.NET Developer’s Reference

VERSION 7.1.08
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Before You Begin

The JADE.NET Developer's Reference is intended as a major source of information when using the JADE.NET class library to develop .NET applications accessing JADE database objects.

Who Should Read this Reference

The main audience for the JADE.NET Developer's Reference is expected to be .NET developers using the .NET Framework.

What’s Included in this Reference

The JADE.NET Developer's Reference has seven chapters and two appendices.

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<td>Chapter 3</td>
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<td>Appendix B</td>
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Related Documentation

Other documents that are referred to in this reference, or that may be helpful, are listed in the following table, with an indication of the JADE operation or tasks to which they relate.

<table>
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<th>Title</th>
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<tr>
<td>JADE Database Administration Guide</td>
<td>Administering JADE databases</td>
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<td>JADE Development Environment Administration Guide</td>
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<td>JADE Encyclopaedia of Primitive Types</td>
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<tr>
<td>JADE Installation and Configuration Guide</td>
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Title | Related to…
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JADE Initialization File Reference | Maintaining JADE initialization file parameter values
JADE Object Manager Guide | JADE Object Manager administration
JADE Synchronized Database Service (SDS) Administration Guide | Administering JADE Synchronized Database Services (SDS), including Relational Population Services (RPS)
JADE Thin Client Guide | Administering JADE thin client environments
JADE Web Application Guide | Implementing, monitoring, and configuring Web applications

Conventions

The JADE .NET Developer’s Reference uses consistent typographic conventions throughout.

<table>
<thead>
<tr>
<th>Convention</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Arrow bullet (⇒)</td>
<td>Step-by-step procedures. You can complete procedural instructions by using either the mouse or the keyboard.</td>
</tr>
<tr>
<td>Bold</td>
<td>Items that must be typed exactly as shown. For example, if instructed to type <strong>foreach</strong>, type all the bold characters exactly as they are printed. File, class, primitive type, method, and property names, menu commands, and dialog controls are also shown in bold type, as well as literal values stored, tested for, and sent by JADE instructions.</td>
</tr>
<tr>
<td>Italic</td>
<td>Parameter values or placeholders for information that must be provided; for example, if instructed to enter <em>class-name</em>, type the actual name of the class instead of the word or words shown in italic type. Italic type also signals a new term. An explanation accompanies the italicized type. Document titles and status and error messages are also shown in italic type.</td>
</tr>
<tr>
<td>Blue text</td>
<td>Enables you to click anywhere on the cross-reference text (the cursor symbol changes from an open hand to a hand with the index finger extended) to take you straight to that topic. For example, click on the &quot;How a .NET Application Connects to JADE&quot; cross-reference to display that topic.</td>
</tr>
<tr>
<td>Bracket symbols ( [ ] )</td>
<td>Indicate optional items.</td>
</tr>
<tr>
<td>Vertical bar (</td>
<td>)</td>
</tr>
<tr>
<td>Monospaced font</td>
<td>Syntax, code examples, and error and status message text.</td>
</tr>
<tr>
<td>ALL CAPITALS</td>
<td>Directory names, commands, and acronyms.</td>
</tr>
<tr>
<td>SMALL CAPITALS</td>
<td>Keyboard keys.</td>
</tr>
</tbody>
</table>
Key combinations and key sequences appear as follows.

<table>
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<tr>
<th>Convention</th>
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</tr>
</thead>
<tbody>
<tr>
<td>KEY1+KEY2</td>
<td>Press and hold down the first key and then press the second key. For example, &quot;press SHIFT+F2&quot; means to press and hold down the SHIFT key and press the F2 key. Then release both keys.</td>
</tr>
<tr>
<td>KEY1,KEY2</td>
<td>Press and release the first key, then press and release the second key. For example, &quot;press ALT+F,X&quot; means to hold down the ALT key, press the F key, and then release both keys before pressing and releasing the X key.</td>
</tr>
</tbody>
</table>

In this document, the term Microsoft Windows refers to Windows 10, Windows 8, Windows 7, Windows Server 2012, Windows Server 2008, Windows Vista, or Windows Mobile. When there are differences between the versions of Microsoft Windows, the specific version of Microsoft Windows is stated.
Chapter 1  Software Requirements

This chapter covers the following topics.

- JADE Requirements
- .NET Requirements

JADE Requirements

When a .NET application uses classes that have been exposed from a JADE system, it uses the APIs from the JadeSoftware.Jade.DotNetInterop.dll and other assemblies in the JADE .NET framework for JADE version 7.0.03 or later. These assemblies are 64-bit DLLs.

The .NET application connects to the JADE database using the binary files from a standard JADE client, which must be a 64-bit client.

.NET Requirements

To develop and compile .NET applications for .NET exposure, you require a minimum of:

- Microsoft Visual Studio 2010
- Microsoft Visual Studio 2010 Express, the free but limited edition of Visual Studio 2010

Note  Microsoft Visual Studio 2013 is recommended.

For external component libraries, you require:

- .NET 4.x components (or .NET 3.x, if you are using components designed for .NET 3.x)
Chapter 2

Object Management

This chapter covers the following topics.

- Overview
- JADE Object Handling
- JADE Object Caches
- JADE Object Concurrency Management
  - Distributed Processing Architecture
- Maintaining Data Consistency and Coherence
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- Object Volatility
  - Volatile Objects
  - Stable Objects
  - Frozen Objects
■ Specifying and Changing Object Volatility
  □ Class Volatility
  □ Individual Object Volatility
■ Frozen Files and Partitions
  □ Freezing User Schema Files

Overview

This chapter describes the JADE Object Manager, which implements object-oriented and distributed processing functionality, including features such as object locking, transactions, transaction isolation, and automatic cache coherency concurrency.

In this chapter, the term **JADE session or JADE session execution** is used to refer to a **JADE process** in a node. This terminology should assist the .NET developer who is unfamiliar with the JADE and could potentially confuse a JADE process with a Windows process.

**JADE Object Handling**

The JADE distributed processing architecture has a single semantic model for all objects and two basic lifetime variations: persistent and transient lifetimes.

Persistent objects, which are permanently stored in the JADE database, live across JADE session executions and are shared by all JADE sessions in all nodes of the system. Concurrency control is enforced for persistent objects. Update operations on persistent objects must be performed within a transaction; typically inside a **JoobContext** **BeginTransaction** and **System.Data.IDbTransaction Commit** method pair.

Changes made to persistent objects within a transaction are hidden from other JADE sessions until committed. This means that other JADE sessions accessing these objects will not see the uncommitted updates, but will instead view the most-recently committed editions.

Transient objects are local to the JADE session that created them; that is, they cannot be accessed by any other JADE session. Because of this, no concurrency control operations are performed when they are updated, which gives optimal performance. These transient objects are automatically removed when the JADE session that created them becomes inactive, typically by disposing its attached **JoobContext** instance.

No transaction is necessary when creating, deleting, or updating transient objects. These objects can be updated at any time.

By default, JADE objects are created with persistent lifetime. To create transient objects, there is a constructor for a JADE object that takes the lifetime of the object as a parameter using the **ClassPersistence** enumeration, which has the values **Persistent** and **Transient**.

**JADE Object Caches**

On each JADE client node, there is a persistent JADE object cache to hold in-memory copies of persistent objects that have been accessed by JADE sessions, through their associated JADE context on that node. One of the benefits of caching an object is that the object can be accessed via JADE contexts attached to the client node at a later time without needing to be fetched from the database server node.
Because objects are retained in cache, it is possible to run out of allocated cache space. When this happens, the least-recently used objects are discarded from cache. If a discarded object is required in the future, the latest edition is fetched from the database.

JADE automatic cache coherency keeps objects in the cache from becoming out of date. When a JADE object is updated, the database server knows which connected caches have copies of the object that are now obsolete. It sends messages to the affected caches, resulting in obsolete objects being discarded. If a discarded object is required in the future, the latest edition is fetched from the database server.

Locking an object guarantees that the copy in cache will be the latest edition.

JADE also maintains a transient JADE object cache on each client node, to contain transient objects created by JADE sessions on that node. Even though cached, the transient objects are visible only to the JADE sessions that created them.

If the transient JADE object cache of a client node overflows, transient objects are written out to a .tmp file. Each transient database file is unique to a specific JADE session and is located in the path specified by the TransientDbPath parameter in the [JadeClient] section of the JADE initialization file.

The file name has the following format.

```
tdb_<host-name>_<pid><designator>.tmp
```

In this format, the `<pid>` value is the operating system executing process identifier and the `<designator>` value is one of the following.

- `[kbp_nnnnnn]`, for transient files associated with a JADE background session
- `[session-oid]`, for transient files associated with a JADE session, where `session-oid` is the object identifier of the JADE session

If a .tmp file is found to be growing, you can identify the JADE session to which it belongs by locating the session identifier in the jommsg.log; for example:

```
2014/08/25 15:58:14.399 0b958-bc0c Jom: Local process sign-on: oid=[187.251],
    process=0x00000000D39DDD0, no=2, id=48140, db=4, type=2, (non-prodn),
    scm=BankingViewSchema, app=DotNetConnection
```

In this log entry example, `[187.251]` is the object identifier of the JADE session. Note that in the message logs, JADE sessions are referred to as local processes.

The temporary (.tmp) file for each session is deleted when the client node terminates. Certain kinds of failure (for example, a node crash) can result in these temporary files not being deleted. You can delete any temporary transient object overflow file that has been left behind, if required.

You can set the size of the JADE caches in the JADE initialization file used by the client node.

- The default size for the persistent object cache (that is, the default value of the `ObjectCacheSizeLimit` parameter in the [JadeClient] and [JadeServer] sections of the JADE initialization file) is 80M bytes, and 40M bytes for the transient object cache (that is, the default value of the `TransientCacheSizeLimit` parameter in the [JadeClient] and [JadeServer] sections of the JADE initialization file).
- The minimum size for the persistent and transient object caches is 3M bytes.
JADE Object Concurrency Management

When multiple threads are accessing and updating JADE database objects at the same time, there are concurrency issues that need to be managed, as follows.

- Data must be kept consistent when being updated.
- Applications need to access consistent, up-to-date data.

JADE provides features such as object locking, transactions, transaction isolation, and automatic cache coherency to address these issues.

Many of the features work automatically, but there are various options to make them more efficient.

This chapter discusses these features and options, describing how to use this area of functionality and the options that are available to write efficient and scalable applications. Topics include:

- Distributed processing architecture
- Maintaining data consistency and currency
- Automatic cache coherency
- The transaction model
- Transaction isolation
- Object locking
- Object volatility (stable and frozen objects)
- Frozen files and partitions
Distributed Processing Architecture

The following diagram is an overview of the JADE distributed processing architecture.

For the purposes of this chapter, a JADE system consists of a JADE database, a JADE database server, and one or more JADE client nodes. Each client node is an executing process containing a pool of JADE sessions that allow threads to connect to JADE using `JoobContext` instances. There is also a cache to hold local copies of JADE objects accessed by JADE sessions on that client node, and a lock table to record which objects are currently locked by active sessions on that node.

The JADE database server has a master lock table to record JADE object locks held by applications running on all nodes.

Nodes

A JADE node is an executing process. There are two main types of nodes: the server node and client node.

The server node has a direct connection to the JADE database and maintains system-wide information (for example, which objects are currently locked). Client nodes connect to the server node for JADE object locking, retrieval, and storage. An executing process that connects to the JADE database server is a client node.

JoobContexts, Sessions, and JoobConnections

Each client node has a pool of JADE sessions, providing an interface to the JADE Object Manager and JADE database.

A process thread attaches to an available JADE session by creating a `JoobContext` object. The thread is detached from the JADE session when the `JoobContext` object is disposed.
A JoobContext object interacts with a JADE session using a JoobConnection object. JoobConnection objects are typically created and disposed of automatically with their owning JoobContext object. In many scenarios, users will not have to explicitly interact with JoobConnection objects.

JADE Object Caches

Each client node has a JADE object cache to hold in-memory copies of JADE database objects.

When an object is retrieved from the JADE database, it is stored locally in the client node’s JADE object cache. The object can be subsequently accessed locally, without needing to be retrieved via the database server.

The JADE object cache is shared by all JADE sessions for that client node.

An object in the JADE object cache could become out of date if the object is updated on another client node. However, automatic cache coherency and object locking keep the JADE object cache up to date, as described later in this chapter.

Object Locking

Object locking is used to coordinate accessing and updating of JADE objects. There are four types of locks: two for reading (Shared and Reserve) and two for updating (Update and Exclusive). Locking is explained in more detail later in this chapter.

The current lock status of JADE objects is system-wide, and is maintained in tables on the server and client nodes.

The server lock table records the locks for all JADE objects, regardless of the client node on which the locking JADE session is executing. Client nodes therefore need to communicate with the server node in order to lock and unlock JADE objects.

Each client node lock table records copies of the JADE objects that are locked by active JADE sessions on the node.

Maintaining Data Consistency and Coherence

This section describes data consistency and data coherence.

Data Consistency

When a JADE session is updating JADE objects, the data must be kept consistent. JADE sessions wanting to update the same object must not interfere with each other, and other sessions viewing the data must not see incomplete updates.

Object locking is used to ensure that only one JADE session at a time can be updating a JADE object. A JADE session must lock an object before it can update it, with a lock type that is available only to one JADE session at a time (that is, an exclusive or an update lock).

JADE sessions can update objects only within a transaction; that is, while the transaction is active (for example, bracketed by JoobContext BeginTransaction and IDbTransaction Commit method calls).

While a transaction is active, any updates are not visible to other JADE sessions. The other JADE sessions instead view the JADE objects, as they were without the uncommitted updates. Committing the transaction causes the updates to be applied to the JADE database and made visible. This is discussed in more detail later in this chapter.
Data Coherence

When a JADE session accesses a JADE object that has been copied into the JADE object cache on a client node, the copy may no longer be current if the object has been updated on another client node. The object will need to be fetched again from the database server node, to bring it up to date.

Automatic cache coherency (discussed in the following section) is a JADE feature that keeps objects in the JADE object cache up to date.

Object locking can also be used to ensure that a JADE object is up to date. When a JADE session has an object locked, its view of the object is guaranteed to be completely up to date.

Automatic Cache Coherency

JADE objects being used by JADE sessions are copied into local memory, in the JADE object cache of the client node. This speeds up access, by minimizing object requests to the database server node. However, this creates the situation where if the object is updated on another client node, the local copy in cache could no longer up to date.

To handle the situation where the local copy in cache would otherwise become out of date, JADE provides a feature, automatic cache coherency, which automatically detects when a JADE object has been updated and causes local copies of the object to be marked for refresh in all of the caches where it has been copied. This means that the next time the object is accessed, it is fetched from the database server node and therefore be up to date. This feature is enabled by default.

For most read operations, this mode of operation is satisfactory and avoids the extra code and overhead involved with having to place object locks. However, there is a small time delay between when the object is updated in the database and when the client nodes are notified. If it is crucial to an application that a JADE object being read is guaranteed to be up to date, a JADE session must lock the object.

Note Automatic cache coherency does not apply to JADE collections, which are kept up to date by being automatically locked whenever accessed.

The Transaction Model

The transaction model is used to group and isolate sets of updates to database objects, in order to maintain data consistency.

All sets of updates must be applied and made visible as a group. Until the updates are ready, they should be invisible to other JADE sessions. If something goes wrong, all of the pending updates must be discarded.

In order to update objects, a JADE session must begin a transaction. The updates are held temporarily until the transaction is committed, at which time they get applied to the JADE database as permanent changes and made visible. Before that happens, other JADE sessions view the objects as they were without the uncommitted updates (this is termed transaction isolation).

If the full set of updates cannot be completed (for example, due to an error), the transaction is rolled back, which cancels the transaction and discards all of the pending updates in the set.

This concept implements the standard transaction ACID principles of atomicity (either all of the updates or none of the updates get applied), and isolation (the updates are not visible until applied).
With JADE, a transaction is typically started using the `J DobContext BeginTransaction` method. This method returns a `System.Data.IDbTransaction` JADE transaction object. The transaction object's `Commit` method commits the transaction, which applies the updates to the database. Alternatively, the `Rollback` method cancels the transaction, discarding the uncommitted updates.

The transaction object must be disposed of at the end of the transaction. If `Commit` is not called before the transaction object is disposed of, the transaction will be rolled back.

You can use a `using` block to carry out a transaction and ensure that the transaction object is disposed of at the end of the block.

The following code fragment illustrates a successful transaction, where updates are permanently applied to the JADE database and made visible.

```csharp
using (J DobContext context = new J DobContext())
{
    using (System.Data.IDbTransaction tran = context.BeginTransaction())
    {
        //... update objects
        tran.Commit();
    }
}
```

The following code fragment illustrates a transaction that is rolled back, where updates are discarded and not applied.

```csharp
using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
    //... update objects
    tran.Rollback();
}
```

**Transaction Isolation**

Transaction isolation is the mechanism that makes updates that have not yet been committed invisible to other JADE sessions. Instead, these JADE sessions view the most-recently committed editions of the JADE objects; that is, the way they were without the uncommitted updates.

While a JADE object is being updated, two copies can exist in the JADE object cache: one with and one without the updates. The copy with the updates is visible only to the updating JADE session. Other JADE sessions access the other copy, which does not include the updates.

When a transaction is committed, any older copies of objects in the cache are removed.

JADE automatically provides transaction isolation for JADE objects.

**Object Locking Overview**

JADE objects are locked individually.

Locking a JADE object does two things. Firstly, it controls concurrent access to an object. Secondly, it ensures that a JADE session accesses the most up-to-date edition of the object.
JADE provides four types of lock.

- Shared
- Reserve
- Update
- Exclusive

Update and exclusive locks are write locks, which allow JADE sessions to update an object and prevent other sessions from updating the object. An exclusive lock also prevents the acquisition of read locks.

Shared and reserve locks are read locks, which prevent other JADE sessions from applying updates to an object without prohibiting other read locks.

Lock types are discussed in more detail in the following section.

Although JADE sessions can access a JADE object without locking, they cannot update it, and the view of the object's data can change if it is updated by another session.

If a JADE session does not want to update an object but wants to have a consistent view that will not change while it is being accessed, it must obtain a lock on the JADE object (of any type). The object cannot have updates committed by another JADE session until the object is unlocked.

If a JADE session wants to update a JADE object, this must be done within a transaction and an exclusive or an update lock must first be acquired, either implicitly or explicitly. This ensures that no other JADE session can update the object, as only one session at a time is allowed an exclusive or update lock on an object. In addition, the lock always remains in place until the transaction has been committed or rolled back.

JADE automatically acquires an implicit exclusive or update lock for any object being updated, if it is not already so locked.

When a JADE session requests a type of lock that is not compatible with the current locks in place by other sessions, it is queued until those locks get unlocked (up to a specific time limit) and the session can acquire the requested lock.

The locking concept helps to implement the standard transaction ACID principle of consistency (that is, data is always consistent).

**JADE Object Locking**

This section describes and discusses object locking in detail. Object locking applies to JADE objects.

**Lock Types**

There are four lock types, each providing different levels of concurrency and updating ability. For details, see the following subsections.

**Shared Locks**

A shared lock allows several JADE sessions to simultaneously read a JADE object but not update it.

Shared locks maintain concurrency while ensuring that a JADE session never works with obsolete data.
Reserve Locks

A reserve lock is available for situations where a JADE session eventually intends to update a JADE object but needs to minimize the length of time the object is locked with an exclusive or update lock.

Using a reserve lock allows other JADE sessions to acquire shared locks, but not any other type of lock.

Reserve locks also provide a way to avoid potential deadlocks (for details, see “Avoiding Deadlock Exceptions”, later in this chapter).

Update Locks

An update lock allows a JADE session to update a JADE object, while still allowing other sessions to acquire shared locks (but not any other type of lock). The other JADE sessions with shared locks see the most-recently committed edition of the object, without the pending updates.

Update locks can be used only within a transaction.

When a JADE session commits a transaction, any update locks are automatically requested to be upgraded to exclusive locks before the updates are committed. This ensures that no other JADE sessions have the objects locked at the time the updates are committed.

Exclusive Locks

An exclusive lock allows a JADE session to update a JADE object, while preventing all other sessions from locking the object.

Lock Type Compatibility

The valid concurrent lock combinations are shown in the following table.

<table>
<thead>
<tr>
<th></th>
<th>Exclusive</th>
<th>Update</th>
<th>Reserve</th>
<th>Shared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exclusive</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Update</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Reserve</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Shared</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

To summarize:

- A JADE object can have multiple shared locks, but only one reserve, update, or exclusive lock.
- Shared locks are compatible with reserve locks and update locks, but not with exclusive locks.
- A reserve lock is compatible with shared locks, but not with update locks or exclusive locks.
- An exclusive lock is not compatible with any other lock type.

Lock Duration

A lock can have transaction duration or session duration.

A transaction duration lock will be unlocked when a transaction ends (that is, it is committed or rolled back). The lock will not be unlocked at the end of a transaction if it has session duration.
Locks with session duration remain in place until unlocked explicitly, or when the JADE session becomes inactive, which typically happens when its JADE context is disposed of. An explicit unlock request will unlock an object regardless of the duration, unless the JADE session currently has a transaction in effect, in which case the unlock request is ignored.

Explicit locks specify the lock duration. Implicitly acquired locks have transaction duration.

Lock Timeout

When a JADE session requests a lock on a JADE object that is currently incompatibly locked by another session, the request is queued until no incompatible locks remain, in which case the request can be granted. However, the lock request is queued only for a specific amount of time before it is rejected and a `JoobObjectLockedException` is thrown.

The timeout value for lock requests is specified in a parameter of the `JoobContext.Lock` method. For locks that are implicitly acquired by JADE, the timeout value is specified in the following section and parameter of the JADE initialization file.

```
[JadeServer]
ServerTimeout=n.nn.nn
```

The `ServerTimeout` parameter specifies the maximum number of milliseconds to wait before an implicit lock request times out. The default value is 10,000 milliseconds.

Lock Kind

As well as duration and type, locks have a kind. Normally, the kind is zero (0), but can have a different value when stable objects are being used. JADE sessions have no direct control of the lock kind. It is of interest only when analyzing current locks.

The possible values are listed in the following table.

<table>
<thead>
<tr>
<th>Kind</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LockKind.Normal</td>
<td>Normal lock</td>
</tr>
<tr>
<td>LockKind.Local</td>
<td>Local lock – a shared lock on a stable JADE object for a specific JADE session</td>
</tr>
<tr>
<td>LockKind.Node</td>
<td>Node lock – a shared lock on a stable JADE object, recorded for a client node rather than a specific JADE session</td>
</tr>
</tbody>
</table>

For more details, see "Stable Objects" and "Object Volatility", later in this chapter.

Explicit Locking and Unlocking

The `Lock` method of the `JoobContext` class is used to explicitly lock objects.

```csharp
void Lock(JoobObject receiver,
          LockType type,
          LockDuration duration,
          TimeSpan waitTime);
```

`LockType` and `LockDuration` are enums with the following sets of values.

- LockType.Shared
- LockType.Reserve
LockType.Update
LockType.Exclusive
LockDuration.Transaction
LockDuration.Session

Objects are explicitly unlocked using the **JoobContext Unlock** method.

```csharp
void Unlock(JoobObject receiver);
```

The **Unlock** method call is ignored if the JADE session is in transaction state (that is, it has a JADE transaction in effect) or in load state (that is, it is executing within a **BeginLoad/EndLoad** bracket, described under "Load State"). Instead, provided that the lock is of transaction duration, the object will be unlocked when the transaction is committed or rolled back, or when load state is terminated.

Session duration locks must be unlocked using the **Unlock** method outside transaction state.

**Note** All locks held by a JADE session are released, regardless of duration, when the session becomes inactive, which typically is when its **JoobContext** instance is disposed of.

The following code fragment locks two JADE objects, then unlocks them:

```csharp
//Request a shared lock, transaction duration, 1 second time out.
context.Lock(obj1, LockType.Shared, LockDuration.Transaction,
            TimeSpan.FromSeconds(1));

//Request a reserve lock, session duration, 5 second time out.
context.Lock(obj2, LockType.Reserve, LockDuration.Session,
            TimeSpan.FromSeconds(5));

color.Unlock(obj1);
color.Unlock(obj2);
```

### Implicit Locking and Unlocking

This section describes implicit locking and unlocking.

#### Implicit Locking

JADE acquires locks implicitly in certain situations.

Whenever a JADE collection is accessed, a shared lock is implicitly acquired on the collection while it is being accessed, if it is not already locked. The implicit shared lock is removed when the access is complete, unless the JADE session is in transaction state or in load state.

When a JADE session is in transaction state, an implicit exclusive or update lock is acquired for any JADE object before it is updated, if it is not yet locked with one of these two types. By default, the implicit lock type is exclusive. However, you can use the **JoobContext SetImplicitUpdatingLockType** method to specify that update locks should be the default for objects that are implicitly locked; for example:

```csharp
context.SetImplicitUpdatingLockType(LockType.Update);
```

The implicit lock type reverts to the default value (exclusive) when the JADE session becomes inactive (that is, when the JADE session is relinquished back to the pool of available sessions).
Implicit lock requests have transaction duration and they use the default timeout value (as specified in the ServerTimeout parameter in the [JadeServer] section of the JADE initialization file).

**Implicit Unlocking**

When a JADE session terminates a transaction (that is, it is committed or rolled back), all of its transaction duration locks are released. This happens regardless of whether the lock was acquired outside of or within transaction state, and whether or not the Unlock method was used within the transaction.

Session duration locks are not released when a transaction ends. You must explicitly unlock them, using the Unlock method.

Ending load state also implicitly unlocks transaction duration locks that were acquired while in load state.

When a JADE session becomes inactive (typically when its JoobContext instance is disposed of), all objects that it still has locked are unlocked, regardless of duration.

**Examples**

The following code sample demonstrates explicit and implicit locking, within and outside of transaction state.

```csharp
// Lock objects outside transaction state.
TimeSpan timeOut = TimeSpan.FromSeconds(10);
context.Lock(obj1, LockType.Reserve, LockDuration.Transaction, timeOut);
context.Lock(obj2, LockType.Shared, LockDuration.Transaction, timeOut);
context.Lock(obj3, LockType.Shared, LockDuration.Session, timeOut);

using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
    // Lock an object in transaction state.
    context.Lock(obj4, LockType.Exclusive, LockDuration.Transaction, timeOut);

    coll1.Add(obj1); // Acquires an implicit exclusive lock on coll1.

    // Acquire an explicit update lock. This can only be done in transaction state.
    context.Lock(coll2, LockType.Update, LockDuration.Transaction, timeOut);

    coll2.Add(obj2); // No implicit lock, as coll2 is already locked.

    context.Unlock(obj2); // This is ignored in transaction state.
    context.Unlock(obj3); // This is ignored in transaction state.

    obj5.Attr1 = "X"; // Acquires an implicit exclusive lock.

    tran.Commit(); // Upgrades coll2’s update lock to exclusive,
    // commits the updates,
    // then unlocks coll1, coll2, obj1, obj2, obj4, and obj5.
    // obj3 remains locked as it has session duration.
}
context.Unlock(obj3); // This will unlock obj3.

// Specify implicit update locks are to be used.
context.SetImplicitUpdatingLockType(LockType.Update);
using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
```
Load State

A JADE session initiates load state using the JobjConnection BeginLoad method. Load state is terminated when the JobjConnection EndLoad method is called, or when a transaction is terminated (that is, it is committed or rolled back).

When a JADE session is in load state, JADE objects remain locked until load state ends, even if explicitly unlocked using the JobjContext Unlock method.

Using load state avoids the overhead of individually unlocking JADE objects, as objects are unlocked together as a single operation. It also avoids repeatedly locking the same objects, as they remain locked until load state ends.

When EndLoad is called to end load state, only those locks that were acquired while in load state are unlocked. Locks that were in place before load state was activated remain locked.

Load state affects only locks with transaction duration. Session duration locks are not affected.

You can nest BeginLoad calls. A matching EndLoad call unlocks only transaction duration locks acquired at the current nesting level. Load state remains in effect until all BeginLoad calls have been matched with EndLoad calls, or a transaction terminates. Terminating a transaction (for example, by calling Commit or Rollback) ends load state for all nested levels.

Load state can be of use where the same JADE collection is being accessed repeatedly in a code sequence. However, you should keep in mind that while locks are in effect, access by other JADE sessions can be restricted, particularly if the sessions want to update the objects that get locked.

The following code fragment is a contrived example that illustrates load state.

```csharp
context.Connection.BeginLoad();
C1 c1a = root.AllC1s["a"];
C1 c2b = root.AllC1s["b"];
C1 c2c = root.AllC1s["c"];
context.Connection.EndLoad();
```

Without load state, the collection root.AllC1s would be implicitly shared-locked and unlocked three times: once for each indexed access. With the use of load state, the collection is locked and unlocked once only, as it remains locked until load state ends.

Upgrading and Downgrading Locks

This section describes upgrading and downgrading locks.

General

A lock upgrade or downgrade occurs when a JADE session has an object locked, and requests a lock with a different type or duration.
An upgrade means that the request is for a type or duration with a greater strength. A downgrade means a type or duration of lower strength is requested.

The strength of the various lock types, from lowest to highest, is as follows.

1. Shared
2. Reserve
3. Update
4. Exclusive

For duration, session duration is stronger than transaction duration.

Locks are not released while being upgraded or downgraded, with one exception: when a shared lock is being upgraded to an update lock, as described in the following section.

**Changing Lock Type**

A type upgrade can queue and potentially time out, causing a `JoobObjectLockedException` to be thrown, if the requested type is not compatible with existing locks. For example, this could happen when upgrading a shared lock to exclusive.

Lock type downgrades will never be queued, as the strength is being lowered so there will be no lock incompatibilities.

When a JADE session is in transaction state, requests to downgrade lock type are ignored. The lock maintains its current type. However, lock types can be upgraded regardless of transaction state.

When a lock type is being upgraded from shared to update, the object is unlocked before the update lock is requested. This happens even if the JADE session is in transaction state, and is the only situation where an object is unlocked while in transaction state. The reason for doing this is to prevent potential deadlocks, as discussed in more detail under “Avoiding Deadlock Exceptions”, later in this chapter.

The following code fragment gives examples of upgrading and downgrading lock types.

```csharp
TimeSpan timeOut = TimeSpan.FromSeconds(10);
context.Lock(obj1, LockType.Shared, LockDuration.Transaction, timeOut);
context.Lock(obj1, LockType.Reserve, LockDuration.Transaction, timeOut);
    // The lock is now upgraded from shared to reserve.
context.Lock(coll, LockType.Exclusive, LockDuration.Transaction, timeOut);

using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
    context.Lock(obj1, LockType.Exclusive, LockDuration.Transaction, timeOut);
    // The lock type is upgraded to exclusive, as
    // locks can be upgraded (but not downgraded)
    // when in transaction state.
    foreach (C1 obj2 in coll)
    {
        // The exclusive lock on coll is not downgraded by the implicit shared
        // lock associated with foreach, because transaction state is in effect.
    }
    context.Lock(obj1, LockType.Shared, LockDuration.Transaction, timeOut);
    // The lock type is not downgraded, but remains as exclusive.
    tran.Commit(); // All transaction duration locks are released.
}
```
Changing Lock Duration

Lock duration can be upgraded only, from transaction to session. The lock duration cannot be downgraded from session to transaction.

A request to downgrade both duration and type is ignored. The lock type for a lock with session duration can be downgraded only by an explicit lock request that specifies session duration.

Lock duration upgrades do not result in queuing, provided they are not accompanied by requests to upgrade the lock type.

JADE keeps track of the lock type associated with a lock’s most-recent session duration request. When a JADE session has a session duration lock and issues a request for a higher lock type but of transaction duration, the lock type is upgraded but the duration remains session duration. If automatic unlocking of transaction duration locks then occurs (for example, when committing or rolling back a transaction), the session duration lock is retained but its lock type reverts to the prior value.

Similarly, when a JADE session is in transaction state and a session duration lock with a lower lock type is requested on an existing lock of transaction duration, the lock duration is upgraded to session but the lock type is not downgraded until the transaction is committed or rolled back.

The following code fragment gives examples of changing lock duration.

```csharp
using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
    context.Lock(obj1, LockType.Shared, LockDuration.Transaction, timeout);
    // obj1’s lock is now shared, session duration.
    context.Lock(obj2, LockType.Exclusive, LockDuration.Session, timeout);
    // obj2’s lock remains exclusive, session duration.
    context.Lock(obj3, LockType.Exclusive, LockDuration.Transaction, timeout);
    context.Lock(obj1, LockType.Exclusive, LockDuration.Session, TimeSpan.FromSeconds(5));
    // obj1’s lock type is upgraded.
    tran.Commit();
    // obj1’s lock reverts to shared, session duration.
    // Session duration locks remain in place.
}
```

```
context.Lock(obj2, LockType.Reserve, LockDuration.Session, timeout);
// obj2’s lock type is downgraded to reserve.
context.Lock(obj2, LockType.Shared, LockDuration.Transaction, timeout);
// This is ignored, as it is requesting to downgrade both duration and type.
// Obj2’s lock remains as reserve, session duration.
context.Unlock(obj3);
context.Unlock(obj2);
context.Unlock(obj1);
```
Collection Locking

JADE collections are composite objects, each comprising a collection header and one or more collection blocks. When JADE collections are being used, it is imperative that all of the composite parts are fully coordinated by being completely up to date and not changing during access. Because of this, whenever collections are accessed and not already locked, they are automatically locked with a shared lock. They get unlocked after the access has completed, unless the JADE session is in transaction state or in load state.

Enumerating JADE Collections

When a JADE collection is traversed using the default enumerator (for example, indirectly in a standard `foreach` statement or directly in conjunction with the `JoobCollection GetEnumerator` method), it remains shared locked until the enumerator is disposed; for example:

```csharp
foreach (C1 obj1 in collA) //Shared lock is now acquired.
{
    //...examine each member...
}
//Shared lock is now released.
```

In other cases, when a JADE collection is traversed (for example, via a LINQ query or in conjunction with `JoobCollection` methods `StartingAtIndex`, `StartingAtKey`, or `StartingAtObject`), the collection is shared locked only for the period when retrieving a snapshot of member references from the associated collection; for example:

```csharp
IEnumerable<C1> query = from C1 obj1 in collA select obj1;
foreach (C1 obj1 in query)
{
    //...collection is not locked within the loop
}
foreach (C1 obj1 in collA.StartingAtIndex(0))
{
    //...collection is not locked within the loop
}
```

The automatic locking of collections is particularly important when transactions are involved. If a JADE collection is accessed when in transaction state, it is shared locked and remains so until the transaction ends. This can hold up other JADE sessions wanting to update the collection, and it can also contribute to deadlocks.

Using update locks can help to prevent JADE sessions from being held up when JADE collections are updated, as update locks are compatible with shared locks. For more details, see “Optimizing Locking”, later in this chapter.

Deadlocks

A deadlock is a situation in which two or more JADE sessions are unable to proceed because they end up waiting on locks held by one another.

Simple Deadlocks

The simple deadlock involves two JADE sessions and two JADE objects.

The initial situation is:

- Session A has an exclusive lock on Object 1
- Session B has an exclusive lock on Object 2
The attempted actions are:
- Session A requests a lock on Object 2
- Session B requests a lock on Object 1

The outcome is:
- Session A is now waiting for Session B to unlock Object 2
- At the same time, Session B is waiting for Session A to unlock Object 1
- Neither JADE session can proceed

**Indirect Deadlocks**

The indirect case involves three or more JADE sessions.

The initial situation is:
- Session A has an exclusive lock on Object 1
- Session B has an exclusive lock on Object 2
- Session C has an exclusive lock on Object 3

The attempted actions are:
- Session A requests a lock on Object 2
- Session B requests a lock on Object 3
- Session C requests a lock on Object 1

The outcome is:
- The sessions cannot proceed because they are all waiting on each other

**Single Object Deadlocks**

A deadlock can occur with only one object being involved. For example, this can happen in conjunction with lock type upgrades, as follows.

The initial situation is:
- Session A and Session B both have a shared lock on Object 1

The attempted actions are:
- Session A attempts to upgrade the lock type to exclusive
- Session B also attempts to upgrade the lock type to exclusive

The outcome is:
- Neither session can proceed, because they are waiting for each other due to them both having a shared lock

This type of deadlock occurs with the following sort of code sequence.

```csharp
TimeSpan timeOut = TimeSpan.FromSeconds(5);
using (System.Data.IDbTransaction tran = context.BeginTransaction())
```
Two JADE sessions simultaneously executing this sequence using the same JADE object can get in a deadlock situation.

This type of sequence can occur subtly. For example, consider the following pattern where a JADE session checks to see if a JADE collection contains an object, then adds it to the collection if it is not there.

```csharp
using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
    if (!allPeople.Contains(person))
        allPeople.Add(person);
    tran.Commit();
}
```

A deadlock can result if two JADE sessions execute this sequence at the same time with the same collection. Using `Contains` places a shared lock on the collection, and adding the member attempts to upgrade the lock to exclusive (or update). Both JADE sessions can end up with a shared lock on the collection, thereby preventing one another from upgrading.

**Deadlock Detection**

JADE automatically detects when a direct or indirect deadlock situation would arise due to a lock or lock upgrade request, and throws a `JoojDeadlockException` if so. By default, the exception is thrown for the JADE session requesting the lock.

This JADE session must release locks to allow other JADE sessions waiting to lock objects to continue and then take appropriate action. If the JADE session is in transaction state, it must roll back the transaction in order to unlock objects.

**Deadlock Exceptions**

By default, the `JoojDeadlockException` is thrown for the JADE session that made the request that caused the deadlock. This can be varied, to throw an exception for both JADE sessions involved, or by using a priority to determine which JADE session gets the exception.

**Double Deadlock Exceptions**

The JADE session that makes the lock request causing a deadlock gets the deadlock exception thrown.

The JADE session that is waiting for the lock held by the session making the request can also have a `JoojDeadlockException` thrown for it, by enabling double deadlock exceptions. This is specified using the following parameter in the JADE initialization file.

```
[JadeServer]
DoubleDeadlockException=true
```

The default value is `false`.

For indirect deadlocks (involving three or more JADE objects), the other sessions involved do not have exceptions thrown for them.
When enabled, double deadlock exceptions apply to all deadlocks that occur.

Double deadlock exceptions can be useful when investigating the causes of deadlocks.

**Avoiding Deadlock Exceptions**

This section describes how to avoid deadlock exceptions.

**Lock Order**

For deadlocks involving multiple JADE objects, the classic technique for avoiding deadlocks is that each JADE session should lock the objects in the same order. The direct and indirect examples described earlier in this chapter could not arise if this principle is used. For example, the following two code fragments cause a deadlock, if executed by different JADE sessions at the same time.

```csharp
context.Lock(obj1, LockType.Shared, LockDuration.Transaction, TimeSpan.FromSeconds(5));
    //...
context.Lock(obj2, LockType.Exclusive, LockDuration.Transaction, TimeSpan.FromSeconds(5));
    //...
context.Unlock(obj2);
context.Unlock(obj1);

context.Lock(obj2, LockType.Shared, LockDuration.Transaction, TimeSpan.FromSeconds(5));
    //...
context.Lock(obj1, LockType.Exclusive, LockDuration.Transaction, TimeSpan.FromSeconds(5));
    //...
context.Unlock(obj1);
context.Unlock(obj2);
```

The first JADE session cannot get the exclusive lock on obj2 because the second session has a shared lock on it. The second JADE session cannot get the exclusive lock on obj1 because the first session has a shared lock on it.

The deadlock cannot occur if the second code sequence locks the objects in the same order as the first, as follows.

```csharp
context.Lock(obj1, LockType.Exclusive, LockDuration.Transaction, TimeSpan.FromSeconds(5));
    //...
context.Lock(obj2, LockType.Shared, LockDuration.Transaction, TimeSpan.FromSeconds(5));
    //...
context.Unlock(obj2);
context.Unlock(obj1);

context.Lock(obj2, LockType.Shared, LockDuration.Transaction, TimeSpan.FromSeconds(5));
    //...
context.Lock(obj1, LockType.Exclusive, LockDuration.Transaction, TimeSpan.FromSeconds(5));
    //...
context.Unlock(obj1);
context.Unlock(obj2);
```

The first JADE session to lock obj1 blocks the other, preventing it from locking obj2 and setting up the deadlock.

Lock ordering issues are not always obvious, as locks are commonly implicitly acquired. For example, accessing a JADE collection implicitly acquires a shared lock, and updating an object implicitly acquires an update or exclusive lock.
**Reserve Locks**

Reserve locks can be a useful way to avoid single object deadlocks due to lock upgrade requests. For example, the following code fragment from an earlier example in this chapter can cause a `JoobDeadlockException` to be thrown if executed by two JADE sessions at the same time with the same object, due to both wanting to upgrade a lock on the `allPeople` collection from shared to exclusive:

```csharp
using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
    if (!allPeople.Contains(person))
        allPeople.Add(person);
    tran.Commit();
}
```

However, if the code initially locks the collection with a reserve lock instead of the implicit shared lock, the deadlock situation will not arise; for example:

```csharp
using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
    context.Lock(allPeople, LockType.Reserve, LockDuration.Transaction,
                   TimeSpan.FromSeconds(5));
    if (!allPeople.Contains(person))
        allPeople.Add(person);
    tran.Commit();
}
```

The first JADE session to execute this code sequence acquires the reserve lock. Other JADE sessions executing this sequence queue until the object is unlocked; that is, when the transaction is committed, as a reserve lock is not compatible with other reserve locks. The lock, therefore, can be readily upgraded to exclusive, and the single object deadlock will not occur.

Using an initial reserve lock as opposed to an exclusive lock has the benefit of not blocking other JADE sessions from obtaining shared locks. This could be significant in cases where there is a reasonable time gap between when the object is first locked and when it is updated. However, when that gap is very short, as in the above code example, an exclusive lock may be preferable, as it avoids the overhead of upgrading the lock.

**Update Locks**

Deadlock exceptions due to lock upgrades can be avoided by using update locks instead of exclusive locks, as an object gets unlocked before its lock is upgraded from shared to update (as mentioned in "Upgrading and Downgrading Locks", earlier in this chapter). For example, you could change the above code sequence to the following.

```csharp
using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
    bool retry = false;
    do
    {
        if (!allPeople.Contains(person))
        {
            if (retry)
                retry = false;
            else
            {
                try
                {
```
A deadlock does not occur when two JADE sessions execute this code sequence at the same time. Even though both JADE sessions can end up with shared locks on the collection, because the collection gets temporarily unlocked, one of the sessions acquires the update lock, allowing it to proceed to transaction completion and unlock the collection, then followed by the other session.

Note that this code fragment has to deal with a `JoobInterveningUpdateException`, which can be thrown if another JADE session updates the collection before the update lock is acquired (while it is unlocked). To do this, the collection is explicitly locked and a catch block is used to indicate the operation should be retried. The `JoobInterveningUpdateException` is thrown after the update lock is acquired, so the object does not need to be locked again. An explicit lock is used, because if an exception is thrown while an implicit lock is being attempted for inverse maintenance, the transaction is rolled back before the catch block is executed. This avoids having to repeat the whole transaction.

For more details, see "Exceptions", later in this chapter.

### Investigating Deadlocks

When a deadlock exception is thrown, the `JoobDeadlockException` object contains properties that allow analysis of the deadlock situation. This information includes a reference to the object for which the lock was requested and a reference to the object for which the other JADE session involved with the deadlock was waiting. (For details, see "JoobDeadlockException", later in this chapter.)

For deadlocks involving more than two JADE sessions, there is no direct way to determine the JADE session that was requesting the lock on the object that the current JADE session has locked. However, to aid analysis, you can configure the JADE initialization file to cause deadlock exceptions to be thrown for both JADE sessions involved. (For details, see "Double Deadlock Exceptions", earlier in this chapter.)

You can obtain additional information about deadlocks by configuring the [Log] section in the JADE initialization file to enable queue and lock tracing in the JADE message log files.

### Exceptions

The three main exceptions related to locking are as follows.

- `JoobObjectLockedException` – object lock request timed out.
- `JoobDeadlockException` – deadlock detected.
JoobInterveningUpdateException – the object was updated before the lock upgrade completed.

**JoobObjectLockedException**

A JoobObjectLockedException is thrown when a lock request cannot be granted within the specified lock timeout interval, due to incompatible locks held by other JADE sessions.

The JoobObjectLockedException object properties that indicate details about the lock request and the JADE session that had the object locked at the time are listed in the following table.

<table>
<thead>
<tr>
<th>Property</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LockTarget</td>
<td>ObjectId</td>
<td>The object requested to be locked</td>
</tr>
<tr>
<td>LockType</td>
<td>LockType</td>
<td>The requested lock type</td>
</tr>
<tr>
<td>LockDuration</td>
<td>LockDuration</td>
<td>The requested lock duration - Transaction or Session</td>
</tr>
<tr>
<td>LockTimeout</td>
<td>TimeSpan</td>
<td>The requested lock timeout period</td>
</tr>
<tr>
<td>TargetLockedBy</td>
<td>ObjectId</td>
<td>The JADE session that had the object locked</td>
</tr>
</tbody>
</table>

If required, you can repeat an explicit lock request, by using a catch block and a loop. This provides a way to extend the lock timeout period in certain circumstances; for example:

```csharp
bool locked = false;
int retries = 0;
while ( !locked )
{
    try
    {
        context.Lock(obj1, LockType.Update, LockDuration.Transaction,
                     TimeSpan.FromSeconds(4) );
        locked = true;
    }
    catch (JoobObjectLockedException ex)
    {
        if ( ++retries > 5 )
            throw ex;
        Console.WriteLine("Object {0} locked by {1} – retrying", obj1.ToString(),
                          ex.TargetLockedBy.ToString());
    }
}
```

The exception can be avoided, by using the JoobContext TryLock method. This method returns true or false, to indicate the outcome of the lock request, instead of throwing an exception if the request times out; for example:

```csharp
if ( !context.TryLock(obj1, LockType.Exclusive, LockDuration.Transaction,
                      TimeSpan.FromSeconds(4)) )
{
    Console.WriteLine("Could not lock {0}", obj1.ToString());
}
```

**Note**   Although the TryLock method does not result in a JoobObjectLockedException being thrown, a JoobDeadlockException can still occur.
A **JoobObjectLockedException** can be thrown as a result of an implicit lock request made by JADE. Implicit lock requests happen when JADE collections are accessed, or objects get implicitly locked for updating, including during inverse maintenance to automatically update collections. For implicit lock requests, the default lock timeout period is specified in the **ServerTimeout** parameter in the [JadeServer] section of the JADE initialization file.

For straightforward implicit lock requests, it may be appropriate to catch the exception and retry the operation that resulted in the implicit lock request, if a longer timeout period was wanted. However, when a **JoobObjectLockedException** is thrown during inverse maintenance (for example, when changing the collection parent reference), the transaction is automatically rolled back, so the operation cannot be retried without reprocessing the whole transaction. The transaction is rolled back in order to maintain referential integrity, which can be compromised if inverse maintenance is not completed.

A **catch** block can check if the transaction has been rolled back by checking the **JoobConnection.IsTransactionActive** property; for example:

```csharp
try
{
    Member member = new Member();
    member.Id = 99;
    member.MyOwner = owner;
    // ...
}
catch
{
    if (!context.Connection.IsTransactionActive)
    {
        Console.WriteLine("Transaction was automatically rolled back");
    }
    else
    tran.Rollback();
}
```

As an alternative, the code can avoid lock exceptions on implicit locks by instead explicitly locking collections before the operation involving inverse maintenance.

When update locks are being used, a lock exception can be thrown when committing a JADE transaction. This happens if an update lock cannot be upgraded to an exclusive lock. In this circumstance, the transaction will have been rolled back. A **catch** block can be used to detect this, for example:

```csharp
using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
    // ...
    try
    {
        tran.Commit();
    }
    catch
    {
        Console.WriteLine("Could not commit transaction due to an exception");
    }
}
```

**JoobDeadlockException**

A **JoobDeadlockException** is thrown when JADE detects that a lock request would result in a deadlock condition. The lock request can be explicit or implicit, including when committing a transaction involving update locks.
At a minimum, the JADE session must abandon the lock request and release the lock that was blocking the other session. If the JADE session is in transaction state, the transaction must be rolled back in order to release the lock. Rolling back the transaction releases all transaction duration locks.

The JoobDeadlockException object properties that indicate details about the deadlock are listed in the following table.

<table>
<thead>
<tr>
<th>Property</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LockTarget</td>
<td>ObjectId</td>
<td>Identifies the object requested to be locked</td>
</tr>
<tr>
<td>LockType</td>
<td>LockType</td>
<td>The requested lock type</td>
</tr>
<tr>
<td>LockDuration</td>
<td>LockDuration</td>
<td>The requested lock duration</td>
</tr>
<tr>
<td>LockTimeout</td>
<td>TimeSpan</td>
<td>The requested lock timeout period</td>
</tr>
<tr>
<td>TargetLockedBy</td>
<td>ObjectId</td>
<td>Identifies the JADE session that has the object locked</td>
</tr>
<tr>
<td>ObtainedLock</td>
<td>ObjectId</td>
<td>Identifies the object that the requesting JADE session has locked, which caused the deadlock</td>
</tr>
</tbody>
</table>

The following code fragment is an example of displaying JoobDeadlockException information.

```csharp
try {
    context.Lock(collA, LockType.Shared, LockDuration.Transaction, timeout);
    // ...
} catch (JoobDeadlockException dlException) {
    Console.WriteLine("Requested object {0}", dlException.LockTarget.ToString());
    Console.WriteLine("Requested type {0}", dlException.LockType.ToString());
    Console.WriteLine("Locked by {0}", dlException.TargetLockedBy.ToString());
    Console.WriteLine(" Obtained lock {0}", dlException.ObtainedLock.ToString());
    // ...
}
```

**JoobInterveningUpdateException**

A JoobInterveningUpdateException is thrown when a JADE session has upgraded a lock on an object from shared to update, but another JADE session has updated the object in the interim when it was unlocked.

The exception is thrown after the update lock has been acquired. An application therefore has the option to ignore the exception and continue execution, if appropriate; for example:

```csharp
TimeSpan timeout = TimeSpan.FromSeconds(5);
using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
    context.Lock(collA, LockType.Shared, LockDuration.Transaction, timeout);
    // ...
    try {
        context.Lock(collA, LockType.Update, LockDuration.Transaction, timeout);
    }
    catch (JoobInterveningUpdateException ex)
    {
        // Ignore the exception: the code does not depend on previously checked values (that may have changed).
        // ...
    }
    // ...
}
```
An alternative would be to resume execution from an earlier point in order to refresh any properties of the object (that is now update locked) that may have changed, without needing to roll back the current transaction.

The following code fragment gives an example of how this could be done.

```csharp
bool retryNeeded;
context.SetImplicitUpdatingLockType(LockType.Update);
using (System.Data.IDbTransaction tran = context.BeginTransaction())
{
    do
    {
        retryNeeded = false;
        try
        {
            //Calling TryGetValue acquires a shared lock on the collection.
            Person existingPerson;
            if ( !allPeople.TryGetValue( person.Id, out existingPerson) )
            {
                //Adding upgrades the lock from shared to update, which
                //unlocks the collection in the interim.
                allPeople.Add(person);
            }
        }
        catch ( JoobInterveningUpdateException ex )
        {
            retryNeeded = true; //Need to check if the person has just been
                                //added to the collection by another process.
        }
    }
    while (retryNeeded);
}
```

In this example, if a `JoobInterveningUpdateException` is thrown, the JADE session needs to check again to see if the person is in the collection, as it could have been added by another JADE session while the collection was unlocked. Note that when retrying, the collection is locked with an update lock.

### Object Volatility

Object volatility refers to the frequency with which a JADE object is updated. This, in turn, can be used to customize locking behavior and provide optimizations.

JADE defines the following three types of volatility.

- **Volatile**, for objects that are regularly updated.
- **Stable**, for objects that are infrequently updated.
- **Frozen**, for objects that are almost never updated.

JADE objects are volatile, by default. Volatility can be specified at the JADE class level. There are also methods that enable you to alter and interrogate the volatility for individual JADE objects.

### Volatile Objects

A volatile object is one that is updated reasonably frequently. Normal locking is used on volatile objects.
A volatile object is recorded as locked by any JADE sessions that have it locked until they unlock it, and whenever locked, the latest edition of the object is fetched from the database server.

The following diagram shows the locks recorded for volatile objects.

Every lock is recorded locally on the client node and remotely on the database server node.

**Stable Objects**

A stable object is one that is mostly read, and only infrequently updated.

For stable objects, each node retains a generic node shared lock, recorded on the server node and the local client node, even after JADE sessions have unlocked the object. Shared lock entries for individual JADE sessions are recorded only on the local client node. The node’s shared lock is released when a JADE session requests an exclusive lock on the object, when the object is swapped out of the client node’s object cache, or when the client node terminates.

Using stable objects avoids the overhead of communication with the database server node to acquire a shared lock and retrieve the object from the JADE database. This is because while a node lock is in place, the lock can be handled locally, and the copy of the object in cache is the latest edition, because the object cannot be updated while the client node’s shared lock is in place.

When an exclusive lock is requested on a stable object, all client nodes that have node shared locks for that object are asked to release the lock. The client nodes release the lock when no JADE sessions on that node have the object locked.

To prevent the exclusive lock request from being held up by other shared lock requests, further lock requests are blocked until after the exclusive lock has been acquired and released (or the request times out).

Requests for reserve locks and update locks are handled normally. Node locks are not involved, as these lock types are compatible with shared locks. In addition, requests for shared locks of session duration are handled normally, and do not involve node locks.

An example of a good use of stable objects would be for JADE collections that are frequently enumerated but infrequently updated.
Chapter 2  Object Management

The trade-off is that although stable objects optimize the acquisition of shared locks, acquiring exclusive locks involves extra overhead, as all client nodes that are holding node locks need to be requested to release the locks first.

Another factor to consider is that using stable objects can result in an increase in the number of locks held in the server node’s lock tables, because shared locks tend to be retained for longer. For very large numbers of concurrent locks (10,000 or more), it may be beneficial to increase the value of the PersistentLockHashSize parameter the PersistentLockHashSize parameter in the [JadeClient] and [JadeServer] section of the JADE initialization file. For details, see the JADE Initialization File Reference.

Node locks are identifiable when lock information is displayed by the JADE Monitor, as node locks have the kind property set to LockKind.Node.

Local shared locks on stable objects (that is, locks held on client nodes by JADE sessions where a node lock is involved) have the kind property set to LockKind.Local.

Other locks have the kind property set to LockKind.Normal.

The following diagram shows the locks recorded for stable objects.

![Diagram showing locks recorded for stable objects]

This example illustrates that shared locks for individual JADE sessions are recorded locally on the session’s client node, whereas a node lock is recorded on the client node and the database server node. Exclusive locks are recorded on the client node and database server node, in the same manner as volatile objects.

**Note**  For convenience, node locks use the client node’s JADE background session as the session that has the lock.

**Frozen Objects**

A frozen object is one that is updated rarely. In fact, when a JADE object is frozen, it cannot be updated until the volatility is changed, and you should do this only when the system is unavailable to general users. Examples of good candidates for being frozen include code tables used for interpreting abbreviations, or JADE objects that do not change after they are created (for example, commercial events or archive data).

For frozen objects, shared and reserve lock requests are ignored. There is no need for the lock to be applied, as frozen objects cannot be updated and therefore a consistent view of the data is guaranteed. In addition, a frozen object in cache is always the latest edition, avoiding the need to fetch the object from the database server node.
Update locks are not allowed on frozen objects.

Exclusive locks on frozen objects are actioned.

Special action is required in order to update an object that is currently frozen. The object must first be thawed, by changing the volatility to volatile or stable, using the `JoobObject SetVolatility` method described under “Specifying and Changing Object Volatility”, later in this chapter.

Thaw a frozen object with caution, as other JADE sessions using the object may temporarily not know that the object has been updated, and could even be assuming that it cannot change as they have requested shared locks on the object (which will have been ignored if the object was frozen).

We recommend two techniques for changing the volatility of frozen objects. The first is to thaw and update frozen objects when you can be sure that no other JADE sessions can be using the object and that there are no copies in local caches; for example, when the system is run in single user mode or it is offline and unavailable to general users.

The second technique is to change the volatility conditionally; that is, to use methods that change the volatility of a frozen object only if the object’s class is not currently in use by another JADE session. For details, see the following section.

The following diagram shows an example of locks held when requesting locks on frozen objects `obj1` and `obj2`.

This example illustrates that exclusive lock requests are honored for frozen objects, whereas shared lock requests are ignored.

## Specifying and Changing Object Volatility

You can specify volatility at the individual object level or at a JADE class level.
Class Volatility

Class volatility is specified in the class definition in the JADE Class Browser. The volatility options are volatile, stable, or frozen. When you specify volatility at the class level, you specify the volatility of all future instances of a class. By default, class instances are volatile.

The volatility specified for a class is not inherited by subclasses. In addition, changing a class's volatility does not affect existing instances. To change the volatility of existing instances, you must use the methods outlined in the following section.

Setting the class volatility to frozen is a good option for objects that do not change once they are created; for example, records of sales and purchases.

Note The initial volatility for exclusive collections is as defined for the collection's class. The volatility of the object containing the collection is not considered.

Individual Object Volatility

For individual JADE objects, the JoobObject Volatility property indicates the object's volatility. It can have one of the following values.

- JoobObjectVolatility.Volatile
- JoobObjectVolatility.Stable
- JoobObjectVolatility.Frozen

An object's volatility can be changed using the JoobObject SetVolatility method, which has the following signature.

```csharp
void SetVolatility(JoobObjectVolatility volatility, bool conditional);
```

The conditional parameter specifies whether changing the volatility of a frozen object should be conditional or unconditional. If conditional, a JoobCannotThawClassInUseException is thrown if the object's class is in use. The conditional parameter is ignored when changing the volatility of volatile or stable objects.

Unconditionally change the volatility of a frozen object only when it can be assured that no other JADE sessions are using the object.

Note If production mode is set, volatility can be conditionally changed only in single user mode. If attempted in multiuser mode, a JoobFeatureNotAvailableException is thrown.

The following example demonstrates defining a collection to be stable.

```csharp
Company company = null;
//...
company.AllStaff.SetVolatility(JoobObjectVolatility.Stable, false);
```

The following example demonstrates checking if an object is stable.

```csharp
if (company.AllStaff.Volatility == JoobObjectVolatility.Stable)
    Console.WriteLine("{0} is stable", company.AllStaff.ToString());
```

The following example demonstrates thawing a frozen object conditionally.

```csharp
company.Codes.SetVolatility(JoobObjectVolatility.Volatile, true);
```
Frozen Files and Partitions

A convenient way to freeze a large number of JADE objects is to freeze a database file or partition. In effect, this makes all objects read from that file or partition frozen. This reduces the number of lock and unlock requests, and brings about the same overhead savings as if the objects had been frozen individually.

Frozen partitions can be used for a class where the partition for instances is determined by a date attribute. Partitions containing old, historical data could be marked frozen. Specific examples include sales or orders, banking transactions, test results, meter readings, and so on.

Use the JADE Database Administration utility to freeze files. The following example shows how to freeze the first (oldest) partition of MyFile.

```
jdbadmin ini=iniFile path=system action=Freeze file=MyFile partition=1
```

Freezing a file or partition overrides any specified object volatility for all instances defined in that file or partition. This means a volatile or stable object stored in a frozen file or partition is treated as a frozen object when the object is read. The objects can be reverted to their actual volatility, by thawing the file or partition.

Use the JADE Database Administration utility to thaw files. The following example shows how to thaw the first (oldest) partition of MyFile.

```
jdbadmin ini=iniFile path=system action=Thaw file=MyFile partition=1
```

For more details, see "Using the JADE Database Administration Utility", in Chapter 2 of the JADE Database Administration Guide.

**Note** Modify the backup strategy to take advantage of the fact that frozen files or partitions cannot be updated, so do not need to be backed up as frequently.

Freezing User Schema Files

The _userscm, _userrf, and _userint user schema database files contain the metaschema entities that describe all user classes, properties, applications, and so on. These files are not updated while a JADE session is running. In fact, they change only when a schema is deployed. Obtain the performance benefits associated with frozen objects by freezing these files.

Use the FreezeSchemaFiles command of the JADE Database Administration utility to freeze the user schema database files, as follows.

```
jdbadmin ini=iniFile path=system action=FreezeSchemaFiles
```

You must thaw user schema database files before deploying a schema.

Use the ThawSchemaFiles command of the JADE Database Administration utility to thaw the user schema database files, as follows.

```
jdbadmin ini=iniFile path=system action=ThawSchemaFiles
```
Chapter 3 Introductory Tutorial to JADE .NET

This chapter covers the following topics.

- Overview
- JADE Banking System
  - Model-View Separation
  - Customer Class
  - Bank Class
  - Application Subclass
- Defining the JADE Connection Application
- Defining the C# Exposure
- Building the Class Exposure Project in Visual Studio
- Adding a WPF Application
  - Adding References
  - Coding the Application Configuration File
  - Designing the Form
  - Coding the Form Constructor and Destructor
  - Listing Customer
  - Adding a Customer
  - Using Notifications
  - Invoking on the GUI Thread

Overview

In this tutorial, the banking system that is built by attendees on the five-day JADE Developer's course is exposed to .NET. You can download the schema files for the completed banking system from the JADE Web site using the hyperlink https://www.jadeworld.com/downloads/tech/JADEDevCourseSchemas.zip.

The following sections explain in detail how the exposure is created using the JADE Exposure wizard and how a WPF application is built in Visual Studio to use the exposed classes to add customers into the JADE database.

JADE Banking System

This section describes the JADE system that is built during the five-day JADE Developer's course. It is based on customers of a bank and their bank accounts.

One of the aims of the tutorial is to demonstrate the functionality of JADE .NET with an exposure that is as small and simple as possible. Consequently, only part of this system is exposed to .NET. To limit the size of the exposure, the bank account classes are not exposed.
Model-View Separation

In the design of the banking system, the model classes (mainly the classes for objects in the persistent database) are in the BankingModelSchema. They are separated from the view classes (mainly the forms and application definitions), which are in the BankingViewSchema.

Customer Class

The address, firstName, lastName, and number properties are part of the exposure because they will be accessed from .NET.

The allBankAccounts reference is not exposed, in accordance with the decision to exclude bank account classes from the exposure.

The myBank reference is not exposed because it refers to the root object, which is the same for all Customer objects and therefore not semantically important. The myBank reference can be regarded as part of the JADE implementation in that when it is set, a Customer object is added to the root object's allCustomers collection through the automatic inverse reference maintenance that is triggered. The setting of the myBank reference is encapsulated in the setPropertiesOnCreate method.

The setPropertiesOnCreate method is exposed. If this method was not exposed, you would need to expose the myBank reference, as explained previously.

Note When you expose a JADE method to .NET, you do not need to expose the properties and methods that are accessed in that method. This is in line with the practice of exposing an interface but hiding the implementation.

The create method is not exposed. However, when a Customer object is created in .NET code, the JADE constructor is executed causing a unique value to be assigned to the number property.
Bank Class

The **Bank** class is the root object class. An important function of a root object is to provide access to collections of other objects from the model classes. In this tutorial, only the **allCustomers** collection is exposed to .NET.

<table>
<thead>
<tr>
<th>Bank</th>
</tr>
</thead>
<tbody>
<tr>
<td>allChequeAccounts</td>
</tr>
<tr>
<td>allCustomers (highlighted)</td>
</tr>
<tr>
<td>allSavingsAccounts</td>
</tr>
<tr>
<td>myBankAcctSeqNum</td>
</tr>
<tr>
<td>myCustomerSeqNum</td>
</tr>
<tr>
<td>nextBankAcctNum()</td>
</tr>
<tr>
<td>nextCustomerNum()</td>
</tr>
</tbody>
</table>

**Note**: When you run the exposure wizard, selecting a reference automatically selects the type of that reference; for example, selecting **allCustomers** automatically exposes the **CustomersByLastName** dictionary class; that is, you do not have to decide which collection classes to select in the exposure wizard.

The properties and methods related to sequence numbers are not exposed, even though they are used by the **create** method of the **Customer** class to generate a unique customer number.

Application Subclass

One of the uses of an application subclass in a JADE system is to hold a reference to the root object, which is an important object in that it enables access to collections of other model objects. The root object reference, which is a key part of the exposure, is **myBank**.

**BankingModelSchema** is the **Application** subclass in the following diagram.

```
<table>
<thead>
<tr>
<th>BankingModelSchema</th>
</tr>
</thead>
<tbody>
<tr>
<td>myBank</td>
</tr>
<tr>
<td>initialize()</td>
</tr>
</tbody>
</table>
```

It is not necessary to include the **initialize** method as part of the exposure. However, the **initialize** method should be specified as the startup method in the definition of the client application that connects the .NET application to the JADE database server.
Defining the JADE Connection Application

A JADE connection application is a client application that is started by the .NET application when the .NET application creates a JoobContext object for the first time.

The JADE connection application connects the .NET application to the JADE database server. The application and schema name of the JADE configuration application to be started are specified in the app.config file of the .NET application. An app.config file is generated by the exposure wizard. For more details about application configuration files, see "Application Configuration File", in Chapter 6.

You can define an application for the connection between .NET and JADE, as shown in the following diagram.

![Define Application Window]

This application is defined in the BankingViewSchema.
Note The **initialize** method sets a reference on the **app** object to the root object of the banking system in the same way as for any other JADE application. For details about how a .NET application accesses the **app** object, see "Accessing JADE System Objects", in Chapter 7.

## Defining the C# Exposure

The following instructions describe how you can create a C# exposure for classes in the banking system. For more details, see "Chapter 17 - Using the C# Exposure Wizard", in the JADE Development Environment User's Guide.

1. From the Browse menu in the **BankingViewSchema**, select the **Exposures** command and then select the **C#** tab. Right-click and then add an exposure.

2. On the Define Exposure step of the wizard, name the exposure **BankingClasses** and then select schemas up to the **BankingModelSchema**.

![Image of C# Exposure Wizard](image-url)
3. On the next step of the wizard, select the following classes.
   - Bank, to enable the application to access the root object's allCustomers collection
   - BankingModelSchema, to enable the root object to be accessed using the myBank reference
   - Customer, because the application will create customers

You do not need to select the SequenceNumber class, which generates unique customer numbers, because the use of this class is built into the JADE constructor method. You do not need direct access to this class from your C# application code. For simplicity in this tutorial, the BankAccount classes are not included.
4. On the Select Features step of the wizard, for the **Bank** class, select the **allCustomers** collection.

**Note** When you select the **allCustomers** collection, the **CustomerByLastName** collection class becomes part of the exposure. You never need to select the class of reference explicitly when using the C# Exposure wizard.
5. For the BankingModelSchema, which is an Application subclass, select the myBank reference to the root object.

6. For the Customer class, select the setPropertiesOnCreate method along with the address, firstName, lastName, and number properties so that it can be invoked from your C# code.
7. The Feature Mappings step of the wizard enables you to specify different names for the exposed classes, properties, and methods. Accept the default names without change.

![Feature Mappings](image)

By default:

- C# class names are the same as those of the corresponding JADE classes
- C# property and method names are derived from the corresponding JADE names with the first letter changed to uppercase
8. The Save step of the wizard summarizes the exposure definition to be saved.

![Save step of the wizard](image)

9. On the Generate step of the wizard, enter `C:\Projects\BankingClasses` as the directory where the C# project file and class files will be created.

Check the option to create a sample C# project file. In addition, check the option to create an application configuration file using the following information specified on the form.

- JADE database path
- JADE initialization file location
- Sign-on schema name
- Sign-on application name, for which you should select `DotNetConnection`
- Mode (multiuser or single user) in which the JADE database should be open when the C# application attempts to connect

**Note** This application configuration information is similar to that provided in the shortcut for a standard JADE client.
10. Click the **Generate** file to generate the files when you build a C# project in the next section.

**Building the Class Exposure Project in Visual Studio**

In the final step of the C# Exposure wizard, a number of C# class files and other files were generated, including the project file **BankingClasses.csproj**.
The instructions in this section enable you to build a class library DLL for the exposed classes from the JADE banking system. The DLL can be referenced by other .NET projects, enabling them to create and access instances of the Customer class.

1. Open the BankingClasses.csproj file in Visual Studio.

![Image of Solution Explorer with BankingClasses project]

The classes exposed in the C# Exposure wizard are visible in the Solution Explorer.

2. Build the project.

![Image of Solution Explorer with BankingClasses.dll]

The BankingClasses.dll library is created in the project's bin\Debug directory. The DLLs from the JADE .NET framework are copied into the same location.
3. Click the **Save All** icon and then enter `C:\Projects\BankingSystem.sln` when prompted for the name and path of the solution file.

## Adding a WPF Application

The following instructions create a WPF project called **BankingApp** to the solution and set the application as the default one to be run for the solution (currently the **BankingClasses** project is the default project). Finally, the project properties are changed to build a 64-bit application.

1. Right-click on the **BankingSystem** solution and then select **Add New Project** from the menu, to add a WPF project. Complete the dialog, as shown.

![Add New Project dialog](image-url)
2. The Solution Explorer shows the **BankingSystem** solution with two projects: **BankingApp** and **BankingClasses**.

3. Right-click on the **BankingApp** project and then select **Set as Startup Project** from the menu. This causes the application to be run when debugging is started.

4. Right-click on the **BankingApp** project and then select **Properties** from the menu. On the Build tab, change the **Platform target** to be **x64**.
Adding References

For the BankingApp project to work with the exposed classes in the BankingClasses project, a reference must be added to the BankingClass.dll that was built earlier. In addition, references to the JADE .NET framework DLLs must be added.

To simplify your application coding that uses classes from the referenced DLLs, using directives are added to the start of the MainWindow.xaml.cs file.

The following instructions add the required references and using directives.

1. Right-click on the BankingApp project then and select Add Reference. On the Reference Manager dialog, select BankingClasses from the solution assemblies.
2. Using the Reference Manager again, add references to the following JADE .NET framework DLLs by browsing for their locations.

- JadeSoftware.Joob.dll
- JadeSoftware.Joob.Common.dll
- JadeSoftware.Jade.DotNetInterop.dll
3. Select the tab for the MainWindow.xaml.cs code file.

4. Add the following using directives for namespaces to your code.

```csharp
using BankingClasses;
using JadeSoftware.Joob;
using JadeSoftware.Joob.Client;
using JadeSoftware.Joob.Exceptions;
using JadeSoftware.Jade.DotNetInterop;
```
Coding the Application Configuration File

The connection string information in the application configuration is used by the .NET application to connect to the database server. It contains the same kind of information you would see in a JADE client shortcut.

An example application configuration file called BankingClasses.exe.config was generated by the C# Exposure wizard, so if you information provided to the wizard was correct, you can use the contents of this file without modification.

1. Open the App.config file for the BankingApp project.

2. Overwrite the XML in this file with the contents of the BankingClasses.exe.config file.

```xml
<?xml version="1.0" encoding="utf-8" ?>
<configuration>
  <startup>
    <supportedRuntime version="v4.0" sku=".NETFramework,Version=v4.0"/>
  </startup>
</configuration>
```

```xml
<connectionStrings>
  <add name="myDefault" providerName="JadeSoftware.Joob.JadeConnection"
       connectionString="DataSource=C:/Jade7009/system/;
                         ConfigFile=C:/Jade7009/system/jade.ini;
                         SingleUser=False;
                         Schema=BankingViewSchema;
                         Application=DotNetConnection;
                         IntegratedSecurity=true"/>
</connectionStrings>
```

```xml
<joob defaultConnection="myDefault">
  <installation directory="C:\Jade7009\bin" />
</joob>
```

```
<startup>
  <supportedRuntime version="v4.0" sku=".NETFramework,Version=v4.0"/>
</startup>
</configuration>
```
Designing the Form

The instructions in this section enable you to design a form to add a customer and to display a list of customer names. The completed form layout is as follows.

1. Add three Label controls and set the Content property to First Names, Last Name, and Address.
2. Add three TextBox controls next to the labels and then set the Name to txtFirstName, txtLastName, and txtAddress. In addition, set the Text property of the text boxes to be an empty string.
3. Add a ListBox control and then set its Name to lstCustomers.
4. Add a Button control with the name btnAdd and then set its Content property to Add.
5. Add a Button control with the name btnRefresh and then set its Content property to Refresh.

Coding the Form Constructor and Destructor

Before you can work with Customer objects, you need to connect to the database. This is provided by a JobbContext object.
The simplest `JoobContext` constructor is the default no-parameters constructor, which uses the `defaultConnection` element from the application configuration file.

To establish a connection, simply create a `JoobContext` object as follows.

```csharp
JoobContext context = new JoobContext();
```

When a connection is no longer needed, dispose of the `JoobContext` object.

```csharp
context.Dispose();
```

If a form utilizes the connection for the entire time it is shown, the form should have a reference to a context object. This reference is available to all code in the form. You can create the context object when the form is opened and dispose of this object when the form is closed.

If the form requires an occasional connection to the JADE database only (perhaps only if a specific button on the form is clicked), you can establish a temporary connection by creating a context object in a `using` block, as follows.

```csharp
using (JoobContext context = new JoobContext())
{
    // access the database
}
```
Another object that is used throughout the application is the root object. The `JoobContext` object provides a way of accessing this object using a template method that can return the first instance of any class. The first (and only) instance of the `Bank` class is the root object.

```csharp
bank = context.FirstInstance<Root>();
```

In the following instructions, a context object is created for the life of the form and a reference to the root object established.

1. In the `MainWindow.xaml.cs` code file, add private member variables called `context` and `bank` to the `MainWindow` class for the context object and the root object, respectively.

   ```csharp
   public partial class MainWindow : Window
   {
       private JoobContext context;
       private Bank bank;
   }
   ```

2. In the form constructor, initialize the `context` and `bank` references.

   ```csharp
   public MainWindow()
   {
       InitializeComponent();
       context = new JoobContext();
       bank = context.FirstInstance<Bank>();
   }
   ```
InitializeComponent();
    context = new JoobContext();
    bank = context.FirstInstance<Bank>();
}

3. Add a form destructor to dispose the JoobContext object.

    ~MainWindow()
    {
        context.Dispose();
    }

Listing Customers

The Bank root object's collection of Customer objects is to be displayed in the lstCustomers list box. For simplicity, only the surname of the customer is displayed.

1. In the MainWindow.xaml form, double-click the Refresh button. This adds a click event method in the MainWindow.xaml.cs code file.

2. Add the following code to the btnRefresh_Click method.

        private void btnRefresh_Click(object sender, RoutedEventArgs e)
        {
            lstCustomers.ItemsSource = bank.AllCustomers;
            lstCustomers.DisplayMemberPath = "LastName";
        }

3. Run the BankingApp application and then click the Refresh button.
If you have created `Customer` objects previously as part of the JADE developer's course, they are displayed.

Adding a Customer

The `JoobContext` object has a method for beginning a transaction. The method returns a transaction object with methods for committing or rolling back a transaction. The transaction object must be disposed of at the end of the transaction.

The simplest syntax for carrying out a transaction uses a `using` statement that implicitly calls the `Dispose` method on the transaction object at the end of the block.

The `SetPropertiesOnCreate` method, which was exposed by the C# Exposure wizard, sets properties of the `Customer` object from values entered in the text boxes on the form.

If the statement calling the `Commit` method is omitted or not executed because an exception is thrown, the transaction is automatically rolled back. With a `using` statement, you do not have to explicitly call the `Rollback` method.

1. In the `MainWindow.xaml` form, double-click the `Add` button. This adds a `click` event method in the `MainWindow.xaml.cs` code file.

2. Add the following code to the `btnAdd_Click` method.

```csharp
private void btnAdd_Click(object sender, RoutedEventArgs e) {
    using (var tran = context.BeginTransaction())
    {
        Customer cust = new Customer();
        cust.SetPropertiesOnCreate(txtAddress.Text,
                                    txtFirstNames.Text,
```
3. Run the BankingApp application and the enter data for a new customer. Click the Add button to add the customer and then click the Refresh button to display the new customer.

Using Notifications

The JoobContext class enables you to register for notifications; that is, subscribe to events. The RegisterClassNotificationHandler method, which registers for notifications for a specific event that happens to any instance of the specified class, has the following parameters.

- Class (when the event happens to an instance of the class, a notification is sent)
- Event type (represented by an integer)
- Event handler method (called when the event occurs)

There is also an UnregisterClassNotificationHandler method.

One use of notifications is to automatically refresh the information displayed in an application when the underlying information changes. The instructions in this section are intended to make the Refresh button redundant.

1. In the MainWindow.xaml.cs code file, add a private refresh method with the same code as the btnRefresh_Click method

```csharp
private void refresh()
{
    // Code...
}
```
2. In the form constructor, register to be notified when Customer objects are created. The customerCreatedNotificationHandler method, which you will code shortly, is the event handler for the notification.

```csharp
public Mainwindow()
{
    InitializeComponent();
    context = new JoobContext();
    bank = context.FirstInstance<Bank>();
    context.RegisterClassNotificationHandler(typeof(Customer),
                                            NotificationEventConstants.SystemCreate,
                                            customerCreatedNoteHandler);
}
```

3. Add a customerCreatedNoteHandler notification event handler method.

```csharp
private void customerCreatedNoteHandler(object sender, NotificationEventArgs e)
{
    MessageBox.Show("Customer added");
    // cannot run refresh() yet because not on GUI thread
}
```

4. Run the BankingApp application form and enter data for a new customer. Click the Add button to add the customer. A message box is displayed.

Notifications are delivered on a separate thread from the GUI thread on which the application runs. The notifications thread can display a message box, as you have seen, but cannot see the list box or other controls on the form. Consequently the refresh method cannot be executed directly from this thread.

**Invoking on the GUI Thread**

As explained in the previous section, the notification is received by a background thread and not by the GUI thread on which the application is running. Although the refresh method cannot be run directly it can be invoked using a delegate.

1. In the MainWindow.xaml.cs code file, define a delegate type for refreshing the display that takes no parameters called RefreshDelegate and declare a member of this type.

```csharp
public partial class MainWindow: Window
{
    private JoobContext context;
    private Bank bank;
    ```
delegate void RefreshDelegate();
RefreshDelegate refreshDelegate;

2. In the form constructor, point the refreshDelegate member to the refresh method.

    public MainWindow()
    {
        InitializeComponent();
        context = new JoobContext();
        bank = context.FirstInstance<Bank>();
        context.RegisterClassNotificationHandler(typeof(Customer), NotificationEventConstants.SystemCreate, customerCreatedNoteHandler);

        refreshDelegate = new RefreshDelegate(refresh);
    }

3. In the customerCreatedNoteHandler notification event handler method, use the Invoke method to marshal the refresh method to the GUI thread.

    private void customerCreatedNoteHandler(object sender, NotificationEventArgs e)
    {
        MessageBox.Show("Customer added");
        Dispatcher.Invoke(refreshDelegate);
    }

4. Run the BankingApp application and then enter data for a new customer. Click the Add button to add the customer. After the message box is closed, the list of customers is refreshed automatically.
Chapter 4  Erewhon .NET Example

This chapter covers the following topics.

- Overview
- Example .NET Files
- Running the WpfErewhonApp Application
  - Notifications
  - Multiprocessing
- Building Your Own Application

Overview

This chapter describes the JADE .NET class exposure example for the JADE Erewhon demonstration system, which is an Internet-enabled online purchasing and tendering application. You can download a zip file containing all of the example systems from the JADE Web site using the hyperlink https://www.jadeworld.com/pdf/white-papers/examples/71/JADEExamples.exe.

The Erewhon .NET example consists of an exposure of classes from the Erewhon system that is used by a WPF application to access the JADE database. The JADE .NET class library functions can be executed in the WPF application to execute a number of actions.

- Display a list of Agent objects
- Create, update, and delete a Client object
- Register and unregister for notifications on system events
- Register and unregister for notifications on user events
- Lock and unlock a Client object
- Arm exception handlers and handle an exception
- Run LINQ queries
- Use multithreading

The code in the WPF application is for demonstration purposes only and is not intended for production systems.

Example .NET Files

The file ErewhonDotNetExample.zip file contains the following directories.

- ErewhonExposure
- WpfErewhonApp

The ErewhonExposure directory contains the files created by running the Exposure wizard from the JADE development environment. This directory was specified as the output directory of the wizard. If you use the wizard to expose all classes in the ErewhonInvestmentModelSchema schema, you would get a matching set of files.
The WpfErewhonApp directory contains the files and directories for a WPF solution built in Visual Studio. The example application code has been added to this solution.

Running the WpfErewhonApp Application

When you run the WpfErewhonApp application, the following form is displayed.

You must first sign on by selecting Single User or Multi User, depending on how the database is opened, and then clicking the Sign on button. A message is displayed in the logging window.
The **SelectAction** combo box displays a list of functions that you can run.

After selecting an action, click the **Run** button. The status and any output generated by that action is recorded in the logging window.

**Notifications**

To demonstrate user notifications, a number of actions must be run in the correct order.

1. Sign on to the **WpfErewhonApp** application.
2. Run the **BeginUserNotification** action to register for user notifications.
3. Run the `CauseUserEvent` action. A message is displayed in the logging window, indicating a user event has been received.

![Logging Window](image1)

4. Run the `EndUserNotification` action to stop receiving user notifications.

5. Sign off from the `WpfErewhonApp` application.

Examine the application code for comments that provide additional explanation.

**Multiprocessing**

Each time you run the `ListAgentsSlowly` action, it is run on a new thread. If you click the Run button repeatedly, multiple threads are started, each executing the `ListAgentsSlowly` method.

![Logging Window](image2)

Running the `ListAgentsSlowly` action repeatedly can result in `Busy` messages being displayed in the logging window.
Building Your Own Application

The following instructions outline how you can build your own WPF application to connect to the JADE database.

1. Create a new WPF project.
2. Build the project and solution.
3. Add the existing project created by the Exposure wizard, ErewhonExposure, to this solution.
4. In the WPF project you created in the first step, add references to:
   - JadeSoftware.Jade.DotNetInterop.dll
   - JadeSoftware.Joob.dll
   - JadeSoftware.Joob.Common.dll
   - ErewhonExposure.dll (the exposure project added to the solution)
5. Ensure that the target platform is set to x64 (64-bit) on the Build tab of the Properties sheet for your WPF application.
Chapter 5  Using the JADE .NET Framework

This chapter covers the following topics.

- Overview
- Exposing JADE Classes
- JADE .NET Framework
- JADE .NET API Documentation
- .NET and JADE
- How a .NET Application Connects to JADE

Overview

The JADE .NET framework enables .NET developers to access classes and their associated properties and methods in the JADE database.

This is achieved by generating a set of classes in .NET that act as proxies for the actual JADE classes. Accessing the proxy classes is similar to the use of the actual classes in JADE.

The .NET library containing the classes is built by exposing the classes (and their methods and properties) of interest in JADE. The wizard used to expose JADE features generates C# class files that you can then build into a re-usable .NET class library.

Exposing JADE Classes

You can use .NET to write the application-related components of your system and access JADE database-related components. The approach consists of the following steps.

1. Use JADE to define the classes for your .NET application.
2. Define a .NET exposure and generate C# source files as the starting point for building the application. For details, see "Using the C# Exposure Wizard", in Chapter 18 of the JADE Development Environment User's Guide.
   
   The C# class definitions contain the properties and methods defined in the exposure that are required to access them in the JADE database.
3. Use the generated C# Visual Studio project file (or create your own) to build a Dynamic Link Library (assembly) that contains the proxy classes.
4. Add a reference to the assembly, generated in the previous step of this instruction, to your own project.
5. Add instructions to your .NET code relating to JADE connection, JADE class access, and transaction control.
6. Build and run your .NET project.
Chapter 5  Using the JADE .NET Framework

JADE .NET Framework

To use the JADE .NET API, you must have the tools to build .NET projects; for example, Microsoft Visual Studio 2010 or later. (Microsoft Visual Studio 2013 is recommended.) The JADE .NET API is implemented in a number of assemblies that provide a set of .NET classes. The following diagram shows the communication and interoperability role played by JadeSoftware.Jade.DotNetInterop.dll and other assemblies in the framework.

JADE .NET API Documentation

The JadeDotNetAPI.chm file, which is located in the installed JADE documentation directory (for example, C:\Jade\documentation), contains documentation of the .NET classes and other components that comprise the JADE .NET API.

.NET and JADE

The JADE object model includes a class hierarchy that is similar to that of .NET. This common object-oriented approach means there is a natural fit between JADE and .NET, enabling .NET objects to be modeled from the JADE database.

How a .NET Application Connects to JADE

A .NET runtime application connects to a JADE system as a standard JADE client using the JadeSoftware.Jade.DotNetInterop.dll library file on Windows. For more details about the code that causes the sign on to occur, see "Connecting to JADE", in Chapter 7.

The JadeSoftware.Jade.DotNetInterop.dll file is one of the files supplied from JADE as part of a standard JADE client installation, and is typically located in the bin directory; for example, C:\Jade\bin.
Chapter 6 .NET Exposure

This chapter covers the following topics.

- Overview
- .NET Exposures
  - Application Configuration File
- Exposed JADE Classes
- Exposed JADE Properties
- Exposed JADE Methods
  - JADE Method Parameter Usage
- Exposed JADE Class Constants
- Collections

Overview

JADE classes, properties, methods, and class constants are exposed using the .NET Exposure Wizard in the JADE development environment. For details, see Chapter 17 of the JADE Development Environment User’s Guide.

The exposure generates C# class files that correspond to the exposed JADE classes. These exposed classes are then built into a .NET class library. You can then use this class library in .NET applications to access, create, and update JADE objects in the JADE database.

The generated class library and your application can use the JADE .NET application programming interface (API) contained in the JadeSoftware.Jade.DotNetInterop.dll file. This API uses the JADE .NET API to access the JADE database.

Any .NET application or library using the JADE .NET API must include references to the following DLLs that are found in your JADE binary directory (that is, bin).

- JadeSoftware.Joob.dll
- JadeSoftware.Joob.Common.dll
- JadeSoftware.Jade.DotNetInterop.dll

.NET Exposures

The Exposures command from the Browse menu in the JADE development environment enables you to define a .NET exposure. For details about using the .NET Exposure wizard, see "Using the .NET Exposure Wizard", in Chapter 17 of the JADE Development Environment User’s Guide.

A .NET exposure definition is a collection of JADE classes, methods, and properties that are generated to create a .NET class library for an existing JADE schema.
When a JADE .NET exposure is generated, the following files are created.

<table>
<thead>
<tr>
<th>File</th>
<th>Contains ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure-name.csproj</td>
<td>A simple C# project file that includes all class files and creates a C# library with the namespace Exposure-name.</td>
</tr>
<tr>
<td>Exposure-name.config</td>
<td>An example application configuration file that can be used without modification for a test application or to provide code fragments for production configuration files.</td>
</tr>
<tr>
<td>Class-name.cs</td>
<td>For each exposed class, a C# class file is created containing the class definition in the namespace Exposure-name.</td>
</tr>
</tbody>
</table>

You can open the Exposure-name.csproj C# project file using the professional or express editions of Microsoft Visual Studio 2013 and create the library file Exposure-name.dll, which defines the namespace Exposure-name containing the exposed classes. You can then include this DLL as a reference in a .NET application project, to enable access to the JADE classes.

**Application Configuration File**

The following is an example of a generated configuration file.

```xml
<?xml version="1.0" encoding="utf-8" ?>
<configuration>
  <configSections>
    <section name="joob"
  </configSections>

  <connectionStrings>
    <add name="myDefault" providerName="JadeSoftware.Joob.JadeConnection"
         connectionString="DataSource=C:/Jade7009/system/;ConfigFile=C:/Jade7009/system/jade.ini;SingleUser=False;Schema=BankingViewSchema;Application=DotNetConnection;IntegratedSecurity=true"></add>
  </connectionStrings>

  <joob defaultConnection="myDefault">
    <installation directory="C:\Jade7009\bin" />
  </joob>

  <startup>
    <supportedRuntime version="v4.0" sku=".NETFramework,Version=v4.0"/>
  </startup>
</configuration>
```

Within the `<configSections>` element there is a `<joob>` section, which defines the JADE configuration and is required if you intend using JADE configuration parameters. Within the `<joob>` section are a number of options that enable you to customize your application.
In the `<connectionStrings>` section, specify the JADE database to which the connection is to be established. The `<add>` sub-element has a `connectionStrings` attribute, which contains a series of comma-separated values that define connection attributes for the JADE database.

- **DataSource.** The location of the folder containing the database control file (._control.dat).
- **ConfigFile.** The full path name of the JADE initialization file.
- **SingleUser.** True or False, depending on the mode in which the database has been opened. The default value is `False`.
- **Schema.** A user schema in the database.
- **Application.** An application defined in the database. The default value is `RootSchemaApp`.
- **IntegratedSecurity.** True or False, depending on whether the connection uses the current Windows identity established on the operating system thread to log on to JADE.

    The default value is `True`. If you specify `False`, you must add `UserName=` and `Password=` values.

Specifying an application causes the JADE `initialize` or `finalize` methods defined on that application to be invoked. (The default application, `RootSchemaApp`, does not have `initialize` or `finalize` methods defined.)

Specifying an application causes the JADE `initialize` and `finalize` methods defined on that application to be invoked. (The default application, `RootSchemaApp`, does not have `initialize` or `finalize` methods defined.)

### Connection String Extensions

You can specify the intended target database in connection strings in one of two ways.

- The existing action; that is, the database control file path and the `ServerNodeSpecifications` parameter value in the [JadeClient] or [ConnectionParams] section of the JADE initialization file.

- Specifying the server URI, which has the following general format.

```
scheme://host-name:port-number or base-name/environment-UUID/
[server-UUID][?parameters]
```

The `scheme` value specifies the transport type, which can be one of the following values:

- Tcplp
- Tcplpv4
- Tcplpv6
- HPSM
- JadeLocal

The `host-name:port-number or base-name` value specifies the target address of the server.

The `environment-UUID` value specifies the database, which is expected to be at the target address. This is optionally followed by the database server identity UUID.

The optional `parameters` values enable you to specify the local address or port for TCP/IP transports.

**Tip**  Connection establishment is fastest when your `connectionString` uses a server URI with both the environment and server UUIDs specified.
The following are examples of **connectionString DataSource** values using:

- **TCP/IP version 4 implicitly**
  
  
  "DataSource=TcpIp://localhost:6005/48cf13df-bf6d-df11-87e2-2e5925024153;..."

- **TCP/IP version 4, explicitly declaring an explicit local address**
  
  "DataSource=TcpIpv4://host.company.com:6005/48cf13df-bf6d-df11-87e2-2e5925024153?localHostname=aHostName;"

- **TCP/IP version 6, declaring an explicit local port**
  
  "DataSource=TcpIpv6://[fe81::6fe:7fff:fe97:bd20]:6005/48cf13df-bf6d-df11-87e2-2e5925024153?localPort=54321;..."

- **HPSM, declaring both environment and server UUIDs**
  
  "DataSource=HPSM://localhost:SRCJoob-HPSM/48cf13df-bf6d-df11-87e2-2e5925024153/48cf13df-bf6d-df11-87e2-2e5925024153;..."

### Exposed JADE Classes

Each exposed JADE class is:

- Generated as a single **Class-name.cs** C# class file
- Generated in the namespace **Exposure-name**
- Inherits from **JoobObject** as the base class
- Contains a constructor to create an object as a transient or persistent JADE object
- Contains exposed properties, methods, and constants

If the exposed JADE class is a subclass of another exposed JADE class, the class hierarchy is retained in the C# definition; for example, if **SubClass1** is a subclass of **Class1** in the JADE definition, the C# class **SubClass1** is derived from **Class1**.

The following example shows an exposed JADE class.

```csharp
public partial class TenderSale: Sale
{
    private static TenderSaleMetadata _metaModel;
    partial void _initialize();
    static TenderSale()
    {
        _metaModel = MetadataCache<TenderSaleMetadata>.GetData(null);
    }
```
The generated classes are decorated with a number of attributes, which are used by the JADE engine to ensure correct and consistent access to the class in the JADE database. For each exposed class, an additional class is generated, which is used internally to ensure consistency between the JADE database definition and the C# definition. The name of this class is formed by appending Metadata to the name of the exposed class. For example, if the TenderSale class is exposed, the class is named TenderSaleMetadata.

The generated classes are decorated with a number of attributes, which are used by the JADE engine to ensure correct and consistent access to the class in the JADE database. For each exposed class, an additional class is generated, which is used internally to ensure consistency between the JADE database definition and the C# definition. The name of this class is formed by appending Metadata to the name of the exposed class. For example, if the TenderSale class is exposed, the class is named TenderSaleMetadata.

**Exposed JADE Properties**

Each exposed JADE property is defined in the C# class in the Jade Properties region. Each property has an accessor and mutator (that is, a get method and a set method).

The data type of the property is based on the JADE type. The conversions for JADE primitive types are listed in the following table.

<table>
<thead>
<tr>
<th>JADE Type</th>
<th>.NET Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binary</td>
<td>Byte[]</td>
</tr>
<tr>
<td>Boolean</td>
<td>Boolean</td>
</tr>
<tr>
<td>Byte</td>
<td>Byte</td>
</tr>
<tr>
<td>Character</td>
<td>Char</td>
</tr>
<tr>
<td>Date</td>
<td>DateTime</td>
</tr>
<tr>
<td>Decimal</td>
<td>Decimal</td>
</tr>
<tr>
<td>Integer</td>
<td>Int32</td>
</tr>
</tbody>
</table>
### JADE Type | .NET Type
--- | ---
Integer64 | Int64
JadeBytes | <not supported>
MemoryAddress | Point (defined in `JadeSoftware.Jade.DotNetInterop`)
Point | Double
String | String
StringUtf8 | String
Time | TimeSpan
TimeStamp | DateTime
TimeStampInterval | TimeSpan
TimeStampOffset | DateTimeOffset

The generated code varies depending on the JADE property type. The following example shows an exposed JADE property.

```csharp
[JadeSoftware.Joob.Client.JoobPropertyAttribute("myTender", typeof(Tender),
   DatabaseTypeName="Tender")]
[System.Runtime.Serialization.DataMemberAttribute()]
public Tender MyTender
{
    get
    {
        return this.GetPropertyReference<Tender>(_metaModel.myTender);
    }
    set
    {
        this.SetPropertyReference(_metaModel.myTender, value, false);
    }
}
```

### Exposed JADE Methods

Each exposed JADE method is defined in the C# class in the **Jade Methods** region.

The data type of the return value and parameters is based on the JADE type. The conversions for JADE primitive types are the same as those for properties. For details, see "Exposed JADE Properties", in the previous section.

### JADE Method Parameter Usage

In the signature of a JADE method, the type of each parameter must be declared along with the **Usage** value, which can be **Usage.Constant**, **Usage.Input**, **Usage.IO** (combination of input and output), or **Usage.Output**.

If you do not specify a usage, a default of **Usage.Constant** is assumed.
The parameter usages are as follows.

- For **Usage.Constant** and **Usage.Input** parameters, the parameter value specified in the method call is passed to the corresponding parameter in the called method.

  **Note** You cannot assign to a **Usage.Constant** or **Usage.Input** parameter.

- For **Usage.Output** parameters, the value is passed in the reverse direction, from the parameter of the called method back to the corresponding parameter of the caller. This copying back of the parameter value occurs when the called method returns.

- For **Usage.IO** parameters, the parameter value is passed in both directions, as follows.
  - From the caller to the called method when the method begins
  - From the called method back to the caller when it returns

The following is an example of an exposed JADE method.

```csharp
public Int32 AddIntegers(Int32 i1, Int32 i2)
{
    using (JadeParam retnParam = new JadeParamInteger(Usage.Output),
          jadeParam1 = new JadeParamInteger(i1),
          jadeParam2 = new JadeParamInteger(i2))
    {
        this.SendMessage(_metaModel.addIntegers,
                          retnParam,
                          jadeParam1,
                          jadeParam2);
        return (retnParam as JadeParamInteger).Value;
    }
}
```

### Exposed JADE Class Constants

Each exposed JADE class constant is defined in the C# class in the **Jade Constants** region.

The data type of the constant is based on the JADE type. The conversions for JADE primitive types are the same as those for properties. For details, see "Exposed JADE Properties", earlier in this chapter.

### Collections

Collection classes are derived from a subclass of various classes in the **JadeSoftware.Joob** namespace listed in the following table, to inherit the required behavior.

<table>
<thead>
<tr>
<th>Collection</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>JadeSoftware.Joob.ObjectArray</td>
<td>Array of JADE objects</td>
</tr>
<tr>
<td>JadeSoftware.Joob.ObjectSet</td>
<td>Set of JADE objects</td>
</tr>
<tr>
<td>JadeSoftware.Joob.MemberKeyDictionary</td>
<td>Dictionary of JADE objects with one or more keys that are in the member class</td>
</tr>
<tr>
<td>JadeSoftware.Joob.ExtKeyDictionary</td>
<td>Dictionary of JADE objects with one or more keys that are externally supplied</td>
</tr>
</tbody>
</table>
The following example shows an exposed JADE Collection class called AgentDictByName that contains JADE objects of type Agent.

```csharp
public partial class AgentDictByName:
    MemberKeyDictionary<AgentDictByNameKey, Agent>
{
    private static AgentDictByNameMetadata _metaModel;
    partial void Initialize();
    static AgentDictByName()
    {
        _metaModel = MetadataCache<AgentDictByNameMetadata>.GetData(null);
    }
    private AgentDictByName():
        this(JadeSoftware.Joob.ClassPersistence.Transient)
    {
    }
    public AgentDictByName(JadeSoftware.Joob.ClassPersistence lifetime):
        base(lifetime, typeof(AgentDictByName), _metaModel.metaClass)
    {
        this.Initialize();
    }
    protected AgentDictByName(JadeSoftware.Joob.ClassPersistence lifetime,
        System.Type type, JadeSoftware.Joob.ClassMetadata metaClass):
        base(lifetime, type, metaClass)
    {
        this.Initialize();
    }
    public virtual Agent this[String name, DateTime dob]
    {
        get
        {
            AgentDictByNameKey key = new AgentDictByNameKey(name, dob);
            return base[key];
        }
        set
        {
            AgentDictByNameKey key = new AgentDictByNameKey(name, dob);
            base[key] = value;
        }
    }
    public virtual bool TryGetValue(String name, DateTime dob,
        out Agent value)
    {
        AgentDictByNameKey key = new AgentDictByNameKey(name, dob);
        return base.TryGetValue(key, out value);
    }
    public virtual bool TryGetValue(String name, DateTime dob,
        JadeSoftware.Joob.SearchStrategy strategy, out Agent value)
    {
        AgentDictByNameKey key = new AgentDictByNameKey(name, dob);
        return base.TryGetValue(key, strategy, out value);
    }
    public virtual IJoobDictionaryEnumerable<AgentDictByNameKey, Agent>
        StartingAtKey(String name, DateTime dob)
    {
    }
```
AgentDictByNameKey key = new AgentDictByNameKey(name, dob);
return base.StartingAtKey(key);
}
public virtual IJoobDictionaryEnumerable<AgentDictByNameKey, Agent> StartingAtKey(String name, DateTime dob, JadeSoftware.Joob.SearchStrategy strategy)
{
AgentDictByNameKey key = new AgentDictByNameKey(name, dob);
return base.StartingAtKey(key, strategy);
}
public virtual void Remove(String name, DateTime dob)
{
AgentDictByNameKey key = new AgentDictByNameKey(name, dob);
base.Remove(key);
}
public virtual void Remove(String name, DateTime dob, Agent member)
{
AgentDictByNameKey key = new AgentDictByNameKey(name, dob);
base.Remove(key, member);
}
public virtual bool ContainsKey(String name, DateTime dob)
{
AgentDictByNameKey key = new AgentDictByNameKey(name, dob);
return base.ContainsKey(key);
}
}

In the following example, root contains a reference AllAgents of type AgentDictByName.

dotnet
{
foreach (Agent agent in root.AllAgents)
{
    agent.DoSomething();
}
}

When indexing a JADE array in .NET, the .NET convention of zero-based arrays is used; that is, the element at position zero (0) is the first element in the array. In the following example, a C# class called SomeClass has an IntegerArray property called MyIntegerArray.

SomeClass obj = joobContext.FirstInstance<SomeClass>();
Int32 i = obj.MyIntegerArray[0];  // returns first element of array
Int32 j = obj.MyIntegerArray.At(0);  // also returns first element of array

In the following example, root contains a reference AllAgents of type AgentDictByName.

dotnet
{
foreach (Agent agent in root.AllAgents)
{
    agent.DoSomething();
}
}

When indexing a JADE array in .NET, the .NET convention of zero-based arrays is used; that is, the element at position zero (0) is the first element in the array. In the following example, a C# class called SomeClass has an IntegerArray property called MyIntegerArray.

SomeClass obj = joobContext.FirstInstance<SomeClass>();
Int32 i = obj.MyIntegerArray[0];  // returns first element of array
Int32 j = obj.MyIntegerArray.At(0);  // also returns first element of array
Chapter 7  Developing Applications in .NET to Use JADE Classes

This chapter covers the following topics.

- Overview
- Using JADE Classes in .NET
  - JADE .NET Assembly Public Keys
  - Connecting to JADE
  - Pool of Available Processes
  - Accessing Database Instances
  - Accessing JADE System Objects
  - Creating Objects
  - Deleting Objects
  - Locking
  - Notifications
  - Exceptions
  - Transactions
- Multiple Database Access for .NET
  - Using Multiple Database Access

Overview

This chapter documents classes in the JADE .NET API that you can use to build .NET applications that work with the JADE classes in an exposure DLL. For more details, see the JADE .NET API documentation (that is, the JadeDotNetAPI.chm file in the installed JADE documentation directory; for example, C:\Jade\documentation).

Using JADE Classes in .NET

The JoobContext and JoobConnection classes in the JadeSoftware.Joob library provide the link between a .NET application and a JADE system.

Any .NET assembly using the JADE .NET API must include references to the following DLLs that are found in the JADE binary (bin) directory.

- JadeSoftware.Jade.DotNetInterop.dll
- JadeSoftware.Joob.dll
- JadeSoftware.Joob.Common.dll

In addition, a reference to the exposure DLL created using the .NET Exposure wizard in the JADE development environment is required. For details about the exposure DLL, see "NET Exposure", in Chapter 6.
To simplify access to these classes in a C# project, add the following `using` directives.

```csharp
using JadeSoftware.Jade.DotNetInterop;
using JadeSoftware.Joob.Client;
using JadeSoftware.Joob;
using <namespace-for-exposed-classes>;
```

### JADE .NET Assembly Public Keys

JADE .NET assemblies are signed. Each release uses the same public key token for its assemblies, but they have different versions, as shown in the following table.

<table>
<thead>
<tr>
<th>Build/Configuration</th>
<th>PublicKeyToken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release_Ansi</td>
<td>x64</td>
</tr>
<tr>
<td>Release_Unicode</td>
<td>x64</td>
</tr>
</tbody>
</table>

An example of the `app.config` file is as follows.

```xml
<configSections>
  <section name="joob"
    type="JadeSoftware.Joob.Configuration.JoobConfigurationSection,
    JadeSoftware.Joob, Version=7.0.9.0, Culture=neutral,
    PublicKeyToken=4ffc2b9eb5630e47">
  </section>
</configSections>
```

An application run with this example `app.config` file requires `JadeSoftware.Joob.dll` with an assembly version of 7.0.9.0 and signed with the `Release_Ansi|x64` key.

Hot fix versions of `JadeSoftware.Joob.dll` (and so on) are released with the same assembly version as the initial consolidated release (for example, 7.0.9.0) but the file version indicates the hot fix number. Your assemblies, therefore, do not need to be rebuilt when a hot fix is installed but they must be rebuilt when a subsequent consolidated release is installed.

### Connecting to JADE

A `JoobContext` object is used to connect to the database. The default no-parameters constructor uses the `defaultConnection` information specified in the application configuration file. For details, see "Application Configuration File", in Chapter 6.

The following syntax creates a context object using the no-parameters constructor and establishes a connection to the JADE database.

```csharp
JoobContext context = new JoobContext();
```

The following syntax establishes a connection using an alternative connection string defined in the application configuration file.

```csharp
JoobContext context =
    new JoobContext(JoobConnectionStringBuilder.CreateFromConfig("other"));
```

When a connection is no longer required, the `JoobContext` object should be disposed of to release the connection back to the pool.

```
context.Dispose();
```
If a connection is required only at certain times in the life of the application, you can create a temporary connection with a `using` statement. The `JoobContext` object is implicitly disposed of at the end of the `using` block.

```csharp
using (JoobContext context = new JoobContext())
{
    // access the database
}
```

For details about using non-default connections and specifying connection parameters from your logic, see the JADE .NET API documentation (that is, the JadeDotNetAPI.chm file in the installed JADE documentation directory; for example, C:\Jade\documentation).

**Pool of Available Processes**

When a connection is first established from a .NET application to JADE, a node is created with a pool of available processes. The connection uses one of the processes and releases it back to the pool when the connection is closed, which happens when the associated `JoobContext` object is disposed of.

If the default connection is used, the number of processes in the pool can be specified in the `defaultPoolSize` attribute of the `<jade>` element of the application configuration file, as shown in the following example.

```xml
<jade defaultConnection="myDefault" defaultPoolSize="15"/>
```

If the `defaultPoolSize` attribute is omitted, the default value of 10 is used.

**Note** If you use the free JADE developer licence, which allows five processes only, reduce the pool size as follows.

```xml
<jade defaultConnection="myDefault" defaultPoolSize="2"/>
```

If you do not change the default value, you will encounter exception 5504 (*You have exceeded the number of Process Licenses*) when creating a `JoobContext` object.

For an alternative connection string defined in the application configuration, you can override the `defaultPoolSize` value with the `poolSize` attribute within the `<tuning>` element, as shown in the following example.

```xml
<tuning>
    <add connection="other" poolSize="20"/>
</tuning>
```

**Accessing Database Instances**

The `JoobContext` class provides methods to access database objects from a specified class.

<table>
<thead>
<tr>
<th>Method</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>FirstInstance&lt;T&gt;</td>
<td>The first instance of a class</td>
</tr>
<tr>
<td>FindInstance&lt;T&gt;</td>
<td>An object with the specified OID</td>
</tr>
<tr>
<td>LastInstance&lt;T&gt;</td>
<td>The last instance of a class</td>
</tr>
<tr>
<td>AllInstances&lt;T&gt;</td>
<td>All instances of a class</td>
</tr>
</tbody>
</table>
The following typical sequence of C# calls returns the first instance of the `Company` class, iterates through a collection on the class, and uses references and methods of the objects in the collection.

```csharp
JoobContext context = new JoobContext();
Company company = context.FirstInstance<Company>();
```

If you know the object identifier (OID) of a JADE database object, you can obtain a reference to that object in your C# code, as shown in the following example.

```csharp
JoobContext context = new JoobContext();
ObjectId oid = new ObjectId(3272, 1);
Agent comp = context.FindInstance<Agent>(oid);
```

In the following example, a virtual collection of instances of the `Stock` class is iterated.

```csharp
JoobContext context = new JoobContext();
foreach (Agent agent in context.AllInstances<Agent>())
{
    // process agent
}
```

### Accessing JADE System Objects

You can obtain the OIDs of the JADE system objects by using the `GetSystemVariables` method of the `JoobContext` instance, which returns an instance of the `SystemVariables` class. The properties of a `SystemVariables` object are the OIDs of the JADE system objects. They are listed in the following table.

<table>
<thead>
<tr>
<th>JADE System Object</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>App</td>
<td>Application subclass (which must be exposed)</td>
<td>The current transient application instance. This is often used to store application-specific data.</td>
</tr>
<tr>
<td>Global</td>
<td>Global subclass (which must be exposed)</td>
<td>The persistent object for a schema, which is shared by all applications running from that schema. This is often used to exchange information between applications or to retain information when an application closes.</td>
</tr>
<tr>
<td>Node</td>
<td>JadeSoftware.Joob.Management.JoobNode</td>
<td>The workstation that hosts the execution of the current process. One node object exists for each <code>logical</code> workstation connected to the server node workstation. There is one fixed server node and none or many client nodes. A node represents a workstation that runs a number of processes.</td>
</tr>
</tbody>
</table>
The following code would obtain a reference to the **Node** object.

```
JoobContext context = JoobContext.CurrentContext;
SystemVariables sv = context.GetSystemVariables();
ObjectId nodeOid = sv.Node;
    node = context.FindInstance<JadeSoftware.Joob.Management.JoobNode>(nodeOid);
```

A typical use of the **App** object is to store a reference to a **root** object, which is a singleton persistent object that contains collections of all objects in a class. For example, in a banking application, the root object would represent the bank itself and would have a collection of all of the customers of the bank. The following code would obtain a reference to the **App** object.

```
JoobContext context = JoobContext.CurrentContext;
SystemVariables sv = context.GetSystemVariables();
ObjectId appOid = sv.App;
ErewhonInvestmentsModelApp
    app = context.FindInstance<ErewhonInvestmentsModelApp>(appOid);
```

**Note** You must expose the classes of the **App** and **Global** system objects for the types to be available to your C# code.

Transient **App** objects are created when a connection to JADE is first established and the pool of processes is created (typically when an application first creates a **JoobContext** instance). An **App** object is associated with each process in the pool. Each **App** object exists for the lifetime of the process and is retained even when a process is released back to the pool (which happens when the associated **JoobContext** object is disposed of).

Because the **App** object for each process is retained, it is available when a **JoobContext** instance is next created and associated with that process. However, the associated process may be any of the processes in the pool.

If an **initialize** method is defined for the database application specified in the connection string, it is invoked when each **App** object is created (typically when the first connection to JADE is established). Similarly, if a **finalize** method is defined, it is invoked when each **App** object is deleted (typically when the .NET application terminates).

A typical use of the **App** object is to store a reference to a **root** object, which is a singleton persistent object that contains collections of all the objects in a class. For example, in a banking application the root object would represent the bank itself and would have a collection of all the customers of the bank. The following code would obtain a reference to the **App** object.

```
JoobContext context = JoobContext.CurrentContext;
SystemVariables sv = context.GetSystemVariables();
ObjectId appOid = sv.App;
ErewhonInvestmentsModelApp
    app = context.FindInstance<ErewhonInvestmentsModelApp>(appOid);
```

Transient **App** objects are created when a connection to JADE is first established and the pool of processes is created (typically when an application first creates a **JoobContext** instance). An **App** object is associated with each process in the pool. Each **App** object exists for the lifetime of the process and is retained even when a process is released back to the pool (which happens when the associated **JoobContext** object is disposed of).
Because the App object for each process is retained, it is available when a JoobContext instance is next created and associated with that process. However, the associated process may be any of the processes in the pool.

If an initialize method is defined for the database application specified in the connection string, it is invoked when each App object is created (typically when the first connection to JADE is established). Similarly, if a finalize method is defined, it is invoked when each App object is deleted (typically when the .NET application terminates).

If an initialize method is defined for the database application specified in the connection string, it is invoked when each App object is created (typically when the first connection to JADE is established). Similarly, if a finalize method is defined, it is invoked when each App object is deleted (typically when the .NET application terminates).

Creating Objects

You can use the new operator to create a persistent or transient instance of an exposed JADE class, together with the no-parameters constructor for the class or the constructor with a ClassPersistence enumeration value of Persistent or Transient.

The following statements are equivalent.

```csharp
Agent agent = new Agent();
Agent agent = new Agent(ClassPersistence.Persistent);
```

Alternatively, you can use the CreateInstance method of the JoobContext class.

```csharp
JoobContext context = JoobContext.CurrentContext;
Agent agent = context.CreateInstance<Agent>(ClassPersistence.Persistent);
```

Transient objects belong to the process that created them and are not accessible by any other process. The transient objects for a process are retained until explicitly deleted or when the process is disposed of (typically when the .NET application terminates).

Because the transient objects for each process are retained, they are available the next time a JoobContext instance is created and associated with that process. However, the associated process may be any of the processes in the pool.

**Note** To create, modify, or delete a persistent object, you must be in transaction state. For details, see "Transactions", later in this chapter.

Deleting Objects

You can use the Delete method, which is inherited from the JoobObject class, to delete an instance of an exposed JADE class.

```csharp
agent.Delete();
```

Alternatively, you can use the DeleteObject method of the JoobContext class.

```csharp
JoobContext context = JoobContext.CurrentContext;
context.DeleteObject(agent);
```

**Note** To create, modify, or delete a persistent object, you must be in transaction state. For details, see "Transactions", later in this chapter.
Locking

The locking-related methods provided by the `JoobContext` class are shown in the following table.

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lock</td>
<td>Locks a JADE object and throws an exception if the attempt fails</td>
</tr>
<tr>
<td>Unlock</td>
<td>Releases a lock on a JADE object</td>
</tr>
<tr>
<td>TryLock</td>
<td>Locks a JADE object and returns <code>False</code> if the attempt fails</td>
</tr>
<tr>
<td>GetLockStatus</td>
<td>Gets the type and duration of the lock on a JADE object by the current process</td>
</tr>
</tbody>
</table>

In the following example, an attempt is made to lock an `agent` object using the `Lock` method. If the object is already locked with an incompatible lock, a normal lock exception is thrown. The JADE concepts of `passback`, `continue`, `resume`, or `abort` (for the action that is taken after the exception handling code has been executed) are not supported.

```csharp
JoobContext context = JoobContext.CurrentContext;
Agent agent = context.FirstInstance<Agent>();
try {
    context.Lock(agent, // object to be locked
                  LockType.Exclusive, // type of lock
                  LockDuration.Session, // session/transaction duration
                  TimeSpan.FromSeconds(5)); // time before exception thrown)
} catch (JoobObjectLockedException) {
    // lock object handling code
}
```

Notifications

The `JoobContext` class provides the `RegisterNotificationHandler` method to request being notified about events for a specified JADE object and the `RegisterClassNotificationHandler` method to request being notified about events for all objects of a specified class.

The first parameter is the `target` of the notifications. The second parameter is the event type number (you can use the constants in the `NotificationEventConstants` class for system events). The third parameter is the name of the event handler method to be invoked.

The following example shows how you can register for notifications.

```csharp
JoobContext context = JoobContext.CurrentContext;
// Register for any kind of system event on the 'agent' object
// the event handler method is called 'myEventHandler'
context.RegisterNotificationHandler(agent,
                                        NotificationEventConstants.SystemAny,
                                        myEventHandler);

// Register for user event 5000 for all instances of the Agent class
// the event handler method is called 'event5000Handler'
context.RegisterClassNotificationHandler(agent, 5000, event5000Handler);
```

There are `UnregisterNotificationHandler` and `UnregisterClassNotificationHandler` methods to stop the sending of notifications. The methods have the same parameters as the methods that register for notifications.
Chapter 7  Developing Applications in .NET to Use JADE Classes

The **Notify** method, which is inherited from the **JoobObject** class, publishes a user event. The first parameter is the event type number. The second parameter is **True** if the event is raised immediately and **False** if it deferred until the next time a transaction is committed. The method is overloaded so that the third parameter, which is user information about the event, can be of any type.

The following example shows how you can cause a user event.

```c
// 'agent' is an instance of the Agent class
agent.Notify(agent, false, 0);
```

An event handler method has a signature similar to any C# event handler.

```c
void myEventHandler(object sender, NotificationEventArgs e)
{
    JoobContext context = sender as JoobContext;
    int eventNo = e.EventNo;
    ObjectId target = e.Target;
}
```

The first parameter is **JoobContext** object that was used to register for notifications. The second parameter is a **NotificationEventArgs** object, which has the following properties.

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>EventNumber</code></td>
<td>The event number integer that was passed as the middle parameter of the</td>
</tr>
<tr>
<td></td>
<td><code>RegisterClassNotificationHandler</code> or <code>RegisterNotificationHandler</code> method.</td>
</tr>
<tr>
<td><code>Target</code></td>
<td>The <strong>ObjectId</strong> of the object to which the event happened.</td>
</tr>
<tr>
<td><code>UserInfo</code></td>
<td>For user events, it is an object representing the <strong>UserInfo</strong> parameter that</td>
</tr>
<tr>
<td></td>
<td>was passed to the <strong>Notify</strong> method when the user event was published. For</td>
</tr>
<tr>
<td></td>
<td>system events, it is a null object reference.</td>
</tr>
</tbody>
</table>

**Notifications in JADE and .NET**

If a .NET application calls a JADE method that executes the **beginNotification** or **beginClassNotification** method, the notification is delivered to the thread that created the **JoobContext** object.

When the **beginNotification** or **beginClassNotification** is executed in a JADE method, it is regarded as subscribing to a different notification than one done by executing the **RegisterNotificationHandler** or **RegisterClassNotificationHandler** method in .NET, even if all of the parameters are equivalent. However, when an event is explicitly (or implicitly) caused in either language, it is delivered to all subscribers even if the language that caused the notification did not subscribe to the notification.

When a **JoobContext** object is disposed of, all subscriptions are cancelled.

As the JADE code is running within .NET, the JADE process will not have an idle state. Consequently, you must execute the **doWindowEvents** method of the **Application** class to enable the notification response method to run. For details about the cautions regarding the use of this method, see **Volume 1** of the **JADE Encyclopaedia of Classes**.

**Notifications in JADE and .NET**

If a .NET application calls a JADE method that executes the **beginNotification** or **beginClassNotification** method, the notification is delivered to the thread that created the **JoobContext** object.
**Exceptions**

The `JadeSoftware.Joob.Exception` namespace contains exception classes, including JOM exceptions that are implemented as subclasses of `JoobJomException`. These exceptions can be caught in the normal manner, as shown in the following example.

```csharp
void catchAnException()
{
    JoobContext context = JoobContext.CurrentContext;
    Client c = context.FirstInstance<Client>();

    try
    {
        c.Name = c.Name; // generated 'update outside transaction' exception
    }
    catch (JoobUpdateOutsideTransactionException)
    {
        // Expected exception
    }
    catch (JoobJomException jje)
    {
        int jomErrorError = jje.ErrorCode;
        String jomErrorText = jje.ErrorText;
    }
    catch (JoobException e)
    {
        String errorMessage = e.Message;
    }
}
```

**Transactions**

The `JoobContext` class provides the `BeginTransaction` method, which returns a transaction object. All JADE actions required to be in transaction state (that is, create, update, or delete actions) must be within the scope of the transaction object returned by the `BeginTransaction` method. The transaction object provides the methods `Commit` and `Rollback`, to commit or abort the transaction, respectively.

The following example shows a method that uses a transaction to delete a persistent `Agent` object.

```csharp
void DeleteClient(Client client)
{
    JoobContext context = JoobContext.CurrentContext;
    using (System.Data.IDbTransaction tx = context.BeginTransaction())
```
{ 
    client.Delete();
    tx.Commit();
}

If the statement that commits the transaction is omitted, the transaction is rolled back when the transaction object is disposed of, at the end of the using block.

**Multiple Database Access for .NET**

The JADE .NET API enables access to multiple JADE databases; that is, a single .NET application (operating system process) can access a number of JADE databases concurrently.

The restrictions on accessing multiple JADE databases are:

- The JADE databases must be at the same feature level.
- Multiple connections to the same database are not allowed.
- There is a limit of 20 concurrent connections.
- Some JADE initialization file parameters (for example, the LogDirectory parameter in the [JadeLog] section) are read-only when the first database connection is opened, and they remain unchanged for the life of the process.

**Tip** Use a common JADE initialization file for all database connections, to ensure that the same jommsg.log file is used, regardless of the order in which database connections are established.

**Using Multiple Database Access**

To access multiple JADE databases, you must supply connection details via the appropriate JoobContext constructor. This can take the form of an existing JoobConnection object, or it can be via a JoobConnectionStringBuilder object, as shown in the following example.

```csharp
using (JoobContext context = new JoobContext
    (JoobConnectionStringBuilder.CreateFromConfig("LocalJade")))
{
    // Established context to database with schema MultipleDb1 as
    // specified by the "LocalJade" connection string in the app.config
}

using (JoobContext remoteContext = new JoobContext
    (JoobConnectionStringBuilder.CreateFromConfig("RemoteJade")))
{
    // Established context to database with schema MultipleDb2 as
    // specified by "RemoteJade" connection string.
}
```

---

*Tip* Use a common JADE initialization file for all database connections, to ensure that the same jommsg.log file is used, regardless of the order in which database connections are established.
The app.config file reads as follows.

```xml
<connectionStrings>
  <add name="RemoteJade" providerName="JadeSoftware.Joob.JoobConnection"
       connectionString="DataSource=tcpip://remoteHost:6005/7bf0f9cd-680a-e111-9eaf-5ae520524153;ConfigFile=\remoteHost\C:\Jade\system\jade.ini;
Schema=MultipleDb2;IntegratedSecurity=True"></add>
  <add name="LocalJade" providerName="JadeSoftware.Joob.JoobConnection"
       connectionString="DataSource=C:\\Jade\system\;ConfigFile=C:\Jade\system\jade.ini;
Schema=MultipleDb1;IntegratedSecurity=True"></add>
</connectionStrings>
```

The model for multiple database access follows the pattern of requiring a live JoobContext before a JoobObject can interact with its database.

When an appropriate JoobContext has been instantiated for a database, JoobObject instances from that database can be retrieved, created, and de-referenced. Each JoobObject instance knows the database to which it belongs and provided that a JoobContext is alive for its database on the current thread, JoobObject manipulation can occur.

For example, a JoobObject variable of a MultipleDb2 class can be declared in BLOCK 1A or BLOCK 2A. You can set, get, or invoke JADE schema-defined properties and methods only from within BLOCK 3. You can locate instances of classes only from schema MultipleDb2 within BLOCK 3. However, you can manipulate instances of classes from MultipleDb1 within BLOCK 2A, BLOCK 2B, and BLOCK 3.
## Appendix A  Mapping JADE Primitives to CLR Data Types

This appendix describes the mapping of JADE primitive types to Common Language Runtime (CLR) data types.

<table>
<thead>
<tr>
<th>CLR Type</th>
<th>JADE Primitive Type</th>
<th>Conversion Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>Boolean</td>
<td></td>
</tr>
<tr>
<td>Byte</td>
<td>Byte</td>
<td></td>
</tr>
<tr>
<td>Int32</td>
<td>Integer</td>
<td></td>
</tr>
<tr>
<td>Int64</td>
<td>Integer64</td>
<td></td>
</tr>
<tr>
<td>Double</td>
<td>Real</td>
<td></td>
</tr>
<tr>
<td>Decimal</td>
<td>Decimal</td>
<td></td>
</tr>
<tr>
<td>Char</td>
<td>Character</td>
<td></td>
</tr>
<tr>
<td>String</td>
<td>String, StringUtf8</td>
<td></td>
</tr>
<tr>
<td>Char[]</td>
<td>String, StringUtf8</td>
<td></td>
</tr>
<tr>
<td>DateTime</td>
<td>Date, TimeStamp</td>
<td>The time part of a CLR <strong>DateTime</strong> is lost when saving to the database.</td>
</tr>
<tr>
<td>DateTimeOffset</td>
<td>TimeStampOffset</td>
<td></td>
</tr>
<tr>
<td>TimeSpan</td>
<td>Time, TimeStampInterval</td>
<td>The JADE <strong>Time</strong> type supports only CLR <strong>TimeSpan</strong> values in the range 0:00:00 through 23:59:59. (There may be an overflow or data loss saving data to the database.)</td>
</tr>
<tr>
<td>Byte[]</td>
<td>Binary</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B  JADE .NET Spatial Feature

This appendix discusses the spatial feature in JADE .NET, which enables you to develop applications to store, edit, and query spatial information directly through the JADE .NET API.

The first part of this appendix focuses on spatial data, explaining how you can create, edit, and analyze spatial objects in JADE .NET. The second part talks about the spatial index used in JADE .NET, which can be helpful when dealing with a large collection of spatial objects.

Spatial Data

Spatial data, also known as geospatial data or geographic information, is the data that describes the geographic location of features and boundaries on the earth.

The geometry data type uses the two-dimensional Cartesian coordinate system, meaning that spatial data of this type are presented in a uniform two-dimensional plane with units of your choice. When dealing with this type of spatial data, or planar data, we assume that the earth is flat.

In JADE .NET, the following interfaces and classes are introduced to assist in the development of spatial components within applications. However, they are generalized to a level higher, so that they can also be used in non-spatial domains in the future.

IMultiDimensionalObject is an interface representing all objects that have dimensionality – not only spatial geometries, but also other non-spatial dimensional data as well. It exposes two properties (Dimension and Envelope) and some predicate methods such as Contains and Touches for evaluating relationships between two instances of IMultiDimensionalObjects.

IEnvelope is an interface representing the envelope of an IMultiDimensionalObject. IEnvelope implements IMultiDimensionalObject.
**MultiDimensionalObject** is an abstract class directly implementing **IMultiDimensionalObject** and it is the base class for **JoobGeometry**, which is discussed in the following section.

Unlike the interfaces and classes in previous paragraphs, **JoobSpatialException** is specific to the spatial domain and is used for reporting errors that occurred during the creation and manipulation of spatial data.

**Working with Geometry**

As shown in the following diagram, there are a few more classes introduced that enable you to create and manipulate geometries in JADE .NET.

- **JoobGeometry** inherits from **MultiDimensionalObject** and can be used to represent all geometry types that JADE .NET supports; that is, **Point**, **LineString**, **LinearRing**, **Polygon**, **MultiPoint**, **MultiLineString**, **MultiPolygon**, and **GeometryCollection**.

- **JoobGeometry** exposes a large number of properties and methods that are useful for querying geometry information and performing spatial analysis. Their implementations are compatible with the Open Geospatial Consortium's (OGC)'s Simple Features specification version 1.1.0:
  - [OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 2: SQL option](https://www.opengeospatial.org/standards/sf)

- **JoobRegion** is a special subclass of **JoobGeometry**, representing the Minimum Bounding Rectangle (MBR) of a specified **JoobGeometry**.

- **JoobGeometryBuilder**, which is described later in this appendix, is a helper class that enables you to create geometries in a point-by-point fashion.

**Creating a Geometry**

In JADE .NET, there are several ways to create a **JoobGeometry** object, by using the:

- **JoobGeometry** constructor to accept a string encoded in the WKT (Well Known Text) format
- **JoobGeometry** constructor to accept a byte array encoded in the WKB (Well Known Binary) format
- **JoobGeometryBuilder** class

Creating a geometry using WKT or WKB is quite straightforward — all you need to do is to supply a valid WKT string or a WKB byte array to a **JoobGeometry** constructor; for example:

```csharp
public void CreateRing()
{
    var wkt = "LineString (10 20, 30 15, 20 15, 10 10, 10 20)";
    using (var geom = new JoobGeometry(wkt))
```
If an invalid WKT or WKB is provided, a JoobSpatialException is thrown. For details about the WKT and WKB formats, see the OGC specification Simple feature access - Part 1: Common.

Geometry data do not always present themselves in WKT or WKB formats; instead, they may come with a series of coordinates. In this circumstance, you can use JoobGeometryBuilder to create a geometry one point at a time.

The following are two examples of using JoobGeometryBuilder: the first one creates a simple line string starting from the coordinate (10, 40) to the coordinate (30, 50), and the second one creates a polygon with one interior ring.

```csharp
public JoobGeometry CreateLineString()
{
    var builder = new JoobGeometryBuilder();
    builder.BeginGeometry(GeometryType.LineString);
        builder.BeginFigure(10, 40);
        builder.AddLine(30, 50);
        builder.EndFigure();
    builder.EndGeometry();
    return builder.GetConstructedGeometry(ClassPersistence.Persistent);
}

public JoobGeometry CreatePolygonWithOneInteriorRing()
{
    var builder = new JoobGeometryBuilder();
    builder.BeginGeometry(GeometryType.Polygon);
        builder.BeginFigure(1, 2);
        builder.AddLine(3, 4);
        builder.AddLine(4, 1);
        builder.AddLine(1, 2);
        builder.EndFigure();
        builder.BeginFigure(2, 2);
        builder.AddLine(3, 3);
        builder.AddLine(3, 2);
        builder.AddLine(2, 2);
        builder.EndFigure();
    builder.EndGeometry();
    return builder.GetConstructedGeometry(ClassPersistence.Persistent);
}
```

It is important to note that there is a finite-state machine embedded in JoobGeometryBuilder to ensure that a JoobGeometry can be built only if valid call sequences are issued. For example, calling BeginFigure without first calling BeginGeometry or when creating a polygon by calling EndFigure without issuing at least three calls to AddLine violate the state machine and result in an exception.
JoobGeometryBuilder can also be used to create composite geometries such as MultiPoint and MultiLineString, or even nested composite geometries; for example, one GeometryCollection nested inside another GeometryCollection, as shown in the following example.

```csharp
public JoobGeometry CreateNestedGeometryCollection()
{
    var builder = new JoobGeometryBuilder();
    builder.BeginGeometry(GeometryType.GeometryCollection);
    {
        builder.BeginGeometry(GeometryType.Point);
        builder.BeginFigure(1, 2);
        builder.EndFigure();
        builder.EndGeometry();
        builder.BeginGeometry(GeometryType.GeometryCollection);
        {
            builder.BeginGeometry(GeometryType.Polygon);
            builder.BeginFigure(1, 2);
            builder.AddLine(3, 4);
            builder.AddLine(4, 1);
            builder.AddLine(1, 2);
            builder.AddLine(1, 2);
            builder.EndFigure();
            builder.EndGeometry();
            builder.BeginGeometry(GeometryType.LinearRing);
            builder.BeginFigure(2, 8);
            builder.AddLine(4, 2);
            builder.AddLine(4, 7);
            builder.AddLine(2, 8);
            builder.EndFigure();
            builder.EndGeometry();
            builder.BeginGeometry(GeometryType.MultiPolygon);
            {
                builder.BeginGeometry(GeometryType.Polygon);
                builder.BeginFigure(1, 2);
                builder.AddLine(3, 4);
                builder.AddLine(4, 1);
                builder.AddLine(1, 2);
                builder.AddLine(1, 2);
                builder.EndFigure();
                builder.EndGeometry();
                builder.BeginGeometry(GeometryType.Polygon);
                builder.BeginFigure(2, 8);
                builder.AddLine(4, 2);
                builder.AddLine(4, 7);
                builder.AddLine(5, 10);
                builder.AddLine(2, 8);
                builder.EndFigure();
                builder.EndGeometry();
            }
            builder.EndGeometry();
        }
        builder.EndGeometry();
    }
    builder.EndGeometry();
}
```
builder.EndGeometry();

return builder.GetConstructedGeometry(ClassPersistence.Persistent);

### Querying and Analyzing Geometries

As mentioned earlier in this appendix, JoobGeometry provides a number of properties and methods for information inquiry and spatial analysis. Most of these properties and methods are self-explanatory and easy to use.

For more details, see the JADE .NET API documentation (that is, the JadeDotNetAPI.chm file in the installed JADE documentation directory; for example, C:\Jade\documentation).

### Spatial Index

Spatial indexes are used to organize a collection of spatial objects in the ways that spatial queries can be optimized. There are many spatial index methods available; for example, Quadtree, R-tree, X-tree, and kd-tree. In JADE .NET, R-tree is chosen as the spatial index method.

**R-tree** is a tree data structure similar to B-tree, but is used for indexing multi-dimensional information. The R in R-tree stands for rectangle, indicating the shape R-tree uses to split space. For more details about R-tree and how it works, see the following Web sites.

- [R-tree on Wikipedia](#)
- [R-tree Portal](#)

Since R-trees deal only with rectangles and different geometries may have the same bounding rectangle, searching an R-tree cannot always give you an accurate answer. For example, if you are looking for geometries in a R-tree that are intersecting with the search region in the following diagram, you end up with two geometries: both the blue one and the green one.

![Rectangle and actual geometry](image)

To obtain the accurate answer, you then need a second level of filtering concerning only the actual geometries, not their bounding rectangles.
However, this second-level filtering could be a much more computational-intensive process, especially when the actual shape of a geometry is complex. Therefore, use R-tree to narrow down the number of geometries before passing them to the second-level filter.

When you are interacting with JADE .NET’s R-tree APIs, you do not have to worry about this two-level filtering process, as it is automatically handled for you.

JADE .NET provides the following classes that enable you to work with R-trees.
JoobRTree is an abstract class encapsulating the implementation of the R-tree algorithm in JADE .NET. It exposes a series of search methods that enable you to find required IMultiDimensionalObjects. Be aware that R-tree can handle multi-dimensional data that may or may not reside in the spatial domain. JoobRTree, as well as MemberKeyRTree and ExtKeyRTree, are therefore generic types and expect you to specify the type parameters when you create subclasses.

In addition to the normal collection methods such as Add and Remove, JoobRTree contains a list of search methods for searching geometries spatially. Currently, JADE .NET supports eight spatial relationships: contain, within, disjoint, intersect, touch, cross, overlap, and equal.

To perform a spatial search, you can call the corresponding search method such as ContainSearch or IntersectSearch, or you can call the generic Search method with a relationship parameter; for example:

```csharp
var rtree = // new ...
rtree.Add(new SpatialObject { Geometry = new JoobGeometry("...") });
rtree.Add(new SpatialObject { Geometry = new JoobGeometry("...") });
...
var searchRegion = new JoobGeometry("POLYGON ((...))");
var results = rtree.IntersectSearch(searchRegion);
// or
results = rtree.Search(searchRegion, MultiDimensionalObjectRelationship.Intersect);
```

MemberKeyRTree is an abstract subclass of JoobRTree. Similar to a MemberKeyDictionary, objects stored in a MemberKeyRTree are keyed using their own properties. However, there can be a single key only for a MemberKeyRTree, and the key must be of type IMultiDimensionalObject.

ExtKeyRTree is also an abstract subclass of JoobRTree. Each ExtKeyRTree can also have only a single key of type IMultiDimensionalObject.

SpatialRTree is a concrete subclass of ExtKeyRTree, with a key type predefined to JoobGeometry.

When you create a subclass from JoobRTree or one of its subclasses, you automatically benefit from all of the advantages provided by the JADE collection implementation; for example, inverse maintenance and distributed processing.