

Using the *GEOMETADB* package

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1 Overview of *GEOMETADB*

The NCBI Gene Expression Omnibus (GEO) represents the largest repository of microarray data in existence. One difficulty in dealing with GEO is finding the microarray data that is of interest. As part of the NCBI Entrez search system, GEO can be searched online via web pages or using NCBI Eutils. However, the web search is not as full-featured as it could be, particularly for programmatic access. NCBI Eutils offers another option for finding data within the vast stores of GEO, but it is cumbersome to use, often requiring multiple

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complicated Eutils calls to get at the relevant information. We have found it **absolutely critical** to have ready access not just to the microarray data, but to the metadata describing the microarray experiments. To this end we have created *GEOMETADB*.

1.1 What is *GEOMETADB*?

The *GEOMETADB* is an attempt to make querying the metadata describing microarray experiments, platforms, and datasets both easier and more powerful. At the heart of *GEOMETADB* is a SQLite database that stores nearly all the metadata associated with all GEO data types including GEO samples (GSM), GEO platforms (GPL), GEO data series (GSE), and curated GEO datasets (GDS), as well as the relationships between these data types. This database is generated by our server by parsing all the records in GEO and needs to be downloaded via a simple helper function to the user's local machine before *GEOMETADB* is useful. Once this is done, the entire GEO database is accessible with simple SQL-based queries. With the *GEOMETADB* database, queries that are simply not possible using NCBI tools or web pages are often quite simple. The relationships between the tables in the *GEOMETADB* SQLite database can be seen in figure 1.

1.2 Conversion capabilities

A very typical problem for large-scale consumers of GEO data is to determine the relationships between various GEO accession types. As examples, consider the following questions:

- What samples are associated with GEO platform “GPL96”, which represents the Affymetrix hgu133a array?
- What GEO Series were performed using “GPL96”?
- What samples are in my favorite three GEO Series records?
- How many samples are associated with the ten most popular GEO platforms?

Because these types of questions are common, *GEOMETADB* contains the function `geoConvert` that addresses these questions directly and efficiently.

1.3 What *GEOMETADB* is not

We have faithfully parsed and maintained in GEO when creating *GEOMETADB*. This means that limitations inherent to GEO are also inherent in *GEOMETADB*. We have made no attempt to curate, semantically recode, or otherwise “clean up” GEO; to do so would require significant resources, which we do not have.

GEOMETADB does not contain any microarray data. For access to microarray data from within R/Bioconductor, please look at the *GEOquery* package. In fact, we would expect that many users will find that the combination of *GEOMETADB* and *GEOquery* is quite powerful.

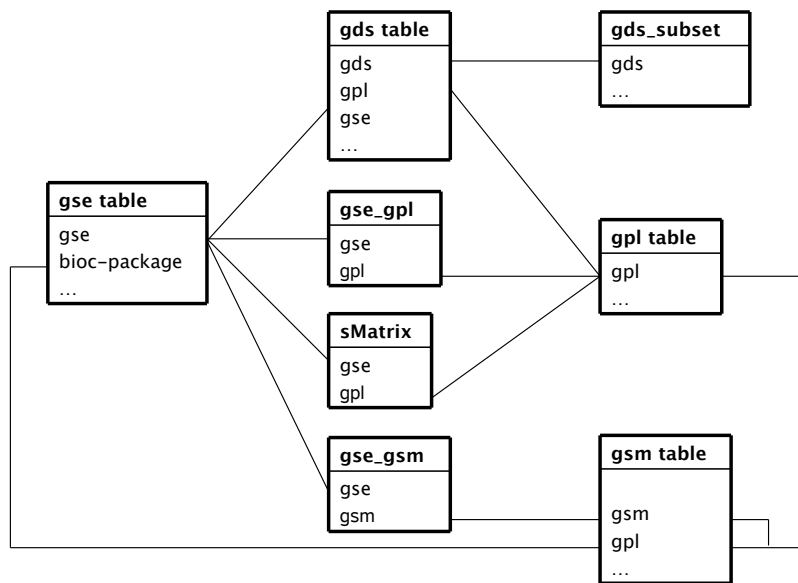


Figure 1: A graphical representation (sometimes called an *Entity-Relationship Diagram*) of the relationships between the tables in the GEOmetadb SQLite database

2 Getting Started

Once *GEOmetadb* is installed (see the Bioconductor website for full installation instructions), we are ready to begin.

2.1 Getting the *GEOmetadb* database

This package does not come with a pre-installed version of the database. This has the advantage that the user will get the most up-to-date version of the database to start; the database can be re-downloaded using the same command as often as desired. First, load the library.

```
> library(GEOmetadb)
```

The download and uncompress steps are done automatically with a single command, `getSQLiteFile`.

```
> getSQLiteFile()
```

Unzipping...

Metadata associate with downloaded file:

	name	value
1	schema version	1.0
2	creation timestamp	2013-10-12 15:58:52
[1]	"D:/biocbld/bbs-2.13-bioc/tmpdir/RtmpS40s2N/Rbuild87c4805f0b/GEOmetadb/inst/doc/GEOm	

The default storage location is in the current working directory and the default filename is “GEOmetadb.sqlite”; it is best to leave the name unchanged unless there is a pressing reason to change it.

Since this SQLite file is of key importance in *GEOmetadb*, it is perhaps of some interest to know some details about the file itself.

```
> file.info('GEOmetadb.sqlite')
```

	size	isdir	mode	mtime	ctime	atime	exe
GEOmetadb.sqlite	2721373184	FALSE	666				
GEOmetadb.sqlite	2013-10-15 00:13:46						
GEOmetadb.sqlite	2013-10-15 00:13:27						
GEOmetadb.sqlite	2013-10-15 00:13:27						no

Now, the SQLite file is available for connection. The standard *DBI* functionality as implemented in *RSQLite* function `dbConnect` makes the connection to the database. The `dbDisconnect` function disconnects the connection.

```
> con <- dbConnect(SQLite(), 'GEOmetadb.sqlite')
> dbDisconnect(con)
```

```
[1] TRUE
```

The variable `con` is an *RSQLite* connection object.

2.2 A word about SQL

The Structured Query Language, or SQL, is a very powerful and standard way of working with relational data. GEO is composed of several data types, all of which are related to each other; in fact, NCBI uses a relational SQL database for metadata storage and querying. SQL databases and SQL itself are designed specifically to work efficiently with just such data. While the goal of many programming projects and programmers is to hide the details of SQL from the user, we are of the opinion that such efforts may be counterproductive, particularly with complex data and the need for *ad hoc* queries, both of which are characteristics with GEO metadata. We have taken the view that exposing the power of SQL will enable users to maximally utilize the vast data repository that is GEO. We understand that many users are not accustomed to working with SQL and, therefore, have devoted a large section of the vignette to working examples. Our goal is not to teach SQL, so a quick tutorial of SQL is likely to be beneficial to those who have not used it before. Many such tutorials are available online and can be completed in 30 minutes or less.

3 Examples

3.1 Interacting with the database

The functionality covered in this section is covered in much more detail in the *DBI* and *RSQLite* package documentation. We cover enough here only to be useful.

Again, we connect to the database.

```
> con <- dbConnect(SQLite(), 'GEOmetadb.sqlite')
```

The `dbListTables` function lists all the tables in the SQLite database handled by the connection object `con`.

```
> geo_tables <- dbListTables(con)
> geo_tables

[1] "gds"                "gds_subset"
[3] "geoConvert"         "geodb_column_desc"
[5] "gpl"                "gse"
[7] "gse_gpl"            "gse_gsm"
[9] "gsm"                "metaInfo"
[11] "sMatrix"
```

There is also the `dbListFields` function that can list database fields associated with a table.

```
> dbListFields(con, 'gse')
```

```
[1] "ID"                "title"
[3] "gse"               "status"
[5] "submission_date"   "last_update_date"
[7] "pubmed_id"         "summary"
[9] "type"              "contributor"
[11] "web_link"          "overall_design"
[13] "repeats"           "repeats_sample_list"
[15] "variable"          "variable_description"
[17] "contact"           "supplementary_file"
```

Sometimes it is useful to get the actual SQL schema associated with a table. As an example of doing this and using an *RSQLite* shortcut function, `sqliteQuickSQL`, we can get the table schema for the *gpl* table.

```
> sqliteQuickSQL(con, 'PRAGMA TABLE_INFO(gpl)')
```

	cid		name	type	notnull	dflt_value	pk
1	0		ID	REAL	0	<NA>	0
2	1		title	TEXT	0	<NA>	0
3	2		gpl	TEXT	0	<NA>	0
4	3		status	TEXT	0	<NA>	0
5	4		submission_date	TEXT	0	<NA>	0
6	5		last_update_date	TEXT	0	<NA>	0
7	6		technology	TEXT	0	<NA>	0
8	7		distribution	TEXT	0	<NA>	0
9	8		organism	TEXT	0	<NA>	0
10	9		manufacturer	TEXT	0	<NA>	0
11	10		manufacture_protocol	TEXT	0	<NA>	0
12	11		coating	TEXT	0	<NA>	0
13	12		catalog_number	TEXT	0	<NA>	0
14	13		support	TEXT	0	<NA>	0
15	14		description	TEXT	0	<NA>	0
16	15		web_link	TEXT	0	<NA>	0
17	16		contact	TEXT	0	<NA>	0
18	17		data_row_count	REAL	0	<NA>	0
19	18		supplementary_file	TEXT	0	<NA>	0
20	19		bioc_package	TEXT	0	<NA>	0

3.2 Writing SQL queries and getting results

Select 5 records from the *qse* table and show the first 7 columns.

```
> rs <- dbGetQuery(con,'select * from gse limit 5')
> rs[,1:7]
```

ID
1
2
3
4
5

	title
1	NHGRI_Melanoma_class
2	Cerebellar development
3	Renal Cell Carcinoma Differential Expression
4	Diurnal and Circadian-Regulated Genes in Arabidopsis
5	Global profile of germline gene expression in C. elegans

	gse	status	submission_date
1	GSE1	Public on Jan 22 2001	2001-01-22
2	GSE2	Public on Apr 26 2001	2001-04-19
3	GSE3	Public on Jul 19 2001	2001-07-19
4	GSE4	Public on Jul 20 2001	2001-07-20
5	GSE5	Public on Jul 24 2001	2001-07-24

	last_update_date	pubmed_id
1	2012-02-23	10952317
2	2012-02-23	NA
3	2012-02-23	11691851
4	2012-02-23	11158533
5	2012-02-23	11030340

Get the GEO series accession and title from GEO series that were submitted by “Sean Davis”. The “

```
> rs <- dbGetQuery(con,paste("select gse,title from gse where",
+                             "contributor like '%Sean%Davis%'",sep=" "))
> rs
```

```

      gse
1  GSE2553
2  GSE4406
3  GSE5357
4  GSE7376

```

5 GSE7882
6 GSE8486
7 GSE9328
8 GSE14543
9 GSE15621
10 GSE16087
11 GSE16088
12 GSE16091
13 GSE16102
14 GSE18544
15 GSE19063
16 GSE20016
17 GSE22520
18 GSE25127
19 GSE25164
20 GSE29428
21 GSE41795
22 GSE5481

1
2 Gene expression profiling of CD4+ T-cells and
3
4 Detection of novel amplifications in
5 Gene Expression and Comparative Genomic Hybridization of Ductal Carcinoma
6 Whole genome DNase hypersensitivity analysis of human and mouse
7
8 A molecular genetic study of the role of the p53 gene in
9 Acute Lymphocytic Leukemia
10 Gene expression profiles of human and mouse
11 Gene expression profiles of human and mouse
12 Gene expression profiles of human and mouse
13 Gene expression profiles of human and mouse
14 Expression Profiling of a Mouse Xenograft Model of "Triple-Negative" Breast Cancer
15 Genome-wide map of PAX3-FKHR fusion gene expression in
16 Analyses of Human Brain Metastases of Breast Cancer Reveal the Association between HK2
17 Mouse Models of Alveolar/Embryonal Rhabdomyosarcoma
18 Ewing Sarcoma and Rhabdomyosarcoma
19
20 A methyl-deviator epigenotype of estrogen-receptor-positive breast carcinoma is
21 Accelerated high-yield generation of limb-innervating myotubes
22

As another example, GEOmetadb can find all samples on GPL96 (Affymetrix hgu133a) that have .CEL files available for download.

```
> rs <- dbGetQuery(con,paste("select gsm,supplementary_file",
+                             "from gsm where gpl='GPL96'",
+                             "and supplementary_file like '%CEL.gz'"))
> dim(rs)
```

```
[1] 24823      2
```

But why limit to only GPL96? Why not look for all Affymetrix arrays that have .CEL files? And list those with their associated GPL information, as well as the Bioconductor annotation package name?

```
> rs <- dbGetQuery(con,paste("select gpl.bioc_package,gsm.gpl,",
+                             "gsm,gsm.supplementary_file",
+                             "from gsm join gpl on gsm.gpl=gpl.gpl",
+                             "where gpl.manufacturer='Affymetrix'",
+                             "and gsm.supplementary_file like '%CEL.gz' "))
> rs[1:5,]
```

	bioc_package	gpl	gsm	supplementary_file
1	<NA>	GPL80	GSM575	ftp://ftp.ncbi.nlm.nih.gov/geo/samples/GSMnnn/GSM575/suppl/GSM575.cel.gz
2	<NA>	GPL80	GSM576	ftp://ftp.ncbi.nlm.nih.gov/geo/samples/GSMnnn/GSM576/suppl/GSM576.cel.gz
3	<NA>	GPL80	GSM577	ftp://ftp.ncbi.nlm.nih.gov/geo/samples/GSMnnn/GSM577/suppl/GSM577.cel.gz
4	<NA>	GPL80	GSM578	ftp://ftp.ncbi.nlm.nih.gov/geo/samples/GSMnnn/GSM578/suppl/GSM578.cel.gz
5	<NA>	GPL80	GSM579	ftp://ftp.ncbi.nlm.nih.gov/geo/samples/GSMnnn/GSM579/suppl/GSM579.cel.gz

Of course, we can combine programming and data access. A simple `sapply` example shows how to query each of the tables for number of records.

```
> getTableCounts <- function(tableName,conn) {
+   sql <- sprintf("select count(*) from %s",tableName)
+   return(dbGetQuery(conn,sql)[1,1])
+ }
> do.call(rbind,sapply(geo_tables,getTableCounts,con,simplify=FALSE))
```

	[,1]
gds	3360
gds_subset	19940
geoConvert	4728726
geodb_column_desc	104
gpl	12108
gse	42057
gse_gpl	51752
gse_gsm	1195315
gsm	1012254
metaInfo	2
sMatrix	49161

3.3 Conversion of GEO entity types

Large-scale consumers of GEO data might want to convert GEO entity type from one to others, e.g. finding all GSM and GSE associated with 'GPL96'. Function `geoConvert` does the conversion with a very fast mapping between entity types.

Covert 'GPL96' to other possible types in the GEOmetadb.sqlite.

```
> conversion <- geoConvert('GPL96')
```

Check what GEO types and how many entities in each type in the conversion.

```
> lapply(conversion, dim)
```

```
$gse
[1] 972  2
```

```
$gsm
[1] 34203  2
```

```
$gds
[1] 351  2
```

```
$sMatrix
[1] 1015  2
```

```
> conversion$gse[1:5,]
```

	from_acc	to_acc
1	GPL96	GSE1000
2	GPL96	GSE10024
3	GPL96	GSE10043
4	GPL96	GSE10072
5	GPL96	GSE10089

```
> conversion$gsm[1:5,]
```

	from_acc	to_acc
1	GPL96	GSM1003058
2	GPL96	GSM1003059
3	GPL96	GSM1003060
4	GPL96	GSM1003061
5	GPL96	GSM1003062

```
> conversion$gds[1:5,]
```

	from_acc	to_acc
1	GPL96	GDS1023
2	GPL96	GDS1036
3	GPL96	GDS1050
4	GPL96	GDS1062
5	GPL96	GDS1063

```
> conversion$sMatrix[1:5,]
```

	from_acc	to_acc
1	GPL96	GSE1000_series_matrix.txt.gz
2	GPL96	GSE10024_series_matrix.txt.gz
3	GPL96	GSE10043_series_matrix.txt.gz
4	GPL96	GSE10072_series_matrix.txt.gz
5	GPL96	GSE10089_series_matrix.txt.gz

3.4 Mappings between GPL and Bioconductor microarray annotation packages

The function `getBiocPlatformMap` is to get GPL information of a given list of Bioconductor microarray annotation packages. Note currently the `GEOmetadb` does not contains all the mappings, but we are trying to construct a relative complete list.

Get GPL information of 'hgu133a' and 'hgu95av2':

```
> getBiocPlatformMap(con, bioc=c('hgu133a', 'hgu95av2'))
```

[1] title	gpl	bioc_package
[4] manufacturer	organism	data_row_count

<0 rows> (or 0-length row.names)

3.5 More advanced queries

Now, for something a bit more complicated, we would like to find all the human breast cancer-related Affymetrix gene expression GEO series.

```
> sql <- paste("SELECT DISTINCT gse.title,gse.gse",
+             "FROM",
+             "  gsm JOIN gse_gsm ON gsm.gsm=gse_gsm.gsm",
+             "  JOIN gse ON gse_gsm.gse=gse.gse",
+             "  JOIN gse_gpl ON gse_gpl.gse=gse.gse",
+             "  JOIN gpl ON gse_gpl.gpl=gpl.gpl",
+             "WHERE",
+             "  gsm.molecule_ch1 like '%total RNA%' AND",
+             "  gse.title LIKE '%breast cancer%' AND",
+             "  gpl.organism LIKE '%Homo sapiens%'",sep=" ")
> rs <- dbGetQuery(con,sql)
> dim(rs)

[1] 542    2

> print(rs[1:5,],right=FALSE)

  title
1 Breast Cancer aCGH
2 Human mammary epithelium and breast cancer
3 Cell-type specific responses to chemotherapeutics in breast cancer
4 E2 and SERM Treatment of MCF-7 Breast Cancer Cells
5 Estradiol Treated Breast Cancer Cells Expressing Mutant Estrogen Receptors
  gse
1 GSE3281
2 GSE53
3 GSE763
4 GSE848
5 GSE1045
```

Finally, it is probably a good idea to close the connection, please see *DBI* for detail.

```
> dbDisconnect(con)
```

```
[1] TRUE
```

If you want to remove old `GEOmetadb.sqlite` file before retrieve a new version from the server, execute the following codes:

```
> file.remove('GEOmetadb.sqlite')
```

```
[1] TRUE
```