Using Bioconductor’s Annotation Libraries

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Overview

The Bioconductor project maintains a rich body of annotation data assembled into R libraries. The purpose of this vignette is to discuss the structure, contents, and usage of these annotation data libraries. Executable code is provided as examples.

Contents

Bioconductor’s annotation data libraries are constructed by assembling data collected from various public data repositories using Bioconductor’s AnnBuilder package and distributed as regular R libraries that can be installed and loaded in the same way an R library is installed/loaded. Each annotation library is an independent unit that can be used alone or in conjunction with other annotation libraries. Figure 1 shows the relationship among libraries that are currently available. Platform specific libraries are a group annotation libraries assembled specifically for given platforms (e.g. Affymetrix HG_U95Av2). CHRLOC and org.XX.eg.db are groups of libraries containing data assembled at genome level for human, mouse, or rat. KEGG.db and GO.db are source specific libraries containing generic data for various genomes.

Each annotation library, when installed, contains a data and man subdirectory filled with assembled data and documentation about the data, respectively. Most assembled data are stored as binary R environment objects (hash table with key-value pairs) associating annotation values to a set of keys. For each environment object in the data directory, there is a corresponding help file in the man directory with detail descriptions of the data file and usage.

Each platform specific library contains R environment objects named following the convention of package name plus environment name. The package name is in lower case letters and the environment names are in capital letters. When a given environment maps platform specific keys to annotation data, only the name of the annotation data is used for the name of the environment. Otherwise, the environment name have a pattern of key name and value name joined by a “2” in between. For example, hgu95av2ENTREZID maps probe ids on an Affymetrix human genome U95Av2 chip to EntrezGene IDs while hgu95av2GO2PROBE maps Gene Ontology IDs to probe IDs. Names of the
Figure 1: A diagram showing the overall structure and inter-relationship of Bioconductor annotation data packages. Boxes show a single or group of data packages. Lines between two boxes indicate connections through the key denoted by the text beside each line.
environment objects in a platform specific data package are not listed here to save space but are easily accessible as shown later in the section for usage.

Genome level annotation libraries are named in the form of XXXCHARLOC and where XXX represents an organism name. Each data package in the CHRLOC group has Entrez Gene ids mapped to chromosomal location where transcription of genes corresponding to the Entrez Gene ids begins and ends. There is a START and END environment for Entrez Gene ids on each of the chromosomes (e.g. humanCHRLOC1START and humanCHRLOC1END for human chromosome number 1). Each library in the LLMappings group provides mappings/reverse mappings between Entrez Gene ids and some other commonly used public repository identifiers. Environment names are a concatenations of the names of mapped ids with a 2 in between (e.g. humanLLMappingsLL2GO).

The KEGG.db library contains mappings between ids such as Locuslink and GO to KEGG pathway ids and thus pathway names. The GO.db library maintain the directed acyclic graph structure of the original data from Gene Ontology Consortium by providing mappings of GO ids to their direct parents or children for each of the three categories (molecular function, cellular component, and biological process). In addition, mappings between Entrez Gene and GO ids are provided with evidence code that specifies the type of evidence that supports the annotation of a gene to a particular GO term.

Usage

All the annotation libraries can be obtained from the Bioconductor web site (http://www.bioconductor.org). To illustrate their usages, we use the library for Affymetrix HG_U95Av2 chip (hgu95av2.db) as an example for platform specific data packages and the GO.db library for non-platform specific data packages. We assume that R (www.r-project.org) and Bioconductor’s Biobase and annotation libraries have already been installed.

Package installation

After downloading libraries hgu95av2.db and GO.db from the link to MetaData of the Bioconductor web site, install the libraries by typing R INSTALL library name in the directory where the library is stored under Unix or click the menu bar Packages and then Install package(s) from local zip files... of an R session under Windows. Alternatively, if the reposTools library has already been installed/loaded, typing install.packages2(library name) installs the library for both Unix and Windows.

Typing library(library name) in an R session will load the library into R. For example,

> library("annotate")
> library("hgu95av2.db")
> library("GO.db")
Documentations

Each library contains documentations for the library in general and each of the individual environment objects contained by the library. Two documents at the library level can be accessed by typing a library basename proceeded by a question mark (e. g. ?hgu95av2) and the library basename followed by a pair of brackets (e. g. hgu95av2()), respectively. The former indicates how the data package was built from what version of public data sources and the latter lists all the environments contained by a library and provides information on the total number of keys within each of the environment objects contained by the library and how many of these keys are annotated.

The documentation for a given environment object can be accessed by typing the name of an environment object proceeded by a question mark (e. g. hgu95av2GO). The resulting documentation provides detail explanations to the environment object, data source used to build the object, and example code for accessing annotation data.

Accessing annotation data within a library

Annotation data of a given library are stored as environment objects in the form of key (items to be annotated) and value (annotation for an key item) pairs. Each environment object provides annotation for keys for a particular subject reflected by the name of the object. For example, hgu95av2GO annotates probes on the HGU95Av2 chip with ids of the Gene Ontology terms the probes correspond to.

The name of an environment object consists of package basename (hgu95av2.db) and environment name (GO) to avoid confusion when multiple libraries are loaded to the system at the same time. Data contained by an environment can be accessed easily using Bioconductor’s existing functions. For example, the following code stores all the keys contained by the hgu95av2GO environment object to variable temp and displays the first five keys on the screen:

```r
> temp <- as.list(hgu95av2GO)
> temp[5]

`

> 1004_at`

> `$1004_at`$`GO:0006928`

> `$1004_at`$`GO:0006928`$GOID

[1] "GO:0006928"

> `$1004_at`$`GO:0006928`$Evidence

[1] "TAS"

> `$1004_at`$`GO:0006928`$Ontology

[1] "BP"
```
[1] "GO:0005886"

$'1004_at'`'GO:0005886'`Evidence
[1] "IEA"

$'1004_at'`'GO:0005886'`Ontology
[1] "CC"

$'1004_at'`'GO:0005887'`GOID
[1] "GO:0005887"

$'1004_at'`'GO:0005887'`Evidence
[1] "TAS"

$'1004_at'`'GO:0005887'`Ontology
[1] "CC"

$'1004_at'`'GO:0001584'`GOID
[1] "GO:0001584"

$'1004_at'`'GO:0001584'`Evidence
[1] "IEA"

$'1004_at'`'GO:0001584'`Ontology
[1] "MF"

$'1004_at'`'GO:0004872'`GOID
[1] "GO:0004872"

$'1004_at'`'GO:0004872'`Evidence
[1] "IEA"

$'1004_at'`'GO:0004872'`Ontology
[1] "MF"

$'1004_at'`'GO:0004945'`GOID
[1] "GO:0004945"
To obtain annotation for a given set of keys, one may use the `mget` function. Suppose we have run an experiment using the HG_U95Av2 chip and found three genes represented by Affymetrix probe ids `738_at`, `40840_at`, and `41668_r_at` interesting. To get the names of genes the three probe ids corresponding to, we do:

```r
> mget(c("738_at", "40840_at", "41668_r_at"), hgu95av2GENENAME)
```

```
$'738_at'
[1] "5'-nucleotidase, cytosolic II"

$'40840_at'
[1] "peptidylprolyl isomerase F (cyclophilin F)"

$'41668_r_at'
[1] "TDP-glucose 4,6-dehydratase"
```

Similarly, identifiers of Gene Ontology terms corresponding to the three probes can be obtained as shown below:

```r
> temp <- mget(c("41561_s_at", "40840_at", "41668_r_at"), hgu95av2GO)
```

In this case, the function `mget` returns a list of pre-defined S4 objects containing data for the ids, ontology, and evidence code of Gene Ontology terms corresponding to the three keys. The following code shows how to access the GO id, evidence code and ontology of the Gene Ontology term corresponding to probe id `40840_at`:

```r
> temp <- get("738_at", hgu95av2GO)
> names(temp)
```
As shown above, probe 40840_at can be annotated by three Gene Ontology terms identified by GO:0005829, GO:0008253, and GO:0016787. The evidence code for GO:0008253 is TAS (traceable author statement) and it belongs to ontology MF (molecular function).

**Accessing annotation data across libraries**

Often, data available in a given data package alone may not be sufficient and need to be sought across packages. Bioconductor’s annotation data packages are linked by common public data identifiers to allow traverse between packages (Fig. 1). Using the example above, we know that probe id 738_at are annotated by three Gene Ontology ids GO:0005829, GO:0008253, and GO:0016787. The Gene Ontology terms for various Gene Ontology ids, however, are stored in another package named GO.db. As package hgu95av2.db and GO.db are linked by GO ids, one can annotate probe id 738_at with Gene Ontology terms by linking data in the two packages using GO id as shown below:

```r
> mget(names(get("738_at", hgu95av2GO)), GOTERM)
```

$'GO:0009117'$

**GOID:** GO:0009117
**Term:** nucleotide metabolic process
**Ontology:** BP
**Definition:** The chemical reactions and pathways involving a nucleotide, a nucleoside that is esterified with (ortho)phosphate or an oligophosphate at any hydroxyl group on the glucose moiety; may be mono-, di- or triphosphate; this definition includes cyclic nucleotides (nucleoside cyclic phosphates).
**Synonym:** nucleotide metabolism

$'GO:0005737'$

**GOID:** GO:0005737
**Term:** cytoplasm
**Ontology:** CC
**Definition:** All of the contents of a cell excluding the plasma...
membrane and nucleus, but including other subcellular structures.

`GO:0005829`
GOID: GO:0005829
Term: cytosol
Ontology: CC
Definition: That part of the cytoplasm that does not contain membranous or particulate subcellular components.

`GO:0000166`
GOID: GO:0000166
Term: nucleotide binding
Ontology: MF
Definition: Interacting selectively with a nucleotide, any compound consisting of a nucleoside that is esterified with (ortho)phosphate or an oligophosphate at any hydroxyl group on the ribose or deoxyribose moiety.

`GO:0000287`
GOID: GO:0000287
Term: magnesium ion binding
Ontology: MF
Definition: Interacting selectively with magnesium (Mg) ions.
Synonym: magnesium binding

`GO:0008253`
GOID: GO:0008253
Term: 5'-nucleotidase activity
Ontology: MF
Definition: Catalysis of the reaction: a 5'-ribonucleotide + H2O = a ribonucleoside + phosphate.
Synonym: 5' nucleotidase activity
Synonym: 5'-mononucleotidase activity
Synonym: 5'-ribonucleotide phosphohydrolase activity
Synonym: 5'-adenylic phosphatase
Synonym: 5'-AMP nucleotidase
Synonym: 5'-AMPase
Synonym: adenosine 5'-phosphatase
Synonym: adenosine monophosphatase
Synonym: AMP phosphatase
Synonym: AMP phosphohydrolase
Synonym: AMPase
Synonym: snake venom 5'-nucleotidase
Synonym: thymidine monophosphate nucleotidase
Synonym: UMPase
Synonym: uridine 5'-nucleotidase

$'GO:0016787$'
GOID: GO:0016787
Term: hydrolase activity
Ontology: MF
Definition: Catalysis of the hydrolysis of various bonds, e.g. C-O, C-N, C-C, phosphoric anhydride bonds, etc. Hydrolase is the systematic name for any enzyme of EC class 3.

It turns out that probe id 738_at (corresponding to $GO:0008253$, and $GO:0016787$) has molecular function (MF) 5'-nucleotidase activity and hydrolase activity.

1 Session Information

The version number of R and packages loaded for generating the vignette were:

R version 2.7.0 (2008-04-22)
x86_64-unknown-linux-gnu

locale:
LC_CTYPE=en_US;LC_NUMERIC=C;LC_TIME=en_US;LC_COLLATE=en_US;LC_MONETARY=C;LC_MESSAGES=en_US;LC_PAPER=en_US;LC_NAME=C;LC_ADDRESS=C;LC_TELEPHONE=C;LC_MEASUREMENT=en_US;LC_IDENTIFICATION=C

attached base packages:
[1] grid tools stats graphics grDevices utils
[7] datasets methods base

other attached packages:
[1] XML_1.93-2 GO.db_2.2.0 Rgraphviz_1.18.0
[4] graph_1.18.0 hgu95av2.db_2.2.0 annotate_1.18.0
[7] xtable_1.5-2 AnnotationDbi_1.2.0 RSQLite_0.6-8
[10] DBI_0.2-4 Biobase_2.0.0

loaded via a namespace (and not attached):
[1] cluster_1.11.10