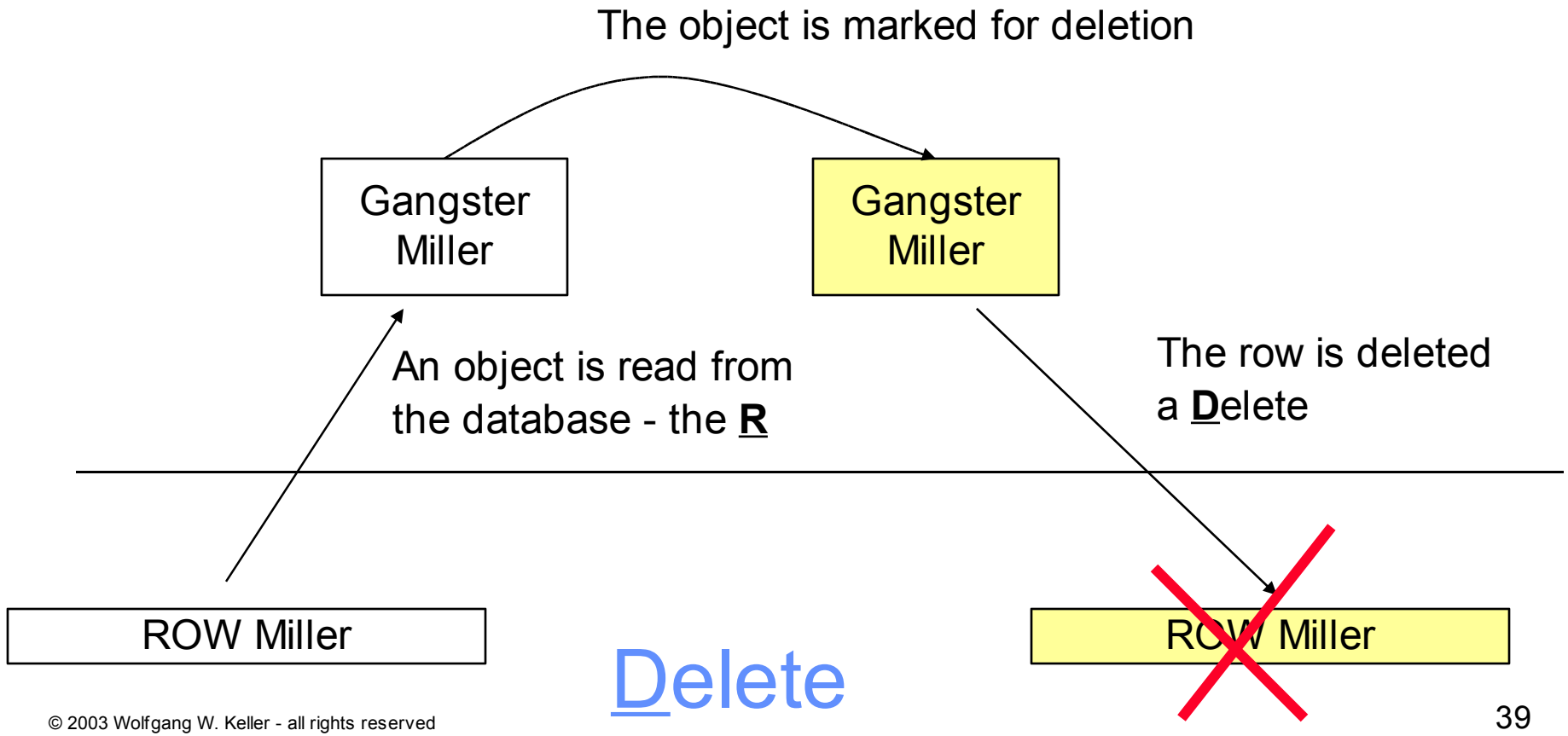
Backup

```
private void storeRow() throws SQLException {
      String updateStatement =
            "update GANGSTER set NAME =  ? ," +
            "NICK_NAME = ? , BADNESS = ? " +
            "where OID = ?";
      PreparedStatement prepStmt =
            con.prepareStatement( updateStatement);

      prepStmt.setString(1,  name);
      prepStmt.setString(2,  nick_name);
      prepStmt.setDouble(3,  badness);
      prepStmt.setString(4,  oid);
      int rowCount = prepStmt.executeUpdate();
      prepStmt.close();

      if (rowCount == 0) {
         throw new EJBException("Storing row for id " + oid + " failed.");
      }
   }
```

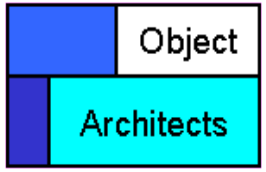
The CRUD pattern (3)
Or how are objects moved up and down between the database and object space




```
deleteHim = Gangster.getByOID(1234567);
deleteHim.markDeleted();
```



Where do you find the CRUD methods? There are several variants



- You can find the methods as an addendum in the domain classes
  - this is straight forward, but not considered very elegant
  - application of the „Multilayer Class“ Pattern*
- you can find the methods in an additional „data container object“**
  - results in a better separation of layers
- you can find code that generates the methods at runtime exploiting meta-information using e.g. the Reflection API in Java, or reflection if you work in Smalltalk
  - browse the the „Reflective CRUD pattern“***

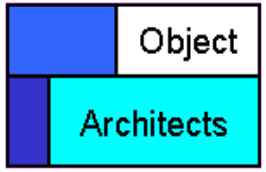
Backup

* find it at http://www.objectarchitects.de/arcus/publicat/multilay.ps.gz

** see „Row Data Gateway“ in Fowler‘s Patterns of Enterprise Apps

*** http://www.inf-cr.uclm.es/www/mpolo/yet/

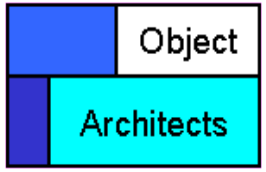
Object Identity and the Identity Cache




```
Gangster capoDeiCapi;
Gangster ilSoloCapo;

capoDeiCapi = Gangster.getByName(„Corleone“, „Vito“); // (1)
ilSoloCapo = Gangster.getByName(„Corleone“, „Vito“); // (2)

capoDeiCapi.setBadness(MAXBADNESS);
if (MAXBADNESS != ilSoloCapo.getBadness()) {
     // Palermo!!! – we’ve got a problem
};
```

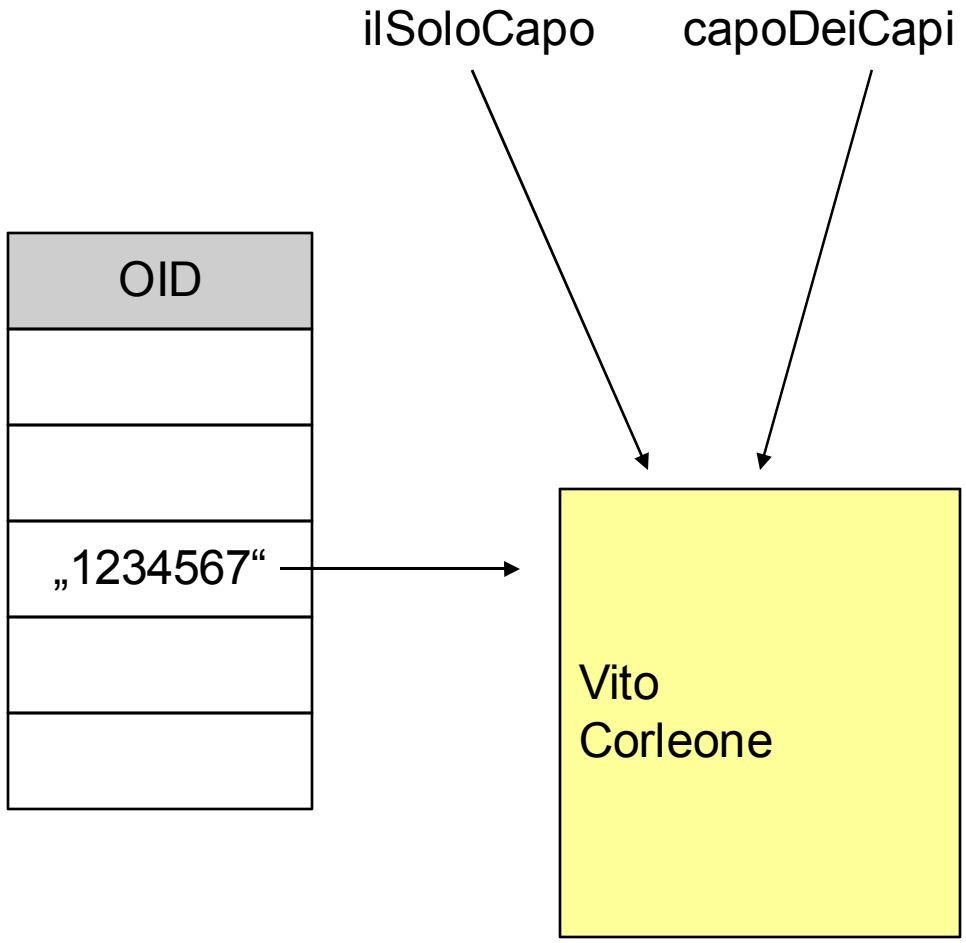
- the same object should be read once and only once from the database in one transaction
- there needs to be a mechanism to guarantee this
- and the mechanism should be hidden from the programmer using the persistence layer

The Identity Cache can be implemented as a Hash Table with an Entry per Loaded Object

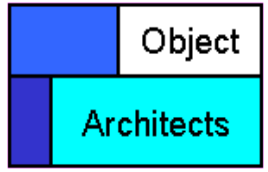


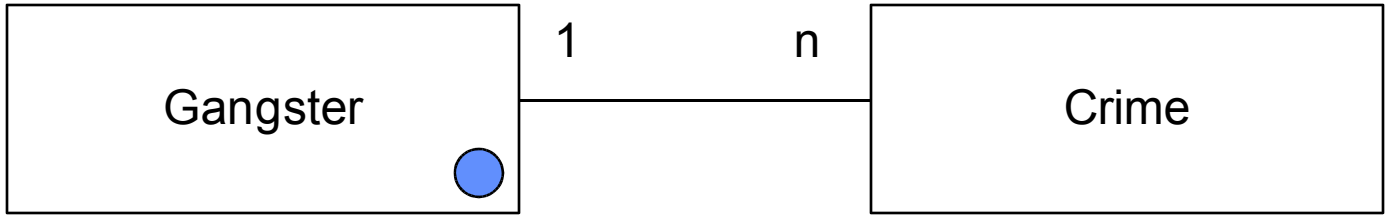
- The first *getByName()* will return the „Vito Corleone“ object
- the second *getByName()* may try to register the „Vito Corleone“ object. It will get a handle to the object already registered and will return it

- There are various versions how to implement this in detail .. But with similar semantics.

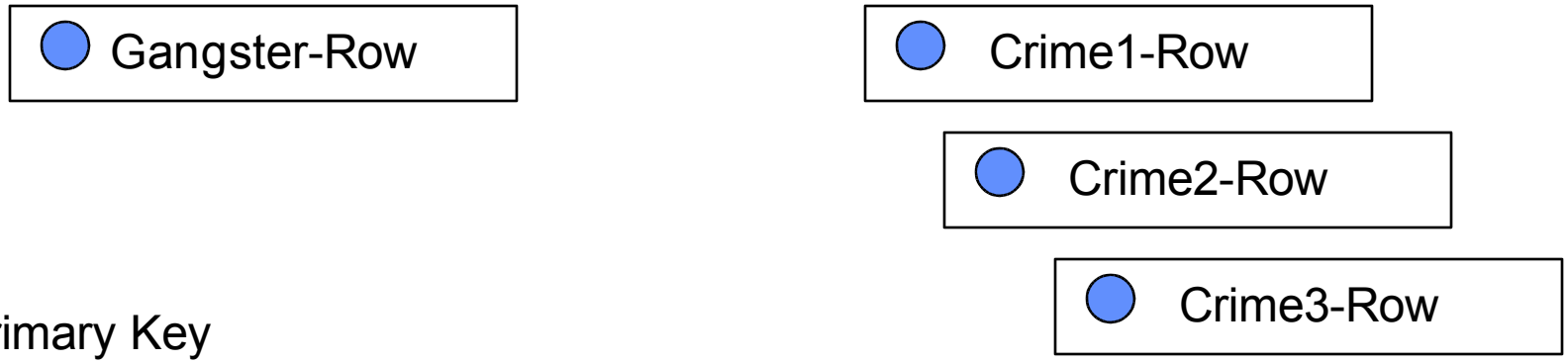


1:n Relations and Lazy Loading



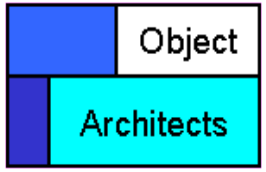



```
public class Gangster {
    ....
    private     Set crimes
    ....

    public void getAllCrimes (Set aCrimeSet) {
        // lazy load goes here ...
    };
}
```



OID, Primary Key

1:n Relations and Lazy Loading

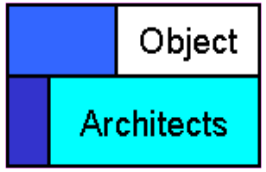


- **Problem:** If you load a Gangster (getByName) you don‘t want to automatically load all crimes (fill the set)
- **therefore** you don‘t fill the Set of Crimes when you load a gangster but implement a special „lazy Set“ that will not load anything before it is actually accessed by a getter-method

- This is known as „lazy loading“*, and various variants of „smart pointers“
- There are variants of this mechanism depending on the persistence API you use - but most layers use it

* see „Lazy Load“ in Fowler‘s Patterns of Enterprise Applications

Persistence „without programming“ - Exploiting Meta Information



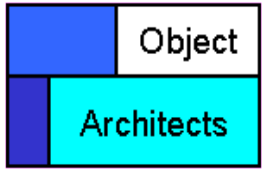
Backup

```
private void storeRow() throws SQLException {
      String updateStatement =
            "update GANGSTER set NAME =  ? ," +
            "NICK_NAME = ? , BADNESS = ? " +
            "where OID = ?";
      PreparedStatement prepStmt =
            con.prepareStatement(updateStatement);

      prepStmt.setString(1, name);
      prepStmt.setString(2, nick_name);
      prepStmt.setDouble(3, badness);
      prepStmt.setString(4, oid);
      int rowCount = prepStmt.executeUpdate();
      prepStmt.close();

      if (rowCount == 0) {
         throw new EJBException("Storing row for id " + oid + " failed.");
      }
   }
```

Observation: code like this need not be written by hand

- it can be generated by a preprocessor
- or it can also be generated at run time using e.g. the Java Reflection API

Exploiting Meta Information
Different mappers use different approaches



Backup

- JDO uses a so called „Class Enhancer“ which „pre“processes Java .class files
  - the enhancements are not direct SQL code but calls to a persistence manager – bur JDO would be another talk
  - see e.g. www.jdocentral.com
- EJB-CMP uses a lot of user provided meta-information
  - code generation at build time
  - see documentation of EJB containers - e.g. www.jboss.org
- Reflective CRUD exploits the Reflection API
  - code generation at run-time
  - see http://www.inf-cr.uclm.es/www/mpolo/yet/

Mapping simple Inheritance - Variant 1
One Inheritance Tree // One Table*

Object Architects

fast

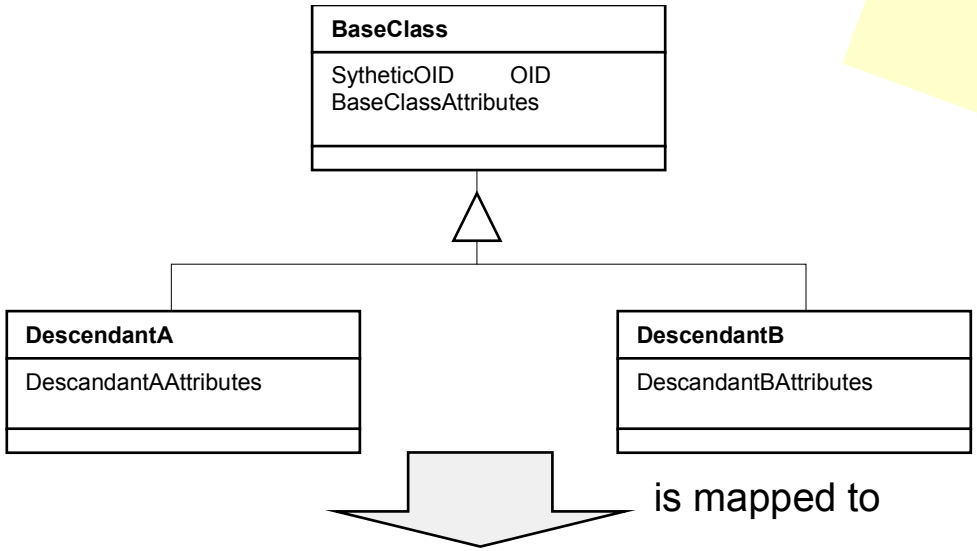


Table for BaseClass, DescandantA, DescandantB

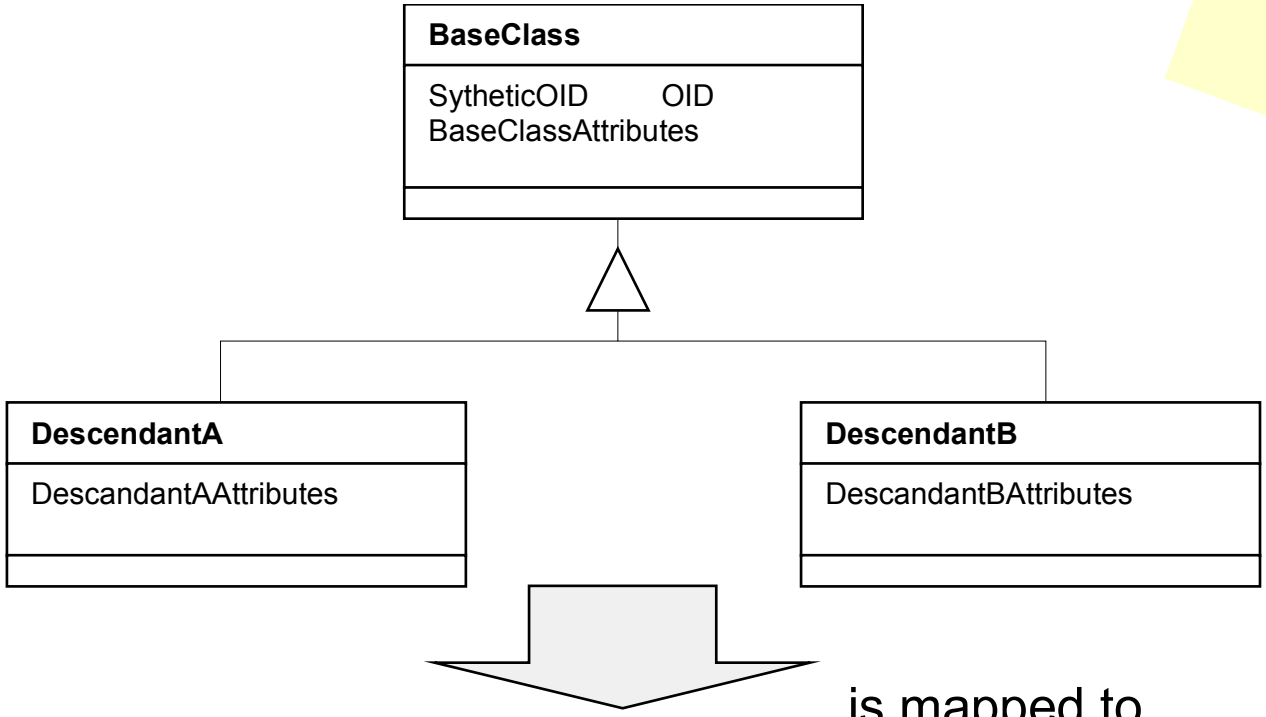
	SytheticOID, BaseClassAttributes	DescandantAAttributes	DescandantBAttributes
BaseClassInstance	Attribute Values	Null Values	Null Values
DescendantA Instance	Attribute Values	Attribute Values	Null Values
DescendantB Instance	Attribute Values	Null Values	Attribute Values

* if you‘re interested in table mappings there‘s a complete paper for free at
http://www.objectarchitects.de/ObjectArchitects/orpatterns/MappingObjects2Tables/mapping_object.htm

Mapping simple Inheritance - Variant 2
One Class // One Table

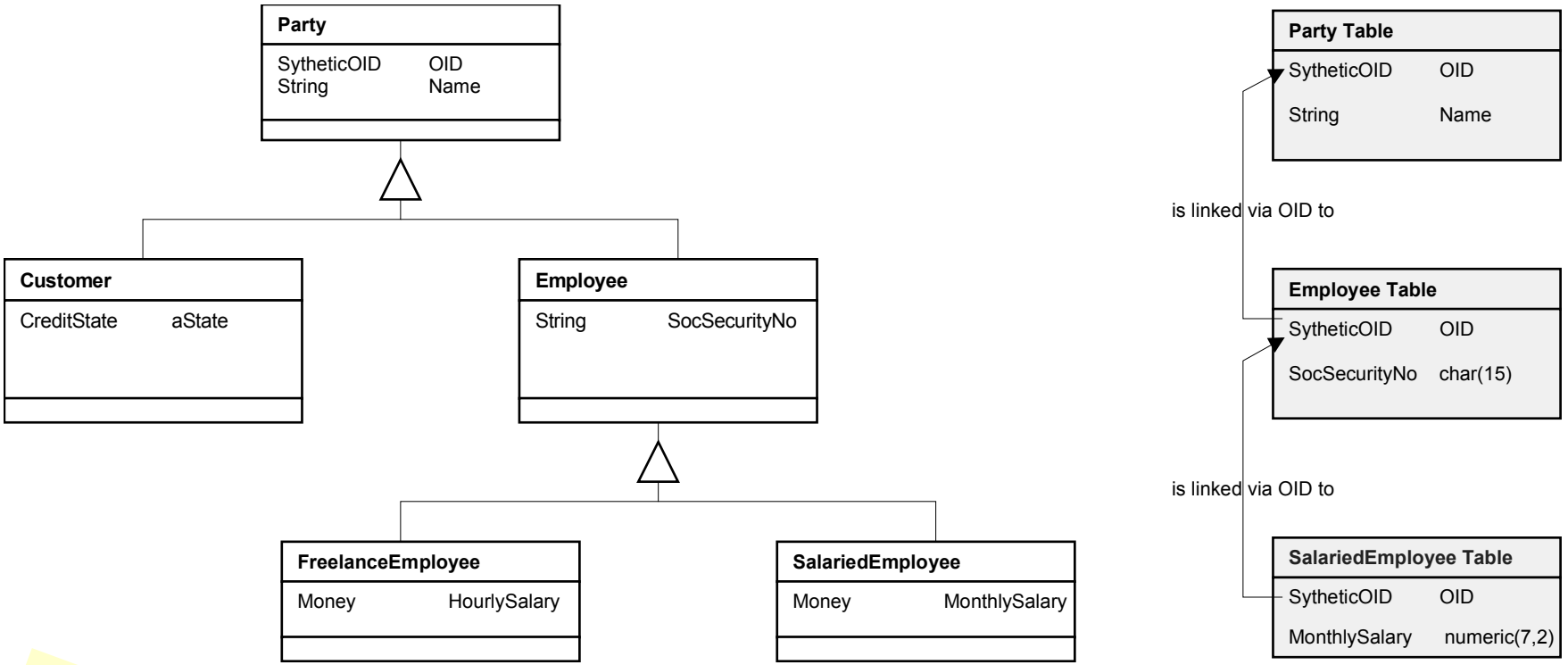
Object Architects

fast



* if you're interested in table mappings there's a complete paper for free at
http://www.objectarchitects.de/ObjectArchitects/orpatterns/MappingObjects2Tables/mapping_object.htm

Mapping simple Inheritance - Variant 2
The main drawback is evident - Performance

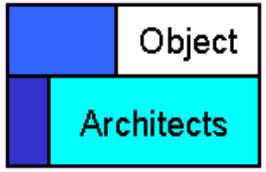


fast

Constructing one object instance needs up to 3 selects

Polymorphic queries potentially need to visit all tables

Mapping - Summary



- there are various aspects that need to be taken into account (see table below // forces)

Pattern	Performance			Space Consumption	Flexibility, Maintainability	Ad-hoc Queries
	Write/ Update	Single Read	Polymorphic Queries			
Single Table Aggregation	+	+	*	+	-	-
Foreign Key Aggregation	-	-	*	+	+	+
One Inheritance Tree One Table	+o	+o	+	-	+	+
One Class One Table	-	-	-o	+	+	-
One Inheritance Path One Table	+	+	-	+	-	-
Objects in BLOBs	+o	+o	o	+	-	-
Foreign Key Association	-	o	*	+	+	+
Association Table	-	o	*	+	+	+
+ good, - poor, * irrelevant, o depends, see detailed discussion						

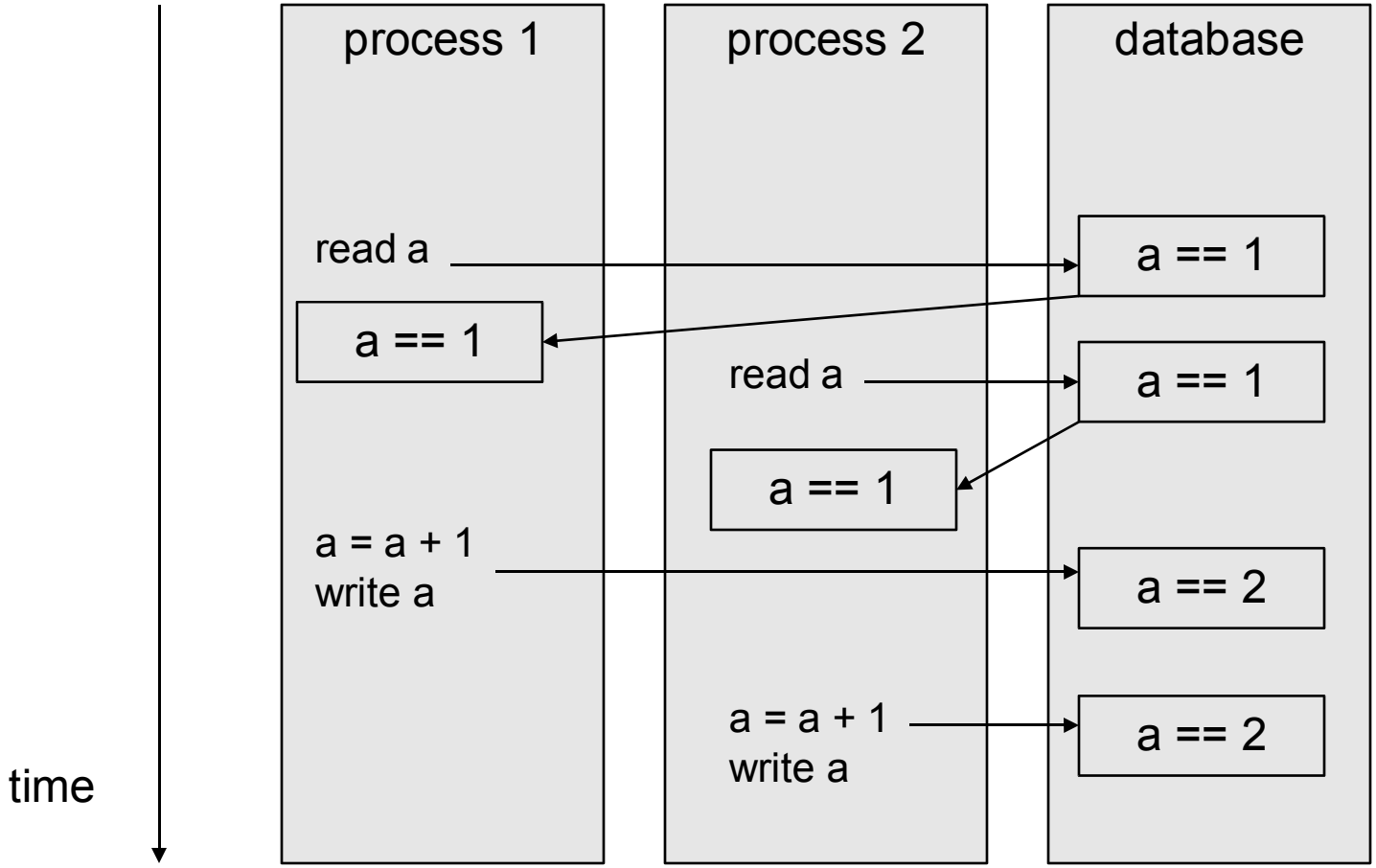
Backup

- there‘s ample and also free literature on the web
  - http://www.objectarchitects.de/ObjectArchitects/orpatterns/ mapping patterns for free
  - or get it from Scott Ambler at http://www.agiledata.org/essays/mappingObjects.html
  - Martin Fowler‘s „Patterns of Enterprise Application Architecture“ has the same in a book

Transactions and Locking
The Lost Update Problem or
2 + 1 + 1 may end up to be 3

Object Architects

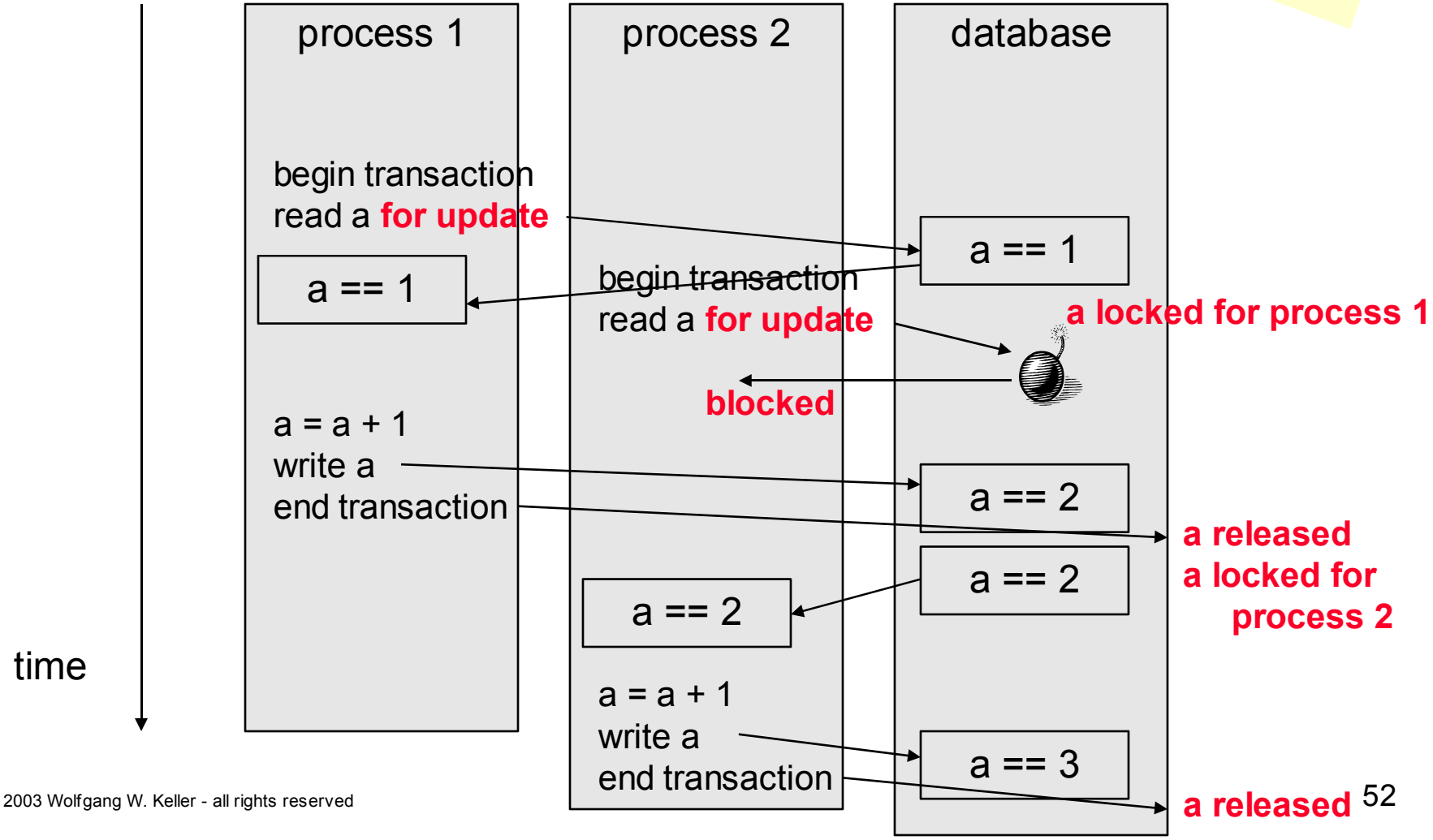
fast



Transactions
Same Use Case
Use of Pessimistic Locking

Object Architects

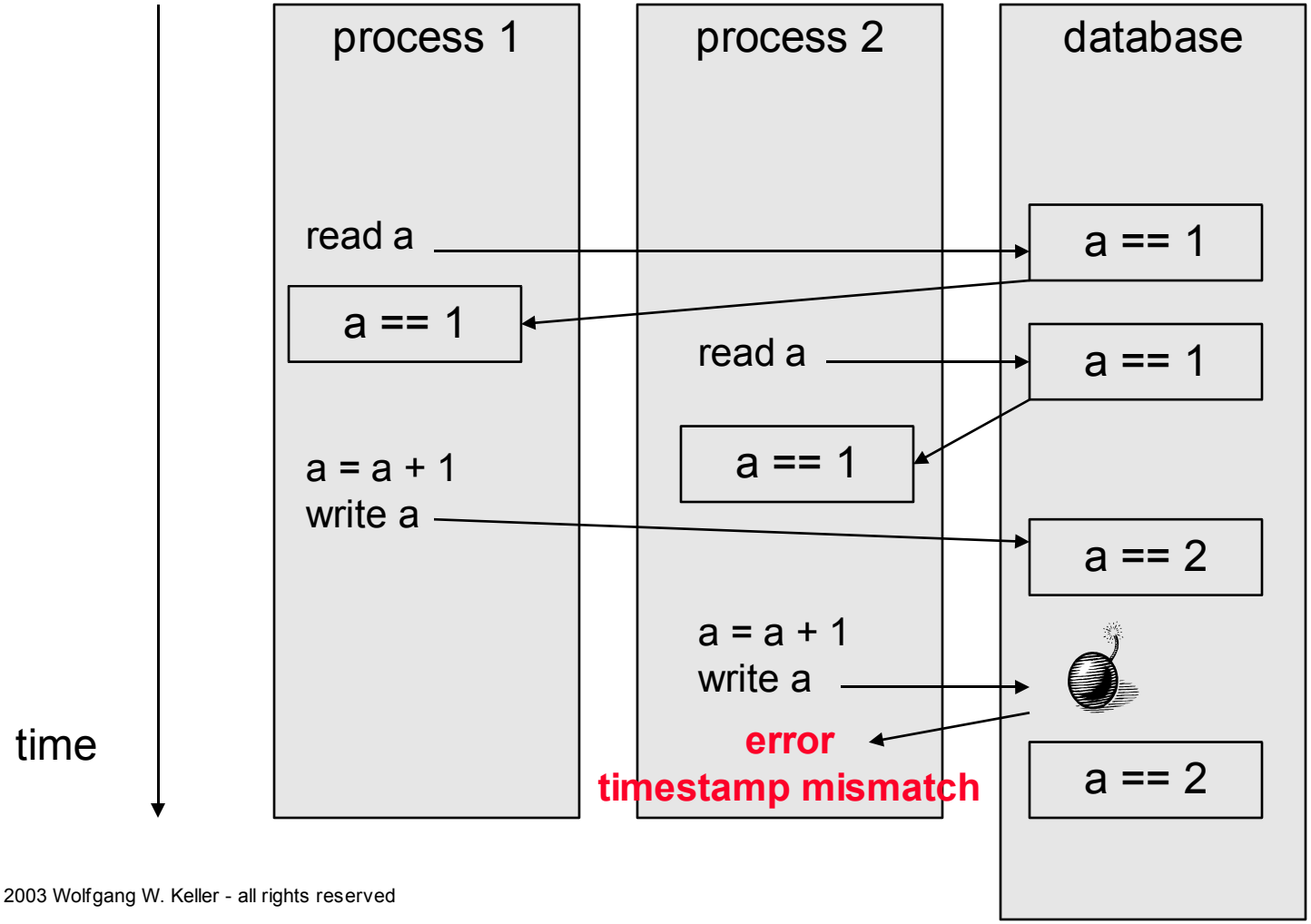
fast



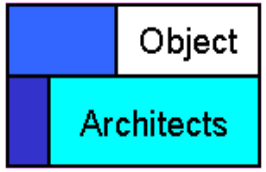
Transactions
Same Use Case
Use of Optimistic Locking

Object Architects

fast

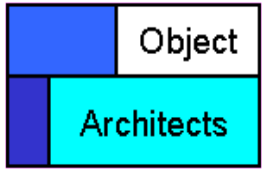


Pessimistic vs.Optimistic Locking



- pessimistic locking is the standard way to prevent the lost update problem provided by relational databases
  - it is appropriate if the application above guarantees that locks are held only for short periods of time
  - it is fatal if somebody holds locks for minutes - even if somebody holds locks for seconds, it pulls down performance
  - pessimistic locking can lead to deadlock situations - which are resolved by the database manager which rolls back transactions
- optimistic locking is offered by most o/r access layers
  - timestamp errors need to be handled by the application - the reaction is domain specific
  - it is appropriate for long transactions
  - with a low likelihood of collisions

Implementing Optimistic Locking

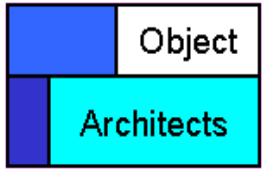


- you need a special transaction object that knows which objects need to be written to a database
  - objects need to be registered with this transaction object
  - this can happen automatically „under the surface“
- you need to add a timestamp field in each table in the physical database design
  - this will also be read upon read
  - and will be compared when updating
- still needs to be based on pessimistic locks, while changes are written

read at home

- as people have thought of all this before, e.g. JDO offers this mechanism as a ready to use option

Persistence in EJBs
A short outline ...

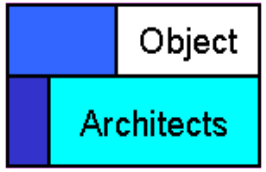


fast

- First of all EJB containers distinguish between
  - Session Beans
    - these are „transient“
  - Entity Beans
    - these are the potentially persistent objects that store business objects
- For Entity Beans there are two persistence mechanisr
  - Bean Managed Persistence (BMP)
    - this is „write your own layer “ persistence
    - might be used in complex mapping cases or performance critical apps
  - Container Managed Persistence (CMP)
    - automatic, using normed protocols
    - vendor specific
    - need not be mapped to a database - may be mapped to a database
    - Clear Advantage: Query Language

seen that before

CMP: Pros and Cons



Pro: Query Language with the power of OQL comes for free

Pro: For simple, straight cases you need not know too much about access layers

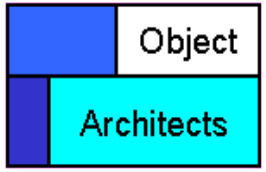
Caveat: Have a look at how you container vendor implements CMP. He might implement it without a database just based on indexed files. The standard does alone does not prevent it.

Con: Lots and lots of deployment information needs to be written

Con: Does not cover really complex data type to database mapping (vendor specific)

For a detailed comparison with e.g. JDO - another mapping layer see backup slides

EJB-Container Managed Persistence (1) versus for example JDO



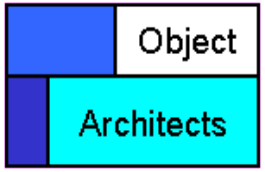
the table can be found at www.jdocentral.com or in David Jordan's and Craig Russel's highly recommendable book on JDO

{PRIVATE}Characteri	CMP beans	JDO persistent classes
Environmental		
Portability of applications	Few portability unknowns	Documented portability rules
Operating environment	Application server	One-tier, two-tier, web server, application server
Independence of persistent classes from environment	Low: beans must implement EJB interfaces and execute in server container	High: persistent classes are usable with no special interface requirements and execute in many environments
Metadata		
Mark persistent classes	Deployment descriptor identifies all persistent classes	Metadata identifies all persistent classes
Mark persistent fields	Deployment descriptor identifies all persistent fields and relationships	Metadata defaults persistent fields and relationships
Modeling		
Domain-class modeling object	CMP bean (abstract schema)	Persistent class
Inheritance of domain-class modeling objects	Not supported	Fully supported
Field access	Abstract get/set methods	Any valid field access, including get/set methods
`Collection`, `Set`	Supported	Supported
`List`, `Array`, `Map`	Not supported	Optional features
Relationships	Expressed as references to CMP local interfaces	Expressed as references to JDO persistent classes or interfaces
Polymorphic references	Not supported	Supported

see:

Backup

EJB-Container Managed Persistence (2) versus for example JDO



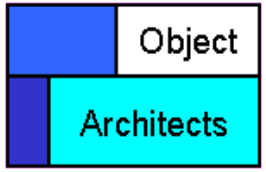
the table can be found at www.jdocentral.com or in David Jordan's and Craig Russel's highly recommendable book on JDO

{PRIVATE}Characteri	CMP beans	JDO persistent classes
Programming		
Query language	EJBQL modeled after SQL	JDOQL modeled after Java Boolean expressions
Remote method invocation	Supported	Not supported
Required lifecycle methods	`setEntityContext`, `unsetEntityContext`, `ejbActivate`, `ejbPassivate`, `ejbLoad`, `ejbStore`, `ejbRemove`	no-arg constructor (may be private)
Optional lifecycle callback methods	`ejbCreate`, `ejbPostCreate`, `ejbFind`	`jdoPostLoad`, `jdoPreStore`, `jdoPreClear`, `jdoPreDelete`
Mapping to relational datastores	Vendor-specific	Vendor-specific
Method security policy	Supported	Not supported
Method transaction policy	Supported	Not supported
Nontransactional access	Not standard	Supported
Required classes/interfaces	`EJBLocalHome`, local interface (if local interface supported); `EJBHome`, remote interface (if remote interface supported); Abstract beans must implement `EJBEntityBean`; Identity class (if nonprimitive identity)	Persistent class; `objectid` class (only for application identity)
Transaction synchronization callbacks	Not supported	Supported

see:

Backup

Summary
The 4 Key Messages revisited

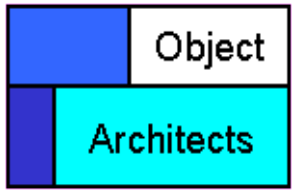


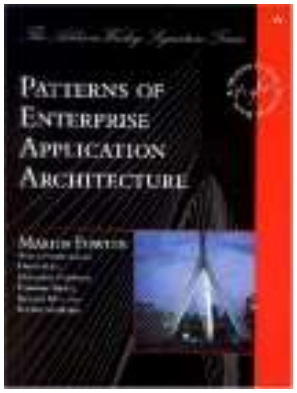
Sloooow :-)

- know you application style before you decide for a certain way to implement persistence
- know the concept of transparent persistence
- don‘t develop your own green-field persistence layer unless you do it for fun. That made sense 10 years ago but in the presence of plenty of commercial and open source software for the area it is nowadays too expensive in most cases
- In case you run into problems, know where to find the patterns and explanations on the mechanics of persistence

Questions

Pointers to Additional Material





- Find many of the patterns free of charge at http://www.objectarchitects.de/
- Find similar patterns in Martin Fowler's book „Patterns of Enterprise Application Architecture“ (ISBN 0-321-12742-0)
- Find distribution schemes and information on EJB mapping at http://www.service-architecture.com/
  - site by Doug Barry - contains a lot on persistence architectures, ODMG, O/R mappers, ...
- Find good code examples for JDO (Java Data Objects) as one possible Java persistence layer at www.JDOcentral.com. Also highly recommended book „Java Data Objects“ by David Jordan and Craig Russel (ISBN 0-596-0026-9)

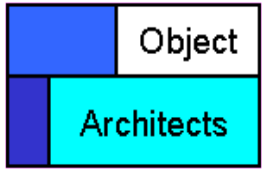
read at home

Pointers to Additional Material

- have a look at one of Scott Ambler‘s web sites http://www.agiledata.org - you‘ll find ample high quality papers for free

read at home

Credits



- parts of this lecture have been developed by Jens Coldewey, Coldewey Consulting. Please visit Jens' web-site at http://www.coldewey.com/
- Thanks to the JBoss people for the Crime Portal idea
- Thanks to David Jordan and Craig Russel for their excellent JDO book (ISBN 0-596-0026-9)