ODBC Connectivity

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Package RODBC implements ODBC database connectivity. It was originally written by Michael Lapsley (St George's Medical School, University of London) in the early days of R (1999), but after he disappeared in 2002, it was rescued and since much extended by Brian Ripley. Version 1.0-1 was released in January 2003, and RODBC is nowadays a mature and much-used platform for interfacing R to database systems.

1 ODBC Concepts

ODBC aims to provide a common API for access to SQL[1]-based database management systems (DBMSs) such as MySQL, PostgreSQL, Microsoft Access and SQL Server, DB2, Oracle and SQLite. It originated on Windows in the early 1990s, but ODBC *driver managers* unixODBC and iODBC are nowadays available on a wide range of platforms (and a version of iODBC ships with recent versions of Mac OS X). The connection to the particular DBMS needs an *ODBC driver*: these may come with the DBMS or the ODBC driver manager or be provided separately by the DBMS developers, and there are third-party[2] developers such as Actual Technologies, Easysoft and OpenLink. (This means that for some DBMSs there are several different ODBC drivers available, and they can behave differently.)

Microsoft provides drivers on Windows for non-SQL database systems such as DBase and FoxPro, and even for flat files and Excel spreadsheets. Actual Technologies sell a driver for Mac OS X that covers (some) Excel spreadsheets and flat files.

A connection to a specific database is called a *Data Source Name* or DSN

[1]SQL is a language for querying and managing data in databases—see http://en.wikipedia.org/wiki/SQL.

[2]but there are close links between unixODBC and Easysoft, and iODBC and OpenLink.

(see http://en.wikipedia.org/wiki/Database_Source_Name). See Appendix B for how to set up DSNs on your system. One of the greatest advantages of ODBC is that it is a cross-platform client-server design, so it is common to run R on a personal computer and access data on a remote server whose OS may not even be known to the end user. This does rely on suitable ODBC drivers being available on the client: they are for the major cross-platform DBMSs, and some vendors provide 'bridge' drivers, so that for example a 'bridge' ODBC driver is run on a Linux client and talks to the Access ODBC driver on a remote Windows machine.

ODBC provides an abstraction that papers over many of the differences between DBMSs. That abstraction has developed over the years, and `RODBC` works with ODBC version 3. This number describes both the API (most drivers nowadays work with API 3.51 or 3.52) and capabilities. The latter allow ODBC drivers to implement newer features partially or not at all, so some drivers are much more capable than others: in the main `RODBC` works with basic features. ODBC is a superset of the ISO/IEC 9075-3:1995 SQL/CLI standard.

A somewhat biased overview of ODBC on Unix-alikes can be found at http://www.easysoft.com/developer/interfaces/odbc/linux.html.

2 Basic Usage

Two groups of functions are provided in `RODBC`. The mainly internal `odbc*` commands implement low-level access to C-level ODBC functions with similar[3] names. The `sql*` functions operate at a higher level to read, save, copy and manipulate data between data frames and SQL tables. The two low-level functions which are commonly used make or break a connection.

2.1 Making a connection

ODBC works by setting up a *connection* or *channel* from the client (here `RODBC`) to the DBMSs as specified in the DSN. Such connections are normally used throughout a session, but should be closed explicitly at the end of the session but `RODBC` will clear up after you if you forget (with a warning that might not be seen in a GUI environment). There can be many simultaneous connections.

The simplest way to make a connection is

```
library(RODBC)
```

[3]in most cases with prefix `SQL` replacing `odbc`.

```
ch <- odbcConnect("some_dsn")
```

and when you are done with it,

```
close(ch)
# or if you prefer
odbcClose(ch)
```

The connection object `ch` is how you specify one of potentially many open connections, and is the first argument to all other `RODBC` functions. If you forget the details, printing it will give some summary information.

If the DBMS user and password are needed and not stored in the DSN, they can be supplied by e.g.

```
ch <- odbcConnect("some_dsn", uid = "user", pwd = "****")
```

Users of the R GUI under Windows[4] have another possibility: if an incompletely specified DSN is given, the driver-specific Data Source dialog box will pop up to allow it to be completed.

More flexibility is available *via* function `odbcDriverConnect`, which works with a *connection string*. At its simplest it is

```
"DSN=dsn;UID=uid;PWD=pwd"
```

but it can be constructed without a DSN by specifying a driver directly *via* `DRIVER=`, and more (in some cases many more) driver-specific parameters can be given. See the documentation for the driver (and Appendix A) for more details.

2.2 Reading from a database

where 'database' can be interpreted very widely, including for example Excel spreadsheets and directories of flat files.

The simplest and most common use of `RODBC` is to extract data from databases held on central database servers. Such access is read-only, and this can be ensured by settings in the DSN or (better) *via* permission settings (also known as *privileges*) on the database.

To find out what tables are accessible from a connection `ch`, use

```
sqlTables(ch)
```

Some drivers will return all visible table-like objects, not just those owned by you. In that case you may want to restrict the scope by e.g.

[4]This does not work from `Rterm.exe`.

```
sqlTables(ch, tableType = "TABLE")
sqlTables(ch, schema = "some_pattern")
sqlTables(ch, tableName = "some_pattern")
```

The details are driver-specific but in most cases *some_pattern* can use wildcards[5] with underscore matching a single character and percent matching zero or more characters. Since underscore is a valid character in a table name it can be handled literally by preceding it by a backslash—but it is rarely necessary to do so.

A table can be retrieved as a data frame by

```
res <- sqlFetch(ch, "table_name")
```

If it has many rows it can be retrieved in sections by

```
res <- sqlFetch(ch, "table_name", max = m)
res <- sqlFetchMore(ch, "table_name", max = m)
...
```

It is often necessary to reduce the data to be transferred: we have seen how to subset rows, but it can be more effective to restrict the columns or to return only rows meeting some conditions. To find out what columns are available, use `sqlColumns`, for example

```
> sqlColumns(ch, "USArrests")
  TABLE_CAT TABLE_SCHEM TABLE_NAME COLUMN_NAME DATA_TYPE TYPE_NAME COLUMN_SIZE
1    ripley        <NA>  USArrests       State        12   varchar         255
2    ripley        <NA>  USArrests      Murder         8    double          15
3    ripley        <NA>  USArrests     Assault         4   integer          10
4    ripley        <NA>  USArrests    UrbanPop         4   integer          10
5    ripley        <NA>  USArrests        Rape         8    double          15
...
```

Then an *SQL Query* can be used to return part of the table, for example (MySQL on Linux)

```
> sqlQuery(sh, paste("SELECT State, Murder FROM USArrests",
+                    "WHERE Rape > 30 ORDER BY Murder"))
       State Murder
1   Colorado    7.9
2    Arizona    8.1
3 California    9.0
4     Alaska   10.0
5 New Mexico   11.4
6   Michigan   12.1
7     Nevada   12.2
8    Florida   15.4
```

Note that although there are standards for SQL, all the major producers of DBMSs have their own dialects, so for example on the Oracle and DB2 systems we tested this query had to be given as

[5]these are the SQL wildcards used for example in `LIKE` clauses.

```
> sqlQuery(ch, paste('SELECT "State", "Murder" FROM "USArrests"',
+                    'WHERE "Rape" > 30 ORDER BY "Murder"'))
```

Describing how to extract data from databases is the *forte* of the SQL language, and doing so efficiently is the aim of many of the DBMSs, so this is a very powerful tool. To learn SQL it is best to find a tutorial specific to the dialect you will use; for example Chapter 3 of the MySQL manual is a tutorial. A basic tutorial which covers some common dialects[6] can be found at http://www.1keydata.com/sql/sql.html: tutorials on how to perform common tasks in several commonly used DBMSs are available at http://sqlzoo.net/.

2.3 Table Names

SQL-92 expects both table and column names to be alphanumeric plus underscore, and `RODBC` does not in general support vendor extensions (for example Access allows spaces). There are some system-specific quoting schemes: Access and Excel allow table names to be enclosed in `[ ]` in SQL queries, MySQL (by default) quotes *via* backticks, and most other systems use the ANSI SQL standard of double quotes.

The `odbcConnnect` function allows the specification of the quoting rules for names `RODBC` itself sends, but sensible defaults[7] are selected. Users do need to be aware of the quoting issue when writing queries for `sqlQuery` themselves.

Note the underscore is a wildcard character in table names for some of the functions, and so may need to be escaped (by backslash) at times.

2.4 Types of table

The details are somewhat DBMS-specific, but 'tables' usually means 'tables, views or similar objects'.

In some systems 'tables' are physical objects (files) that actually store data—Mimer calls these *base tables*. For these other 'tables' can be derived that present information to the user, usually called 'views'. The principal distinctions between a (base) table and a view are

- Using `DROP` on a table removes the data, whereas using it on a view merely removes the convenient access to a representation of the data.

[6]MySQL, Oracle and SQL Server.

[7]backticks for MySQL, `[ ]` for the Access and Excel convenience wrappers, otherwise ANSI double quotes.

- The access permission (*privilege*) of a view can be very different from those of a table: this is commonly used to hide sensitive information.

A view can contain a subset of the information available in a single table or combine information from two or more tables.

Further, some DBMSs distinguish between tables and views generated by ordinary users and *system tables* used by the DBMS itself. Where present, this distinction is reflected in the result of `sqlTable()` calls.

Some DBMSs support *synonyms* and/or *aliases* which are simply alternative names for an existing table/view/synonym, often those in other schemas (see below).

Typically tables, views, synonyms and aliases share a name space and so must have a name that is unique (in the enclosing schema where schemas are implemented).

3 Writing to a Database

To create or update a table in a database some more details need to be considered. For some systems, all table and column names need to be lower case (e.g. PostgreSQL, MySQL on Windows) or upper case (e.g. some versions of Oracle). To make this a little easier, the `odbcConnect` function allows a remapping of table names to be specified, and this happens by default for DBMSs where remapping is known to be needed.

The main tool to create a table is `sqlSave`. It is safest to use this after having removed any existing table of the same name, which can be done by

```
sqlDrop(ch, "table_name", errors=FALSE)
```

Then in the simplest usage

```
sqlSave(ch, some_data_frame)
```

creates a new table whose name is the name of the data frame (remapped to upper or lower case as needed) and with first column `rownames` the row names of the data frame, and remaining columns the columns of the data frame (with names remapped as necessary). For the many options, see the help page.

`sqlSave` works well when asked to write integer, numeric and reasonable-length[8] character strings to the database. It needs some help with other

[8]which of course depends on the DBMS. Almost all have an implementation of `varchar` that allows up to 255 bytes or characters, and some have much larger limits. Calling `sqlTypeInfo` will tell you about the data type limits.

types of columns in mapping to the DBMS-specific types of column. For some drivers it can do a good job with date and date-time columns; in others it needs some hints (and e.g. for Oracle dates are stored as date-times). The files in the `RODBC/tests` directory in the sources and the installed file `tests.R` provide some examples. One of the options is the `fast` argument: the default is `fast=TRUE` which transfers data in binary format: the alternative is `fast=FALSE` which transfer data as character strings a row at a time—this is slower but can work better with some drivers (and worse with others).

The other main tool for writing is `sqlUpdate` which is used to add rows to or change rows in an existing table. Note that `RODBC` only does this is a simple fashion, and on up-market DBMSs it may be better to set cursors and use direct SQL queries, or at least to control transactions by calls to `odbcSetAutoCommit` and `odbcEndTran`. The basic operation of `sqlUpdate` is to take a data frame with the same column names (up to remapping) as some or all of the columns of an existing table: the values in the data frame are then used either to replace entries or to create new rows in the table.

Rows in a DBMS table are in principle unordered and so cannot be referred to by number: the sometimes tricky question is to know what rows are to replaced. We can help the process by giving one or more `index` columns whose values must match: for a data frame the row names are often a good choice. If no `index` argument is supplied, a suitable set of columns is chosen based on the properties of the table.

3.1 Primary keys and indices

When a table is created (or afterwards) it can be given additional information to enable it to be used effectively or efficiently.

Primary keys are one (usually) or more columns that provide a reliable way to reference rows in the table: values of the primary key must be unique and not `NULL` (SQL parlance for 'missing'). Primary keys in one table are also used as *foreign keys* in another table: this ensure that e.g. values of `customer_id` only take values which are included in the primary key column of that name in table `customers`. Support of foreign keys is patchy: some DBMSs (e.g, MySQL < 6.0) accept specifications but ignore them.

`RODBC` allows primary keys to be set as part of the `sqlSave()` function when it creates a table: otherwise they can be set by `sqlQuery()` in DBMS-specific ways (usually by `ALTER TABLE`).

Columns in a table can be declared as `UNIQUE`: primary keys and such columns are usually used as the basis for table indices, but other indices (sometimes called *secondary indices*) can be declared by a `CREATE INDEX` SQL command. Whether adding primary keys or other indices has any effect on performance depends on the DBMS and the query.

4 Data types

This can be confusing: R has data types (including `character`, `double`, `integer` and various classes including `Date` and `POSIXt`), ODBC has both C and SQL data types, the SQL standards have data types and so do the various DBMSs *and they all have different names* and different usages of the same names.

Double- and single-precision numeric values and 32- and 16-bit integers (only) are transferred as binary values, and all other types as character strings. However, unless `as.is=TRUE`, `sqlGetResults` (used by all the higher-level functions to return a data frame) converts character data to an date/date-time class or *via* `type.convert`.

You can find out the DBMS names for the data types used in the columns of a table by a call to `sqlColumns`, and further information is given on those types in the result of `sqlTypeInfo`. For example in MySQL,

```
  TABLE_CAT TABLE_SCHEM TABLE_NAME COLUMN_NAME DATA_TYPE TYPE_NAME COLUMN_SIZE
1    ripley        <NA>  USArrests       State        12   varchar         255
2    ripley        <NA>  USArrests      Murder         8    double          15
3    ripley        <NA>  USArrests     Assault         4   integer          10
4    ripley        <NA>  USArrests    UrbanPop         4   integer          10
5    ripley        <NA>  USArrests        Rape         8    double          15
  BUFFER_LENGTH DECIMAL_DIGITS NUM_PREC_RADIX NULLABLE REMARKS COLUMN_DEF
1           255             NA             NA        0                ''
2             8             NA             NA        1              <NA>
3             4              0             10        1              <NA>
4             4              0             10        1              <NA>
5             8             NA             NA        1              <NA>
  SQL_DATA_TYPE SQL_DATETIME_SUB CHAR_OCTET_LENGTH ORDINAL_POSITION IS_NULLABLE
1            12               NA               255                1          NO
2             8               NA                NA                2         YES
3             4               NA                NA                3         YES
4             4               NA                NA                4         YES
5             8               NA                NA                5         YES
```

This gives the DBMS data by name and by number (twice, once the number used in the DBMS and once that used by SQL—they agree here). Other things of interest here are the column size, which gives the maximum size of the character representation, and the two columns about 'nullable' which indicate if the column is allowed to contain missing values (SQL `NULL`s).

The result of `sqlTypeInfo` has 19 columns and in the version of MySQL used here, 52 types. We show a small subset of the more common types:

```
> sqlTypeInfo(channel)[c(1:3,7,16)]
> sqlTypeInfo(channel)[<...>, c(1:3,7,16)]
     TYPE_NAME DATA_TYPE COLUMN_SIZE NULLABLE SQL_DATATYPE
1          bit        -7           1        1           -7
2      tinyint        -6           3        1           -6
6       bigint        -5          19        1           -5
18        text        -1       65535        1           -1
19 mediumtext         -1    16777215        1           -1
20   longtext         -1  2147483647        1           -1
22        char         1         255        1            1
23     numeric         2          19        1            2
24     decimal         3          19        1            3
25     integer         4          10        1            4
37    smallint         5           5        1            5
41      double         6          15        1            6
43       float         7           7        1            7
45      double         8          15        1            8
47        date        91          10        1            9
48        time        92           8        1            9
49        year         5           4        1            5
50    datetime        93          21        1            9
51   timestamp        93          14        0            9
52     varchar        12         255        1           12
```

Note that there are both duplicate names and duplicate numbers.

Most DBMSs started with their own data types and later mapped the standard SQL data types on to them, although these may only be partially implemented. Some DBMSs allow user-defined data types, for example enumerations.

Commonly used data types fall into a number of groups:

Character types Character types can be classified three ways: fixed or variable length, by the maximum size and by the character set used. The most commonly used types[9] are `varchar` for short strings of variable length and `char` for short strings of fixed length (usually right-padded with spaces). The value of 'short' differs by DBMS and is at least 254, often a few thousand—often other types will be available for longer character strings. There is a sanity check which will allow only strings of up to 65535 bytes when reading: this can be removed by recompiling `RODBC`.

Many other DBMSs have separate types to hold Unicode character strings, often with names like `nvarchar` or `varwchar`. Note that currently `RODBC` only uses the current locale for character data, which could be UTF-8 (and will be on Mac OS X and in many cases on Linux and other Unix-alikes), but is never UCS-2 as used on Windows. So if character data is stored in the database in Unicode, it will be translated (with a possibly loss of information) in non-Unicode locales. (This may change in future versions of `RODBC`.)

[9]the SQL names for these are `CHARACTER VARYING` and `CHARACTER`, but these are too cumbersome for routine use.

Integer types Most DBMSs have types for 32-bit (`integer`, synomyn `int`) and 16-bit (`smallint`) integers. Some, including MySQL, also have unsigned versions and 1-bit, 8-bit and 64-bit integer types: these further types would usually be transferred as character strings and converted on reading to an `integer` or `double` vector.

Type names `int2`, `int4` and `int8` are common as synonyms for the basic type names.

The SQL standard does not require `integer` and `smallint` to be binary (rather than decimal) types, but they almost always are binary.

Note that 64-bit integers will be transferred as character strings and read by `sqlGetResults` as character vectors or (for $2^{31} \leq |x| < 2^{53}$) as a `double` vectors.

Floating-point types The basic SQL floating-point types are 8 and 7 for double- and single-precision binary types. The SQL names are `double precision` and `real`, but beware of the variety of names. Type 6 is `float` in the standard, but is used by some DBMSs[10] for single-precision and by some for double-precision: the forms `float(24)` and `float(53)` are also commonly supported.

You should not assume that these types can store `Inf`, `-Inf` or `NaN`, but they often can.

Other numeric types It is common to store decimal quantities in databases (e.g. currency amounts) and types 2 and 3 are for decimals. Some DBMSs have specialized types to handle currencies, e.g. `money` in SQL Server.

Decimal types have a *precision* (the maximum number of significant decimal digits) and *scale* (the position of the decimal point). `numeric` and `decimal` are usually synonymous, but the distinction in the standards is that for `numeric` the precision is exact whereas for `decimal` the DBMS can use a larger value than that specified.

Some DBMSs have a type `integer(`*p*`)` to represent up to *p* decimal digits, and this may or may not be distinct from `decimal(`*p*`, 0)`.

DBMSs do not necessarily fully implement decimal types, e.g. MySQL currently stores them in binary and used to store them as character strings.

Dates and times The handling of dates and times is very much specific to the DBMS. Some allow fractional seconds in date-times, and some

[10] In Oracle the `FLOAT` type is a decimal and not a binary type.

do not; some store timezones with date-times or always use UTC and some do not, and so on. Usually there are also types for time intervals.

All such types are transferred as character strings in `RODBC`.

It is possible (but rare) for the DBMS to support data types that the ODBC driver cannot handle. Most DBMSs have binary data types which have no corresponding R data type (`raw` corresponds to a single byte, not a fixed or variable length set of bytes): these are not currently covered by `RODBC`.

4.1 Data types when saving a data frame

When `sqlSave` creates a table, there is some choice as to the SQL data types used.

The default is to select the SQL data type from the R type via the `typeInfo` argument to `sqlSave`. If this is not supplied (usual) a default mapping is looked up using `getSqlTypeInfo()` or by interrogating `sqlTypeInfo()`. This will almost always produce the correct mapping for numeric, integer and character columns of up to 254 characters (or bytes). In other cases (include dates and date-times) the desired SQL type can be specified for each column *via* the argument `varTypes`, a named character vector with names corresponding to (some of) the names in the data frame to be saved.

Only a very few DBMSs have a logical data type and the default mapping is to store R logical vectors as `varchar(5)`. For others DBMSs `BIT`, `TINYINT` or an enumeration type could be used (but the column may be need to be converted to and from a suitable representation). For example, in MySQL we could use `enum('FALSE', 'TRUE')`, but this is actually stored as `char(5)`. Note that to represent `NA` the SQL data type chosen needs to be nullable, which `BIT` often is not. (Mimer has a nullable data type `BOOLEAN` but this is not supported by the ODBC client.)

4.2 SQLite

SQLite's concept of 'data type' is anomalous: version 3 does recognize types of data (in version 2 everything was a character string), but it does not have a fixed type for a column in a table (although the type specified in the `CREATE TABLE` statement is a 'recommended' type for the values of that column). Every value is categorized as null, integer (of length 1, 2, 3, 4, 6 or 8 bytes), double, text (UTF-8 or UTF-16) or BLOB (a sequence of bytes). This does not fit well with the ODBC interface which pre-determines a type for each column before reading or writing it: the 'SQLite ODBC' driver falls

SQL_CHAR	1	SQL_LONGVARCHAR	-1
SQL_NUMERIC	2	SQL_BINARY	-2
SQL_DECIMAL	3	SQL_VARBINARY	-3
SQL_INTEGER	4	SQL_LONGVARBINARY	-4
SQL_SMALLINT	5	SQL_BIGINT	-5
SQL_FLOAT	6	SQL_TINYINT	-6
SQL_REAL	7	SQL_BIT	-7
SQL_DOUBLE	8	SQL_WCHAR	-8
SQL_DATETIME	9	SQL_WVARCHAR	-9
SQL_INTERVAL	10	SQL_WLONGVARCHAR	-10
SQL_TIMESTAMP	11	SQL_GUID	-11
SQL_VARCHAR	12		
SQL_TYPE_DATE	91		
SQL_TYPE_TIME	92		
SQL_TYPE_TIMESTAMP	93		

Table 1: Mapping between ODBC SQL data type names and numbers. (GUIDs are 16-byte numbers, Microsoft's implementation of UUIDs.)

back to a `SQL_VARCHAR` or `SQL_LONGVARCHAR` type if the column type is not available.

4.3 ODBC data types

ODBC defines two sets of data types: *SQL data types* and *C data types*. SQL data types indicate the data types of data stored at the data source using standard names. C data types indicate the data types used in the compiled code in the application (here `RODBC`) when transferring data, and are the same for all drivers.

The ODBC SQL data types are abstractions of the data types discussed above with names like `SQL_INTEGER`. They include `SQL_LONGVARCHAR` for large character types and `SQL_WVARCHAR` for Unicode character types. It is usually these types that are returned (by number) in the `SQL_DATA_TYPE` column of the result of `sqlColumns` and `SQL_DATATYPE` column of the result of `sqlTypeInfo`. The mapping from names to numbers is given in table 1.

The only ODBC C data types currently used by `RODBC` are `SQL_C_DOUBLE`, `SQL_C_SLONG` (32-bit signed integers) and `SQL_C_CHAR` for reading and writing, and `SQL_C_FLOAT` (single-precision) and `SQL_C_SSHORT` (16-bit signed integers) for reading from the database.

http://msdn.microsoft.com/en-us/library/ms713607%28VS.85%29.aspx is the defintiive source of information about ODBC data types.

5 Schemas and Catalogs

This is a more technical section: few users will need to deal with these concepts.

'Schemas' are collections of objects (such as tables and views) within a database that are supported by some DBMSs: often a separate schema is associated with each user (and 'schema' in ODBC 3 replaced 'owner' in ODBC 2). In SQL-92, schemas are collected in a 'catalog' which is often implemented as a database. Where schemas are implemented, there is a *current schema* used to find unqualified table names, and tables in other schemas can be referred to within SQL queries using the `schema.table` notation. You can think of a schema as analogous to a name space; it allows related objects to be grouped together without worrying about name clashes with other groups. (Some DBMSs will search for unqualified table names in a search path: see the detailed descriptions below.)

Note that 'schema' is used in another sense in the database literature, for the design of a database and in particular of tables, views and privileges.

Here are some details of various DBMSs' interpretations of `catalog` and `schema` current at the time of writing (mid 2009). (These descriptions are simplistic, and in some cases experimental observations.)

- SQLite uses dotted names for alternative databases that are attached by an `ATTACH DATABASE` command.[11] There is a search path of databases, so it is only necessary to use the dotted name notation when there are tables of the same name on attached databases. The initial database is known as `main` and that used for temporary tables as `temp`.
- MySQL uses `catalog` to refer to a database. In MySQL's parlance, 'schema' is a little-used synonym for 'database'.
- PostgreSQL only allows a session to access one database, and does not use 'catalog' except to refer to the current database. Version 7.3 introduced schemas—users can create their own schemas with a `CREATE SCHEMA` query. Tables are by default in the `public` schema, and unqualified table names are searched for along a 'search path' of schemas (by default, containing `public`).
- Oracle uses schemas as synonymous with 'owner' (also known as 'user').
- IBM DB2 uses schemas as name spaces for objects that may lie on different databases: using *aliases* allows objects to be in more than

[11]and may be subsequently detached by a `DETACH DATABASE` command

one schema. The initial current schema is named the same as the user (`SQLID` in DB2 parlance).

- Microsoft SQL Server 2008 uses both `catalog` and `schema`, `catalog` for the database and `schema` for the type of object, e.g. `"sys"` for most of the system tables/views and (default) `"dbo"` for user tables. Further schemas can be created by users. The default schema for a user can be set when the user is created and changed *via* `ALTER USER`.

  Prior to SQL Server 2005, 'schema' meant 'user', and the search path for unqualified names was the database user then `"dbo"`.

- The Microsoft Excel and Access ODBC drivers do not use schemas, but do use `catalog` to refer to other database/spreadsheet files.

- Mimer (www.mimer.com) uses schemas which are normally the same as users (which it calls *IDENT*s), but users can create additional schemas. There are also system schemas.

It is often possible to use `sqlTables` to list the available catalogs or schemas: see its help page for the driver-specific details.

`RODBC` usually works with tables in the current schema, and so tables in other schemas can only be used in a few functions (`sqlClear`, `sqlDrop` and `sqlFetch`) and in SQL queries passed to `sqlQuery`. What the 'dotted name' notation means depends on the DBMS: the SQL-92 meaning is *schema.table* and this is accepted by PostgreSQL, Oracle, DB2 and Mimer. However, MySQL and SQLite use *database.table*. Microsoft SQL Server allows (depending on the version) up to four components: *linked_server.catalog.schema.table*. PostgreSQL does allow *database.schema.table*, but this is not useful as *database* must be the currently connected database.

Functions `sqlTables`, `sqlColumns` and `sqlPrimaryKeys` have arguments `catalog` and `schema` which in principle allow tables in other schema to be listed or examined: however these are only partially implemented in many current ODBC drivers. See the help page for `sqlTables` for some further details.

For other uses, the trick is to select the schema(s) you want to use, which is done *via* an SQL statement sent by `sqlQuery`. For Oracle you can set the default schema (owner) by

```
ALTER SESSION SET CURRENT_SCHEMA = schema
```

whereas for PostgreSQL the search path can be changed *via*

```
SET search_path TO schema1,schema2.
```

In DB2, creating an alias in the current schema can be used to access tables in other schemas, and a `CURRENT SCHEMA` query can be used to change the current schema. In MySQL and SQL Server a database can be selected by a `USE` *`database`* query.

6 Internationalization Issues

Internationalization issues are made more complex by ODBC being a client-server system, and the ODBC client (`RODBC`) and the server may be running on different machines with different OSes on different continents. So the client may need some help.

In most cases numeric data are transferred to and from R in binary form, so the representation of the decimal point is not an issue. But in some cases it could be (e.g. decimal rather than binary SQL data types will be transferred as character strings) and then the decimal point to be used will be taken from `options("dec")`: if unset this is set when `RODBC` is loaded from the setting of the current locale on the machine running R (*via* `Sys.localeconv`). Some ODBC drivers (e.g. for SQL Server, Oracle) allow the locale ('NLS') to be used for numeric values to be selected for the connection.

The other internationalization issue is the character encoding used. When R and the DBMS are running on the same machine this is unlikely to be an issue, and in many cases the ODBC driver has some options to translate character sets. SQL is an ANSI (US) standard, and DBMSs tended to assume that character data was ASCII or perhaps 8-bit. More recently DBMSs have started to (optionally or by default) to store data in Unicode, which unfortunately means UCS-2 on Windows and UTF-8 elsewhere. So cross-OS solutions are not guaranteed to work, but most do.

Encoding issues are best resolved in the ODBC driver or in DBMS settings. In the unusual case that this cannot be done, the `DBMSencoding` argument to `odbcDriverConnect` allows for recoding when sending data to or from the ODBC driver and thence the DBMS.

7 Excel Drivers

The Microsoft Excel ODBC driver (Windows only) has a number of peculiarities which mean that it should be used with care.

It seems that its concept of a 'table' is principally a *named range*. It treats worksheets are system tables, and append a dollar to their name (making then non-standard SQL table names: the quoting convention used is to enclose such names in square brackets).

Column names are taken as the first row of the named range/worksheet. Non-standard SQL names are allowed here too, but the driver maps `.` to `#` in column names. Annoyingly, `sqlTables` is allowed to select named ranges only by `tableType = "TABLE"` but not to select only worksheets.

There are at least two known problems with reading columns that do not have a format set *before* data entry, and so start with format 'General'. First, the driver uses the first few rows to determined the column type, and is over-fond of declaring 'Numeric' even when there are non-numeric entries. The default number of rows consulted is 8, but attempts to change this in the DSN setup are ignored. Second, if a column is declared as 'Text', numeric entries will be read as SQL nulls and hence R `NA`s. Unfortunately, in neither case does reformatting the column help.

The connection is by default read-only. It is possible to de-select this in the DSN (and the convenience wrapper `odbcConnectExcel` has a `readOnly = FALSE` argument to do so), but this does not support deletion, including SQL `DROP`, `DELETE`, `UPDATE` and `ALTER` statements). In particular, `sqlDrop` will remove the data in a worksheet but not the worksheet itself. The driver does allow a worksheet to be updated by `sqlUpdate`, and for a new worksheet (with a different name from existing worksheets) to be created by `sqlSave` (which also creates a named range).

As far as we know, no similar issues affect the Actual Technologies Mac OS X Excel driver: however, it allows only read-only access to Excel files and does not support Excel 2007/2008 `.xlsx` files.

8 DBMS-specific tidbits

This section covers some useful DBMS-specific SQL commands and other usefule details.

Recent versions of several DBMSs have a schema `INFORMATION_SCHEMA` that holds many predefined system views. These include MySQL (the name of a database, mainly populated beginning with MySQL 5.1), SQL Server and Mimer.

MySQL

We have already mentioned `USE` ***`database`*** as the way to change the database in use. `SHOW DATABASES` lists the databases 'for which you have some kind of privilege', and can have a LIKE clause to restrict the result to some pattern of database names.

The DESCRIBE *table* command is a compact way to get a description of a table or view, similar to the useful parts of the result of a call to sqlColumns. (It is also known as SHOW COLUMNS FROM *table*.)

SHOW TABLES is the command to produce a table of the tables/views on the current database, similar to sqlTables.

For example,

```
> sqlQuery(channel, "USE ripley")
[1] "No Data"
> sqlQuery(channel, "SHOW TABLES")
  Tables_in_ripley
1        USArrests
> sqlQuery(channel, "DESCRIBE USArrests")
     Field         Type Null Key Default Extra
1    State varchar(255)   NO PRI      NA    NA
2   Murder       double  YES          NA    NA
3  Assault      int(11)  YES          NA    NA
4 UrbanPop      int(11)  YES          NA    NA
5     Rape       double  YES          NA    NA
```

SHOW FULL TABLES gives an additional additional column Table_type, the types of the tables/views.

There is useful information for end users in the INFORMATION_SCHEMA *database*, much more extensively as from MySQL 5.1.

Some of the non-standard behaviour can be turned off, e.g. starting MySQL with --sql-mode=ANSI gives closer conformance to the standard, and this can be set for a single session by

```
SET SESSION sql_mode='ANSI'
```

To change just the behaviour of quotes (to use double quotes in place of backticks) replace ANSI by ANSI_QUOTE.

PostgreSQL

Table pg_tables lists all tables in all schemas; you probably want to filter on tableowner='*current_user*', e.g.

```
> sqlQuery(channel, "select * from pg_tables where tableowner='ripley'")
  schemaname tablename tableowner tablespace hasindexes hasrules hastriggers
1     public     dtest     ripley         NA          0        0           0
```

There are both ANSI and Unicode versions of the ODBC driver on Windows.

SQLite

These comments are only about SQLite 3 and Christian Werner's SQLite ODBC driver.

Table `sqlite_master` lists tables and indices, and the `sql` column gives the SQL command used. E.g.

```
> tmp <- sqlQuery(channel, "select * from sqlite_master")
> tmp[, "sql"] <- substr(tmp[, "sql"], 1, 16)
> tmp
   type                         name  tbl_name rootpage              sql
1 table                    USArrests USArrests        2 CREATE TABLE "US
2 index sqlite_autoindex_USArrests_1 USArrests        4             <NA>
```

My current versions of SQLiteODBC store character data in the current locale's charset (e.g. UTF-8) on Unix-alikes and in Unicode (UCS-2) on Windows (unless de-selected in the DSN configuration).

The default collation for text data is byte-by-byte comparisons, so avoid comparing non-ASCII character data in SQLite.

Views are read-only in SQLite.

Oracle

Tables `cat`, `user_table` and `user_catalog` contain useful information on tables. Information on columns is in `all_tab_columns`, e.g.

```
> sqlQuery(channel,
           "select * from all_tab_columns where table_name='USArrests'")
   OWNER TABLE_NAME COLUMN_NAME DATA_TYPE DATA_TYPE_MOD
1 RIPLEY  USArrests       State  VARCHAR2            NA
2 RIPLEY  USArrests      Murder     FLOAT            NA
3 RIPLEY  USArrests     Assault    NUMBER            NA
4 RIPLEY  USArrests    UrbanPop    NUMBER            NA
5 RIPLEY  USArrests        Rape     FLOAT            NA
...
```

Oracle's character data types are `CHAR`, `VARCHAR2` (character set specified when the database was created) and `NCHAR`, `NVARCHAR2` (Unicode), as well as `CLOB` and `NCLOB` for large character strings. For the non-Unicode types the units of length are either bytes or charactor (set as a default for the database) but can be overriden by adding a `BYTE` or `CHAR` qualifier.

DB2

Schema `syscat` contains many views with information about tables: for example view `syscat.tables` lists all tables, and

```
> sqlQuery(channel,
           "select * from syscat.columns where tabname='USArrests'")
  TABSCHEMA   TABNAME  COLNAME COLNO TYPESCHEMA TYPENAME LENGTH SCALE
1  RIPLEY   USArrests    State     0   SYSIBM    VARCHAR    255     0
2  RIPLEY   USArrests   Murder     1   SYSIBM     DOUBLE      8     0
3  RIPLEY   USArrests  Assault     2   SYSIBM    INTEGER      4     0
4  RIPLEY   USArrests UrbanPop     3   SYSIBM    INTEGER      4     0
5  RIPLEY   USArrests     Rape     4   SYSIBM     DOUBLE      8     0
...
```

SQL Server

There are several hundred views in schemas `INFORMATION_SCHEMA` and `sys` which will be listed by `sqlTables` and also by the stored procedure `sp_tables`. Another way to list tables is

```
SELECT * FROM sysobjects WHERE xtype='U'
```

where the condition restricts to user tables.

`USE` *`database`* changes the database in use.

Mimer

There are tens of views in schema `INFORMATION_SCHEMA` which can be read by SQL `SELECT` queries of the form

```
SELECT column-list
FROM INFORMATION_SCHEMA.view-name
WHERE condition
```

See the Mimer SQL Reference Manual chapter on Data Dictionary views for full details: two views are `TABLES` and `VIEWS`.

A session can be set to be read-only by the SQL command `SET SESSION READ ONLY`.

Mimer uses Latin-1 for its default character types but Unicode types (`NCHAR` and `NVARCHAR`) are also available. Unsurprisingly given that the company is Swedish, different collations are allowed for both Latin-1 and Unicode character types.

A Installation

RODBC is simple to install, and binary distributions are available for Mac OS X and Windows from CRAN.

To install from the sources, an *ODBC Driver Manager* is required. Windows normally comes with one (it is part of MDAC and can be installed separately if required). Mac OS X since 10.2 has shipped with iODBC, which is also available for other Unix-alikes. But for other systems the driver manager of choice is unixODBC, part of almost all Linux distributions and with sources downloadable from http://www.unixODBC.org. In Linux binary distributions it is likely that package unixODBC-devel or unixodbc-dev or some such will be needed.

In most cases the package's configure script will find the driver manager files, and the package will install with no extra settings. However, if further information is required, use --with-odbc-include and --with-odbc-lib or environment variables ODBC_INCLUDE and ODBC_LIBS to set the include and library paths as needed. A specific ODBC driver manager can be specified by the --with-odbc-manager configure option, with likely values odbc or iodbc: if this is done for odbc and the program odbc_config is found, it is used to set the libpath as a last resort (it is often wrong), and to add any additional CFLAGS.

Sources of drivers

A fairly comprehensive list of drivers is maintained at http://www.sqlsummit.com/ODBCVend.htm, and one for unixODBC[12] at http://www.unixodbc.org/drivers.html. unixODBC ships with a number of drivers (although in most cases the DBMS vendor's driver is preferred)—these include for MySQL, PostgreSQL, Mimer and flat files.

MySQL provides drivers under the name 'Connector/ODBC' (formerly MyODBC') in source form, and binaries for all common R platforms.

PostgreSQL has an associated project at http://pgfoundry.org/projects/psqlodbc/ and another project for a driver in development at http://pgfoundry.org/projects/odbcng/.

An SQLite ODBC driver for Unix-alikes and Windows are available from http://www.ch-werner.de/sqliteodbc/.

Oracle provides ODBC drivers as a supplement to its 'Instant Client' for some of its platforms (including 32-bit Windows and ix86 Linux, but not

[12]that the author works for Easysoft is conspicuous.

Mac OS X nor x86_64 Linux). See http://www.oracle.com/technology/software/tech/oci/instantclient/. One quirk of the Windows driver is that the Oracle binaries must be in the path, so PATH should include e.g c:\Oracle\bin.

For IBM's DB2, search its site for drivers for 'ODBC and CLI'. There are some notes about using this under Linux at http://www.unixodbc.org/doc/db2.html.

Mimer (www.mimer.com) is a cross-platform DBMS with integral ODBC support, so

> 'The Mimer SQL setup process automatically installs an ODBC driver when the Mimer SQL client is installed on any Windows or UNIX platform.'

The 'HowTos' at http://developer.mimer.se/howto/index.tml provide some useful hints.

Some details of the Microsoft 'ODBC Desktop Database Drivers' (for Access, Excel, Paradox, dBase and text files on Windows) can be found at http://msdn.microsoft.com/en-us/library/ms709326%28VS.85%29.aspx. There is also a Visual FoxPro driver and an (outdated) Oracle driver.

Windows drivers for Access 2007 and Excel 2007 are bundled with Office 2007 but can be installed separately *via* the installer AccessDatabaseEngine.exe available from http://www.microsoft.com/downloads/details.aspx?FamilyID=7554f536-8c28-4598-9b72-ef94e038c891&DisplayLang=en

For recent versions of Mac OS X, low-cost and easy-to-use drivers are available from http://www.actualtechnologies.com/products.php: these cover MySQL/PostgreSQL/SQLite (one driver), SQL Server/Sybase, Oracle, and a read-only driver for Access and related formats (including Access 2007 and Excel, but not Excel 2007). That SQLite driver needs believeNRows = FALSE set.

Mac OS X drivers for the MySQL, PostgreSQL and the major commercial databases are available from http://uda.openlinksw.com/.

Specifying ODBC drivers

The next step is to specify the ODBC drivers to be used for specific DBMSs. On Windows installing the drivers will register them automatically. This might happen as part of the installation on other systems, but usually does not.

```
$ cat /etc/odbcinst.ini
[MySQL]
Description    = ODBC 3.51.26 for MySQL
Driver         = /usr/lib64/libmyodbc3.so
FileUsage      = 1

[MySQL ODBC 5.1 Driver]
Description     = ODBC 5.1.05 for MySQL
Driver          = /usr/lib64/libmyodbc5.so
UsageCount      = 1

[PostgreSQL]
Description     = ODBC for PostgreSQL
Driver          = /usr/lib64/psqlodbc.so
FileUsage       = 1

[sqlite3]
Description = sqliteodbc
Driver = /usr/local/lib64/libsqlite3odbc.so
Setup = /usr/local/lib64/libsqlite3odbc.so
FileUsage = 1
```

Figure 1: A system ODBC driver file from a `x86_64` Fedora 10 Linux system using `unixODBC`.

Both `unixODBC` and `iODBC` store information on drivers in configuration files, normally system-wide in `/etc/odbcinst.ini` and per-user in `~/.odbcinst.ini`. However, the system location can vary, and on systems with `unixODBC` can be found by at the Unix command line by one of

```
$  odbcinst -j
$  odbc_config --odbcinstini
```

For `iODBC` use `iodbc_config`: on Mac OS X the system location is `/Library/ODBC/odbcinst.ini`.

The format can be seen from figure 1. (`unixODBC` allows `Driver64` here to allow for different paths on 32-bit and 64-bit platforms sharing a file system.) The MySQL and PostgreSQL drivers were installed from the Fedora RPMs `mysql-connector-odbc` and `postgresql-odbc`, and also from the `mysql-connector-odbc` RPM in the MySQL distribution (which inserted the entry in the driver file).

The MySQL manual gives detailed information (including screenshots) of installing its drivers and setting up DSNs that may also be informative to users of other DBMSs.

B Specifying DSNs

The ODBC driver managers have 'User DSNs' and 'System DSNs': these differ only in where the information is stored, the first on a per-user basis and the second for all users of the system.

Windows has a GUI to set up DSNs, called something like 'Data Sources (ODBC)' under 'Administrative Tools' in the Control Panel. You can add, remove and edit ('configure') DSNs there (see figure 2). When adding a DSN, first select the ODBC driver and then complete the driver-specific dialog box. There will usually be an option to test the DSN and it is wise to do so.

If `Rgui` is to be used on Windows, incomplete DSNs can be created and the dialog box will be brought up for completion when `odbcConnect` is called—this can be helpful to avoid storing passwords in the Windows Registry or to allow alternate users or databases. On that platform, calling `odbcDriverConnect()` with no arguments will bring up the main ODBC Data Sources dialog box to allow a DSN to be constructed on the fly.

Mac OS X comes with a very similar GUI (figure 3) found at Applications / Utilities / ODBC Administrator.

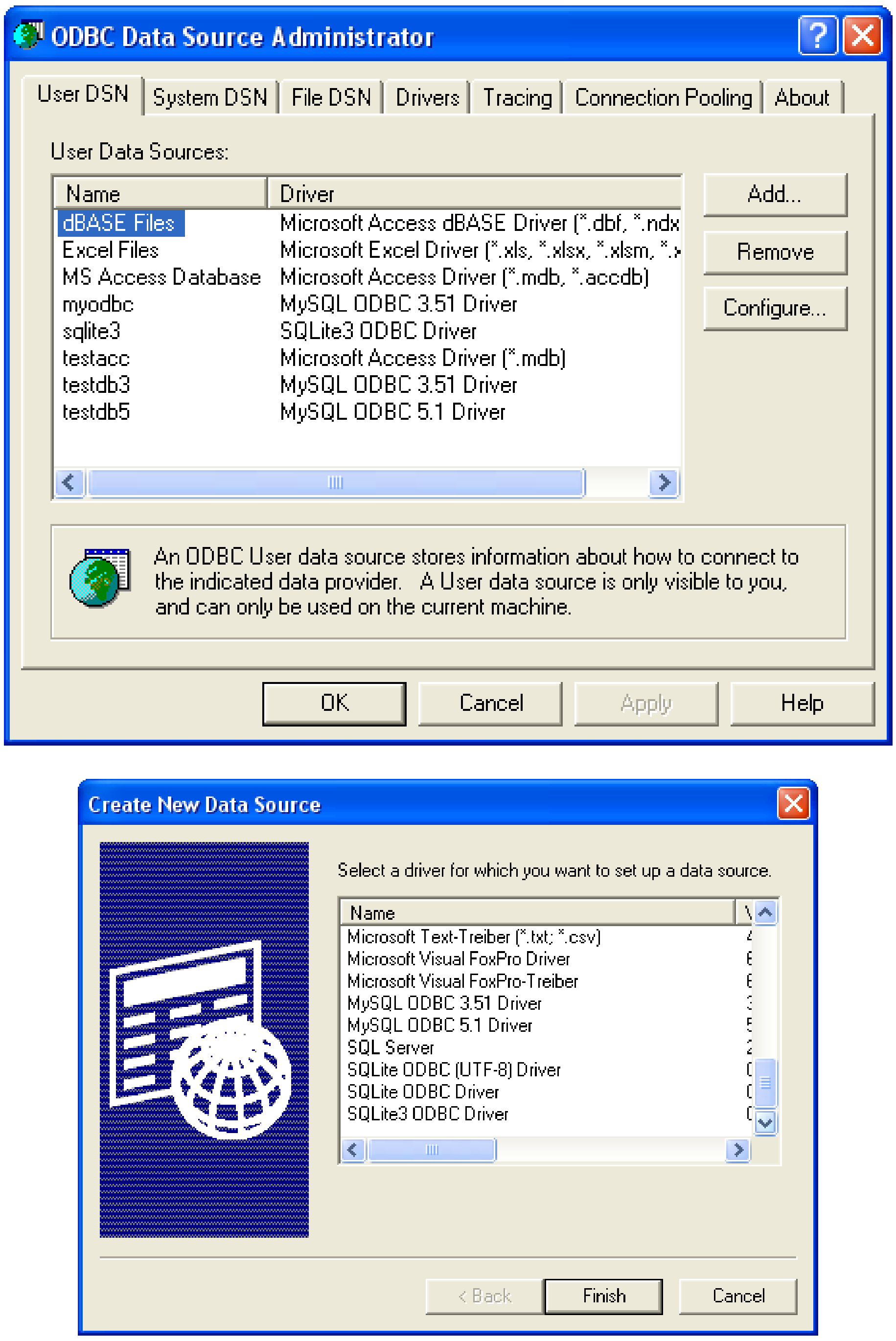
Both `unixODBC` and `iODBC` provide GUIs (which might be packaged separately in binary distributions) to create DSNs, and `iODBC` also has a web-based DSN administrator. UnixODBC's GUI is currently called `ODBCConfig` (see figure 4), and there is a KDE control widget called `DataManager` to manage both ODBC drivers and DSNs. See the `unixODBC` user manual at http://www.unixodbc.org/doc/UserManual/. (On Fedora these are in the `unixODBC-kde` RPM. It has been announced that they will become separate projects after `unixODBC 2.2.14`.)

On Unix-alikes DSNs can also be specified in files (and the graphical tools just manipulate these files). The system-wide file is usually `/etc/odbc.ini` and the per-user file[13] `~/.odbc.ini`. Some examples of the format are shown figure 5.

What fields are supported is driver-specific (and it can be hard to find documentation). There is no clear distinction between fields that specify the driver and those which specify the DSN, so any parts of the driver specification which might differ between connections can be used in the DSN file.

Things that are often set here are if the connection is read-only (`test_pg` is *not* readonly) and the character encoding to be used.

[13]`~/Library/ODBC/odbc.ini` on Mac OS X.



User Data Sources:

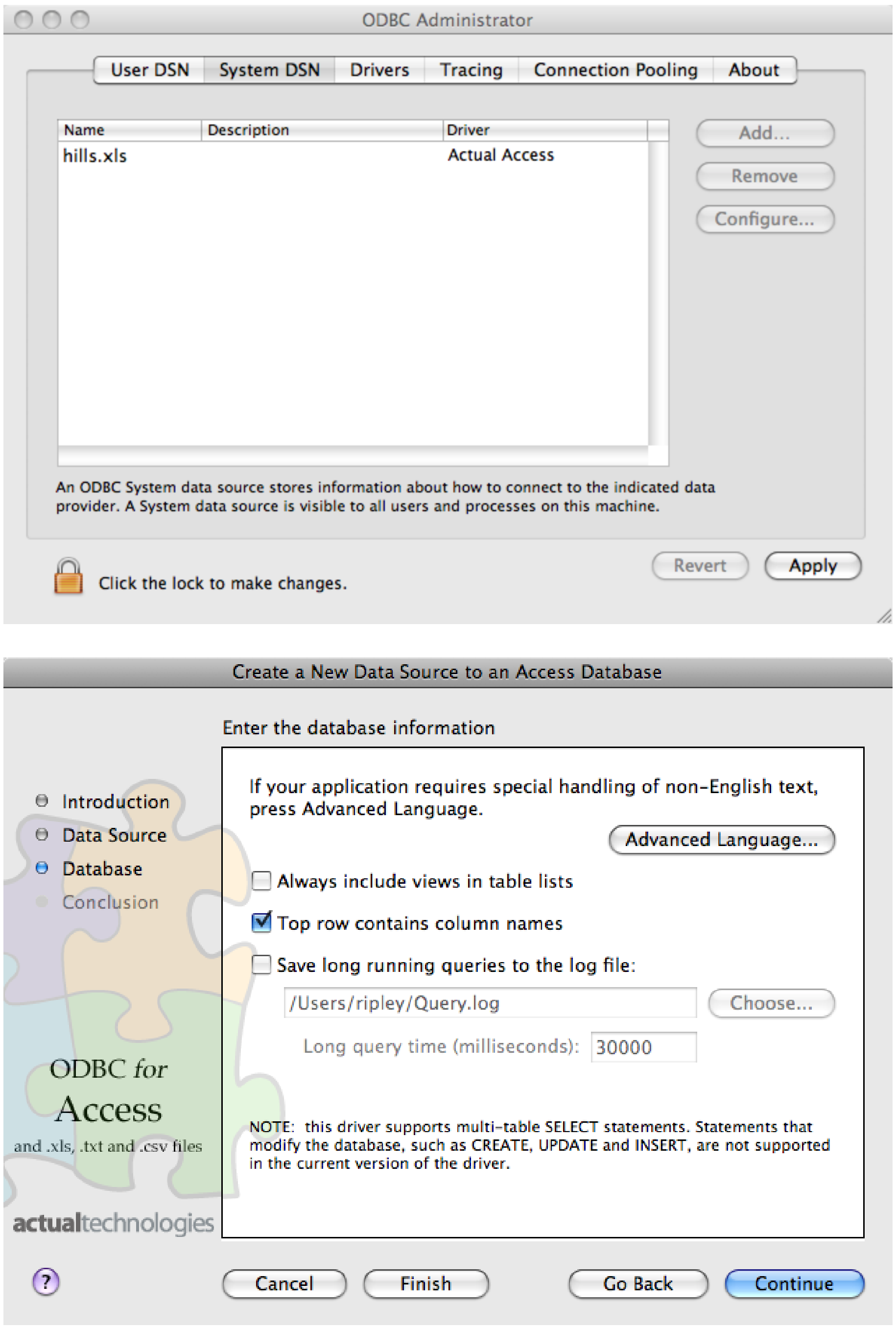
Name	Driver
dBASE Files	Microsoft Access dBASE Driver (*.dbf, *.ndx
Excel Files	Microsoft Excel Driver (*.xls, *.xlsx, *.xlsm, *.x
MS Access Database	Microsoft Access Driver (*.mdb, *.accdb)
myodbc	MySQL ODBC 3.51 Driver
sqlite3	SQLite3 ODBC Driver
testacc	Microsoft Access Driver (*.mdb)
testdb3	MySQL ODBC 3.51 Driver
testdb5	MySQL ODBC 5.1 Driver

An ODBC User data source stores information about how to connect to the indicated data provider. A User data source is only visible to you, and can only be used on the current machine.

Select a driver for which you want to set up a data source.

Name
Microsoft Text-Treiber (*.txt; *.csv)
Microsoft Visual FoxPro Driver
Microsoft Visual FoxPro-Treiber
MySQL ODBC 3.51 Driver
MySQL ODBC 5.1 Driver
SQL Server
SQLite ODBC (UTF-8) Driver
SQLite ODBC Driver
SQLite3 ODBC Driver

Figure 2: (Top) The main Data Sources (ODBC) dialog box from a Windows XP system. (Bottom) The dialog box to select a driver that comes up when the Add button is clicked.



Name	Description	Driver
hills.xls		Actual Access

An ODBC System data source stores information about how to connect to the indicated data provider. A System data source is visible to all users and processes on this machine.

Click the lock to make changes.

Enter the database information

If your application requires special handling of non-English text, press Advanced Language.

☐ Always include views in table lists

✓ Top row contains column names

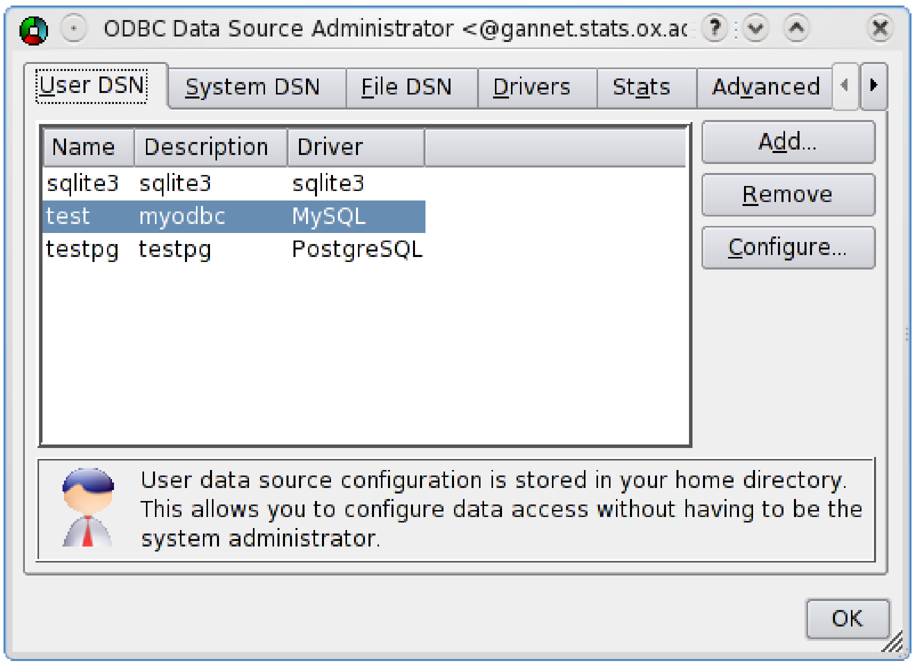
☐ Save long running queries to the log file:

/Users/ripley/Query.log

Long query time (milliseconds): 30000

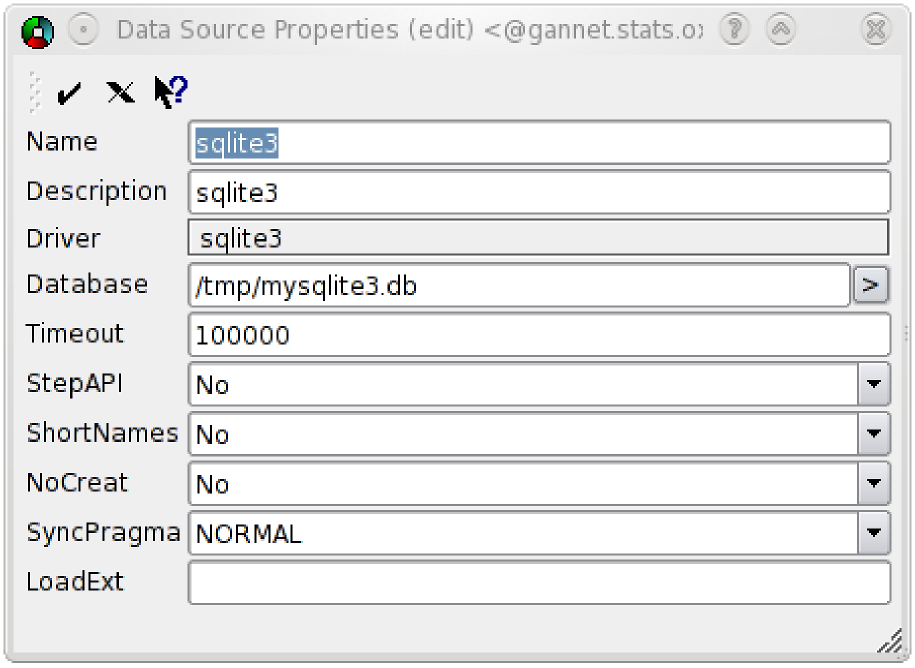
NOTE: this driver supports multi-table SELECT statements. Statements that modify the database, such as CREATE, UPDATE and INSERT, are not supported in the current version of the driver.

Figure 3: (Top) The main ODBC Administrator dialog box from a Mac OS X system. (Bottom) A page of the dialog box to specify a DSN for the Actual Technologies Access/Excel driver.


ODBC Data Source Administrator <@gannet.stats.ox.ac

Name	Description	Driver
sqlite3	sqlite3	sqlite3
test	myodbc	MySQL
testpg	testpg	PostgreSQL

User data source configuration is stored in your home directory. This allows you to configure data access without having to be the system administrator.


Data Source Properties (edit) <@gannet.stats.o

Name	sqlite3
Description	sqlite3
Driver	sqlite3
Database	/tmp/mysqlite3.db
Timeout	100000
StepAPI	No
ShortNames	No
NoCreat	No
SyncPragma	NORMAL
LoadExt	

Figure 4: The dialog box of `ODBCconfig` on Fedora 10 Linux, and the Configure screen for the SQLite driver.

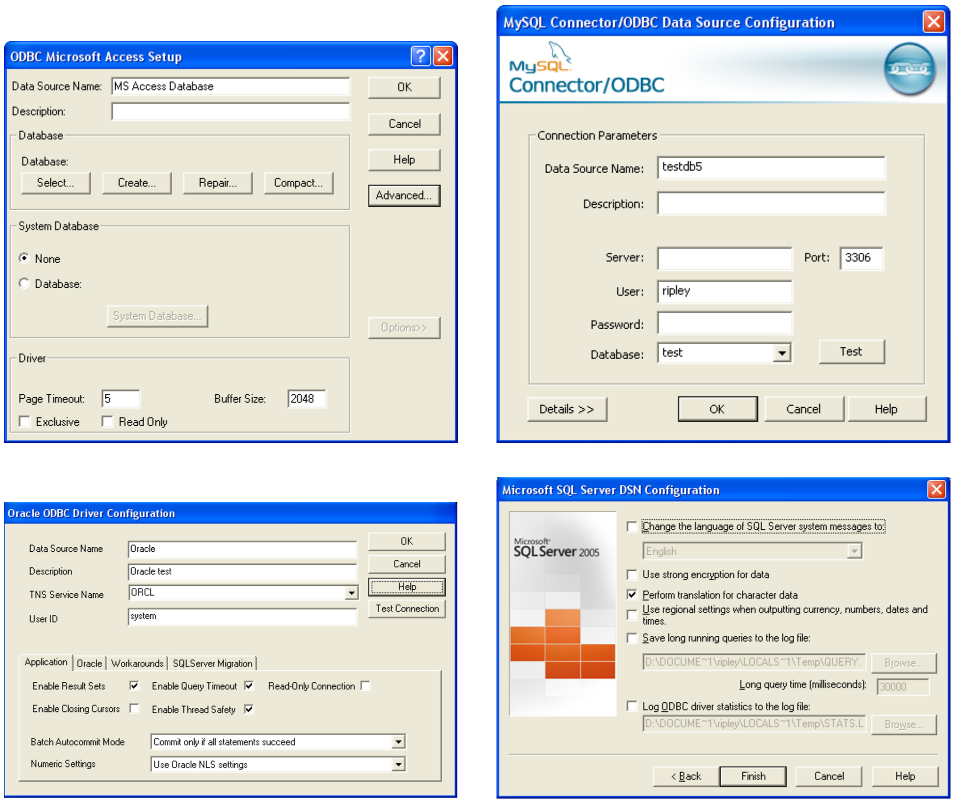
```
[test_mysql]
Description     = test MySQL
Driver          = MySQL
Trace           = No
Server          = localhost
Port            = 3306
Database        = test

[test_mysql5]
Description     = myodbc5
Driver          = MySQL ODBC 5.1 Driver
Server          = gannet
Port            = 3306
Database        = ripley

[test_pg]
Description     = test PostgreSQL
Driver          = PostgreSQL
Trace           = No
TraceFile       =
ServerName      = localhost
UserName        = ripley
Port            = 5432
Socket          =
Database        = testdb
ReadOnly        = 0

[test_sqlite3]
Description     = test SQLite3
Driver          = sqlite3
Database        = /tmp/mysqlite3.db
```

Figure 5: A personal (`~/.odbc.ini`) file from a Fedora 10 Linux system using `unixODBC`.

Command-line programs `isql` (`unixODBC`) and `iodbctest` (`iODBC`) can be used to test a DSN that has been created manually in a file. The formats are

```
$ isql -v dsn db_username db_password
$ iodbctest
```

Both give a command-line SQL interface: use `quit` to terminate.



ODBC Microsoft Access Setup

Data Source Name: MS Access Database
Description:
Database
Database:
System Database
[✓ None] Database:
Driver
Page Timeout: 5
Buffer Size: 2048
☐ Exclusive ☐ Read Only

MySQL Connector/ODBC Data Source Configuration

Connection Parameters
Data Source Name: testdb5
Description:
Server:
Port: 3306
User: ripley
Password:
Database: test

Oracle ODBC Driver Configuration

Data Source Name: Oracle
Description: Oracle test
TNS Service Name: ORCL
User ID: system

Application | Oracle | Workarounds | SQLServer Migration
Enable Result Sets ✓ Enable Query Timeout ✓ Read-Only Connection ☐
Enable Closing Cursors ☐ Enable Thread Safety ✓
Batch Autocommit Mode: Commit only if all statements succeed
Numeric Settings: Use Oracle NLS settings

Microsoft SQL Server DSN Configuration

☐ Change the language of SQL Server system messages to: English
☐ Use strong encryption for data
✓ Perform translation for character data
☐ Use regional settings when outputting currency, numbers, dates and times.
☐ Save long running queries to the log file: D:\DOCUME~1\ripley\LOCALS~1\Temp\QUERY.
Long query time (milliseconds): 30000
☐ Log ODBC driver statistics to the log file: D:\DOCUME~1\ripley\LOCALS~1\Temp\STATS.L

Figure 6: Parts of the ODBC driver configuration screens on Windows XP for Microsoft Access, MySQL Connector/ODBC 5.1, Oracle's ODBC driver and Microsoft SQL Server.