CSQL Main Memory Database Cache

User Manual

www.csqldb.com

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1. Introduction

The CSQL Main Memory Database Cache is an easily accessible and powerful database that can serve as a source of information for performance related research. This constitutes of two major components

- CSQL Main memory Database
- CSQL Cache

1.1 What is CSQL

CSQL is a compact main memory database SQL engine that supports limited set of features and gives ultra fast response for database queries. Many applications like telecom, process control, airline reservation, stock market etc., require real time access to data.

Main memory databases, which have become more feasible recently with the increasing availability of large amounts of memory at very low costs, can provide better performance and consistent throughput than disk based database systems.

The basic philosophy behind CSQL's design is the fact that accessing data from main memory is an order of magnitude faster than accessing data from disk. And recent technological advancements have only shown that memory speeds and network speeds are advancing in leaps and bounds, whereas disk I/O speeds are not increasing in the same proportions. Hence the major platform dependency in CSQL is not on the disk, but on the memory and going ahead will be the network.

CSQLCache, a client side caching mechanism for any disk-based database (Oracle, Sybase, DB2, MySql, etc.) shall increase the throughput of existing applications by multi-folds without requiring any application changes. It will retrieve the frequently accessed tables from the target database and place it in main memory database (CSQL). Any further operations will be carried out from the main memory database rather than target database. There are many options supported for synchronizing the data between the cache and the target database.

CSQL and its associated suite of products have a single design objective and that is undisruptive performance, close to 100 times faster than traditional options and it has achieved these performances because it has been designed from scratch to achieve performance.

1.2 CSQL is Unique

CSQL is unique for the following reasons.

- It keeps the data in main memory rather than disk.

- It is 20 times* faster than any disk based database system.

** Test results are shown in Appendix A*

- No buffer manager overhead is present since all the records are stored in main memory.
- The data structures and algorithms are targeted for memory access.
- Supports primitive SQL, ODBC and JDBC.
- Proprietary SQL API and DBAPI for faster access.
- Client side cache for any target database

The future will see an increase in demand for main memory databases as performance will be the crucial deciding factor and CSQL will ensure that performance expectations are exceeded

1.3 CSQL as Open Source software

Released on the 15th of May 2008, the CSQL MMDB is available as Open Source software at Sourceforge (www.sourceforge.net), world's largest development and download repository of open source code and applications.

CSQL is available at www.csqldb.com and also at http://www.sourceforge.net/projects/csql. This release includes client side caching for any disk based database systems.

The current release of CSQL works on Linux Platform and it supports DDL operations like CREATE TABLE, DROP TABLE and DML operations like INSERT, SELECT, UPDATE and DELETE on single tables.

1.4 Who can use CSQL

CSQL has been designed from scratch with a single point benefit – to provide undisruptive performance benefits in application domains where real time access to data is a core necessity. For example –

- Financial and Insurance Industry
- Information Technology
- Telecommunication Industry

But again that does not mean CSQL is the preserve of white-coated DBAs sitting in chilled rooms!!!

CSQL through its simplicity of design and usage is equally appealing to individual researchers, students or some one simply interested in experimenting on another Open Source database.

As an Open Source initiative we would welcome brickbats and bouquets at feedback@csqldb.com

2. Getting Started

2.1 Where to find CSQL

- Go to www.csqldb.com and follow the Download link. It is also available at http://www.sourceforge.net/projects/csql
- Download the source file `csql-src-2.0.tar.gz`

2.2 OS / Platform and Compiler support

- CSQL runs on Linux operating system on Intel x86 architecture.
- The g++ compiler must be present to build CSQL (it is a default install with any Linux distro).

2.3 How to build / compile CSQL

To build CSQL, i.e. to compile the CSQL source make sure you have the following tools installed on the Linux box:

- Make
- Automake
- Autoconf
- libtool
- unixODBC
- jdk 1.5

Most of these are installed by default during the Linux installation; just make sure that “Development packages” are included during the installation process. During the installation process, it will ask for the packages that need to be installed. It will appear in the screen with combo box unchecked under the item “Development packages”. This check box needs to be checked before you press the ‘Next’ button for these packages to be installed during the process.

Building CSQL from source file

- Copy the source file csql-src-2.0.tar.gz into your <home-dir>.
- Extract the files

```
$ tar zxvf csql-src-2.0.tar.gz
```

This will extract the files under `csql-src-2.0` directory in the current directory.

- Go to `csql-src-2.0` directory and run

```
$ export JDK_HOME=<path of your jdk installation>
```

To know the path to your JDK installation, please do the following –

```
$ locate javac
```

If the output is

```
/home/csql/jdk1.5.0_14/bin/javac
/home/csql/jdk1.5.0_14/man/ja_JP.eucJP/man1/javac
.1
/home/csql/jdk1.5.0_14/man/man1/javac.1
/opt/java/jdk1.6.0_04/bin/javac
```

Then set the directory which has java1.5 compiler as below

```
$ export JDK_HOME=/home/csql/jdk1.5.0_14
$ export PATH=$JDK_HOME/bin:$PATH
$./build.ksh
$ make
$ make install
$./csqlinstall.ksh
```

Now the CSQL build is ready. Check Section 2.5 on how to configure CSQL.

2.3.1 Building CSQL from the CVS repository

This project's SourceForge.net CVS repository can be checked out through anonymous (pserver) CVS with the following instruction set.

```
$ cvs - \
>d:pserver:anonymous@csql.cvs.sourceforge.net:/cv
sroot/csql \
login
```

When prompted for a password for anonymous, simply press the Enter key.

```
$ cvs -z3 \
> -d:pserver:anonymous@csql.cvs.sourceforge.net:/cvsroot/csql \
> co -P csql
```

This will place all the files in the csql directory, which will be created under the current working directory.

```
$ cd csql
$ export JDK_HOME=<path of your jdk installation>
```

Note: Refer section 2.3 for information on find the correct jdk installation path.

```
$ export PATH=$JDK_HOME/bin:$PATH
$ ./build.ksh
$ make
$ make install
$ ./csqlinstall.ksh
```

Now the CSQL build is ready. Check Section 2.5 on how to configure CSQL.

2.4 Directory Layout and Files

CSQL directory layout is divided mainly into the following five directories.

- src
- include
- docs
- examples
- test

2.4.1 src

This directory contains the following subdirectories that contain c++ source code for all the modules like CSQLCache, SQL Engine, JDBC and ODBC drivers, SQL API, DB API etc.

- adapter
- cache
- gateway
- jdbc

- network
- server
- sql
- sqllog
- tools

2.4.2 include

This directory contains all the header files that include class declarations of various classes of CSQL.

2.4.3 docs

This directory contains the User Manual in pdf format.

For creating API documentation, the “doxygen” tool can be used. Refer README file for details.

2.4.4 examples

This directory is subdivided into the following subdirectories that explain how to interact with CSQL with different supported APIs.

- dbapi
- isql
- odbc
- jdbc
- sqlapi

Refer to Section 2.7 for how to run the examples present in these directories.

2.4.5 test

This directory includes most of the test scripts that have been written during the development phases of the CSQL database. These test scripts are the most comprehensive and exhaustive.

It includes the following subdirectories.

- dbapi
- jdbc
- odbc
- sqlapi
- performance
- system
- tools

Each of it subdirectory represents test module and each module contains test scripts which tests each and every functionality of that module.

Please refer to Section 2.8 to know, how to run these test scripts.

2.5 How to Configure CSQL

The default database size is 10 MB. If you wish to change the size to more than 30 MB, then the system variable `kernel.shmmax` should be set to either same size or more than the size of the database. Only the superuser has the privilege to run this command.

You can ask your system administrator to set it for you in case you are not the super user of the system.

The following command sets the kernel parameter to 1 GB,

```
# /sbin/sysctl -w kernel.shmmax=1000000000
kernel.shmmax=1000000000
```

```
$ cd <CSQL_ROOT>
$ . ./setupenv.ksh
```

This will set all the environmental variables defined in `setupenv.ksh` file present in <CSQL_ROOT> directory. Refer to Section 3.1 for environmental variables.

2.6 Starting and Stopping csqlserver

Once CSQL is built and configured the server is ready to start. The CSQL Server can be invoked by running the following command:

```
$ csqlserver
ConfigValues
 getPageSize 8192
 getMaxProcs 100
 ....
 ....
 ....
 getMaxLogStoreSize 1048576
 getNetworkID 1
 getCacheNetworkID -1
sysdb size 1048576 dbsize 10485760
System Database initialized
Database server started
```

If the ensuing screen output looks similar to the above, then the server is ready for operations. To stop the server just press <Ctrl + C> from the terminal where the server is running –

```
Received signal 2
Stopping the server
Server Exiting.
```

The above output message is displayed during the exit. This will stop the server gracefully by removing the database and doing the necessary clean ups.

2.7 Running examples

You are now ready to run some examples given in examples directory. This directory contains following subdirectories

dbapi – contains dbapiexample.c with Makefile and README

sqlapi - contains sqlapiexample.c with Makefile and README

isql - contains sql input files and README

jdbc - contains jdbcexample.java, gwexample.java with Makefile and README

odbc - contains odbcexample.c with Makefile and README

Each of these subdirectory contain README file that will guide you to compile and run these examples.

2.8 How to run test scripts from test directory

Set the environment variables by running `setupenv.ksh` present in the CSQL root directory

```
$ cd <CSQL_ROOT>
$ . ./setupenv.ksh
```

Create a directory in your home directory

```
$ cd
$ mkdir testResults
```

Set the environmental variable `TEST_RUN_ROOT` to point to this directory.

```
$ export TEST_RUN_ROOT=<user-home>/testResults
```

Go to the test directory in CSQL root directory.

```
$ cd <CSQL_ROOT>/test
```

Run the following command and wait for it to finish.

```
$ make runall
```

It may take several minutes to finish this test. It will generate a test report once running through all the test scripts mentioning the number of scripts passed and failed in each module. The testResults directory will have the logs of all the test scripts under appropriate subdirectories.

3. How to Use CSQL

3.1 Environmental variables

CSQL has a set of environmental variables that need to be set after the build is ready and before starting the server. To carry out the various database operations, either by using the csql tools or using executables which link with csql libraries, the following environmental variables need to be set.

Note: Let us assume `CSQL_ROOT` is the absolute path where CSQL is installed.

3.1.1 CSQL_CONFIG_FILE

There is a configuration file called `csql.conf` in the CSQL root directory, which the `csqlserver` reads during loading up. This file has the configuration variables that the CSQL system needs during setting up of the server. These variables are explained in detail in Section 8.

```
$ export CSQL_CONFIG_FILE=<CSQL_ROOT>/csql.conf
```

3.1.2 LD_LIBRARY_PATH

This variable is set to locate the CSQL `lib` directory that contains CSQL specific libraries.

```
$ export \
> LD_LIBRARY_PATH=<CSQL_ROOT>/install/lib:$LD_LIBRARY_PATH
```

3.1.3 PATH

This variable is set to locate the CSQL `bin` directory that contains the CSQL executables.

```
$ export PATH=<CSQL_ROOT>/install/bin:$PATH
```

3.1.4 CLASSPATH

This variable is set to locate the libraries for the JDBC driver of CSQL.

```
$ export /
> CLASSPATH=<CSQL_ROOT>/install/lib/CSqlJdbcDriver.jar:.
```

Running the following script from the CSQL root directory will set the above variables automatically.

```
$ . ./setupenv.ksh
```

3.2 CSQL Tool

CSQL provides an interactive SQL client tool called `csql`, which communicates with the CSQL database. It supports most of the standard SQL statements like the DDL and DML. It executes as a sub-shell and executes the SQL statements on the database. The csql interface is invoked as below –

```
$ csql
CSQL>
```

Refer Section 10 for more about CSQL tools.

3.3 SQL Data Definition Language (DDL)

The CSQL Tool supports standard DDL statements such as `CREATE TABLE` and `DROP TABLE`.

3.3.1 CREATE TABLE

`CREATE TABLE` creates a table in the database.

Syntax:

```
CREATE TABLE <table name>
( <col1> <datatype> constr,
  <col2> <datatype> constr,

  ...,
[primary key (col1)]);
```

Where

`col1,col2` – are the columns in the table

`datatype` – type of the data that the column represents,

`constr` - the constraint that applies to the column.

- **DATATYPES**

  The Datatypes supported by CSQL are

Datatype name	Description
`CHAR(size)`	A string of fixed length
`TINYINT`	A 8-bit signed integer value
`SMALLINT`	A 16-bit signed integer value
`INTEGER or INT`	A 32-bit signed integer value. The range of INTEGER is -2147483648 to 2147483647
`BIGINT`	A 64-bit signed integer value
`FLOAT`	A 64-bit precision floating point value. These types are analogous to the Java double type
`REAL`	A higher precision numeric value
`DATE`	A date value in month/day/year
`TIME`	A time of day value
`TIMESTAMP`	A month/day/year and time of day value

- **CONSTRAINT**

  At present only `NOT NULL` constraints are supported by CSQL in `CREATE TABLE` statement. The `UNIQUE` constraints are supported through the `CREATE INDEX` statement.

  Syntax:

```
create table t1
(    f1 int, f2 char(20),
     f3 float,
     primary key (f1));
```

  `f1` is a primary key and it will be `NOT NULL` and `UNIQUE`.

```
create table t2
(    f1 int  Not Null,
     f2 char(30) Not Null);
```

  `f1` and `f2` are not null fields.

  Currently CSQL supports only one primary key field per table and it should be mentioned at the end of the table definition.

3.3.2 DROP TABLE

`DROP TABLE` removes the table from the database.

Syntax:

```
DROP TABLE <table name>;
```

3.4 SQL Data Manipulation Language (DML)

CSQL tool supports standard DML statements such as INSERT, UPDATE and DELETE commands to store, modify and remove data from the database.

3.4.1 INSERT

The `INSERT` command adds one row at a time into the table.

Syntax:

```
INSERT INTO <table-name> [(column-list)]
VALUES (value list)
```

This form has an optional column-list specification. Only the columns listed will be assigned values. Unlisted columns are set to `null`, so these columns must allow null values. The values from the `VALUES` Clause are assigned to the corresponding column in column-list in order.

If the optional column-list is missing, the default column list is substituted. The default column list contains all columns in table-name in the order they were declared in `CREATE TABLE`.

Table T1 before `INSERT` –

F1	f2	f3

```
INSERT INTO t1 VALUES(1001,'Ravi',5000.00);
```

Table T1 after `INSERT` –

F1	f2	f3
1001	Ravi	5000.00

```
INSERT INTO t1(f1) VALUES(1002);
```

Table T1 after `INSERT` –

F1	f2	f3
1001	Ravi	5000.00
1002	NULL	NULL

Presently CSQL adds only one row at a time.

3.4.2 UPDATE

The `UPDATE` statement modifies column values in selected table rows. It has the following general format:

```
UPDATE <table-name>
SET <set-list>
[WHERE predicate]
```

The optional `WHERE` clause chooses which table rows to be updated. If it is missing, all rows in table-name are updated. The set-list contains assignments of new values for selected columns.

- `SET` clause

The `SET` clause in the `UPDATE` statement updates (assigns new value to) columns in the selected table rows. It has the following general format:

```
SET col1 = value1
[, col2 = value2]
...
```

- `WHERE Clause`

The `WHERE` clause specifies which rows needs to be updated. If it is not specified, then all the rows in the table are updated.

`col1` and `col2` are columns in the table. `value1` and `value2` are expressions that can reference columns from the table which is being updated. They also can be the keyword -- `NULL`. Since the assignment expressions can reference columns from the current row, the expressions are evaluated first. After the values of all `set` expressions have been computed, they are then assigned to the referenced columns.

```
UPDATE t2 SET qty=100;
```

T2 before updation –

no	item	qty
1	Bolts	10
2	Nuts	20

T2 after updation –

no	item	qty
1	Bolts	100
2	Nuts	100

```
UPDATE t1 SET qty = 150 WHERE item='Nuts';
```

T2 before updation –

no	item	qty
1	Bolts	100
2	Nuts	100

T2 after updation –

no	item	Qty
1	Bolts	100
2	Nuts	150

3.4.3 DELETE

The `DELETE` Statement removes selected rows from a table.

Syntax:

```
DELETE FROM <table-name>
[WHERE predicate]
```

The optional `WHERE` Clause has the same format as in the `UPDATE` Statement.

The `WHERE` clause specifies which rows needs to be deleted. If it is not specified, then all the rows in the table are removed.

```
DELETE FROM t2 WHERE no=2;
```

T2 before deletion –

no	item	Qty
1	Bolts	100
2	Nuts	150

T2 after deletion –

No	item	Qty
1	Bolts	100

```
DELETE FROM t2;
```

T2 before deletion –

no	item	Qty
1	Bolts	100

T2 after deletion –

no	item	Qty

3.5 SQL Data Query Language (DQL)

CSQL tool supports standard DQL statement, SELECT to view the data present in the table.

3.5.1 SELECT

The SQL `SELECT` statement queries data from tables in the database. The statement begins with the `SELECT` keyword. The basic `SELECT` statement has 3 clauses:

- `SELECT`
- `FROM`
- `WHERE`

The `SELECT` clause specifies the table columns that are to be retrieved.

The `FROM` clause specifies the table to be accessed.

The `WHERE` clause specifies which table rows are selected. It is optional; if missing, all table rows are selected.

Syntax:

```
SELECT <select-list>
FROM <table-name>
[WHERE predicate]
```

If select-list is specified as *, then it projects all the columns for those rows that satisfy the `where` clause.

```
SELECT *

FROM <table-name>
```

```
[WHERE predicate]
```

To view the records of a table named `tab`

No	Name	Age	Wt
1	Tom	25	60
2	Dick	30	70
3	Harry	35	80

```
SELECT Name, Age FROM tab
WHERE Wt < 75;
```

Result set of the above `select` statement –

Name	Age
Tom	25
Dick	30

```
SELECT Name, Wt FROM tab WHERE Age > 25;
```

Output –

Name	Wt
Dick	70
Harry	80

```
SELECT Name FROM tab WHERE Wt < 100;
```

Output –

Name
Tom
Dick
Harry

```
SELECT * FROM tab;
```

Output –

No	Name	Age	Wt
1	Tom	25	60
2	Dick	30	70
3	Harry	35	80

4. JDBC Driver

This section explain various Interfaces and methods in JDBC APIs and their uses, which would help in writing applications to access CSQL main memory database using the CSQL's JDBC Driver.

The JDBC (Java Database Connectivity) is one of the standard interfacing subsystems in CSQL Database. It supports most of the JDBC 2.0 APIs and all-primitive data types, along with the `date`, `time` and `timestamp`.

In order to make things simple, the JDBC sub-system talks to the SQLAPI, which is, implemented by the SQL Engine, this SQL Engine in turn accesses the storage engine through DBAPI.

4.1 What is JDBC

JDBC is an API (Application Programming Interface) which consists of a set of classes, interfaces and exceptions and a specification used for application development.

Using these standard interfaces and classes, programmers can write applications that connect to CSQL, send queries written in SQL and process the results.

4.1.1 Implemented Interfaces

The JDBC API is consistent with the style of the core Java interfaces and classes, such as `java.lang` and `java.awt`. The table below describes the `interfaces`, `classes` and `exception classes` that make up the JDBC API.

Interface/class/exception	Description
Interfaces:	
`java.sql.Connection`	Interface used to establish a connection to CSQL.SQL statements run within the context of a connection.
`java.sql.PreparedStatement`	Interface used to send precompiled SQL statements to the database driver and obtain results.
`java.sql.ResultSet`	Interface used to process the results returned after executing an SQL statement.
`java.sql.Statement`	Interface used to send static SQL statements to the database server
Classes:	
`java.sql.Date`	Subclass of java.util.Date used for the SQL DATE data type.
`java.lang.DriverManager`	Class used to manage a set of JDBC drivers.
`java.sql.Time`	Subclass of java.util.Date used for the SQL TIME data type.

`java.sql.Timestamp`	Subclass of java.util.Date used for the SQL TIMESTAMP data type.
Exception classes:	
`java.sql.SQLException`	Exception that provides information about a database error.

Because JDBC is a standard specification, any Java program that uses the JDBC API can connect to CSQL using the JDBC driver.

What is a JDBC driver

The JDBC API defines the Java Interfaces and Classes that programmers use to connect to CSQL and send queries.

Basically, JDBC consists of two parts:

- **JDBC API:**

It provides a programmatic access to relational data from the Java programming language. Using the JDBC API, applications can execute SQL statements, retrieve results, and propagate changes back to an underlying data source.

- **JDBC Driver Manager:**

The JDBC `DriverManager` class defines objects, which can connect Java applications to a JDBC Driver. It has traditionally been the backbone of the JDBC architecture.

4.1.2 JDBC Datatype

This JDBC 2.0 supports all primitive types like – `integer, char, float, string,` including `Date, Time, TimeStamp`.

The table below shows the JDBC prescribed "SQL-to-Java datatype" mappings.

SQL datatypes supported in JDBC 2.0:

SQL Type (from java.sql.types)	Java Type
TINYINT	Byte
SMALLINT	Short
INTEGER	Int
BIGINT	Long
REAL	Float
FLOAT DOUBLE	Double
CHAR	java.lang.String
DATE	java.sql.Date
TIME	java.sql.Time
TIMESTAMP	java.sql.Timestamp

These mappings are the JDBC specification for direct type mapping.

Lets take an example where you create a table in the CSQL with two fields,

```
create table t1
(f1 integer, f2 char(20));
```

The following sections describe how to connect to the CSQL and to create a table 'T1' in it, and perform insertion, updation, fetch and deletion of records and ultimately drop the table 'T1' from CSQL Database.

Please refer to the `jdbcexample.java` file for source code, which is present in the `jdbc` sub-directory of `example` directory.

4.2 Establishing a Connection

First, you need to establish a connection with the CSQL. Establishing a connection involves two steps: Loading the driver, and making the connection.

4.2.1 Loading the Driver:

The `jdbcexample.java` program must first open a connection to a database, and can then execute SQL statements. But before opening a connection, it is necessary to load the appropriate drivers for the database by using `Class.forName`.

Loading the driver you want to use is very simple. It involves just one line of code in your program. To add the appropriate Driver, add the following line of code:

```
Class.forName("csql.jdbc.JdbcSqlDriver");
```

In the above code, `JdbcSqlDriver` is the driver for CSQL.

Calling the `class.forName` automatically creates an instance of a driver and registers it with the `DriverManager`, so you don't need to create an instance of the class.

Now you have loaded the driver and it can make a connection with a DBMS.

4.2.2 Making the Connection

The second step in establishing a connection is to have the appropriate driver connect to the CSQL.

- Using the `DriverManager` Class

The `DriverManager` class works with the driver interface to manage the set of drivers available to a JDBC Client. When the client requests a connection and provides a URL, the `DriverManager` is responsible for finding a driver that recognizes the URL and connects to the data source. The connection URL would have the following syntax:

```
"jdbc:csql"
```

The `jdbc:csql` portion of the URL identifies the database.

- The `getConnection` method establishes a connection:

Actually basic database access starts with the `Connection` object, when this object is created this is simply a direct link to the database.

```
Connection con =
DriverManager.getConnection("jdbc:csql", "root",
"manager");
```

You need to use `root` for the user name and `manager` for the password. This will establish a connection with CSQL.

If the loaded driver recognizes the parameters supplied to the method `DriverManager.getConnection`, then it establishes a connection to the CSQL database. The `DriverManager` class encapsulates and manages the connection process.

The connection returned by the method `DriverManager.getConnection()` is connection to the CSQL Database. Now we can create JDBC functions that pass the SQL statements to CSQL using this connection.

4.3 Creating Table

Now you can create a statement handle on the `Connection` and use it to execute an SQL statement. Once you are connected, you can create a new SQL statement object by using the `Connection` object.

```
Statement cStmt = con.createStatement();
```

The `Statement` class provides an `execute()` method to execute the SQL Statements.

You can then execute this statement to create a table `T1` with two fields in the CSQL and we do that by executing a `CREATE SQL` statement.

```
cStmt.execute("CREATE TABLE T1 (f1 integer, f2 char
(20));");
```

4.3.1 Creating Index

You can use the same statement object to create a unique index.

```
cStmt.execute("CREATE INDEX IDX ON T1 ( f1);");
```

After executing this SQL Statement, it will be creating a unique index 'IDX' for f1 column.

4.3.2 Closing and committing the `Statement` object

```
cStmt.close();
```

The code closes the `Statement` object `cStmt` through a `close()` method. This `cStmt` object holds database resources, so its good to close any instance of this object when we are done with them.

In the code snippet above, you used one statement object, which is generated by `Connection`. Connection object provides methods to `commit` (or rollback) all the statement executed in that connection context.

```
con.commit();
```

In the example `jdbcexample.java`, you can observe that the `Statement` object is used for SQL Create and Drop statements. And for other SQL statements like `INSERT, UPDATE, DELETE`, you use the `PreparedStatement` interface. Because, each SQL statement needs to be parsed by the database engine, a corresponding query plan ("query-tree") has to be formulated before it can actually be executed.

If each DDL statement needs a new query plan then the database builds one for it.

If statements, which generate the same query plan, were being executed consecutively, then going by the above criteria you would waste processing cycles. In order to get rid of this, you use the `PreparedStatement` interface, which ensures a one-time creation of query plan and subsequently the same query plan is just re-used whenever needed. Refer to example `jdbcexample.java`.

4.4 Inserting tuples

In the last example, you created a table T1 with two fields. Now we will try to insert 10 tuples (rows) with different values for both fields.

```
PreparedStatement stmt = null, selStmt= null;
stmt = con.prepareStatement("INSERT INTO T1 (f1, f2)
VALUES (?, ?);");
int count =0;
int ret =0;
for (int i =0 ; i< 10 ; i++) {
        stmt.setInt(1, i);
        stmt.setString(2, String.valueOf(i+100));
        ret = stmt.executeUpdate();
        if (ret != 1) break; //error
        count++;
     }
stmt.close();
con.commit();
System.out.println("Total Rows inserted " + count);
```

The steps involved in the record insertion code snippet above are –

- Use the `prepareStatement` function to generate the one-time query plan.
- Bind the parameters with the respective fields and execute the prepared statement (the same query plan is re-used).

- Close the `PreparedStatement` object
- Commit the transaction

The `prepareStatement` method:

The prepareStatement method enables a SQL statement to contain parameters, and you can execute a single statement repeatedly with different values for those parameters and to assign values to these parameters is called binding.

```
stmt = con.prepareStatement("INSERT INTO T1 (f1, f2)
VALUES (?, ?);");
```

Binding the parameters and executing the prepared statement:

Using the `PreparedStatement` object, you pass the SQL statement to the database through the `prepareStatement()` method in `java.sql.Connection`. You execute the resulting "prepared" SQL statement multiple times inside the `for` loop, the query plan had been built once at the start.

```
stmt.setInt(1, i);
stmt.setString(2, String.valueOf(i+100));
ret = stmt.executeUpdate();
```

Before each execution of the prepared statement, you pass to JDBC the values to be used as input for that execution cycle. In order to bind the input parameters, `PreparedStatement` provides `setInt()` and `setString()` method. These methods bind the parameters from left to right in the order you placed them in the prepared statement.

Close the `PreparedStatement` object:

The `PreparedStatement` object is closed with the `close()` method.

```
stmt.close();
```

Closing `stmt` object implicitly closes instances associated with it and frees the associated memory.

Commit the transaction:

The Connection object sets up the connection with the CSQL database. In order to close the connection you use the `commit` method.

```
con.commit();
```

You can use the `con` object to generate implementations of `java.sql.Statement` tied to the same database transaction.

4.5 Updating Rows

You would now look into a code snippet for updating rows in table 'T1'.

You create a `PreparedStatement` object that can receive 2 parameters using the `Connection` method - `prepareStatement`:

```
stmt = con.prepareStatement("UPDATE T1 SET f2 = ?
WHERE f1 = ?;");
for (int i =0 ; i< 10 ; i +=2) {
     stmt.setString(1, String.valueOf(i+200));
     stmt.setInt(2, i);
     ret = stmt.executeUpdate();
     if (ret != 1) break; //error
     count++;
}
stmt.close();
con.commit();
```

The variable `stmt` contains the SQL Statement, `UPDATE T1 SET f2=? WHERE f1=?`, which is sent to the DBMS and precompiled into a query plan.

Here the f1 and f2 fields can be supplied with values using the `setString` and `setInt` method in accordance to the column positions in the prepared statement from left to right.

Subsequently the `executeUpdate` method executes the `update` SQL statement at the database level.

4.6 Deleting Rows

In this example you will delete some rows from the table "T1" using `PreparedStatement` parameters.

```
stmt = con.prepareStatement("DELETE FROM T1 WHERE f1 =
?;");
for (int i =0 ; i< 10 ; i +=3) {
     stmt.setInt(1, i);
     ret = stmt.executeUpdate();
     if (ret != 1) break; //error
     count++;
}
```

```
stmt.close();
con.commit();
```

In the prepared statement the `f1 = ?` signifies that the rows to be deleted will be based on the parameter being passed through `setInt()` method.

Post deletion, you commit the Statement objects associated with that Connection.

4.7 Fetching the Rows

You can create a `PreparedStatement` object based on a result-set generated through a `SELECT` query, for example –

```
PreparedStatement  selStmt= null;
selStmt = con.prepareStatement("SELECT * from T1 where
f1 = ?;");
```

The `executeQuery()` method of the statement object is used to generate the result set. It returns an object that implements the `ResultSet` interface. The following code snippets depicts the above –

```
ResultSet rs = null;
for (int i =0 ; i< 10 ; i++) {
     selStmt.setInt(1, i);
     rs = selStmt.executeQuery();
     while (rs.next())
     {
          System.out.println("Tuple value is " +
          rs.getInt(1)+ " "+ rs.getString(2));
          count++;
     }
     rs.close();
}
selStmt.close();
con.commit();
```

The `ResultSet` interface provides methods for retrieving and manipulating the results of executed queries, and these objects can have different functionality and characteristics. The result set is generated upon executing query statements on the table data.

The code snippet above displays how to generate the result set using a query statement through a Java program.

The variable `rs`, (in the code snippet above) is an instance of `ResultSet`, and contains the rows of T1 which have been "selected". In order to access the f1and f2 field values, the `ResultSet` object maintains a cursor, which points to its current row of data.

When a `ResultSet` object is created, the cursor is positioned before the first row. To move the cursor down the rows, we use the following methods:

- **`next()`** --- moves the cursor forward by one row. Returns true if the cursor is now positioned on a row and false if the cursor is positioned after the last row.

  You can iterate through the `ResultSet` to obtain values for each field of the T1 table and print these values on the user console.

  ```
  while (rs.next())
  System.out.println("Tuple value is " + rs.getInt(1)+ "
  "+ rs.getString(2));
  ```

  At the end, close the `ResultSet`, `PreparedStatement` and `Connection` objects as depicted below –

  ```
  rs.close();
  selStmt.close();
  con.commit();
  ```

  Once the rows are fetched, commit the transaction.

4.8 Drop the table

In order to drop a table from the CSQL database –

```
cStmt.execute("DROP TABLE T1;");
```

Once this is executed, it will drop the T1 table from the CSQL Database.

4.9 Close the connection

```
cStmt.close();
```

When `close()` method is invoked, it implicitly closes all `PreparedStatement` instances associated with the `Connection`.

5. ODBC Driver

This section explains various functions in ODBC API and their uses, which would help in writing applications to access the CSQL database using the CSQL ODBC driver.

The ODBC (Open Database Connectivity) is the other standard interfacing subsystem in CSQL Database (the other one is JDBC). CSQL supports most of ODBC 2 APIs and all primitive data types, including Date, Time and TimeStamp data types.

Let us start with an example where you create a table in the CSQL database to store employee details, lets say the table is EMP and the fields are empId (int), name (char(20)) and sal (float).

The following sections describe how to connect to the database, how to create table, how to `insert`, `update` and `delete` tuples in the table and how to drop table.

5.1 Why ODBC

Due to the inherent limitations in SQL in performing certain complex computations, they must be written in a host language, such as C or C++, with embedded SQL queries which in turn access the data in the CSQL database.

To access the CSQL, the SQL statements need to be executed from within the host language application, using an API, which can be used to send DML and DDL statements to the CSQL and retrieve the results. This programming interface is called the ODBC API.

The ODBC API is a library of ODBC functions that lets ODBC-enabled applications to connect to CSQL, execute statements, and retrieve results. For doing this an ODBC driver is available.

The goal of ODBC is to make data access possible in any database from any application, this is achieved by inserting a middle layer called the “database driver” between an application and the DBMS. This layer translates the application’s data queries into commands that the DBMS understands.

5.2 Components of ODBC

- An ODBC compliant application i.e. an application that uses the ODBC API to talk to CSQL (DBMS).

- The ODBC Driver manager is a repository containing the list of installed ODBC drivers and data sources. It is the interface between an ODBC application and an ODBC Driver. Applications requiring ODBC access, interface with the driver

manager and make ODBC API calls, which causes the driver manager to load the appropriate ODBC Driver.

- An ODBC driver translates the ODBC API calls into something that the backend CSQL understands.

- Header files required to build the ODBC application – `stdlib.h, sql.h, sqlext.h & sqlucode.h`

  Normally C applications need to include –
  `sql.h` – which contains most of the definitions you'll need
  `sqlext.h` – which contains mostly additions for ODBC 3
  `sqlucode.h` is automatically included by sqlext.h and
  `sqltypes.h` is automatically included from sql.h

5.3 ODBC API Overview

Before you get into the various functions provided by the ODBC API, let's look at a few key concepts. In this section, you will look at allocating various handles that are used by ODBC and some important APIs which are frequently used in any ODBC application.

5.3.1 ODBC Handles

The ODBC API introduces new handle types that are used to reference information about your application's ODBC environment, specific database connections and SQL statements.

In ODBC 3, each of these handle types are allocated with a single function `SQLAllocHandle()` and freed with a single function `SQLFreeHandle()`

In ODBC, there are three main handle types, which you need to know in order to do access the data.

- `SQLHENV` – environment handle
  This is the first handle you will need as everything else is effectively in the environment. Once you have an environment handle you can define the versions of ODBC you require, enable connection pooling and allocate connection handles.

- `SQLHDBC` – connection handle
  You need one connection handle to make the connection. Like environment handles, connection handles have attributes which you can retrieve and set.

- `SQLSTMT` – statement handle
  Once you have a connection handle and have connected to CSQL you allocate handles to execute SQL or retrieve data. As with the other handles you can set and get statement attributes with this handle also.

SQLAllocHandle:

`SQLAllocHandle` is a generic function for allocating environment, connection and statement handles.

Prototype of the Function:

```
SQLRETURN SQLAllocHandle(SQL_SMALLINT HandleType,
SQLHANDLE InputHandle, SQLHANDLE * OutputHandlePtr);
```

The arguments for `SQLAllocHandle` are listed in below table

Type	Name	Description
`SQLSMALLINT`	`HandleType`	The type of handle to allocate.
`SQLHANDLE`	`InputHandle`	The handle to base on the new handle. This is either an environment or connection handle. To create a new handle from scratch, pass in NULL.
`SQLHANDLE*`	`OutputHandle`	Pointer to the storage for the newly create handle.

Note: - An application allocates different handles to use with different API functions. The handle provides a context for each function .The supported handle types are.

`Environment`	`SQL_TYPE_ENV`	These handles are used to create an environment. Each environment contains generic information that allows you to access the **CSQL**. A new transaction is associated with a newly-created environment handle.
`Connection`	`SQL_TYPE_DBC`	A connection handle is used to open a connection to a specific CSQL Database. Connections can be based on the same environment handle, hence sharing the same transaction across multiple database connections. However, a maximum of **eight** connections can share a single environment.
`Statement`	`SQL_TYPE_STMT`	The statement handle contains information about the compiled SQL statement and its result sets.

Returns: `SQLAllocHandle` returns `SQL_SUCCESS` if it is successful. Otherwise, it returns `SQL_ERROR`.

SQLFreeHandle:

`SQLFreeHandle` is a generic function to free environment, connection, and statement handles.

Prototype of the Function:

```
RETCODE  SQLFreeHandle(SQLSMALLINT handleType,
SQLHANDLE handle)
```

SQLFreeHandle Arguments:

Type	Name	Description
SQLSMALLINT	handleType	The type of handle to free.
SQLHANDLE	handle	The handle to free.

Returns

`SQLFreeHandle` returns `SQL_SUCCESS` if it is successful. Otherwise, it returns `SQL_ERROR`.

5.4 ODBC API

In this section, we describe some important APIs .

5.4.1 SQLPrepare

`SQLPrepare` prepares an SQL String for execution. In our examples you have used this function for DML statements.

ODBC allows us to prepare SQL statements in a separate step so that you can generate the query plan once after the parsing and for every subsequent execution you could simply re-use the same query plan.

Prototype of the function:

```
SQLRETURN   SQLPrepare(
            SQLHSTMT      StatementHandle,
            SQLCHAR *      StatementText,
            SQLINTEGER   TextLength);
```

Arguments:

StatementHandle	:	[Input] Statement handle
StatementText	:	[Input]SQL text string
TextLength	:	[Input] Length of *Statement Text in Characters.

This function returns SQL_SUCCESS, if it successfully prepares the SQL Statements.

5.4.2 SQLExecute

SQLExecute executes a prepared statement using the current values of the parameter marker variables if any exists in the statement.

Prototype of the Function:

```
SQLRETURN SQLExecute(SQLHSTMT  StatementHandle)
```

Arguments:

StatementHandle: [Input] StatementHandle.

This function returns SQL_SUCCESS on successful execution.

5.4.3 SQLBindParameter

It binds a buffer to a parameter marker in an SQL statement.

You will see in following sections that how we bind the parameter using this function for Insert, Update and Delete statements.

```
SQLRETURN SQLBindParameter(
    SQLHSTMT        StatementHandle,
    SQLUSMALLINT    ParameterNumber,
    SQLSMALLINT     InputOutputType,
    SQLSMALLINT     ValueType,
    SQLSMALLINT     ParameterType,
    SQLULEN         ColumnSize,
    SQLSMALLINT     DecimalDigits,
    SQLPOINTER      ParameterValuePtr,
    SQLINTEGER      BufferLength,
```

```
        SQLLEN *        StrLen_or_IndPtr );
```

Arguments:

`StatementHandle`	: [Input] Statement handle.
`ParameterNumber`	: [Input] Parameter number, sequentially increasing parameter order starting at 1.
`InputOutputType`	: [Input] The type of the parameter. SQL_PARAM_INPUT is used for parameters in SQL Statements and SQL_PARAM_OUTPUT or SQL_PARAM_INPUT_OUTPUT are used for stored procedure parameters.
`ValueType`	: [Input] The C data type of the parameter.
`ParameterType`	: [Input] The SQL data type of the parameter.
`ColumnSize`	: [Input] The size of the column.
`DecimalDigits`	: [Input] The decimal digits of the column or expression of the corresponding parameter marker .
`ParameterValuePtr`	:[Deferred Input]A pointer to a buffer for the parameter's data.
`BufferLength`	: [Input/Output] Length of the parameterValuePtr buffer in bytes.
`StrLen_or_IndPtr`	: [Deferred Input] A pointer to a buffer for the parameter's length.

This function returns `SQL_SUCCESS`, if it successfully binds the parameter.

5.4.4 SQLBindCol

This function binds application data buffers to columns in the result set. You use this function for select statements.

```
SQLRETURN SQLBindCol(
     SQLHSTMT       StatementHandle,
     SQLUSMALLINT   ColumnNumber,
     SQLSMALLINT    TargetType,
     SQLPOINTER     TargetValuePtr,
     SQLLEN         BufferLength,
     SQLLEN *       StrLen_or_Ind);
```

Arguments:

`StatementHandle`	: [Input] Statement handle

ColumnNumber	: [Input] Number of the result set column to bind. Columns are numbered in increasing column order starting at 1.
TargetType	: [Input] The identifier of the C datatype of the *TargetValuePtr Buffer, when it is retrieving data from the data source with SQLFetch.
TargetValuePtr	: [Deferred Input/Output] pointer to the data buffer to bind to the column. SQLFetch return data in this buffer.
BufferLength	: [Input] Length of the targetValuePtr buffer in bytes.
StrLen_or_IndPtr	: [Deffered Input/Output] Pointer to the length buffer to bind to the column.

This function returns SQL_SUCCESS, if it successfully binds the column**.**

5.5 Data Types

CSQL supports all primitive Data types like int, float, char etc and Date, Time, TimeStamp.

ODBC uses two sets of data types – SQL datatypes and C Datatypes. SQL data types are used in the data source and C data types are used as part of the host language application.

SQL Type Identifier: SQL data types are the types in which data is stored in the data source.

For example, SQL_CHAR is the type identifier for a character column with a fixed length, typically between 1 and 254 characters. These characteristics correspond to the CHAR data type found in data source. Thus when application discovers that the type identifier for a column is SQL_CHAR, it can assume it is probably dealing with a CHAR column.

In our sample ODBC source code, you create an emp table with three fields. Field eid is integer, ename is character and salary is float, for these three fields the SQL Identifiers are SQL_SHORT, SQL_CHAR, SQL_FLOAT.

C Type Identifier: ODBC also defines the C data types that are used by application variables and their corresponding type identifiers. The buffers that are bound to the result set columns and statement parameters use these. For example, an application wants to retrieve data from a result set column in character format. It declares a variable with the SQLCHAR* data types and binds this variable to the result set column with type identifier of SQL_C_CHAR.

Here also for the three fields, the data types will be `SQL_C_SHORT, SQL_C_CHAR, SQL_C_FLOAT` for integer, character, float respectively.

SQL Definition	SQL Type Identifier	C Type Identifier
CHAR(n)	SQL_CHAR	SQL_C_CHAR
SMALLINT	SQL_SMALLINT	SQL_C_SSHORT
INTEGER	SQL_INTEGER	SQL_C_SLONG
REAL	SQL_REAL	SQL_C_FLOAT
FLOAT	SQL_FLOAT	SQL_C_FLOAT
DOUBLE	SQL_DOUBLE	SQL_C_DOUBLE
TINYINT	SQL_TINYINT	SQL_C_TINYINT
BIGINT	SQL_BIGINT	SQL_C_SBIGINT
DATE	SQL_TYPE_DATE	SQL_C_TYPE_DATE
TIME	SQL_TYPE_TIME	SQL_C_TYPE_TIME
TIMESTAMP	SQL_TYPE_TIMESTAMP	SQL_C_TYPE_TIMESTAMP

5.6 ODBC API with Examples

Let us start with an example where you create a table in the CSQL database to store employee details, say `emp(eid int, ename char(20), salary float).`

5.6.1 Connect to the CSQL

Refer to ODBCman1.c for the source code

You have to allocate the internal structures for the various handle types through

`SQLAllocHandle` function.

```
SQLHENV   env;
SQLHDBC   dbc;
SQLRETURN   ret;

ret = SQLAllocHandle (SQL_HANDLE_ENV,
SQL_NULL_HANDLE, &env);

ret = SQLSetEnvAttr
(env,SQL_ATTR_ODBC_VERSION,(void*)SQL_OV_ODBC3,
0);

ret = SQLAllocHandle (SQL_HANDLE_DBC, env, &dbc);
```

Firstly, `SQLAllocHandle` function allocates an environment handle.

SQL_HANDLE_ENV is used to create an environment and a new transaction is associated with it.

SQL_NULL_HANDLE specifies the structure from which a new handle is derived. An environment handle, however, isn't derived from another handle, so InputHandle should be set to SQL_NULL_HANDLE.

The OutputHandle pointer – env should point to the new handle that is to be allocated.

Secondly, SQLSetEnvAttr function sets the application's ODBC Version. The ODBC driver manager is designed to support version 2 drivers and applications, as well as newer *ODBC 3* components. Depending on the version of ODBC that your application is using, certain functionalities will behave differently. This requires that our application specify which version of the ODBC API it is using before you go on to allocate Connection handles. The version can be set using SQLSetEnvAttr() to set the SQL_ATTR_ODBC_VERSION environment attribute to SQL_OV_ODBC3.

Thirdly, SQLAllocHandle function allocates a Connection handle.

SQL_HANDLE_DBC is used to open a connection to a specific CSQL database.

The input handle env specifies the handle from which the Connection handle is allocated. The outpu thandle ptr 'dbc' is allocated.

If the new handle is successfully allocated, SQLAllocHandle() will return SQL_SUCCESS; otherwise, it will return SQL_ERROR.

After you allocate a connection handle with SQLAllocConnect(), you must connect the handle to a data source before you can start operating on that data source.

ODBC functions to connect to a data source

SQLConnect	**:**Loads a driver and establishes a connection to data source.
SQLDriverConnect	**:**Connects to a specific driver using a connection string or requests the Driver Manager to connect to the specified DSN (Data Source Name).

SQLConnect

This function provides the most direct programmable control of the connection.

Prototype for `SQLConnect()`.

```
SQLRETURN SQLConnect
     (SQLHDBC  ConnectionHandle, SQLCHAR*
     ServerName,SQLSMALLINT NameLength1,SQLCHAR*
     Username,SQLSMALLINT NameLength2,SQLCHAR*
     Authentication, SQLSMALLINT NameLength3);
```

`ConnectionHandle` is allocated with `SQLAllocHandle()`.
`ServerName` passes the name or URL of the database server.
`Username` passes the login user id
`Authentication` passes the password.
The username and password can be passed as NULL if the DSN resides on the local machine.

Connect to CSQL:

```
rc = SQLConnect (dbc,
             (SQLCHAR *) "test", (SQLSMALLINT)
             strlen ("test"),
                (SQLCHAR *) "root",
                (SQLSMALLINT) strlen ("root"),
                (SQLCHAR *) "",
                (SQLSMALLINT) strlen (""));
```

When you call **`SQLConnect()`**, the ODBC Driver manager will load the requested driver, if it isn't already loaded and will connect to the requested data source. If an error occurs, **`SQLConnect()`** will return **`SQL_ERROR.`**

`SQLDriverConnect:`

It is an alternative to `SQLConnect`. It supports data sources that require more information. And those that are not defined in the `ODBC.INI` file.

```
SQLCHAR  outstr[1024];

SQLSMALLINT  outstrlen;

rc = SQLDriverConnect  (dbc,
NULL,(SQLCHAR*)"DSN=myodbc3;", SQL_NTS, outstr,
sizeof(outstr), &outstrlen, SQL_DRIVER_NOPROMPT);
```

`dbc` – allocated connection handle with `SQLAllocHandle`.

`NULL` – is set for the window handle for the any dialog boxes that may be created.

`DSN=myodbc3` – `InConnectionString` parameter which points to a connection string that is passed into `SQLDriverConnect`.

All string parameters that are passed as inputs to ODBC functions will consist of a pointer to the string and a separate parameter for its length, which is used to support languages that require this. For C/C++ applications, you should pass a pointer to a null-terminated string and set the length parameter to `SQL_NTS` (Null-Terminated String).

`outstr` – can extract status of data source and its attributes.

`outstrlen` – records the buffer length.

`SQL_DRIVER_NOPROMPT` disables user interaction.

When the connection to the data source is established, `SQLDriverConnect()` will return the actual connection string that was used in `OutConnectionString`.

5.6.2 Transactions

So far, each SQL statement has been atomic, i.e., each statement can stand on its own and if one fails, others are not affected and the database is left in a consistent state. By default, ODBC is in "auto-commit" mode, where each statement is either committed as soon as it succeeds or rolled back if it fails.

SQLTransact

It requests a commit or rollback operation for all active operations on all statements associated with a connection. SQLTransact can also request that a commit or rollback operation be performed for all connections associated with the environment.

Prototype of `SQLTransact`:

```
RETCODE  SQLTransact(env,dbc,ftype);
```

`env` : input environment variable.
`dbc` : input connection handle
`ftype` : input one of the following two values : `SQL_COMMIT`, `SQL_ROLLBACK`.

When you connect to a database, a transaction starts automatically; you can execute as many SQL statements as you need. Once these SQL statements are processed, if you want to commit a transaction, which means all changes made by

DML statements will be reflected in the table, call `SQLTransact` with the option `SQL_COMMIT`. In order to abort a transaction, replace SQL_ROLLBACK with SQL_COMMIT.

ODBC Commit Modes:

In ODBC, transactions can be handled in two different ways. The connection can be set to either auto-commit mode (the default) or manual-commit mode. The commit mode for a Connection is set by calling `SQLSetConnectAttr( )` with the `SQL_ATTR_AUTOCOMMIT` option.

Auto-commit Mode – The default mode for a new connection is auto-commit, which is supported by all drivers. In this mode, each statement operates as a separate transaction; the driver will take care of committing each operation on the database automatically.

If you submit a batch of SQL statements in a single `SQLExecute()` call, ODBC doesn't define whether this is treated as a single transaction or each statement is a separate transaction. If you want to send a batch as a transaction, use manual-commit mode.

Manual-Commit Mode – In cases where you want to ensure that multiple SQL statements be executed as ONE transaction, you should use manual-commit mode, which requires the application to explicitly end the transaction with a call to `SQLEndTran()`.

```
ret = SQLSetConnectAttr(dbc, SQL_ATTR_AUTOCOMMIT,
(void*)SQL_AUTOCOMMIT_OFF, SQL_IS_UINTEGER);
```

Applications can specify the transaction mode with the `SQL_ATTR_AUTOCOMMIT` attribute. `SQL_AUTOCOMMIT_OFF` changes to manual commit mode.

To commit or roll back a transaction in manual-commit mode, an application calls `SQLEndTran`.

5.6.3 Create Table

Refer to ODBCman2.c for the source code

Once the connection is established you can execute the SQL statements against the connected data source.

Statement Handles: Before executing a statement, you must allocate a statement handle, which provides a data structure for ODBC to keep track of the SQL statement to be executed and the results it will return.

```
SQLHSTMT  stmt;
ret  =  SQLAllocHandle (SQL_HANDLE_STMT, dbc,
&stmt);
```

`SQL_HANDLE_STMT`– handle type should be set to `SQL_HANDLE_STMT`

`dbc` – InputHandle should receive a previously allocated connection handle

`&stmt` – OutputHandle should point to a new handle of type SQLHSTMT that will be initialized.

In our examples, you will use `SQLExecuteDirect()` function for DDL Statements like creating or dropping tables as these statements will execute. On the other hand `SQLPrepare` and `SQLExecute` functions for DML Statements as they will be executed multiple times.

`SQLExecDirect():`

For statements that will be executed only once, this is the fastest method of submitting SQL statements.

```
SQLCHAR  table[100] = "create table emp(eid int,
ename char(20),salary  float)";
ret =  SQLExecDirect (stmt, table, SQL_NTS);
```

This function simply takes a null-terminated string (`table`) containing an SQL statement and executes it on the data source connected to the statement handle (`stmt`). The length parameter is set to SQL_NTS.

If `SQLExecDirect( )` returns `SQL_SUCCESS`, then the statement was successfully executed against data source otherwise it returns `SQL_ERROR`.

5.6.4 Insert records into the table.

Refer to ODBCman3.c for the source code.

In the last session you saw "`emp`" table has been created with three fields. This table is present in the CSQL database. Now, you can insert some records in it using the appropriate APIs.

The stages for Inserting Records:

- Prepare
- Bind buffers
- Execute the Prepared Statement
- Commit the Transaction

Prepare the Statement

During the statement preparation, the ODBC standard SQL grammar which is passed to `SQLPrepare()` is translated into SQL for the data source.

ODBC allows the preparation of a statement prior to its submission, to facilitate the parsing and creation of the query plan once, which can subsequently be re-used multiple times with different parameters each time. This as earlier stated enhances efficiency.

```
ret = SQLPrepare(stmt,(unsigned char*)"insert
into emp values(? ,?,?);", SQL_NTS);
```

This function takes a statement `(stmt)` handle as its first parameter which is previously allocated with `SQLAllocHandle();` the second parameter is a pointer to null terminated string that contains the `INSERT` statement. `SQL_NTS` is the last parameter for text length.

Bind buffer

The `SQLBindParameter()` function allows to bind a buffer in memory to a given parameter marker, prior to the execution of the statement.

```
int eid1 =  1001;
char ename1[20] = "Ritish";
float  salary1 = 2500;
size_t slen=strlen(ename1);

ret = SQLBindParameter(stmt, 1, SQL_PARAM_INPUT,
SQL_C_SHORT, SQL_INTEGER, 0, 0, &eid1, 0, NULL);

ret = SQLBindParameter(stmt, 2, SQL_PARAM_INPUT,
SQL_C_CHAR, SQL_CHAR, 196, 0, (void*)ename1,
slen, NULL);

ret = SQLBindParameter(stmt, 3, SQL_PARAM_INPUT,
SQL_C_FLOAT, SQL_REAL,  0, 0,  &salary1, 0,
NULL);
```

The 1st parameter - `stmt` refers to the statement handle that you are using to execute the SQL statement.

2nd parameter specifies the parameter position in the SQL Statement. The positions are numbered as 1, 2, 3, …etc from left to right.

The `SQL_PARAM_INPUT` parameter specifies how the parameter is used – input to write value to the field, `SQL_PARAM_OUTPUT` to read value from the field.

The 4th parameter is the `ValueType` parameter. This is a C type Identifier. ODBC defines many standard data types. There are C data types – used in the application code, and SQL data types – used to describe the type of data that is used within the data source. Many of the ODBC calls that move data from the application to the data source, or vice versa, can perform implicit type conversion.

Here you have used `SQL_C_SHORT, SQL_C_CHAR, SQL_C_FLOAT` for the corresponding fields – `eid, ename, salary` which are represented at the data source level by the SQL type identifiers – `SQL_INTEGER, SQL_CHAR, SQL_REAL` for this three field.

Parameters 6 and 7 are used to specify the size of the SQL parameter and its precision.

Parameter 8 is points to the buffer in the application that holds the value to be substituted in the SQL Statement,

Parameter 9 is used to pass the length of the buffer for binary or character parameters.

Parameter 10 is usually set to NULL pointer or pointer to length of the buffer for binary or character parameters. If it is set to NULL pointer, the driver assumes that all input parameter values are non-NULL and that character and binary data is null-terminated. This is not used internally in CSQL. So it is usually set to NULL in CSQL.

Executing SQL Statements

After the statement is prepared by `SQLPrepare( ),` you can execute the statement by calling `SQLExecute( ).`

```
ret = SQLExecute(stmt);
```

The `SQLExecute()` executes a prepared statement, using the current values of the parameter marker variables.

Commiting the transaction

After inserting the data into the database, committing it will make sure that all the records inserted will be present in the database permanently.

```
ret = SQLTransact (env, dbc, SQL_COMMIT);
```

5.6.5 Fetch the records

Refer to ODBCman4.c for the source code.

The result set returned by a query is like a temporary table. These rows can be retrieved from the result set using cursors, which come in several different flavors. The default cursor used in ODBC is a forward-only cursor, which allows to access the rows in the result set only one row at a time.

The stages for Fetching:

- Prepare
- Bind buffer for column values
- Execute the prepared statement
- Fetch the row values.
- Close the cursor

Prepare the statement

It's the same as in the previous section.

```
ret = SQLPrepare(stmt,(unsigned char*)"select * 
from emp",SQL_NTS);
```

Binding Columns

This is done to assign the memory location into which a column's data would be copied when the row is fetched. In most cases, the best way to retrieve data from a result set is to bind the columns to specific memory locations / buffers that you have bound for that column.

This is done using `SQLBindCol()`.

```
ret=SQLBindCol(stmt,1,SQL_C_SHORT,&eid1,0,NULL);

ret=SQLBindCol(stmt,2,SQL_C_CHAR,ename1,
sizeof(ename1),NULL);

ret= SQLBindCol(stmt,3,SQL_C_FLOAT,&salary,
```

```
0,NULL);
```

The `SQLBindColumn()` is called once each for the 3 fields.

The 2nd parameter is the field identifier to be bound. As mentioned earlier the number is from left to right in the table structure.

The 3rd parameter specifies the target data type.

The 4th parameter is the buffer or memory location which will holding the data being read from that field.

Parameter 5 is the sizeof the memory location or buffer.

Parameter 6 is the pointer to the length/indicator buffer to bind to the column. This is an input/output parameter and is not used internally in CSQL. So it is usually set to NULL in CSQL.

Execute the Statement

The SQL statements prepared before are executed.

```
ret = SQLExecute(stmt);
```

Fetch the results

The next step is to fetch the rows from the result set. `SQLFetch()` fetches the next row-set of data from the result set and returns the data for all bound columns.

The application here calls `SQLFetch()` to retrieve the first row of data and place the data from that row in the variables bound with `SQLBindCol()`.

```
while(SQL_SUCCEEDED(ret = SQLFetch(stmt)))
 {
      printf("eid = %d  ename = %s salary = %f",
eid1,ename1,salary);
       count++;
  }
```

If you want to get the row count of a result set, simply scroll through it using `SQLFetch()` until no more records are found.

Closing the cursor

When you call a function that creates a result set, such as `SQLExecute(), a` cursor is opened, when you are finished working with the result set, you should close the cursor and free the memory by using `SQLCloseCursor( ).`

```
ret = SQLCloseCursor(stmt);
```

5.6.6 Update Records

Refer to `ODBCman5.c` for the source code.

You can make changes to the tables by executing UPDATE statements. Update statements are often more efficient when they are used with parameters.

The Stages for update:

- Prepare the statement
- Bind a Buffer.
- Execute the Prepared Statement
- Commit the Transaction.

Prepare Statement

For example, the following statement can be prepared and repeatedly executed to update rows in the `emp` table.

```
ret = SQLPrepare(stmt,(unsigned char*)"update emp
set eid=?,salary=? where eid = ?;",SQL_NTS);
```

Bind the parameters

You have to bind the parameters with the help of `SQLBindParameter()` function.

```
ret= SQLBindParameter(stmt,1,SQL_PARAM_INPUT,
SQL_C_SHORT,SQL_INTEGER,0,0,&eid1,0,NULL);

ret= SQLBindParameter(stmt,2,SQL_PARAM_INPUT,
SQL_C_FLOAT,SQL_REAL,0,0,&salary1,0,NULL);

ret = SQLBindParameter(stmt,3,SQL_PARAM_INPUT,
SQL_C_SHORT,SQL_INTEGER,0,0,&eid2,0,NULL);
```

Execute the statement

```
ret = SQLExecute(stmt);
```

`SQLExecute()` executes a prepared statement, using the current values of the parameter marker variables if any parameter markers exist in the statement.

Commit the transaction

```
ret = SQLTransact(env,dbc,SQL_COMMIT);
```

5.6.7 Delete Records

Refer to the `ODBCman6.c` for the source code.

The stages for Delete:

- Prepare the statement
- Bind a Buffer.
- Execute the Prepared Statement
- Commit the Transaction.

Prepare statement

```
ret = SQLPrepare(stmt,(unsigned char*)
"delete from emp where eid = ?;",SQL_NTS);
```

Bind the Parameters

```
ret = SQLBindParameter(stmt,1,SQL_PARAM_INPUT,
SQL_C_SHORT,SQL_INTEGER,0,0,&eid1,0,NULL);
```

Execute the statement

```
ret = SQLExecute(stmt);
```

After binding the value you execute the statements using the current value of the parameter marker.

Commit the transaction

Committing permanently deletes the records from the table.

```
ret = SQLTransact(env,dbc,SQL_COMMIT);
```

5.6.8 Drop the Table

Refer to the `ODBCman6.c` for the source code.

The SQL Statement `drop table emp;` will drop the mentioned table. As this is a one time activity, we might use the `SQLExecDirect()` function (it is the same for all DDL statements).

```
ret = SQLExecDirect(stmt  ,  (unsigned
char*)"drop table emp;" , SQL_NTS);
```

5.6.9 Freeing Handles and Disconnect from the CSQL

There is the `SQLFreeHandle()` to free up a handle and its associated resources.

Note that handles generally need to be freed in the opposite order to which they were allocated and that handles cannot be freed if they are in use.

In section 5.5.1, we discussed about the each and every parameters of `SQLFreeHandle()`

```
ret = SQLFreeHandle(SQL_HANDLE_STMT,stmt);

ret - SQLDisconnect(dbc);

ret = SQLFreeHandle(SQL_HANDLE_DBC,dbc);

ret = SQLFreeHandle(SQL_HANDLE_ENV,env);
```

6. SQL API

This section explains various interfaces in SQL API and their references along the way, which would help in writing applications to access the CSQL database.

Let us start with an example where you create a table in the CSQL database to store employee details, say

```
table EMP (int empId, char name(20), float sal).
```

The following sections describe how to connect to the database, how to create a table, how to insert, update and delete tuples in the table and how to drop the table.

6.1 Connect to the Database

Refer `manSQLAPIinsert.c` for the source to understand how the SQL API works.

First of all you need to create the connection with the database which is done by the following classes – `SqlFactory`, `AbsSqlConnection`

```
AbsSqlConnection *con = SqlFactory::createConnection(CSql);

rv = con->connect("root", "manager");
```

The first one declares an `SqlConnection` object that helps to connect with the CSQL databaseas is evident from the argument CSql.

The second class actually connects the user to the database using the `createConnection()` method.

6.2 Create and Set the statement for the connection

At this stage the `SqlStatement` object is created and set to the `SqlConnection` object as follows.

```
AbsSqlStatement *stmt =
SqlFactory::createStatement(CSql);

stmt->setConnection(con);
```

The first instruction declares the `SqlStatement` object that helps in preparing and executing the SQL statements to carry out the DDL and DML operations.

The second one sets the `SqlConnection` to let the `SqlStatement` talk to the database.

6.3 Create the table

Now you should prepare the sql statement to create the table into the CSQL database.

6.3.1 Prepare Statement

The statement is prepared by the following function.

```
rv = stmt->prepare(statement);
```

Where `statement` is a memory location pointing to the string holding the SQL statement that needs to be prepared for execution.

Make sure that you have the SQL statement to prepare and execute before calling the above function. Preparation of the statement, is done by allocating memory for statement and copying the create table statement into the memory.

```
char statement[200];
```

```
strcpy(statement, "CREATE TABLE EMP(EID INT,ENAME
CHAR(20), SALARY FLOAT);");
```

Prepare sets all that need to be done to execute the statement, internally. In this scenario it will set the type of statement, which is Create Table, sets the table name, name of fields, and their types and size based on the data types specified in the statement.

6.3.2 Execute the Statement and release the memory

Once preparation is done its time to execute the statement. This is done as follows –

.

```
stmt->execute(rows);
```

It executes the SQL statement, internally and does the required job.

You can release the memory by calling

```
stmt->free()
```

This releases all the memory that was allocated internally for the `SqlStatement` object. This must be done, otherwise it might lead to memory leaks for long running processes.

6.4 Insert tuples into the table

Now let us insert some tuples into the table EMP.

6.4.1 Prepare the statement

You first copy the `INSERT` SQL statement into a memory location and pass the address of that memory location to the prepare function –

```
strcpy(statement,"INSERT INTO EMP
VALUES(?,?,?);");

...

rv = stmt->prepare(statement);
```

If you notice the statement above, the values are given as three '?'s separated by commas. This is called "**parameterizing**" the fields of the table in the order mentioned during the definition of the table.

6.4.2 Start the transaction

For any operation to take place in the table like `INSERT, UPDATE, DELETE or SELECT`, a transaction needs to be started. This is done as below –

```
con->beginTrans();
```

6.4.3 Parameterize the fields

You need to tell the `SqlStatement` object to pick the values from an allocated area of memory and you need to parameterize all the three fields in the table as per our requirement in the example. It is done as show below –

```
stmt->setIntParam(1, eid);
stmt->setStringParam(2, ename);
stmt->setFloatParam(3, salary);
```

All three are functionally similar except for the fact that is for varying types of data. The 1st argument is the position of the '?' in the `INSERT` statement starting from 1 and the 2nd argument is the memory location from where the value for the field is picked up during execution

In our example, the 1st parameter to be inserted is `integer`, 2nd one is String and 3rd one is float type, hence the function calls are in that order.

Suppose if the statement were to be

```
“insert into EMP values(?, 'Kishor', 123.0);”
```

There is only one field to be parameterized and that should have been the integer type with position number 1.

If the statement were to be

```
“insert into EMP values(eid, ?, ?);”
```

There are two fields to be parameterized and that should be String and Float type with position numbers 1 and 2 respectively.

6.4.4 Execute the insert statement

The inserting of a row is done one row at a time by the following function.

```
stmt->execute(rows);
```

This function receives an argument `rows`, which is a reference variable populated by the `execute` function. This is always 1 if successful. Since this is an insert statement and always one row is inserted at a time.

In the example you have called this function in a loop so as to insert 10 rows.

6.4.5 Commit the transaction

After inserting 10 rows you can commit the transaction by using

```
con->commit();
```

The release the memory by calling

```
stmt->free() ;
```

This releases all the memory that was allocated internally for the `SqlStatement` object. As already mentioned, if this is not done, it might lead to memory leaks.

The first 3 rows in the table EMP look like this logically when you compile and run `manSQLAPIinsert.c`

Table: EMP

empId	name	salary
1001	Praba	1000.00
1002	Kishor	2000.00
1003	Jiten	3000.00

6.5 Read the tuples (rows) from the table

6.5.1 Read tuples from the table.

Now let us read all the tuples that were last inserted into the table. For that the statement `SELECT * FROM EMP;` needs to be prepared.

6.5.2 Prepare the statement

```
strcpy(statement," SELECT * FROM EMP;");
rv = stmt->prepare(statement);
```

6.5.3 Bind the fields

```
stmt->bindField(1, &eid);
stmt->bindField(2, ename);
stmt->bindField(3, &salary);
```

Since the query projects all fields using `*`, the entire field values are to be fetched from the table according to the sequence they are in the table, the first parameter

being the column position in the tuple and second parameter being the memory location to store the fetched values.

Supposing the statement was to look like `select EID, ENAME from EMP;` Then the binding would take place for only two parameters EID and ENAME with param position 1 and 2 respectively.

```
stmt->bindField(1, &eid);
stmt->bindField(2, ename);
```

Supposing the statement was to look like `select SALARY, ENAME from EMP;` .Then the binding should take place for only two parameters SALARY and ENAME with param position 1 and 2 respectively.

```
stmt->bindField(1, &salary);
stmt->bindField(2, ename);
```

6.5.4 Begin transaction and execute the statement

Any DML operation needs to start a transaction and the following statement does it

```
con->beginTrans();
```

Now execute the statement by calling the following function.

```
stmt->execute(rows);
```

This will set the condition for fetching the required tuples and initialize the appropriate iterations for picking up the tuples.

6.5.5 Fetch the tuples

Calling the `fetch()` function will return the address of each tuple in the database. Fetch will also copy the values from the database to the bound locations.

```
stmt->fetch();
```

Fetch will return one tuple at a time that satisfies the condition set in the statement. Here you have selected all the tuples hence it should show all the tuples present in the table. After fetching all the tuples commit the connection using

```
conn->commit();
```

6.6 Update some tuples

Now let us update some of the tuples in table EMP.

Refer `manSQLAPIupdate.c which updates the tuples where EID =1001, 1003, 1005.` To update the tuples you need to repeat the Section 6.1 and 6.2.

Prepare the SQL statement – `"Update EMP SET SALARY, ENAME where EID = ?;`

This statement is prepared using

```
stmt->prepare(statement);
```

Begin the transaction by calling

```
con->beginTrans();
```

Now call

```
stmt->setIntParam(1, eid);
stmt->setStringParam(2, ename);
stmt->setFloatParam(3, salary);
```

Respectively corresponding to the order of their appearance.

Now call

```
stmt->execute(rows);
```

To execute the prepared statement

Now commit the transaction.

```
conn->commit();
```

Check for the updated values (as per section 6.5) by creating another select statement after freeing the current one.

6.7 Delete tuples

Refer `manSQLAPIdelete.c` which `deletes the tuples where EID > 1006.`

To delete the tuples you need to repeat the Section 6.1 and 6.2.

Prepare the statement as explained in Section 6.5.1. The statement for this one would be – `Delete from EMP WHERE EID > 1006;`

This statement is prepared using

```
stmt->prepare(statement);
```

The transaction would have been started using

```
con->beginTrans();
```

Now call

```
stmt->execute(rows);
```

Finally commit the transaction

```
conn->commit();
```

All the required fields are deleted based on the condition.

Check for the deleted values by creating another select statement after freeing that statement.

7. DB API

This section explains various interfaces in DB API and their references along the way, which would help in writing applications to access CSQL database directly through the storage engine.

Let us start with an example where you create a table in the CSQL database to store employee details, say `table EMP (int empId, char name(20), float sal).`

The following sections describe how to connect to the database, how to create a table, how to insert, update and delete tuples in the table and how to drop the table.

7.1 Connect to the database

Refer to `manDBAPIinsert.c`

Firstly you need to create a Connection object and open the connection as follows.

```
Connection conn;
rv = conn.open("root", "manager");
```

This will connect the application to the database. The return value `rv` is defined as an enumerator. The parameters "`root`" and "`manager`" are the username and password respectively. The return value of OK defines success and the rest are errors. Refer `ErrorType.h` for list of error codes.

7.2 Database Manager creates the table

To create the table you need the `DatabaseManager`, which is required to create, open, close and drop the table.

7.2.1 Get the DatabaseManager

```
DatabaseManager *dbMgr =
conn.getDatabaseManager();
```

7.2.2 Define the table

Before creating the table you need to define the table and to do that you need to create a `TableDef` object. The `TableDef` object will have all the information that a table should have.

Call the `addField` function as many times as there are fields in the table with appropriate parameters as follows.

```
TableDef tabDef;
tabDef.addField("empId", typeInt, 0, NULL, true);
tabDef.addField("name", typeString, 20);
tabDef.addField("salary", typeFloat);
```

Here `addfield` is the overloaded function with the parameters being `name, type, length, defaultValue and notNull.`

By default
`length` is 0 for known type of fields like integer, float etc.
`defaultValue` value is NULL.
`notNull` is false.

Here `empId` field is the field with primary key hence `notNull` parameter is true.

7.2.3 Create table

Now the table can be created with a name as follows

```
rv = dbMgr->createTable("EMP", tabDef);
```

`EMP` is the table name and since `tabDef` object has all the field information, passing the object as reference to the `dbMgr` will be sufficient to create the table.

7.2.4 Create index for primary key field

Primary key is created whenever a field is unique, which means that the field cannot have duplicate values. In our example `empId` will be the field with primary key value, for obvious reasons. Primary key is created using following lines of code.

```
HashIndexInitInfo *idxInfo = new
HashIndexInitInfo();
strcpy(idxInfo->tableName, "EMP");
idxInfo->list.append("empId");
idxInfo->isUnique = true;
idxInfo->isPrimary = true;
idxInfo->indType = hashIndex;
```

`HashIndex` is used for point look-ups for conditions like `empId = 1005` etc on primary key fields during retrieval of records.

The object is initialized with rest of the details and the `DatabaseManager` finally creates the index with the following function.

```
rv = dbMgr->createIndex("indx1", idxInfo);
```

7.3 Insert tuples into the table

The table has been created in the last section. Let us insert some tuples into the table.

7.3.1 Open the table

To insert tuples into the table you need to first open the table and store the table handle, which is done as follows

```
Table *table = dbMgr->openTable("EMP");
```

The Database Manager opens the table and the table name `EMP` is the parameter to it. It returns the table handle, which is stored in `table` variable.

7.3.2 Bind each field of the table

The table in the database needs to know from where to fetch the data for each field in the table.

```
table->bindFld("empId", &id1);
table->bindFld("name", name);
table->bindFld("salary", &sal);
```

`bindFld` is called by the table handle and it will give the address of the memory location from where the data can be fetched for each field in the table.

7.3.3 Start the transaction

For any operation to take place in the table like inserting, selecting, updating and deleting, a transaction needs to be started.

```
conn.startTransaction();
```

The above function is called using Connection object. To call this function a connection should be open. One connection can have only one transaction. To start any other transaction for this connection the current transaction should either be committed or rolled back.

7.3.4 Insert the tuples

Now as the connection is started you can insert some records in the table.

```
rv = table->insertTuple();
```

Before calling this function, make sure that you have the desired values stored in the fields that have been bound by `bindFld` function.

7.3.5 Commit the transaction

After inserting all the rows, commit the transaction by calling the following function.

```
conn.commit();
```

Remember any modification operation to the table has to be done between `startTransaction` and the `commit` / `rollback` functions of `Connection` class.

Now all the rows are inserted into the ‘EMP’ table and, it would look like

Table: EMP

empId	name	salary

1001	Praba	1000.00
1002	Kishor	2000.00
1003	Jiten	3000.00

7.4 Read the tuples from the database

Now let us read the tuples that you have inserted in the last section.

7.4.1 Set and execute condition to read all the inserted tuples

To read the tuples you need to set the condition to get all the tuples. This is done by the following function.

```
table->setCondition(NULL);
rv = table->execute();
```

The `setCondition` function is called with the address of `Condition` object. Here the function is called with `NULL`, which means you set no condition and the table should return all the tuples. You will see how to set condition in a later section. The `execute` function sets the information about how to go about fetching the tuples that satisfy the given condition.

7.4.2 Fetch the tuples

Now the table is all ready to fetch the tuples. It is done by the following function.

```
tuple = (char*)table->fetch();
```

The `fetch` function traverses through each of the tuples in the table and returns the address of the first tuple that satisfies the condition.

It will fill the values of each field in the memory area bound earlier by `bindFld` function. You can rebind those fields with some other memory location if you wish by calling `bindFld` again.

Make sure you start the transaction to read the tuples and ultimately commit or rollback to complete the transaction.

7.5 Update some of the tuples

Now let us update some of the tuples in table EMP. Refer `manDBAPIupdate.c`. As usual to update the tuples, you need to open the table with the help of Database Manager and the Table handle.

7.5.1 Set a condition to update the tuples

Create a `Condition` object.

Call `setTerm` on that object to prepare the condition.

```
Condition p1;
int val1 = 1006;
p1.setTerm("empId", OpLessThan, &val1);
```

`setTerm` is an overloaded function which has four types.

```
void setTerm(const char* f1, ComparisionOp op,
const char *f2);
```

To handle comparisons between two fields such as f1 & f2, etc.

```
void setTerm(const char* f1, ComparisionOp op, void
*opnd);
```

To handle comparisons where operand `opnd` is a costant such as f1 =5, etc.

```
void setTerm(Predicate *p1, LogicalOp op,
Predicate *p2 = NULL);
```

To handle conditions where two or more logical comparisons like f1 < 5 and f2 > 7, etc

In our example, the second type is called by the `Condition` object on `empId` field.

The second and third parameters are the type of comparison and the operand used for that comparison. Here you used `OpLessThan` and `val1` as the parameters for the condition `empId < 1006`.
Now `setCondition` is called by table object with the Condition object as the parameter. (Table.h).

Now the condition for Update is set.

7.5.2 Start transaction and be prepared to update

Since you are doing an operation on the table you need to start a transaction first by calling

```
conn.startTransaction();
```

Then you call

```
table->execute()
```

as you did in last section to set up the table for scanning.

```
conn.startTransaction();
rv=table->execute();
```

7.5.3 fetch and update the tuples

Now you fetch tuples that satisfy the above set condition by calling `fetch`.

```
tuple = (char*)table->fetch();
```

Remember `fetch` will populate the values of each field in the tuple with the memory location that was bound earlier by calling `bindFld`.

The tuples are now fetched for the condition `empId < 1006`
Now you can easily update the values as needed by the application as depicted by the following code by updating the values in the bound memory.

```
if (id1 == 1001) {
      strcpy(name,"Shubha");
      sal = 1111.00;
      table->updateTuple();
}
```

Now the tuples are updated where id1 = 1001, 1003 and 1005.

Once after updation transaction should be commited by calling `conn.commit()`. In the source the values are read again as explained in Section 7.4 to test for the updation.

7.6 Delete some of the tuples

Refer `manDBAPIdelete.c` for the source.

Deleting tuples is exactly similar to the way you update the tuples. You call

```
table->deleteTuple()
```

Finally the table is closed and it is deleted from the database by calling

```
dbMgr->dropTable("EMP");
```

8. CSQL as cache for MySQL database

In keeping with its design goals, CSQL MMDB shall also act as middle-tier data cache for any disk resident database. In this section we outline and demonstrate how CSQL can be configured to work as data cache for MySQL database.

CSQL Cache is a high performance, bi-directional updateable data-caching infrastructure that sits between the clustered application process and back-end data sources to provide unprecedented high throughput to your application by offloading the computing cycles from expensive backend systems along with reduction in costly network calls, thereby enabling real time application to provide faster and predictive response time.

CSQL Cache uses the fastest Main Memory Database (CSQL MMDB) designed for high performance and high volume data computing for caching the table and provides most flexible and cost-effective way to cache and manage enterprise information without compromising on transactional and indexed access to the data. This main memory database is 10-20 times faster than traditional disk based database system as the database completely resides in main memory and developed to be used on real time high computing data platforms.

Functionalities of the CSQL cache are listed below.

8.1.1 Updateable Cache Tables

Most of the existing cache solutions are read only which limits their usage to small segment of the applications, non-real time applications.

8.1.2 Bi-Directional Updates

For updateable caches, updates, which happen in cache, should be propagated to the target database and any updates that happen directly on the target database should come to cache automatically.

8.1.3 Synchronous and Asynchronous update propagation

The updates on cache table shall be propagated to target database in two modes. Synchronous mode makes sure that after the database operation completes the updates are applied at the target database as well. In case of Asynchronous mode the updates are delayed to the target database.
Synchronous mode gives high cache consistency and is suited for real time applications. Asynchronous mode gives high throughput and is suited for near real time applications.

8.1.4 Multiple cache granularity

CSQL supports Table level and Result-set caching. Major portions of corporate databases are historical and infrequently accessed. But, there is some information that should be instantly accessible like premium customer's data, etc

8.1.5 Recovery for cached tables

Incase of system or power failure, during the restart of caching platform all the committed transactions on the cached tables should be recovered.

8.1.6 Tools to validate the coherence of cache

In case of asynchronous mode of update propagation, cache at different cache nodes and target database may diverge. This needs to be resolved manually and the caching solution should provide tools to identify the mismatches and take corrective measures if required.

8.1.7 Horizontally Scalable

Clustering is employed in many solutions to increase the availability and to achieve load balancing. Caching platform should work in a clustered environment spanning to multiple nodes thereby keeping the cached data coherent across nodes.

8.1.8 Transparent access to non-cached tables reside in target database

Database Cache should keep track of queries and should be able to intelligently route to the database cache or to the origin database based on the data locality without any application code modification.

8.1.9 Transparent Fail over

There should not be any service outages, incase of caching platform failure. Client connections should be routed to the target database.

No or very minimal changes to application for the caching solution.

Support for standard interfaces JDBC, ODBC etc that will make the application to work seamlessly without any application code changes. It should route all stored procedure calls to target database so that they don't need to be migrated.

Caching happens at table level granularity in CSQL, which means that the tables, which are frequently accessed by the applications, shall be specified in CSQL configuration file (csqltable.conf), which will be loaded into CSQL during the `csqlserver` startup. Once these tables are loaded, they are treated like normal CSQL tables and any DML operation is allowed on these tables.

The difference between normal CSQL table and cached table is that, the DML operations `INSERT`, `UPDATE`, `DELETE` on cached tables are propagated to MySQL automatically by the CSQL server. For the application, they see only CSQL tables and CSQL takes care of propagating the updates internally to MySQL table.

Apart from caching the MySQL tables, CSQL also acts as a transparent gateway, which allows the application to access the tables, which are not cached in CSQL. This provides a unified interface to the applications and it does not need to deal with the location of the table, making the underlying database caching architecture transparent to the application layer.

8.2 Configuration

Configuration file, `csql.conf` has five parameters associated with caching. They can be found in the Cache section of the `csql.conf` file. They are `CACHE_TABLE`, `DSN`, `ENABLE_BIDIRECTIONAL_CACHE`, `CACHE_RECEIVER_WAIT_SECS` and `TABLE_CONFIG_FILE`.

- `CACHE_TABLE` is a boolean parameter which needs to be set to true when `csql` should cache tables from MySQL
- `DSN` is a string parameter, which needs to be set to the data source name of the MySQL ODBC driver specified in the `odbc.ini` file.
- `TABLE_CONFIG_FILE` is a string parameter which contains the complete path to the file which holds the cache table information
- `ENABLE_BIDIRECTIONAL_CACHE` is a boolean parameter which needs to be set to true when direct updates to MySQL needs to be brought into CSQL cache table automatically.
- `CACHE_RECEIVER_WAIT_SECS` is an integer parameter, which needs to be set to interval it waits if there are no update logs from the target database.

If `csql` needs to cache table `t1` and `t2`, then entries for `t1` and `t2` needs to be present in csqltable.conf file. Add the following lines to `TABLE_CONFIG_FILE` that is

```
1:t1
1:t2
```

A sample configuration file is present in the csql root directory. If you want to cache tables at run time, that is when csqlserver is running, then cachetable tool shall be used for that. Refer tool reference section for the syntax and usage.

The first field denotes the mode and it should be specified as always 1, which represents the update propagation mode for cached tables.

`1->` Synchronous mode (updates are propagated during the DML operation itself)
`2->` Asynchronous mode (logs are generated and propagated later for DML operations on cached tables).

This release currently supports only the synchronous mode of update propagation.

8.3 MySQL Configuration Settings

For CSQLCache to work you need to install the MySQL server, MySQL ODBC Connector, unixODBC packages on your system. Please make sure that these packages are installed in your system before you proceed.

Once you install `mysqlserver`, start the server by using the following command after logging in with user '`mysql`'

```
$/etc/init.d/mysqld start
```

After that you have to install MySQL ODBC connector, which contains the ODBC driver to connect to MySQL server. This shall be downloaded from the MySQL web site. Usually this library is named as `libmyodbc3.so`.

After this you need to install unixODBC package, which is the driver manager for ODBC drivers. Once you install unixODBC, copy the following lines into `~/.odbc.ini` file

```
[ODBC Data Sources]
myodbc3     = MyODBC 3.51 Driver DSN

[myodbc3]
Driver       = /home/csql/mysql-connector-odbc-
3.51.23-linux-x86-32bit/lib/libmyodbc3.so
Description  = Connector/ODBC 3.51 Driver DSN
SERVER       = localhost
PORT         = 3306
USER         = root
Password     =
Database     = test
OPTION       = 16
SOCKET       = /var/lib/mysql/mysql.sock
```

The above assumes that MySQL ODBC connector is installed at location

```
/home/csql/mysql-connector-odbc-3.51.23-linux-x86-
32bit
```

You can check whether you have configured MySQL ODBC driver correctly using the `isql` command

```
$isql myodbc3
It should display the following
+---------------------------------------+
| Connected!                            |
|                                       |
| sql-statement                         |
| help [tablename]                      |
```

```
| quit                                    |
|                                         |
+-----------------------------------------+
SQL>
```

If you get the above output, it means that you have configured the ODBC driver manager and MySQL ODBC connector properly and it can connect to MySQL server.

Create the tables in MySQL server so that they shall be cached in CSQL.

In the SQL prompt enter the following statements

```
SQL>CREATE TABLE t1 (f1 integer, f2 char (196),
primary key (f1));
SQL>CREATE TABLE t2 (f1 integer, f2 integer, primary
key (f1));
SQL>CREATE TABLE t3 (f1 integer, f2 integer, primary
key (f1));
SQL>INSERT INTO t1 (f1, f2) values (100, '100');
SQL>INSERT INTO t2 (f1, f2) values (102, 102);
SQL>INSERT INTO t3 (f1, f2) values (103, 103);
SQL>quit;
```

The above statements create tables namely t1, t2 and t3, which will be cached in CSQL later.

8.4 Starting the csqlserver

`csqlserver` supports `-c` option which loads the cached tables into CSQL during the startup. Before you run make sure that filename pointed to by `csql.conf` parameter `TABLE_CONFIG_FILE` contains the table names which needs to be loaded into CSQL.

Run the below command to cache the tables in CSQL server

```
$ csqlserver -c
```

8.5 Working with CSQL gateway

In another terminal run csql tool with -g option. This creates an isql session which acts as gateway to csql and mysql.

```
$ csql -g
```

It will show the CSQL prompt as follows

```
CSQL>
```

To retrieve records from table t1, enter the following statement in CSQL prompt.

```
CSQL>select * from t1;
```

It will display

```
------------------------------------------------------
        f1      f2
------------------------------------------------------
        100     100
```

It displays the values inserted into MySQL from CSQL.

You can also perform any DML operations on these cached tables, for example

```
CSQL>insert into t1 values (200, '200');
```

This will insert one record in CSQL as well as in MySQL. You can verify this by accessing MySQL through isql tool.

```
$isql myodbc3;
SQL>select * from t1;
+-----------+-----------------------------------------
----------------------------------------------------
----------------------------------------------------
-----------------------------------------------+
| f1        |f2
|
+-----------+-----------------------------------------
----------------------------------------------------
----------------------------------------------------
-----------------------------------------------+
| 100       | 100
|
| 200       | 200
|
+-----------+-----------------------------------------
----------------------------------------------------
----------------------------------------------------
-----------------------------------------------+
```

It displays both the records from MySQL database.

You can also retrieve records in tables, which are not cached in CSQL and are present in MySQL

```
$ csql -g
CSQL>select * from t3;
```

It will display

```
24083:3086153424:DatabaseManagerImpl.cxx:599:Table not
exists t3
24083:3086153424:SelStatement.cxx:245:Unable to open
the table:Table not exists
-------------------------------------------------------
---
        f1      f2
-------------------------------------------------------
---
        103     103
```

First it displays that the table is not present in `CSQL`, then it checks with MySQL whether the table is present there and if present it retrieves the records from MySQL.

8.6 Programming with CSQL gateway

You can find a JDBC sample program `gwexample.java` under the `examples/jdbc` directory. It will demonstrate how to use the CSQL gateway through Java programs.

Note: You shall also use gateway through JDBC and SQLAPI interfaces. The ODBC interface does not support gateway in this release.

From SQL API, use `CSqlGateway` to create connection and statement objects in `SqlFactory` class like below:

```
AbsSqlConnection *con = SqlFactory::
                    createConnection(CSqlGateway);

rv = con->connect("root", "manager");

if (rv != OK) return 1;
AbsSqlStatement *stmt = SqlFactory::
                    createStatement(CSqlGateway);

stmt->setConnection(con);

//---other statements follow----
```

8.7 Configuring Bi-Directional Cache

The default caching in CSQL is uni-directional caching, which means all updates (INSERT, UPDATE, DELETE) on cached tables will be automatically propagated to target database (MySQL). CSQL also supports bi-directional caching in which, direct updates on MySQL are propagated to CSQL cache automatically.

Bi-directional caching is implemented using triggers of the target database. This requires additional triggers, which needs to be installed on the tables in target database, which needs to be cached in bi-directional mode.
Sample trigger code is available in the file trigger.sql under the CSQL root directory.

Lets say for cached table ‘p1’ having primary key field ‘f1’, following is the format for creating the triggers in MySQL database.

```
use test;
drop trigger if exists triggerinsertp1;
drop trigger if exists triggerupdatep1;
drop trigger if exists triggerdeletep1;

DELIMITER |
create trigger triggerinsertp1
AFTER INSERT on p1
FOR EACH ROW
BEGIN
Insert into csql_log_int (tablename, pkid, operation)
values ('p1', NEW.f1, 1);
End;

create trigger triggerupdatep1
AFTER UPDATE on p1
FOR EACH ROW
BEGIN
Insert into csql_log_int (tablename, pkid, operation)
values ('p1', OLD.f1, 2);
Insert into csql_log_int (tablename, pkid, operation)
values ('p1', NEW.f1, 1);
End;
create trigger triggerdeletep1
AFTER DELETE on p1
FOR EACH ROW
BEGIN
Insert into csql_log_int (tablename, pkid, operation)
values ('p1', OLD.f1, 2);
End;
|
```

Note: Trigger name ends with the table name. Replace ‘p1’ in the above script to the cached table name and ‘f1’ to the primary key fieldname of the cached table.

After editing the trigger.sql file as per your need, you shall execute it by

$ mysql –u root –p <trigger.sql

Apart from the triggers, `ENABLE_BIDIRECTIONAL_CACHE` parameter in csql.conf should be set to true for bi-directional caching of tables.

9. Configuration

CSQL subsystem requires some system parameters that need to be set before starting CSQL database. Hence CSQL defines some of the system configuration variables that need to be defined. These configuration variables are defined in a file called `csql.conf`. Some of the parameters mentioned in this file may have to be tweaked based on the requirements.

The lines starting with # are ignored as comments and the rest are treated as configuration variables. All the other lines are read from this file during server start up.

These configuration variables are divided logically into following classes.

- **Server section variables**
- **Client section variables**
- **Cache section variables**

9.1 Server section variables

It is very important to note that for Server section parameters, the value should be the same for the server process and all the CSQL client processes, which connects to it. Otherwise, behavior is undefined.

9.1.1 PAGE_SIZE

Each database is logically divided into pages and allocation happens in this unit of pages. Increasing this value will reduce frequent allocation of pages. This value should be a multiple of 1024 bytes. This value may be set to the OS page size which is usually 8192 bytes.

9.1.2 MAX_PROCS

This is the number of process that can connect and work with the database concurrently. This value can be set anywhere between 10 and 8192 depending on the number of users who may access the database.

9.1.3 MAX_SYS_DB_SIZE

This is the maximum size of the system database where the metadata are stored. The value can be anywhere between 1 MB and 1GB. It should be multiples of PAGE_SIZE.

9.1.4 MAX_DB_SIZE

This is the maximum size of the user database where user data are stored. This value can be set anywhere between 1MB and 2GB. It should be multiples of PAGE_SIZE.

9.1.5 SYS_DB_KEY

Shared memory key to be used by the system to create and locate system database. The value can be anywhere between 10 and 8192.

9.1.6 USER_DB_KEY

Shared memory key to be used by the system to create and locate user database. The value can be anywhere between 10 and 8192. This should not be the same as SYS_DB_KEY.

9.1.7 LOG_FILE

Full path of the directory where the important CSQL system specific log files are created. Make sure that this directory exists before you start the server.

9.1.8 MAP_ADDRESS

This is the virtual memory start address at which the shared memory segment will be created and attached.

9.2 Client section variables

9.2.1 MUTEX_TIMEOUT_SECS

Mutex timeout interval in seconds. When requesting for mutex, if it is acquired by anybody else, then the requester will wait for this specified time interval before it checks whether it is released.

9.2.2 MUTEX_TIMEOUT_USECS

Mutex timeout interval in microseconds. The cumulative of the seconds and microseconds set will be used for the mutex timeout.

9.2.3 MUTEX_TIMEOUT_RETRIES

Number of retries before csql gives mutex timeout error.

9.2.4 LOCK_TIMEOUT_SECS

Lock timeout interval in seconds. When requesting for lock, if it is acquired by anybody else, then the requester will wait for this interval before it checks whether it is released.

9.2.5 LOCK_TIMEOUT_USECS

Lock timeout interval in microseconds. The cumulative of the seconds and microseconds set will be used for the lock timeout.

9.2.6 LOCK_TIMEOUT_RETRIES

Number of retries before csql gives lock timeout error.

9.3 Cache section variables

9.3.1 CACHE_TABLE

Enables the caching of tables from the target database. Default value is false.

9.3.2 DSN

DSN Name to connect to the target database. This name should be present in the `odbc.ini` file with the respective ODBC library specified in it.

9.3.3 TABLE_CONFIG_FILE

File name where the cached table information is stored. Specify the file name with full path.

9.3.4 ENABLE_BIDIRECTIONAL_CACHE

Enables the bi-directional caching for cached tables. Direct updates to MySQL will be brought into CSQL cache table automatically making cache coherent.

9.3.5 CACHE_RECEIVER_WAIT_SECS

Interval it waits if there is no update logs from the target database for bi-directional caching.

10. Tool reference

CSQL provides certain tools to access data from CSQL database. These are

- `csql`
- `catalog`
- `csqldump`

10.1 CSQL

CSQL provides a tool called csql, which is a sub-shell used to access the CSQL database. It supports most of the standard SQL statements.

Type `csql` to run CSQL sub shell. Make sure that `csqlserver` is running prior to running this tool.

```
$ csql
CSQL>
```

Once you have the CSQL prompt the tool is ready to access the database.

10.2 Catalog

`Catalog` is a tool, which provides the information about system metadata and user metadata of tables stored in the CSQL database.

```
catalog [-u username] [-p password] [-l]
[-i] [-d] [-T table]
[-I index] [-D <lock|trans|proc>]
```

Options:

`-u username`	username of the user
`-p password`	password of the user
`-l`	lists all the tables with field information
`-i`	reinitialize catalog tables dropping all the tables
`-d`	prints the database usage statistics for system and user database
`-T table`	prints the table information
`-I index`	prints the index information
`-D lock | trans | proc`	prints debug information for system tables

If the username is not mentioned then it will list all the tables with only their names.

If multiple options are specified then only the last option is considered for processing.

Let us understand some of the outputs of the command.

You create two tables in the database as follows with the help of CSQL tool.

```
$ csql

CSQL> create table t1(f1 int, f2 char(20), f3
float);
Statement Executed

CSQL>create table emp(eid int, name char(20), sal
float);
statement Executed

CSQL>quit;
```

We have two tables, `t1` and `emp` created. Let us see how the `catalog` tool displays the details of the two tables.

```
$ catalog -l
  <TableNames>
     <TableName> t1 </TableName>
     <TableName> emp </TableName>
  </TableNames>
```

This is a default behavior as mentioned before since there is no username provided.

```
$ catalog -u root -p manager -l
```

This will list all the tables with field information and index information

```
$ catalog -u root -p manager -d
```

This will print the database usage statistics

```
$ catalog -u root -p manager -T <table-name>
```

This will list Field and Index information of the table specified.

```
$ catalog -u root -p manager -I <index-name>
```

This will list index information of the index specified.

```
$ catalog -u root -p manager -D proc
```

This will list process table information

```
$ catalog -u root -p manager -D lock
```

This will list lock table information

```
$ catalog -u root -p manager -D trans
```

This will list transaction table information

```
$ catalog -u root -p manager -ild
```

This is same as -d option

```
$ catalog -u root -p manager -i
```

This will drop all the tables from the database

10.3 Csqldump

`csqldump` is a tool that generates a standard file readable by the `csql` tool and dumps on the standard output. This file is fed into the csql tool to build the database that was present at the time of the file generation. This can be viewed as a back up mechanism where one can close down the server by generating this file and rebuild the database next time when the server is started again.

```
csqldump [-u username] [-p password] [-c] [-n
numberOfStmtPerCommit] [-T tableName]

$ csqldump -?

Usage: csqldump [-u username] [-p passwd] [-c] [-n
noOfStmtsPerCommit]

     n -> number of statements per commit
     Default value is 100. If system database size is
     bigger, then it shall be increased.

     T->  Will dump only the table specified with this
     option.

     c ->includes all the cache tables in the dump output

Note: csqldump does not output cache tables by default. Use
c option to include cache tables.
```

Now let us create some tables and insert some of the tuples into those tables.

Run the csqlserver in one terminal.
Open another terminal.
Run csql tool.

```
$ csql
CSQL> set autocommit off;
```

```
AUTOCOMMIT Mode is set to OFF
CSQL> create table t1(f1 int, f2 char(30), primary key(f1));
Statement Executed
CSQL> insert into t1 values(1, 'Lakshya');
Statement Executed: Rows Affected = 1
CSQL> insert into t1 values(10, 'Uttara');
statement Executed: Rows Affected = 1
CSQL> commit;
CSQL> create table emp(empId int, empName char(40), empSal
float, primary key (empId));
Statement Executed
CSQL> insert into emp values(1001, 'Jitendra', 1000.00);
Statement Executed: Rows Affected = 1
CSQL> insert into emp values(1002, 'Dharmendra', 2000.00);
Statement Executed: Rows Affected = 1

CSQL> commit;
CSQL> quit;
```

Two tables are now created in the `csql` database with each table having two tuples. Now running `csqldump` will dump the file on the standard output.

```
$ csqldump
CREATE TABLE t1 (f1 INT  NOT NULL , f2 CHAR (30));
CREATE INDEX t1_idx1_Primary on t1 ( f1 )  UNIQUE;
CREATE TABLE emp (empId INT  NOT NULL , empName CHAR (40),
empSal FLOAT );
CREATE INDEX emp_idx1_Primary on emp ( empId )  UNIQUE;
SET AUTOCOMMIT OFF;
INSERT INTO t1 VALUES(1, 'Lakshya');
INSERT INTO t1 VALUES(10, 'Uttara');
COMMIT;
INSERT INTO emp VALUES(1001, 'Jitendra',1000.000000);
INSERT INTO emp VALUES(1002, 'Dharmendra',2000.000000);
COMMIT;
```

Again run `csqldump` and redirect the output to `backup.sql`.

```
$ csqldump > backup.sql
```

Close the server by hitting Ctl + C.
Open the server again. At this point server is in virgin state.
Now run `csql` tool with the file as input as follows.

```
$ csql -u root -p manager -s backup.sql
Statement Executed
Statement Executed
Statement Executed
Statement Executed
AUTOCOMMIT Mode is set to OFF
Statement Executed: Rows Affected = 1
```

```
Statement Executed: Rows Affected = 1
Statement Executed: Rows Affected = 1
Statement Executed: Rows Affected = 1
```

The first 4 lines are for creation of table and index for both tables. Then the `autocommit` mode is set OFF by the `csqldump` tool and the last 4 rows are the output resulting from the insertion of 2 tuples each for each table.

In order to check whether the tuples are loaded appropriately or not, do the following

Start the csql tool.

```
$ csql
CSQL>show tables;
=============TableNames===================
   t1
   emp
==========================================

CSQL>select * from t1;
----------------------------------------------------------
        f1      f2
----------------------------------------------------------
        1       Lakshya
        10      Uttara

CSQL>select * from emp;
----------------------------------------------------------
        empId   empName empSal
----------------------------------------------------------
        1001    Jitendra        1000.000000
        1002    Dharmendra      2000.000000

CSQL>quit;

$ csqldump -T t1
CREATE TABLE t1 (f1 INT  NOT NULL , f2 CHAR (30));
CREATE INDEX t1_idx1_Primary on t1 ( f1 )  UNIQUE;
SET AUTOCOMMIT OFF;
INSERT INTO t1 VALUES(1, 'Lakshya');
INSERT INTO t1 VALUES(10, 'Uttara');
COMMIT;
```

10.4 cachetable

`cachetable` is a tool to cache the table from the target database into CSQL. This needs to be invoked when the csqlserver process is running.

```
Syntax:
cachetable [-U username] [-P password] -t tablename
```

```
            [-R] [-s] [-r]

        tablename -> table name to be cached in csql from target
db.
        R -> recover all cached tables from the target database.
        s -> load only the records from target db. Assumes table
is already created in csql
        r -> reload the table. get the latest image of table from
target db
        u -> unload the table. if used with -s option, removes
only records and preserves the schema
```

For the below command to work, table t1 should exist in the target database and should not exist in CSQL.

To create the table and insert records in MySQL,

```
$ isql myodbc3
+---------------------------------------+
| Connected!                            |
|                                       |
| sql-statement                     |
| help [tablename]                      |
| quit                                  |
|                                       |
+---------------------------------------+
SQL> create table emp (empId int, empName char(40), empSal
float, primary key (empId));
SQLRowCount returns 0
SQL> insert into emp values(1001, 'Jitendra', 1000.00);
SQLRowCount returns 1
SQL> insert into emp values(1002, 'Dharmendra', 2000.00);
SQLRowCount returns 1
SQL> insert into emp values(1003, 'Rajendra', 3000.00);
SQLRowCount returns 1
SQL> insert into emp values(1004, 'Narendra', 4000.00);
SQLRowCount returns 1
```

Now 4 rows are added into the MySQL database, which is our target database.

If you want to cache table `emp`, then run the following command

```
$ cachetable -u root -p manager -t emp
```

After loading you can check whether the records are loaded into CSQL using csql tool

$ csql

CSQL>select * from emp;

It will display all the records inserted into MySQL table 'emp'

10.5 csqlverify

cacheverify is a tool that will display the missing records in the specified cached table either in csql or in target database, if any.

```
cacheverify [-U username] [-P password] -t tableName [-p] [-f]
```

```
$ cacheverify -?
Usage: cacheverify [-U username] [-P passwd] -t tablename
       [-p] [-f]
       username -> username to connect with csql.
       password -> password for the above username.
       tablename -> cached table name in csql from target db.
       p -> verification at primary key field level
       f -> verification at record level
       ? -> help
```

Table name must be specified and it must be a cached table having a primary key field.

By default, that is without -p or -f switch the tool will display only the count of the records in both the databases.

With -p switch, the tool will display only the missing records in either of the database with primary key field value.

The switch -f, has not been implemented and it shall display the missing records in either of the database and the mismatching fields in the records present in both the databases having same primary key field value.

Now let us see how the tool works.

Create a table t1 in target database as follows. We used mysql as the target database at our end.

```
$ isql myodbc3
+---------------------------------------+
| Connected!                            |
|                                       |
| sql-statement                     |
| help [tablename]                      |
| quit                                  |
|                                       |
+---------------------------------------+
```

```
SQL> create table emp(empId int, empName char(40), empSal
float, primary key (empId));
SQLRowCount returns 0
SQL> insert into emp values(1001, 'Jitendra', 1000.00);
SQLRowCount returns 1
SQL> insert into emp values(1002, 'Dharmendra', 2000.00);
SQLRowCount returns 1
SQL> insert into emp values(1003, 'Rajendra', 3000.00);
SQLRowCount returns 1
SQL> insert into emp values(1004, 'Narendra', 4000.00);
SQLRowCount returns 1
```

Now 4 rows are added into the mysql database which is our target database.
Let us cache this table into csql.
To cache this table into csql add an entry

```
1:emp
```

on a new line in csqltable.conf.

Now run

```
$ csqlserver -c
ConfigValues
 getPageSize 8192
 getMaxProcs 100
 getMaxSysDbSize 1048576
 getMaxDbSize 10485760
 getSysDbKey 1222
 getUserDbKey 4555
 getLogFile /tmp/log/csql/log.out
 getMapAddress 400000000
 getMutexSecs 0
 ...
 ...
 ...
 getTableConfigFile /tmp/csql/csqltable.conf
 isTwoWayCache 1
 getCacheWaitSecs 10
Sysdb size 1048576 dbsize 10485760
System Database initialized
Database server recovering cached tables...
Recovering table emp
Cached Tables recovered
Starting Cache Recv Server
filename is
/home/kishoramballi/csql/install/bin/csqlcacheserver
Cache Recv Server Started pid=6414
Database server started
Cache server started
```

Now the table emp is cached into the csql server.
Let us now check the output of cacheverify for the default option and for the -p option.

Open another terminal and setup the environment by moving into csql root directory and entering the following command

```
$ . ./setupenv.ksh
$ cacheverify -t emp
--------------------+---------------+----------------------+
       Data         |    In CSQL    |     In TargetDb      |
--------------------+---------------+----------------------+
 Number of Tuples   |       4       |          4           |
--------------------+---------------+----------------------+

$ cacheverify -t emp -p
Primary key field name is 'empId'
The data in both the servers is consistent
```

Let us delete one row with primary key field value 1002 from target database and one row with primary key value 1004 from csql as follows.

```
$ isql myodbc3
+---------------------------------------+
| Connected!                            |
|                                       |
| sql-statement                         |
| help [tablename]                      |
| quit                                  |
|                                       |
+---------------------------------------+

SQL> delete from emp where empId = 1002;
SQLRowCount returns 1
SQL> quit;

$ csql
CSQL>delete from emp where empId = 1004;
Statement Executed: Rows Affected = 1
CSQL>quit;
```

Now one row each is deleted from each of the databases. Let us see what happens to the output of cacheverify.

```
$ cacheverify -t emp
--------------------+---------------+----------------------+
       Data         |    In CSQL    |     In TargetDb      |
--------------------+---------------+----------------------+
 Number of Tuples   |       3       |          3           |
--------------------+---------------+----------------------+

$ cacheverify -t emp -p
Primary key field name is 'empId'
-----------------+-----------------+----------------------+
```

```
     empId        |   not in csql    |    not in targetdb    |
------------------+------------------+-----------------------+
      1002        |                  |           X           |
      1004        |        X         |                       |
------------------+------------------+-----------------------+
```

The first output shows number of tuples present in both the databases.
And the second output shows the missing records based on the primary key field values 1002 and 1004 in the sorted incresing order.

11. Troubleshooting

11.1 Errors while building CSQL

11.1.1 Please set JDK_HOME

```
$ ./build.ksh
Please set JDK_HOME
```

This error is thrown when `JDK_HOME` is not set. CSQL requires Java Development Toolkit (JDK) Version 1.5 or higher. If it is not present in the system then please install it.

Set up the `JDK_HOME` by following the steps below –

```
$ export JDK_HOME=/home/csql/jdk1.5.0_14
```

In the above example it is assumed that the JDK is based in the /home/csql directory, you might change the path based on your system. Now run `./build.ksh` and it should work.

11.1.2 Cannot find –lodbc

```
$ make
...
/usr/lib/gcc/i586-suse-
linux/4.2.1/../../../../i586-suse-linux/bin/ld:
cannot find -lodbc

collect2: ld returned 1 exit status

make[3]: *** [libcsqlodbcadapter.la] Error 1
...
```

```
...
```

This error is thrown when `unixodbc` module is not installed in the system. Please download and install unixodbc rpm package from http://rpm.pbone.net/index.php3/stat/3/srodzaj/1/search/unixODBC

To install the rpm

```
$ rpm -ivh <rpm-package-file>
```

Now run `make` and it should work.

11.2 Errors while running csqlserver

11.2.1 – bash: csqlserver Command not found

```
$ csqlserver
-bash: csqlserver: command not found
```

This error is thrown when the `$PATH` environmental variable may not have been set for `CSQL`. Run the following command from `CSQL_ROOT` directory

```
$ . ./setupenv.ksh
```

Now run `csqlserver` and it should work.

11.2.2 Unable to create the log file

```
$ csqlserver

4822:3086075584:Logger.cxx:101:Unable to create
log file. Check whether server started
Unable to start the logger
```

This error is thrown when `csqlserver` is not able to create the log file. Please create the directory defined for `LOG_FILE` in `csql.conf` file, which is present in `CSQL_ROOT` directory.

For example if `LOG_FILE=/tmp/log/csql/log.out` then create the directory as follows.

```
$ mkdir -p /tmp/log/csql
```

If you wish to create the log file in different directory then create that directory and change the value of LOG_FILE in `csql.conf` file.

Now run `csqlserver` and it should work.

12. Getting Support

The primary mechanism for CSQL communication is through its mailing lists. Anyone who is using this product shall participate in user mailing lists. You can search for the archive of past discussions before you post your question to the mailing lists.

The main channel for user support is csql-users@lists.sourceforge.net mailing list. As is usual with mailing lists, be prepared to wait for an answer.

Please summarize any off-list knowledge gained and post it for the benefit of all. For example, if a user asks a question and gets a response, post that to csql-users@lists.sourceforge.net

13. How to contribute

For beginners, items, which come first in the list, are a good starting point. It is ordered on the basis of complexity

- Check out, build the code and run the tests.
- Add functional, stress and scalability Tests.
- Fix bugs.
- Add new test cases for user exposed interfaces
- Develop test cases, run them and create bugs
- Review bug fixes, new feature's design and its code
- Test the Documentation
    - Review the manual and test all the examples. If you find something that looks wrong, create bug and specify "Documentation" as category
- Develop New Features
- Testing New Features
- Read Architecture in csql wiki page and update missing links
- Suggesting new features

- Improve subsystems (code reorganization, performance improvement, etc)

If you find any issues or any queries on CSQL please get back to us at feedback@csqldb.com.

Appendix – A (Benchmark Results)

All times are in microseconds and benchmarking is done against leading open source database. Read operation is point lookup on the primary key field, F1.SQLAPI in the native C++ interface of CSQL for its SQL Engine.
The benchmark is done on most frequently used database operations

- INSERT one record
- SELECT on the primary key field with equality predicate
- UPDATE one field with equality predicate on primary key field
- DELETE with equality predicate on the primary key field

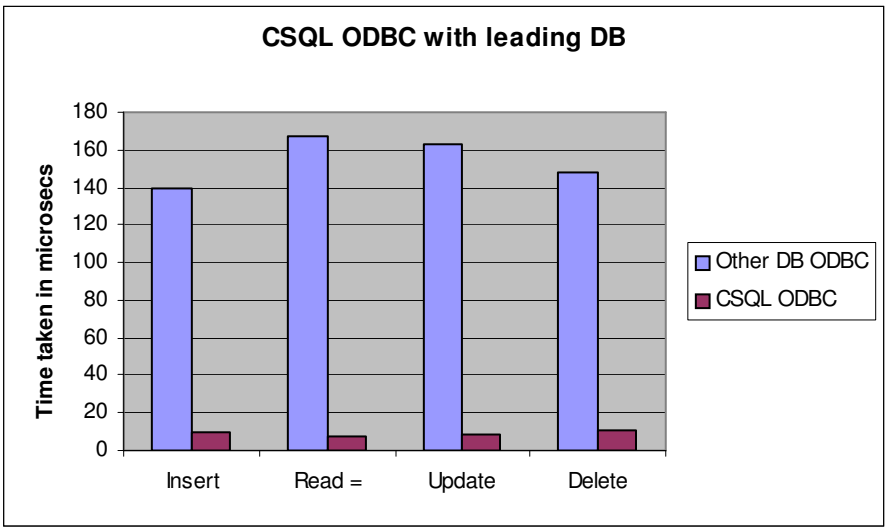
Machine Configuration
Dell OPTIPLEX 320, Intel Pentium D 800 MHz Dual core, 1GBRAM, Linux 2.6 Kernel

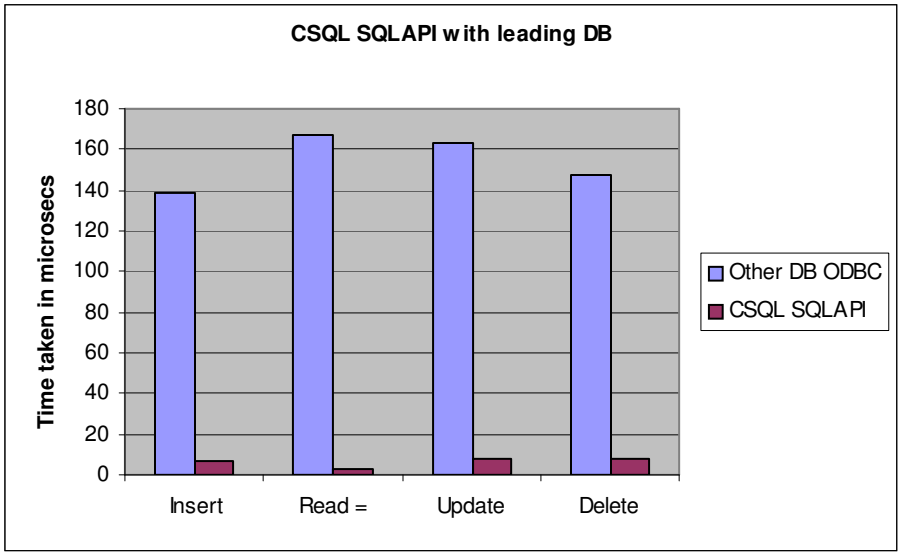
Schema Definition
CREATE TABLE T1 (F1 INTEGER, F2 CHAR (200), PRIMARY KEY (F1));

CSQL MMDB Benchmark Results

For the above said operations, time taken is measured in microsecond for leading traditional database system and for CSQL Main Memory Database System. The benchmarking application and the database server runs in the same machine/host and table fully cached in RAM during the test.

Operation	Other DB ODBC	CSQL ODBC	ODBC Times Faster	CSQL SQLAPI	SQLAPI Times Faster
Insert	139	10	**13.90**	6.9	**20.14**
Read =	167	7.5	**22.27**	3.2	**52.19**
Update	163	9	**18.11**	7.9	**20.63**
Delete	148	11	**13.45**	8.2	**18.05**





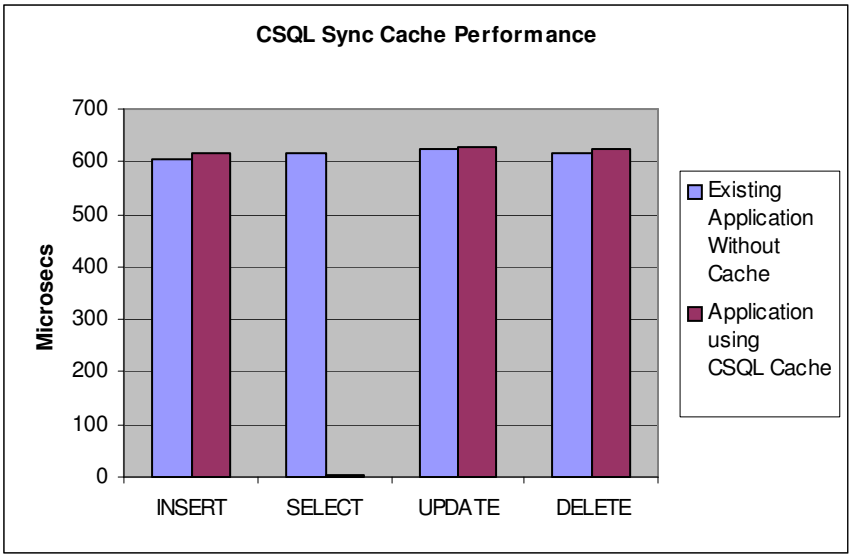
From the above results, it is evident that CSQL is 22 times faster than leading database with standard ODBC interface and 52 times faster with proprietary C++ SQL API. This demonstrates CSQL's ability to meet the most demanding service levels which traditional disk based database systems cannot deliver.

CSQL Cache Benchmark Results

Time taken for the above operations in microsecond granularity for an application, which access the table in the target database directly (Column-2 of the below table) and after it caches the table using CSQL cache (Column-3 of the below table). The fourth column in the table tells how many times performance of the above said operations increase after employing CSQL Cache.

Network: Application host and target db host connected through 10/100Mb Fast Ethernet switch

Database Operation	Existing Application Without Cache	Application using CSQL Cache	Times Faster
INSERT	603	616	0.98
SELECT	618	4	**154.50**
UPDATE	623	628	0.99
DELETE	617	625	0.99



From the above results, for sync cache update propagation mode, it is evident that CSQL queries are **150** times faster than the existing database system and there is no degradation of performance in case of write operations.