

R PROFILING AND OPTIMISATION

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PENDING CHANGES

Warning: this is under construction.

This vignette contains experimental material which may sink down to the package implementation, or vanish.

Known issues:

- Control information may be included as special stack in raw format.
- A list of profiles may become default. Only one profiling interval value per profile.
- Nodes may be implemented as *factor*. Work-around for the R factor handling needs to be added, i.e. *factor* as a data structure.
- changing timing interval is too expensive, as rle is not transparent to data frames. Implement profiles as a list, with a time interval attribute per list element.

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An R vignette for package sprof.

URL: <http://sintro.r-forge.r-project.org/>

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PROFILING FACILITIES IN R

R provides the basic instruments for profiling, both for time based samplers as for event based instrumentation. Information on R profiling is in Section 3.2 “Profiling R code for speed” and section “3.3 Profiling R code for memory use”. of Writing R Extensions <http://cran.r-project.org/doc/manuals/R-exts.html>. Specific information on memory profiling is in <http://developer.r-project.org/memory-profiling.html>.

However this source of information seems to be rarely used.

Maybe the supporting tools are not adequate. The summaries provided by R reduce the information beyond necessity. Additional packages are available, but these are not sufficiently action oriented.

With package *sprof* we want to give a data representation that keeps the full profile information. Tools to answer common questions are provided. The data structure should make it easy to extend the tools as required.

The package is currently distributed at r-forge as part of the *sintro* material.

To install this package directly within R, type

```
install.packages("sprof", repos="http://r-forge.r-project.org")
```

To install the recent package from source directly within R, type

```
install.packages("sprof", repos="http://r-forge.r-project.org", type="source")
```

L^AT_EX LAYOUT TOOLS AND R SETTINGS

You may want to skip this section, unless you want to modify the vignette for your own purposes, or look at the internals.

This is the main library we are going to use.

Input

```
library(sprof)
search()
```

Output

```
[1] ".GlobalEnv"      "package:Rgraphviz"
[3] "package:graph"    "package:sna"
[5] "package:grid"      "package:wordcloud"
[7] "package:RColorBrewer" "package:Rcpp"
[9] "package:xtable"    "package:sprof"
[11] "package:stats"     "package:graphics"
[13] "package:grDevices" "package:utils"
[15] "package:datasets"  "package:methods"
[17] "Autoloads"         "package:base"
```

We want immediate warnings, if necessary. Set to level 2 to handle warnings as error.

Input

```
message("switching options(warn=1) -- immediate warning on")
options(warn=1)
```

We want a second chance on errors. So we install an error handler.

Input

```
options(error = recover)
```

Print parameters used here:

Input

```
options(width = 72)
options(digits = 6)
```

For `str` output, we generally use these settings:

Input

```
strx <- function(x,
  max.level=2, vec.len=3,
  nchar.max=40,
  list.len=12,
  width=70, strict.width="wrap",...)
{
  cat(paste("##strx:", deparse(substitute(x)), "\n"))
  str(x, max.level=max.level,
    vec.len=vec.len,
    nchar.max=nchar.max,
    list.len=list.len,
```

```

        width=width, strict.width=strict.width,...)
    }

```

ToDo: add keep3 to keep header, some middle, tail

For larger tables and data frames, we use a kludge to avoid long outputs.

```

                                Input
xcutdata.frame <- function(df,  cut, margin=5)
{
  #! keep3, to add: margin top - random center - margin bottom
  if (!is.data.frame(df)) return(df)
  nrow <- nrow(df)
  # cut a range if it is not empty.
  # Quiet noop else.
  # Does not cut single lines.
  cutrng <- function(cutfrom,cutto){
    if (cutfrom<cutto){
      df[cutfrom,] <- NA
      if (!is.null(rownames(df))) rownames(df)[cutfrom] <- "< cut >"
      if (!is.null(df$name)) df$name[cutfrom] <- ""

      cutfrom <- cutfrom+1
      df[-(cutfrom:cutto),]
    }#if
  }

  if (!missing(cut)) {df <- cutrng(cut[1],cut[2]); return(df)}

  if (!missing(margin)) { # changed. Set to default 5.
    if (length(margin)==1) margin <- c(margin,margin)
    cut <- c(margin[1]+1,nrow-margin[2])
    df <-cutrng(cut[1],cut[2]);
    return(df)}

  #   if (!missing(keep3)) { cut <- c(keep3[1]+1, keep3[1]+1,
  #                                   nrow-keep3[3]-1,nrow-keep3[3]-1)
  #   if (cut[3]-cut[4] > keep3[2]+2){delta<-(cut[3]-cut[2]) div 2
  #   cut[3]<-0
  #   browser()
  #   } else df <- cutrng(cut[1],cut[4])
  #   cutrng(cut[1],cut[4]) return(df)}
}

```

We use the R function `xtable()` for output and L^AT_EX `longtable`. A convenient wrapper to use this in our *Sweave* source is given here. Among others, it adds `zero.print`.

ToDo: remove text vdots from string/-name columns. Note: this may be a factor. Use empty string.

```

                                Input
library(xtable)
prxt <- function (x, digits=2, cut=TRUE, caption=NULL,
  label=NULL, zero.print=NULL, print.results=TRUE,...) {
  if (cut) {margin <- 10
    if (nrow(x)> 2*margin+3) x <-xcutdata.frame(x, margin=margin)}

```

```

pr <- print(
  xtable(x, digits=digits, caption=caption,
        label=label, ...),
  floating=FALSE,
  tabular.environment="longtable",
  caption.placement="top",
  zero.print = ".",
  NA.string="\vdots",
  print.results=FALSE)
#   NA.string="", #NA.string="\vdots",

pr <- gsub( "$\\backslash$\vdots", "\vdots", x=pr, fixed=TRUE)

if(!is.null(zero.print))
  pr <- gsub( " 0 ", zero.print, x=pr, fixed=TRUE)

if (print.results) cat(pr)
invisible(pr)
}

```

This is to be used with `<<print=FALSE, results =tex, label=tab:prxx>>=`

The graph visualisation family is not friendly. We try to get control by using a wrapper which is at least used to the members of the *graphviz* clan. This will be used in later sections.

```

plotviz <- function(x,y="dot", main=NULL, sub=NULL,...)
{
  if (!is.null(sub)) sub <- as.character(sub)
  if (is.null(main))
    main <- paste0("plotviz( ", deparse(substitute(x)), ", ", y, " ) ") else
    main <- paste0(main, "\n plotviz( ", deparse(substitute(x)), ", ", y, " ) ")

  plot(x=x, y=y,
       attrs=list(node=list(cex=4, fontsize=40,
                           shape="ellipse")),
       cex.main=1.5,
       main=main,...)

  title(sub=paste0(sub, " ", as.character(class(x))),
        legend("topleft",
              legend=c(class(x), "method: ", y),
              title="class:",
              bg="#FFFFE040",
              seg.len=0)
        )
}
#"lightyellow",

```

1. PROFILING

The basic information provided by all profilers is a protocol of sampled stacks. For each recorded event, the protocol has one record, such as a line with a text string showing the sampled stack.

We use profiles to provide hints on the dynamic behaviour of programs. Most often, this is used to improve or even optimise programs. Sometimes, it is even used to understand some algorithm.

Profiles represent the program flow, which is considered to be laid out by the control structure of a program. The control structure is represented by the control graph, and this leads to the common approach to (re)construct the control graph, map the profile to this graph, and used graph based methods for further analysis. The prime example for this strategy is the GNU profiler *gprof* (see <http://sourceware.org/binutils/docs/gprof/>) which is used as master plan for many common profilers.

It is only half of the truth that the control graph can serve as a base for the profiled stacks. In R, we have some peculiarities.

lazy evaluation: Arguments to functions can be passed as promises. These are only evaluated when needed, which may be at a later time, and may then lead to insertions in the stack. So we may have information resulting from the data flow, interspersed with the control flow.

memory management: Allocation of memory, and garbage collection, may interfere and leave their traces in the stack. While allocation is closely related to the visible control flow, garbage collection is a collective effect largely out of control of the code to execute.

primitives: Internal functions may escape the usual stack conventions and execute without leaving any identifiable trace on the stack.

control structures: In R, many control structures are implemented as function. Most notably, the *apply()* family appears as function calls and can lead to cliques in the graph representation that do not correspond to relevant structures. Since these functions are well known, they can have a special treatment.

So while the stack follows an overall well known dynamics, in R there are exceptions from regularity.

The general approach, by *summaryRprof()* and others, is to reduce the profile to node information, or to consider single transitions.

We take a different approach. We take the stacks, as recorded in the profiles as our basic information unit. From this, we ask: what are the actions we need to answer our questions? Representation in graphs may come later, if they can help.

If the stacks would come from the control flow only, we could make use of the sequential nature of stacks. But since we have to live with the R specific interferences, we stay with the raw stacks.

ToDo: rearrange
stacks? detect
order?

In this presentation, we will use a small list of examples. Since *Rprof* is not implemented on all systems, and since the profiles tend to get very large, we use

some prepared examples that are frozen in this vignette and not included in the distribution, but all the code to generate the examples is provided.

1.1. Simple regression example.

Input

```
n <- 10000
x <- runif(n)
err <- rnorm(n)
y <- 2 + 3 * x + err
reg0data <- data.frame(x=x, y=y, err=err)
rm(x,y,err)
```

We will use this example to illustrate the basics. Of course the immediate questions are the variance between varying samples, and the influence of the sample size n . We keep everything fixed, so the only issue for now is the computational performance under strict iid conditions.

Still we have parameters to choose. We can determine the profiling granularity by setting the timing interval, and we can use repeated measurements to increase precision below the timing interval.

The timing interval should depend on the clock speed. Using for example 1ms amounts to some 1000 steps on a current CPU, per kernel.

If we use repeated samples, the usual rules of statistics applies. So taking 100 runs and taking the mean reduces the standard deviation by a factor 1/10.

By the usual R conventions, seconds are used as time base for parameters. However report will use ms as a time base.

Here is an example how to take a profile, using basic R. See section 1.1.2 on page 10 how to use *sampleRprof* in package *sprof* for an easier solution.

Input

```
profininterval <- 0.001
simruns <- 100
Rprof(filename="RprofsRegressionExpl.out", interval = profinterval)
  for (i in 1:simruns) xxx<- summary(lm(y~x, data=reg0data))
Rprof(NULL)
```

We now have the profile data in a file *RprofsRegressionExpl.out*. For this vignette, we use a frozen version *RprofsRegressionExpl01.out*.

1.1.1. *R basic*. The basic R functions invite us to get a summary.

Input

```
sumRprofRegressionExpl <- summaryRprof("RprofsRegressionExpl01.out")
#str(profile_nodes_rle, max.level=2, vec.len=3, nchar.max=40, list.len=6)
strx(sumRprofRegressionExpl)
```

Output

ToDo: Can we calibrate times to CPU rate? Introduce cpu clock cycle as a time base

```
##strx: sumRprofRegressionExpl
List of 4
$ by.self : 'data.frame': 41 obs. of 4 variables:
..$ self.time : num [1:41] 0.087 0.057 0.051 0.043 0.042 0.04 0.032
  0.026 ...
..$ self.pct : num [1:41] 16.67 10.92 9.77 8.24 ...
..$ total.time: num [1:41] 0.113 0.099 0.069 0.043 0.474 0.045 0.033
  0.114 ...
..$ total.pct : num [1:41] 21.65 18.97 13.22 8.24 ...
$ by.total : 'data.frame': 62 obs. of 4 variables:
..$ total.time: num [1:62] 0.522 0.522 0.521 0.521 0.521 0.521 0.521
  0.521 ...
..$ total.pct : num [1:62] 100 100 99.8 99.8 ...
..$ self.time : num [1:62] 0.006 0 0.001 0 0 0 0 ...
..$ self.pct : num [1:62] 1.15 0 0.19 0 0 0 0 ...
$ sample.interval: num 0.001
$ sampling.time : num 0.522
```

The summary reduces the information contained in the profile to marginal statistics per node. This is provided in two data frames giving the same information, only in different order.

The file contains several spurious recordings: nodes that have been recorded only few times. It is worth noting these, but then they better be discarded. We use a time limit of 4ms, which given our sampling interval of 1ms means we require more than four observations.

```
Input
prxt(sumRprofRegressionExpl$by.self,
      caption="summaryRprof result: by.self as final stack entry, all records",
      label="tab:prSRREbs")
```

Table 1: summaryRprof result: by.self as final stack entry, all records

	self.time	self.pct	total.time	total.pct
"lm.fit"	0.09	16.67	0.11	21.65
"[.data.frame"	0.06	10.92	0.10	18.97
"model.matrix.default"	0.05	9.77	0.07	13.22
"as.character"	0.04	8.24	0.04	8.24
"lm"	0.04	8.05	0.47	90.80
"summary.lm"	0.04	7.66	0.04	8.62
"structure"	0.03	6.13	0.03	6.32
"na.omit.data.frame"	0.03	4.98	0.11	21.84
"anyDuplicated.default"	0.02	4.21	0.02	4.21
"as.list.data.frame"	0.02	4.21	0.02	4.21
< cut >	⋮	⋮	⋮	⋮
"FUN"	0.00	0.19	0.01	1.34
"%in%"	0.00	0.19	0.00	0.77
"deparse"	0.00	0.19	0.00	0.38
"\$"	0.00	0.19	0.00	0.19

"as.list.default"	0.00	0.19	0.00	0.19
"as.name"	0.00	0.19	0.00	0.19
"coef"	0.00	0.19	0.00	0.19
"file"	0.00	0.19	0.00	0.19
"NCOL"	0.00	0.19	0.00	0.19
"terms.formula"	0.00	0.19	0.00	0.19

```

Input
prxt(sumRprofRegressionExpl$by.total[sumRprofRegressionExpl$by.total$total.time>0.004,],
caption="summaryRprof result: by.total, total time > 4ms",
label="tab:prSRREbt")

```

Table 2: summaryRprof result: by.total, total time > 4ms

	total.time	total.pct	self.time	self.pct
"<Anonymous>"	0.52	100.00	0.01	1.15
"Sweave"	0.52	100.00	0.00	0.00
"eval"	0.52	99.81	0.00	0.19
"doTryCatch"	0.52	99.81	0.00	0.00
"evalFunc"	0.52	99.81	0.00	0.00
"try"	0.52	99.81	0.00	0.00
"tryCatch"	0.52	99.81	0.00	0.00
"tryCatchList"	0.52	99.81	0.00	0.00
"tryCatchOne"	0.52	99.81	0.00	0.00
"withVisible"	0.52	99.81	0.00	0.00
< cut >	:	:	:	:
"as.list"	0.02	4.41	0.00	0.00
"anyDuplicated.default"	0.02	4.21	0.02	4.21
"as.list.data.frame"	0.02	4.21	0.02	4.21
"sapply"	0.01	2.68	0.00	0.19
"match"	0.01	2.11	0.00	0.19
"[[.data.frame"	0.01	1.53	0.00	0.19
"["	0.01	1.53	0.00	0.00
"rep.int"	0.01	1.34	0.01	1.34
"FUN"	0.01	1.34	0.00	0.19
"list"	0.01	0.96	0.01	0.96

1.1.2. *Package sprof*. In contrast to the common R packages, in the *sprof* implementation we take a two step approach. First we read in the profile file to an internal representation. Analysis is done in later steps.

Input

```
sprof01<- readRprof("RprofsRegressionExpl01.out")
```

The data contain identification information for reference. This will be used in the functions of *sprof* and shown in the displays. Here is the summary of this section:

Input

```
str(sprof01$info)
```

Output

```
'data.frame':      1 obs. of  8 variables:
 $ id      : Factor w/  1 level  "\"RprofsRegressionExpl01.out\" 2013-06-13 23:46:04":  1
 $ date    : POSIXct, format: "2013-08-13 21:33:38"
 $ nrnodes  : int 62
 $ nrstacks : int 50
 $ nrrecords: int 522
 $ firstline: Factor w/  1 level  "sample.interval=1000":  1
 $ ctllines : Factor w/  1 level  "sample.interval=1000":  1
 $ ctllinenr: num 1
```

For this vignette, we change the *id* information. So in this context:

Input

```
sprof01$info$id <- "sprof01"
```

We keep this example and use the copy *sprof01* of it extensively for illustration.

Input

```
save(sprof01, file="sprof01lm.RData")
```

To run the vignette with a different profile, replace *sprof01* by your example. You still have the file for reference.

Package *sprof* provides a function *sampleRprof()* to take a sample and create a profile on the fly, as in

Input

```
sprof01temp <- sampleRprof(runif(10000), runs=100)
```

The basic data structure consists of four data frames. The *info* section collects global information from the input file, such as an identification strings and various global matrix. The *nodes* section initially gives the same information marginal information as *summaryRprof*. The *stacks* section puts the node information into their calling context as found in the input profile file. The *profiles* section gives the temporal context. It is implemented as a list, but conceptually it is a data frame. Implementing it as a list allows run length encoding of variables, which unfortunately is not allowed by R in data frames.

ToDo: add sampling.interval, sampling.time for backward compatibility

Input

```
strx(sprof01)
```

```
##strx: sprof01
List of 4
 $ info : 'data.frame': 1 obs. of 8 variables:
  ..$ id : chr "sprof01"
  ..$ date : POSIXct[1:1], format: "2013-08-13 21:33:38"
  ..$ nrnodes : int 62
  ..$ nrstacks : int 50
  ..$ nrrecords: int 522
  ..$ firstline: Factor w/ 1 level "sample.interval=1000": 1
  ..$ ctllines : Factor w/ 1 level "sample.interval=1000": 1
  ..$ ctllinenr: num 1
 $ nodes : 'data.frame': 62 obs. of 5 variables:
  ..$ name : Factor w/ 62 levels "!", "..getNamespace", ...: 1 2 3 4 5 6 7
    8 ...
  ..$ self.time : num [1:62] 2 0 2 0 0 57 0 1 ...
  ..$ self.pct : num [1:62] 0.38 0 0.38 0 ...
  ..$ total.time: num [1:62] 2 1 4 26 99 99 8 8 ...
  ..$ total.pct : num [1:62] 0.03 0.01 0.05 0.34 1.29 1.29 0.1 0.1 ...
 $ stacks : 'data.frame': 50 obs. of 7 variables:
  ..$ nodes :List of 50
  .. .. [list output truncated]
  ..$ shortname : Factor w/ 50 levels
    "S<A>eFttCtCLtCOdTCwVeesleem.m..n.n...[\"| __truncated__,...: 27 17
    19 1 35 36 37 30 ...
  ..$ refcount : num [1:50] 1 5 26 55 13 43 51 87 ...
  ..$ stacklength : int [1:50] 19 20 19 21 14 15 15 14 ...
  ..$ stackheadnodes: int [1:50] 52 52 52 52 52 52 52 52 ...
  ..$ stackleafnodes: int [1:50] 27 28 41 6 39 14 38 30 ...
  ..$ stackssrc : Factor w/ 50 levels "!.data.frame [
    na.omit.data.frame na.\"| __truncated__,...: 27 28 39 5 37 13 36 30
    ...
 $ profiles:List of 4
  ..$ data : int [1:522] 1 2 2 3 4 4 5 5 ...
  ..$ mem : NULL
  ..$ malloc : NULL
  ..$ timesRLE:List of 2
  .. ..- attr(*, "class")= chr "rle"
 - attr(*, "class")= chr [1:2] "sprof" "list"
```

The nodes do not come in a specific order. Access via a permutation vector is preferred. This allows different views on the same data set. For example, table 4 on page 13 uses a permutation by total time, and a selection (compare to table 2 on page 9). The only difference is that *sprof* works uses a millisecond (ms) base, whereas R in general uses seconds as a base.

```
nodes <- sprof01$nodes[order(sprof01$nodes$self.time, decreasing=TRUE),]
prxt(nodes[nodes$self.time>4,],
caption="plot result: by.self, self time > 4ms",
label="tab:prspbtself")
```

Table 3: splot result: by.self, self time > 4ms

	name	self.time	self.pct	total.time	total.pct
30	lm.fit	87.00	16.67	113.00	1.47
6	[.data.frame	57.00	10.92	99.00	1.29
38	model.matrix.default	51.00	9.77	69.00	0.90
14	as.character	43.00	8.24	43.00	0.56
29	lm	42.00	8.05	474.00	6.16
51	summary.lm	40.00	7.66	45.00	0.59
49	structure	32.00	6.13	33.00	0.43
41	na.omit.data.frame	26.00	4.98	114.00	1.48
13	anyDuplicated.default	22.00	4.21	22.00	0.29
16	as.list.data.frame	22.00	4.21	22.00	0.29
40	na.omit	20.00	3.83	134.00	1.74
39	model.response	13.00	2.49	56.00	0.73
36	model.frame.default	12.00	2.30	168.00	2.18
46	rep.int	7.00	1.34	7.00	0.09
10	<Anonymous>	6.00	1.15	522.00	6.79
28	list	5.00	0.96	5.00	0.07

At this level, it is helpful to note the expectations, and only then inspect the timing results. Since we are using a linear model, we are not surprised to see functions related to linear models on the top of the list. We may however be surprised to see functions related to data access and to character conversion very high on the list. The sizeable amount of time spent on NA handling is another aspect that is surprising.

```

Input
nodes <- sprof01$nodes[order(sprof01$nodes$total.time, decreasing=TRUE),]
prxt(nodes[nodes$total.time>4,],
caption="splot result: by.total, total time > 4ms",
label="tab:prspbt")

```

Table 4: splot result: by.total, total time > 4ms

	name	self.time	self.pct	total.time	total.pct
10	<Anonymous>	6.00	1.15	522.00	6.79
52	Sweave	0.00	0.00	522.00	6.79
21	doTryCatch	0.00	0.00	521.00	6.78
22	eval	1.00	0.19	521.00	6.78
23	evalFunc	0.00	0.00	521.00	6.78
55	try	0.00	0.00	521.00	6.78
56	tryCatch	0.00	0.00	521.00	6.78
57	tryCatchList	0.00	0.00	521.00	6.78
58	tryCatchOne	0.00	0.00	521.00	6.78
62	withVisible	0.00	0.00	521.00	6.78
< cut >	\vdots	⋮	⋮	⋮	⋮

61	vapply	3.00	0.57	23.00	0.30
13	anyDuplicated.default	22.00	4.21	22.00	0.29
16	as.list.data.frame	22.00	4.21	22.00	0.29
47	sapply	1.00	0.19	14.00	0.18
31	match	1.00	0.19	11.00	0.14
7	[[	0.00	0.00	8.00	0.10
8	[[.data.frame	1.00	0.19	8.00	0.10
25	FUN	1.00	0.19	7.00	0.09
46	rep.int	7.00	1.34	7.00	0.09
28	list	5.00	0.96	5.00	0.07

Given the sampling structure of the profiles, two aspects are common. The sampling picks up scaffold functions with a high, nearly constant frequency. And the sampling will pick up rare recordings that are near to detection range. The display functions hide these effects by default. In our example, about half of the nodes are cleared by this garbage collector.

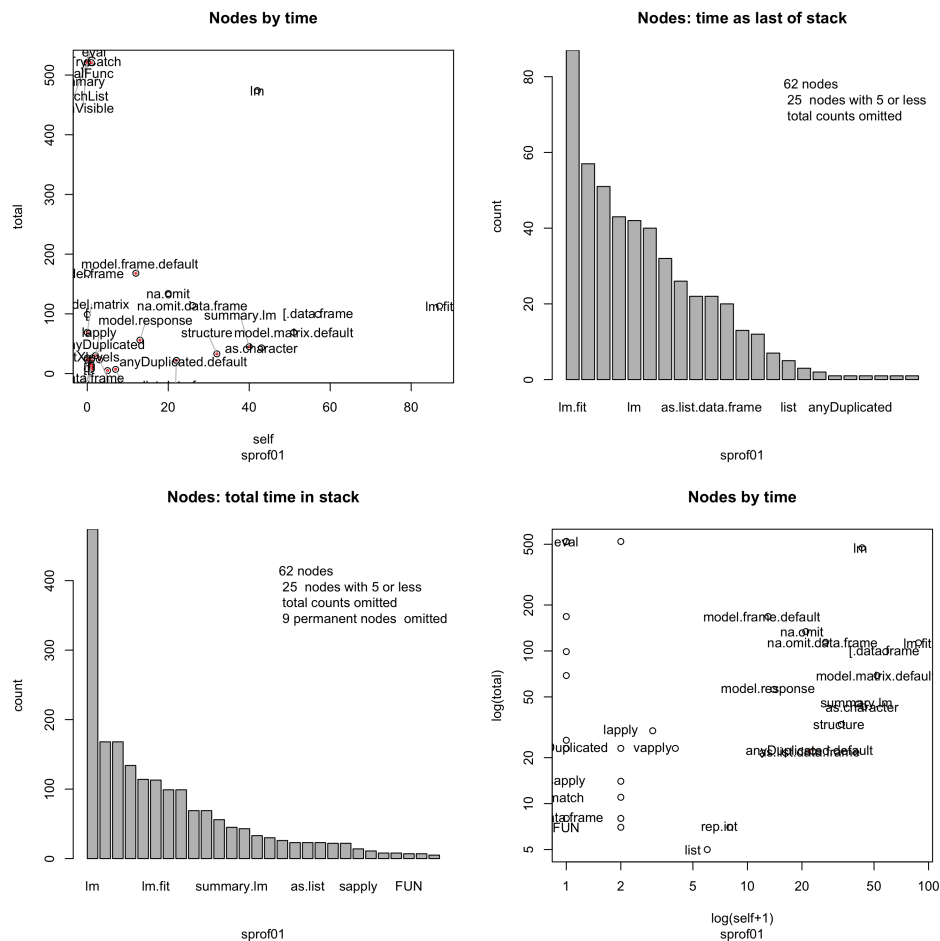
Common rearrangements as by total time and by self time are supplied by the display functions.

`plot_nodes()`, for example, currently gives a choice of four displays for nodes, and supports trimming by default. Our profile starts with 62 nodes. The defaults cut off 34 nodes as uninformative, either because they are too rare, or ubiquitous.

ToDo: remove text
vdots from string/
name columns

Input

```
#8
oldpar <- par(mfrow=c(2,2))
plot_nodes(sprof01)
par(oldpar)
```



Basic information on node level: see fig. 1 on the next page.

Information in the time scatterplots may sometimes be more accessible when using a logarithmic scale, so this is added.

If you prefer, you can have the bar charts in horizontal layout, giving more space for labels.

Input

```
#8
oldpar <- par(mfrow=c(2,2))
plot_nodes(sprof01, horiz=TRUE)
par(oldpar)
```

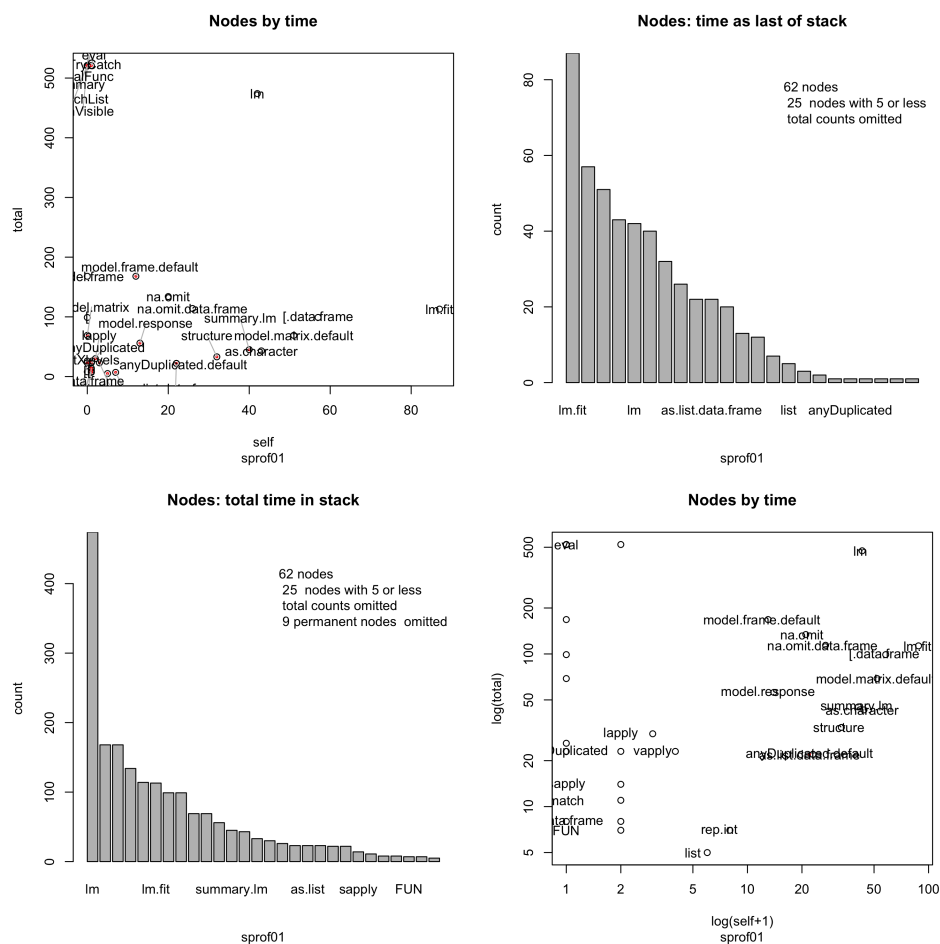
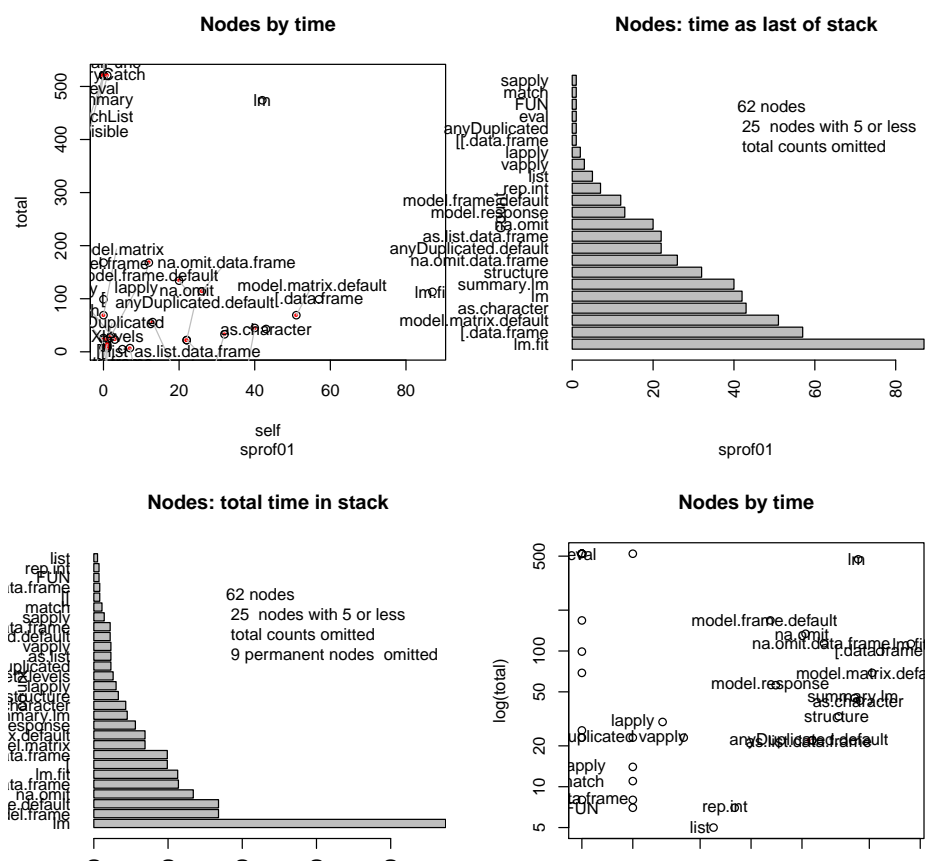


FIGURE 1. Basic information on node level



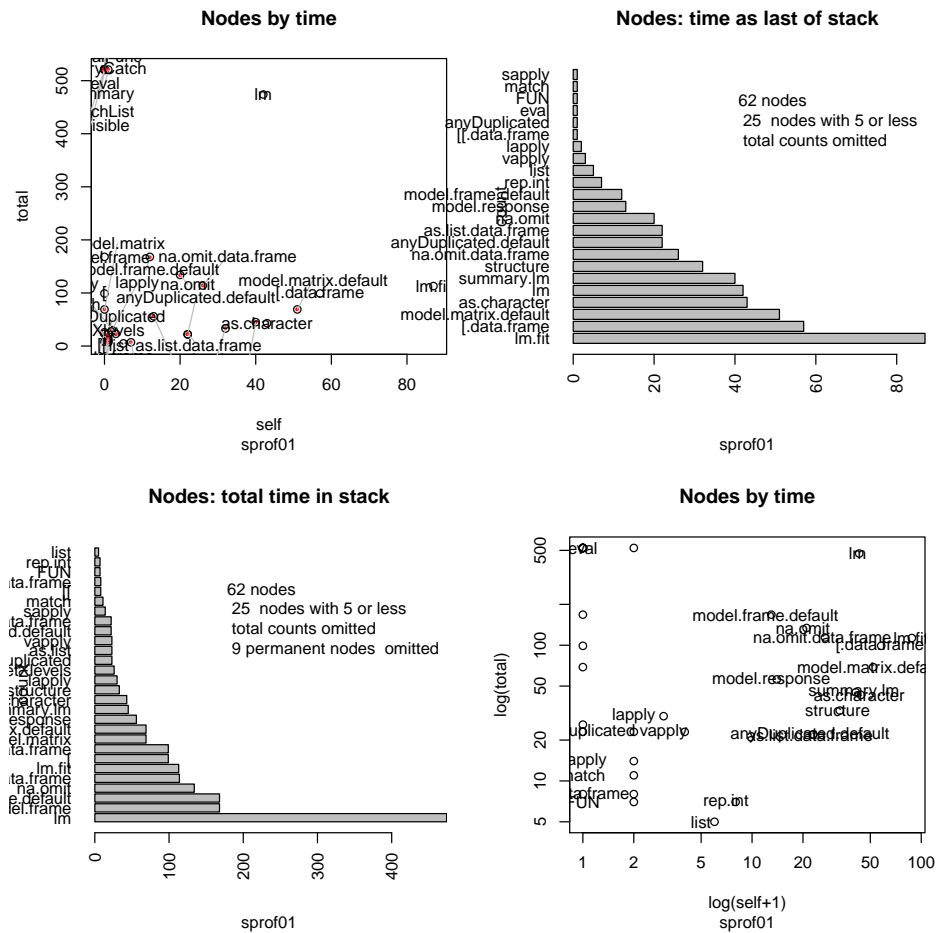


FIGURE 2. Basic information on node level

Basic information on node level - horizontal bars: see fig. 2.

We can add colour. To illustrate this, we encode the frequency of the nodes as colour. As a palette, we choose a heat map here.

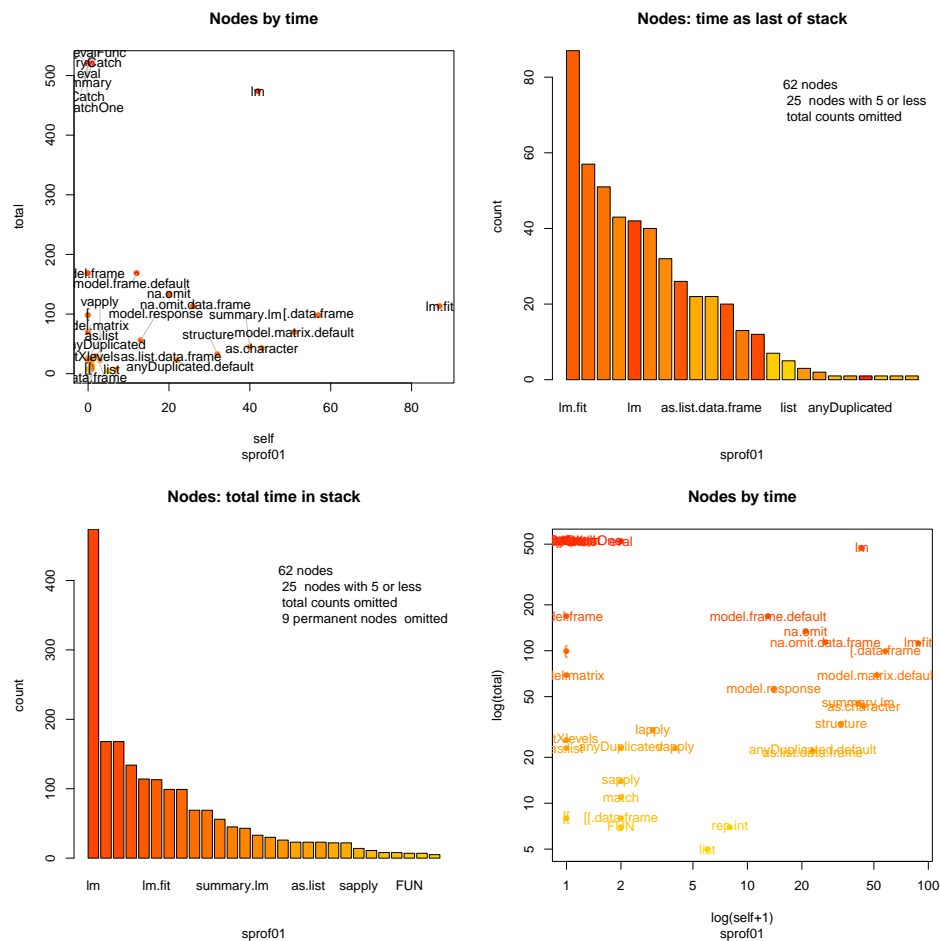
ToDo: apply colour to selection?

ToDo: spread colour on displayed part

```
Input
freqrank01 <- rkindex(-spro01$nodes$total.time, ties.method="random")
freqrankcol01 <- heat.colors(length(freqrank01))
```

Here is the node view using these choices:

```
Input
#10
spro01$nodes$icol <- freqrank01
oldpar <- par(mfrow=c(2,2))
plot_nodes(spro01, col=freqrankcol01)
par(oldpar)
```



Basic information on node level, colour by total time: see fig. 2 on the preceding page.

Colour is considered a volatile attribute. So you may need to pay some attention to keep colour indices (and colour palettes) aligned to your context. You may want to do experiments with colour, trying to find a good solution for your visual preferences. The recommended way is to use some stable colour index (the slot `icol` is reserved for this) and use this as an index to a choice of colour palettes. So `icol` becomes a part of the data structure, and the colour palette to be used is passed as a parameter. Package *RColorBrewer* may be a helpful source for colour palettes. You find more information and references on this in the vignette “Bertin matrices” of package *bertin*, <http://bertin.r-forge.r-project.org>.

ToDo: improve
colour: support
colour in a structure

1.1.3. Node classes. We can add attributes to the plots. But we can also add attributes to the nodes, and use these in the plots. In principle, this has been always available. We are now making explicit use of this possibility.

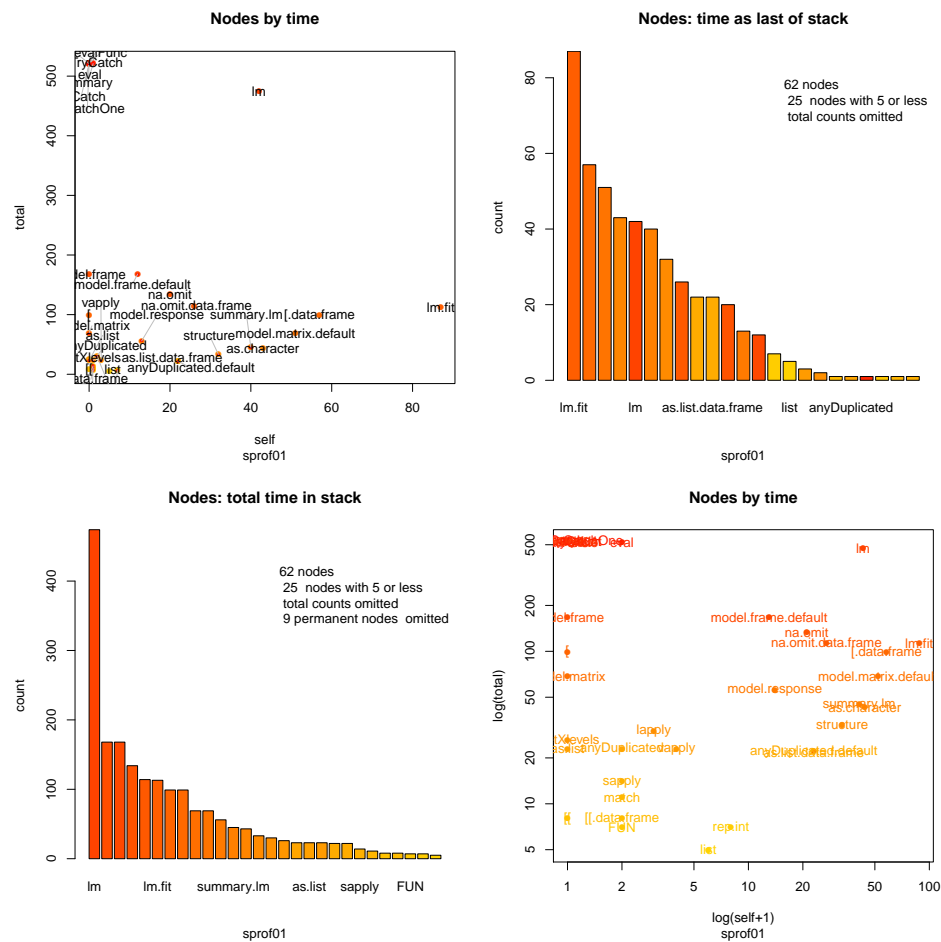


FIGURE 3. Basic information on node level, colour by total time.

The attribute *icol* is a special case which we used above. If present, it will be interpreted as an index to a colour table. For example, we can collect special well known functions in groups.

ToDo: colour by class – redo. Bundle colour index with colour?

The node information is to some part arbitrary. You may achieve the same functionality by different functions, and you will see different load in the profiles. Grouping nodes may be a mean to clarify the picture.

Grouping may also help you to focus your attention. “HOT” and “cold” may be very helpful tags. These can be used in a flexible way.

ToDo: Move class attributes to package code

ToDo: add class by keyword

Input

```
nodekeyword0 <- function(node)
{
}
```

Input

```
nodepackages <- nodepackage(sprof01$nodes$name)
names(nodepackages) <- sprof01$nodes$name
table(nodepackages)
```

Output

```
nodepackages
<not found>      base      stats      utils
           6         41         14         1
```

Input

```
sprof01$nodes$icol <-as.factor(nodepackages)
```

Nodes by package, colours by RColorBrewer: see fig. 4 on the following page.

Input

```
x_apply <- c("apply", "lapply", "vapply", "sapply")
x_as <- c("as.list", "as.data.frame", "as.list.data.frame",
         "as.character", "as.list.default", "as.name")
```

(Extend as you need it) and then use, as for example:

Input

```
nodeclass <- rep("x_nn", sprof01$info$nrnodes)
nodeclass[sprof01$nodes$name %in% x_apply] <- "x_apply"
nodeclass[sprof01$nodes$name %in% x_as] <- "x_as"
```

or use assignments on the fly

Input

```
nodeclass[sprof01$nodes$name %in%
  c("eval", "evalFunc",
    "try", "tryCatch", "tryCatchList", "tryCatchOne",
    "doTryCatch")
  ] <- "x_eval"
nodeclass[sprof01$nodes$name %in%
  c("model.frame", "model.matrix.default", "model.frame.default",
    "model.response", "model.matrix", "model.response")
  ] <- "x_model"
nodeclass[sprof01$nodes$name %in%
  c("lm", "lm.fit", "summary.lm")
  ] <- "x_lm"
nodeclass[sprof01$nodes$name == "<Anonymous>"] <- "x_Anon"
```

Input

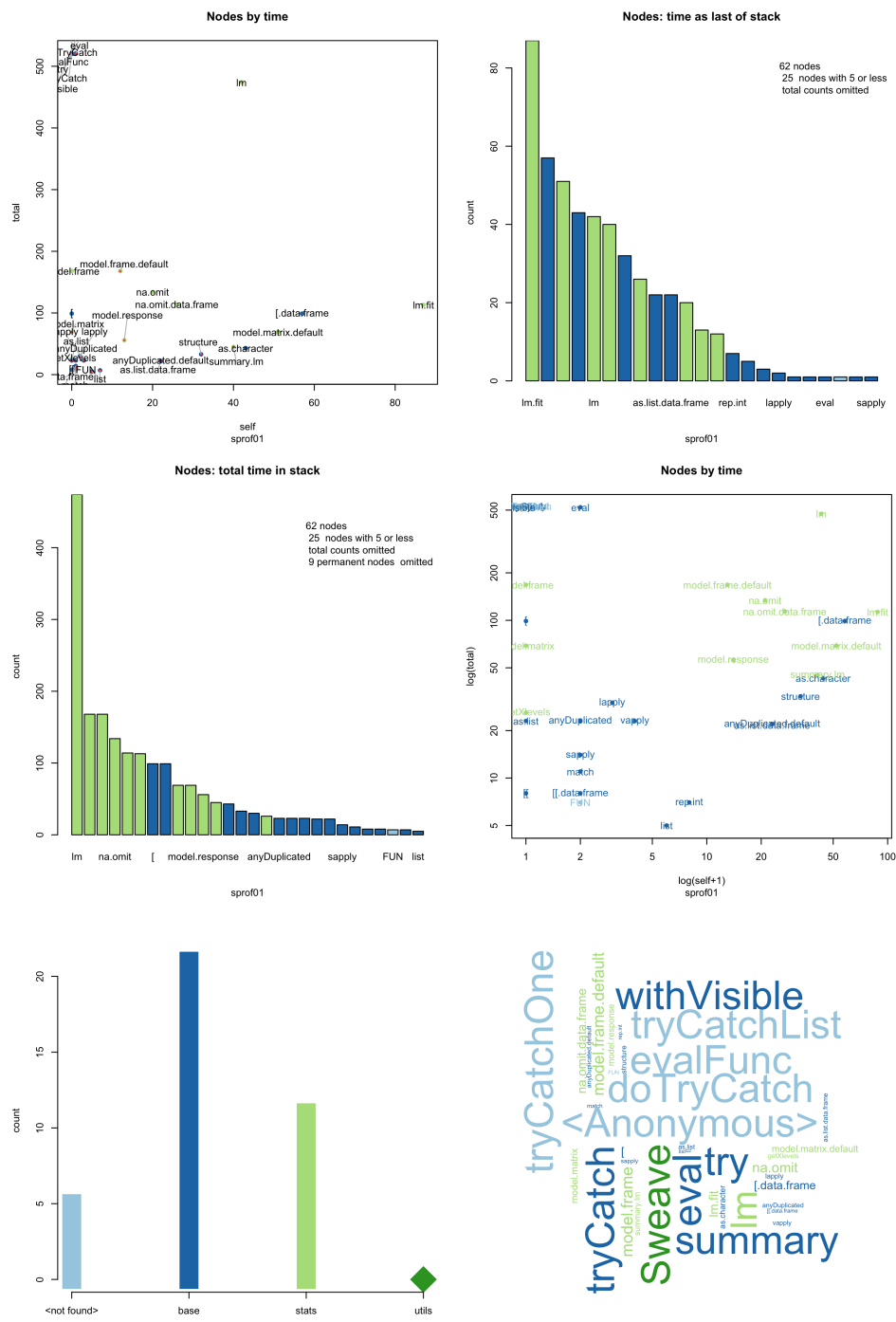
```
sprof01$nodes$icol <-as.factor(nodeclass)
```

adds a sticky colour attribute. To interpret, you should choose your preferred colour palette, for example

Input

```
classcol <- c("red", "green", "blue", "yellow", "cyan", "magenta", "purple")
```

ToDo: Defaults by class



Input

```
#8 12
oldpar <- par(mfrow=c(3,2))
plot_nodes(sprof01, which=1:6, col=classcol)
par(oldpar)
```

Nodes by class, user defined colors: see fig. 5 on the next page.

ToDo: classes need
separate colour
palette

Input

```
#8 12
oldpar <- par(mfrow=c(3,2))
plot_nodes(sprof01, which=1:6)
par(oldpar)
```

Nodes by class: default colour selection: see fig. 6 on page 23.

You can break down the frequency by classes of your choice. But beware of Simpson's paradox. The information you think you see may be strongly affected by your choices - what you see are reflections of conditional distributions. These may be very different from the global picture.

If package `wordcloud` is installed, a different view is possible. This is added in the plots above.

2. A BETTER GRIP ON PROFILE INFORMATION

The basic information provided by all profilers in R is a protocol of sampled stacks. The conventional approach is to break the information down to nodes and edges. The stacks provide more information than this. One way to access it is to use linking to pass information. This has already been used on the node level in section 1.1.2 on page 10.

ToDo: add at-
tributes to stacks,
and discuss scope

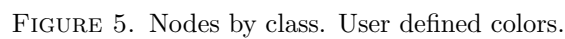
2.1. The internal details. For each recorded event, the protocol records one line with a text string showing the sampled stack (in reverse order: most recent first). The stack lines may be preceded by header lines with event specific information. The protocol may be interspersed with control information, such as information about the timing interval used.

ToDo: sorting/ar-
ranging stacks

We know that the structural information, static information as well as dynamic information, can be represented with the help of a graph. For a static analysis, the graph representation may be the first choice. For a dynamic analysis, the stack information is our first information. A stack is a connected path in the program graph. If we start with nodes and edges, we lose information which is readily available in record of stacks.

As we know that we are working with stacks, we know that they have their peculiarities. Stacks tend to grow and shrink. Subsequent events will have extensions and shrinkages of stacks (if the recording is on a fine scale), or stack sharing common stumps (if the recording is on a coarser scale). We could exploit this information, but it does not seem worth the effort.

ToDo: re-think:
sort stacks



There have always been interrupts, and these show up in profiles. In R, there is a related problem: garbage collection (GC) may interfere and leave traces in the stack.

Stack information is first. The call graph is a second instance that is (re)constructed from the stack recording. The graph represents cumulated one-step information. Longer scale information contained in the stacks is lost in the graph.

Here is the way we represent the profile information:

The profile log file is sanitised:

- Control lines are extracted and recorded in a separate list.
- Head parts, if present, are extracted and recorded in a matrix that is kept line-aligned with the remainder
- Line content is standardised, for example by removing stray quotation marks etc.

After this, the sanitised lines are encoded as a vector of stacks, and references to this.

If necessary, these steps are done by chunks to reduce memory load.

From the vector of stacks, a vector of nodes (or rather node names) is derived.

The stacks are now encoded by references to the nodes table. For convenience, we keep the (sanitised) textual representation of the stacks.

So far, texts are in reverse order. For each stack, we record the trailing leaf, and then we reverse order. The top of stack is now on first position.

Several statistics can be accumulated easily as a side effect.

Conceptually, the data structure consist of three tables (the implementation may differ, and is subject to change).

The profiles table is the representation of the input file. Control lines are collected in a special table. With the control lines removed, the rest is a table, one row per input line. The body of the line, the stack, is encoded as a reference to a stacks table (obligatory) and header information (optional).

The stacks table contains the collected stacks, each stack encoded as a list of references to the node table. This is obligatory. This list is kept in reverse order (root at position 1). A source line representing the stack information may be kept (optional).

The nodes table keeps the names at the nodes.

Sometimes, it is more convenient to use a simple representation, such as a matrix. Several extraction routines are provided for this, and the display routines make heavy use of this. See table 5 on the facing page.

ToDo: complete
matrix conversion

We now can go beyond node level.

This is what we get for free from the node information on our three levels: node, stack, and profile.

ToDo: check and
stabilise colour linking

ToDo: clean up
colour handling

TABLE 5. Extraction and conversion routines

<code>profiles_matrix()</code>	incidence matrix: nodes by event
<code>stacks_matrix()</code>	incidence matrix: nodes by stack
<code>list.as.matrix()</code>	fill list to equal length and convert to matrix
<code>stackstoadj()</code>	stacks to (correspondence) adjacency matrix
<code>adjacency()</code>	sprof to (correspondence) adjacency matrix

Input

```
#8 rainbow
sprof01$nodes$icol <- freqrank01; freqrankcol <- rainbow(62)
shownodes(sprof01, col=freqrankcol)
```

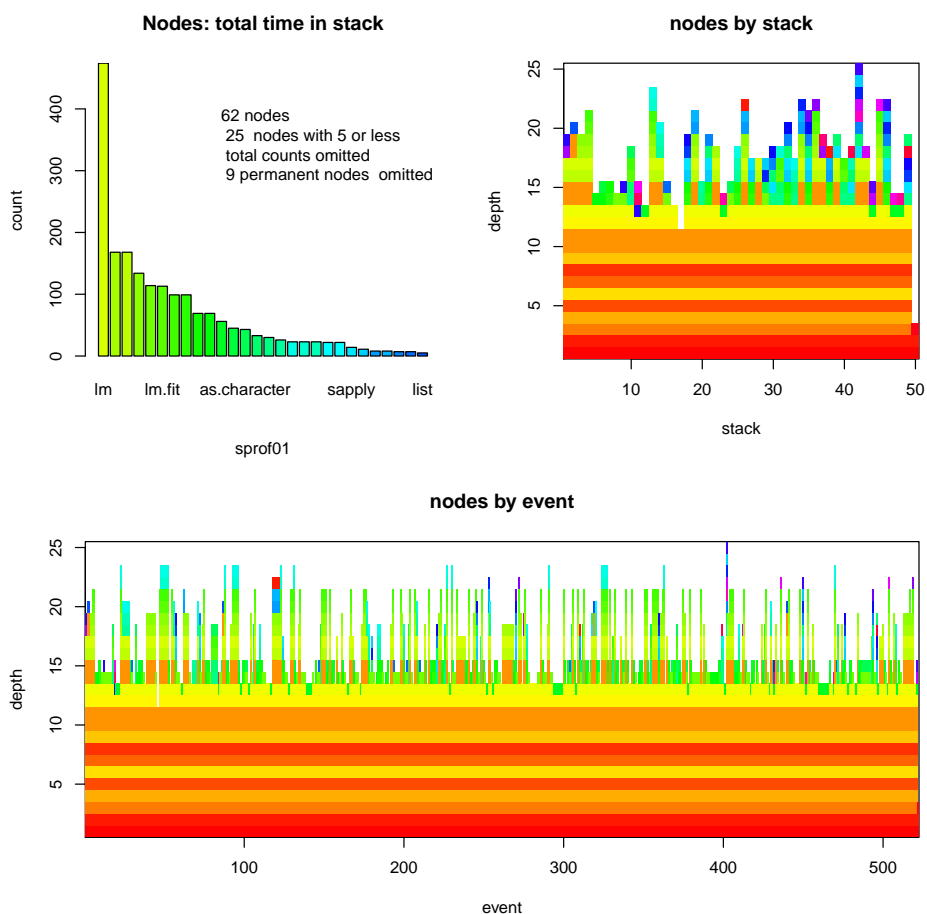


FIGURE 7. Nodes by stack and profile

See fig. 7 for a summary by nodes.

The obvious message is that if seen by stack level, there are different structures. Profiling usually takes place in a framework. So at the base of the stacks, we find entries that are (almost) persistent. Then usually we have some few steps where the algorithm splits, and then we have the finer details. These can be identified using information on the stack level, but of course they are not visible on the node or edge level in a graph representation. On the stack level, we see a socket. If we want a statistic, we can look at number of different nodes by level.

Input

```
stacks_nodes <- list.as.matrix(sprof01$stacks$nodes)
nrnodes <- apply(stacks_nodes,1,function(x) {length(unique(x))})
cat("nr unique nodes per stack level\n")
```

Output

```
nr unique nodes per stack level
```

Input

```
nrnodes
```

Output

```
[1]  1  1  2  2  2  2  2  2  2  2  2  2  4 11 12 10 10 16  9  8  6  8
[23]  3  2  2
```

Input

```
plot(x=nrnodes, y= 1:length(nrnodes), xlab="nr of unique nodes", ylab="stack level")
abline(h=2.5,col="green")
abline(h=12.5,col="green")
```

ToDo: check and synchronise

Nr. of unique nodes by stack level: See fig. 8 on the facing page.

We will come to finer tools in section 2.4 on page 35 but for the moment the rough information should suffice to take a decision. In our example, it is only a matter of taste whether we cut off 12 levels, or we want to work with five components after cutting 13 levels

Not so often, but a frequent phenomenon is to have some “burn in” or “fade out”. To identify this, we need to look at the profile level. The indicator to check is to whether we have very low frequency stacks at the beginning or the end of our recording. The counts to be takes as reference can be seen from the summary.

Input

```
summary(sprof01$stacks$refcount)
```

Output

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
1.0	1.0	2.0	10.4	12.0	87.0

ToDo: we could do smart smoothing of the stacks here

This summary has to be taken with caution. As the program runs, the stacks are build up und teared down, and we only take random samples. So in dynamic parts, we see images with some fluctuation, as one stack may be a snapshot of an other under construction. A better information is to cut off fluctuations and use this summary as a reference.

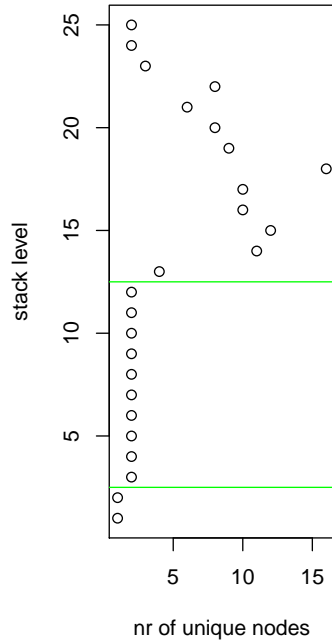


FIGURE 8. Nr of unique nodes by stack level.

Input

```
summary(sprof01$stacks$refcount[sprof01$stacks$refcount>2])
```

Output

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
3.00	7.75	16.00	24.30	40.50	87.00

Input

Input

```
df <- data.frame(stack=sprof01$profiles$data,
                  count=sprof01$stacks$refcount[sprof01$profiles$data])
prxt(df, caption="Stacks by event: burn in/fade out",
      label="tab:margin",
      digits=c(0,0,0) )
```

Table 6: Stacks by event: burn in/fade out

	stack	count
	1	1
	2	5

3	2	5
4	3	26
5	4	55
6	4	55
7	5	13
8	5	13
9	6	43
10	7	51
< cut >	:	:
513	3	26
514	3	26
515	3	26
516	3	26
517	4	55
518	3	26
519	36	2
520	16	42
521	44	2
522	50	1

Here at least one recording on either side is a candidate to be off. We may have a look at the next recordings and decide to go beyond and cut off events 1 : 3 and 519 : 522.

At a closer look, we may find stack patterns (maybe marked by specific nodes) that indicate administrative intervention and rather should be handled as separators between distinct profiles rather than as part of the general dynamics. Again we may use some indicator nodes to be used as marker for special stacks.

Stable framework effects sometimes are obvious and can be detected automatically. “burn in” or “fade out” may need a closer look, and special stacks need an individual inspection on low frequency stacks. Tools for trimming are in section 2.3.1 on page 32.

2.2. The free lunch. What you have seen so far is what you get for free when using package *sprof*.

If you want to wrap up the information and look at it from a graph point of view, here is just one example. More are in section 3 on page 39 and vrefsec:moregraph. But before changing to the graph perspective, we recommend to see the next sections, not to skip them.

The preview, at this point, taking package *graph* as an example. *graph* on its side has an undocumented feature: it needs *Rgraphviz* to handle graph attributes. We have to take two steps. we extract the graph information from *sprof*, using and adjacency matrix here as a simple solution. This is then converted to the “*graphNEL*” format which is shared by *graph* and *Rgraphviz*. *Rgraphviz* is hidden

ToDo: example

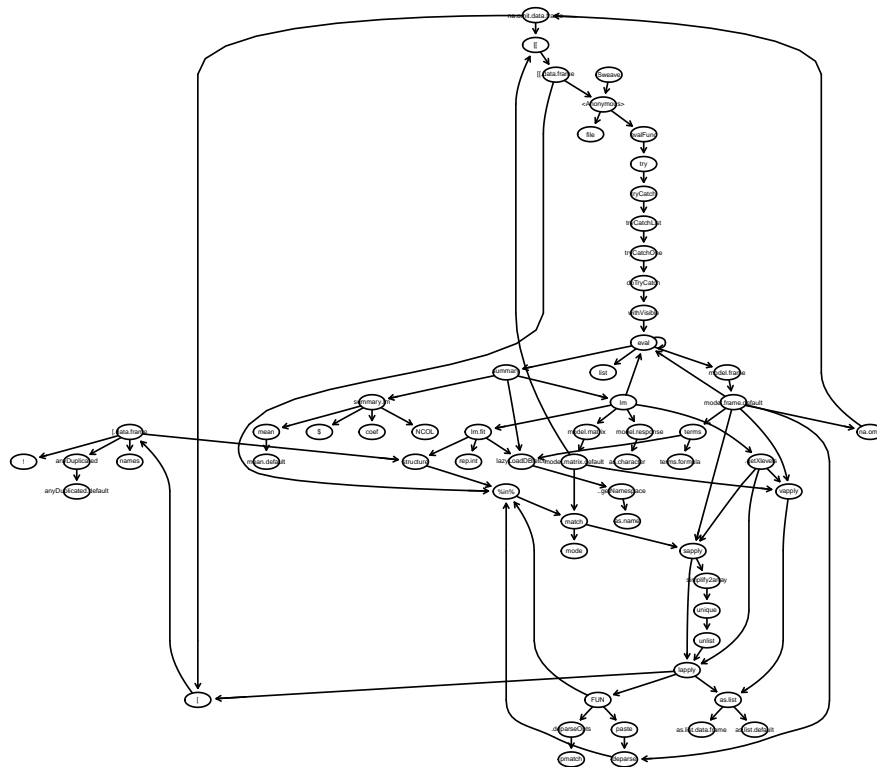
ToDo: colours. re-colour. Propagate colour to graph.

in the use of `plot()`. So here is a bare foot approach. A more sophisticated function implementation is in section 3 on page 39.

Input

```
#6 sprofadjNEL02
library(graph)
sprof01adjNEL <- as(adjacency(sprof01),"graphNEL")
plot(sprof01adjNEL, main="sprof01: graph layout example",
     sub=sprof01$info$id,
     attrs=list(node=list(cex=4, fontsize=40, shape="ellipse")),
     cex.main=2)
rm(sprof01adjNEL)
#detach("package:Rgraphviz") ;
#detach("package:graph")
```

sprof01: graph layout example



2.3. Cheap thrills. Before starting additional inspection, the data better be trimmed. Trimming routines are in section 2.3.1 on page 32, but the data structure is robust enough to allow manual intervention as used here.

ToDo: updateRprof needs careful checking. For now, we are including long listings here to provide the necessary information

```
Input
sprof02 <- sprof01; sprof02$info$id <- "sprof02: trimmed"
```

On the stack level, we take brute force to cut off the basic stacks.

```
Input
basetrim <- 13
sprof02$stacks$nodes <- sapply(sprof02$stacks$nodes,
  function (x){if (length(x)> basetrim) x[-(1:basetrim)] })
```

We have noted burn in/fade out. This is on the profile level. Taking the big knife is not advisable, since time information and stack data must be synchronised. So we are more cautious.

```
Input
sprof02$profiles$data[1:3] <- NA
sprof02$profiles$data[519:522] <- NA
```

ToDo: handle empty stacks and zero counts gracefully

ToDo: add a purge function

At this point, it is a decision whether to adapt the timing information, or keep the original information. Since this decision does affect the structural information, it is not critical. But analysis is easier if unused nodes are eliminated. The *info* section is inconsistent at this point. Another reason to call `updateRprof()`.

```
Input
strx(sprof02$info)
```

```
Output
##strx: sprof02$info
'data.frame':      1 obs. of  8 variables:
 $ id : chr "sprof02: trimmed"
 $ date : POSIXct, format: "2013-08-13 21:33:38"
 $ nrnodes : int 62
 $ nrstacks : int 50
 $ nrrecords: int 522
 $ firstline: Factor w/ 1 level "sample.interval=1000": 1
 $ ctllines : Factor w/ 1 level "sample.interval=1000": 1
 $ ctllinenr: num 1
```

```
Input
prxt(sprof02$nodes,
  caption="sprof02, before update",
  label="tab:sprof02info1",
  digits=c(0,0,0,2,0,2,0),
  zero.print=" . "
)
```

Table 7: sprof02, before update

	name	self.time	self.pct	total.time	total.pct	icol
1	!	2	0.38	2	0.03	48
2	..getNamespace	.	0.00	1	0.01	59
3	.deparseOpts	2	0.38	4	0.05	42
4	.getXlevels	.	0.00	26	0.34	28

5	[	.	0.00	99	1.29	19
6	[.data.frame	57	10.92	99	1.29	20
7	[[	.	0.00	8	0.10	36
8	[[.data.frame	1	0.19	8	0.10	35
9	%in%	1	0.19	4	0.05	41
10	<Anonymous>	6	1.15	522	6.79	3
< cut >	\vdots	:	:	:	:	:
53	terms	.	0.00	2	0.03	49
54	terms.formula	1	0.19	1	0.01	58
55	try	.	0.00	521	6.78	9
56	tryCatch	.	0.00	521	6.78	5
57	tryCatchList	.	0.00	521	6.78	11
58	tryCatchOne	.	0.00	521	6.78	6
59	unique	3	0.57	4	0.05	43
60	unlist	.	0.00	1	0.01	61
61	vapply	3	0.57	23	0.30	29
62	withVisible	.	0.00	521	6.78	10

Input

Input

```
sprof02 <- updateRprof(sprof02)
sprof02$info$id <- "sprof02 updated"
```

Input

```
strx(sprof02$info)
```

Output

```
##strx: sprof02$info
'data.frame':      1 obs. of  9 variables:
 $ id : chr "sprof02 updated"
 $ date : POSIXct, format: "2013-08-13 21:33:38"
 $ nrnodes : int 62
 $ nrstacks : int 50
 $ nrrecords : int 522
 $ firstline : Factor w/ 1 level "sample.interval=1000": 1
 $ ctllines : Factor w/ 1 level "sample.interval=1000": 1
 $ ctllinenr : num 1
 $ date_updated: POSIXct, format: "2013-08-13 21:33:43"
```

Input

```
prxt(sprof02$nodes,
     caption="sprof02, after update",
     label="tab:sprof02info2",
     digits=c(0,0,0,2,0,2,0),
     zero.print=" . ")
```

Table 8: sprof02, after update

	name	self.time	self.pct	total.time	total.pct	icol
1	!	1	0.23	1	0.06	48
2	..getNamespace	.	0.00	1	0.06	59
3	.deparseOpts	2	0.46	4	0.25	42
4	.getXlevels	.	0.00	26	1.64	28
5	[	.	0.00	98	6.17	19
6	[.data.frame	57	13.16	98	6.17	20
7	[[	.	0.00	8	0.50	36
8	[[.data.frame	1	0.23	8	0.50	35
9	%in%	1	0.23	4	0.25	41
10	<Anonymous>	6	1.39	6	0.38	3
< cut >	\vdots	:	:	:	:	:
53	terms	.	0.00	1	0.06	49
54	terms.formula	1	0.23	1	0.06	58
55	try	.	0.00	.	0.00	9
56	tryCatch	.	0.00	.	0.00	5
57	tryCatchList	.	0.00	.	0.00	11
58	tryCatchOne	.	0.00	.	0.00	6
59	unique	3	0.69	4	0.25	43
60	unlist	.	0.00	1	0.06	61
61	vapply	3	0.69	23	1.45	29
62	withVisible	.	0.00	.	0.00	10

Input

Input

```
#8 8
shownodes(sprof02)
```

Nodes by stack and profile: see fig. 9 on the facing page.

ToDo: This section needs to be reworked
ToDo: trimexample
ToDo: add trim by keyword

2.3.1. *Trimming.* Note: trimming may be supported by the graph packages.

Input

```
trimstacks <- function(sprof, level){
  lapply(sprof$stacks$nodes, function(x) {x[-(1:level)]})
}
```

Input

```
sprof01Tr <- trimstacks(sprof01, 11)
#profile_nodesTr <- profiles_matrix(sprof01Tr)
#image(x=1:ncol(profile_nodesTr),y=1:nrow(profile_nodesTr), t(profile_nodesTr),xlab="event", ylab="
```

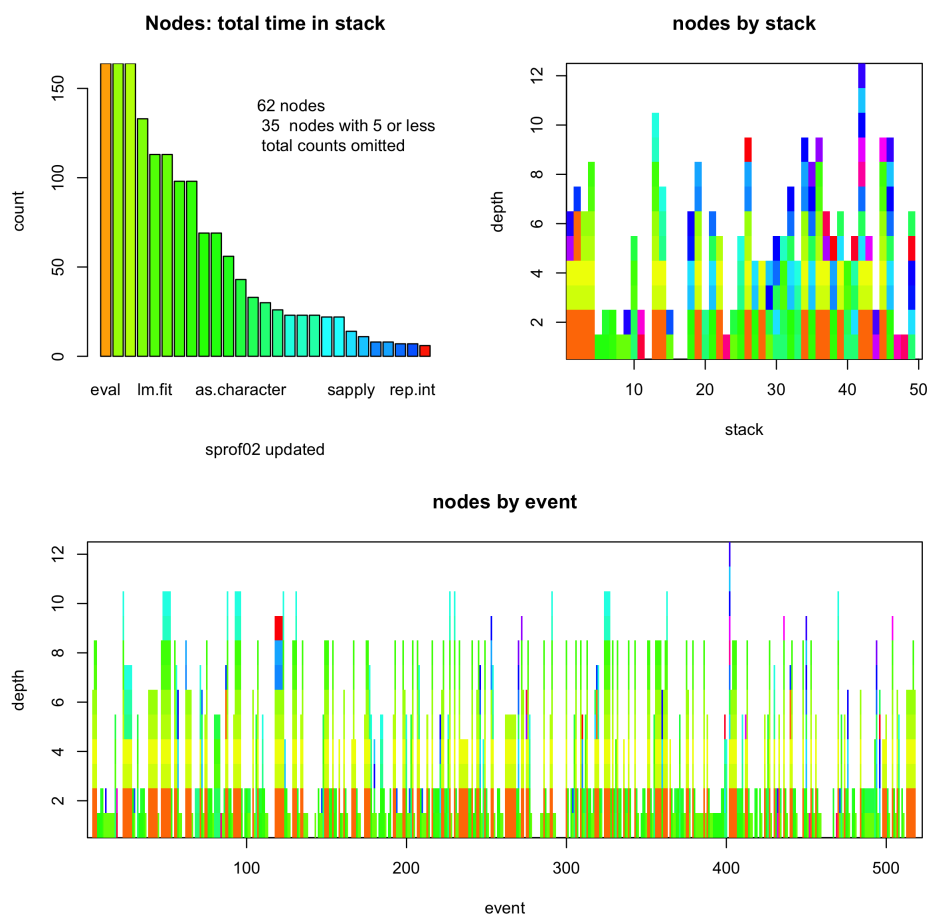



FIGURE 9. sprof02: Nodes by stack and profile

There is no statistics on profiles. Profiles are our elementary data. However we can link to our derived data to get a more informative display. For example, going one step back we can encode stacks and use these colour codes in the display of a profile.

Or going two steps back, we can encode nodes in colour, giving coloured stacks, and use these in the display of profile data.

2.3.2. *Surgery.* Note: surgery may be supported by the graph packages.

Looking at nodes gives you a point-wise horizon. Looking at edges gives you a one step horizon. The stacks give a wider horizon, typically a step size of 10 or more. The stacks we get from R have peculiarities, and we can handle with this broader perspective. These are not relevant if we look point-wise, but may become dominating if we try to get a global picture. We take a look ahead (details to come in section 3 on page 39 and have a preview how our example is represented as a

graph. Left is the original graph as recovered from the edge information, right the graph after we have cut off the scaffold effects.

ToDo: cut next level

Control structures may be represented in R as function, and these may lead to concentration points. Using information from the stacks, we can avoid these by introducing substitute nodes on the stack level. For example, `lapply` is appearing in various contexts and may be confusing any graph representation. We can avoid this by replacing a short sequence. `"[" "lapply" ".getXlevels" -> "<.getXlevels_[">` If the node does not exist, we want to add it to our global variable. For now, we do it using expressions on the R basic level and avoid tricks like simulating “call by reference”.

ToDo: Implement.
Currently best handled on source=text level

ToDo: function
addnode using “call by reference” to be added

Input

```

sprof03 <- sprof02; sprof03$info$id <- "sprof03: surgery"
node <- "<.getXlevels_[">"
#nodei <- function(sprofx, node, warn = TRUE)
{
  i <- match(node, sprof03$nodes$name, nomatch=0)
  if (i==0){
    sprof03$nodes$name <- as.character(sprof03$nodes$name)
    sprof03$nodes <- rbind(sprof03$nodes,NA)
    i <- length(sprof03$nodes$name)
    sprof03$nodes$name[i] <- node
    if (as.logical(options("warn")))
      message("node added. An updateRprof() may be necessary.")
  }
  nodei <- i
}
# sprof <- sprof01; nodei(sprof,"kiki"); sprof$nodes

```

Now we have to identify the stacks that may get a replacement. First find the candidates.

Input

```

targeti <- match("lapply", sprof03$nodes$name, nomatch=0)
found <- lapply(sprof03$stacks$nodes, function(X) match(targeti,X))
found <- data.frame(stack=1:length(found), position=as.matrix(found))
found[!is.na(found$position),]

```

Output

	stack	position
10	10	2
21	21	5
30	30	3
31	31	2
32	32	5
33	33	2
35	35	5
39	39	6
40	40	2
41	41	3
42	42	6

```
46      46      5
49      49      6
```

```
# as.factor(sprof03$stacks$nodes[!is.na(found)],
#           levels=1: length(sprof03$nodes$name), labels=sprof03$nodes$name)
```

For now, these are just candidates.

Other candidates are:

```
"as.list" "vapply" "model.frame.default" -> "<model_as.list>"
```

or

```
"as.list" "vapply" "model.matrix.default" -> "<model_matrix_as.list>"
```

ToDo: implement replacement on the stack level.

ToDo: implement

```
newchopnode <- function(nodenames, chop) {
  tmpname <- paste("<", as.character(nodenames[chop]), ">")
  # chec for existing.
  # add if necessary
  tmpname
}
chopstack <- function(x, chop, replacement)
{
  # is chop in x`
  # y: cut x.
  # merge x <- head + replacement + tiail
  return(x)
}
```

2.4. Run length. For a visual inspection, runs of the same node and level in the profile are easily perceived. For an analytical inspection, we have to reconstruct the runs from the data. In stacks, runs are organised hierarchically. On the root level, runs are just ordinary runs. On the next levels, runs have to be defined given (within) the previous runs. So we need `rrle()`, a recursive version of `rle`, applied to the profile information. This gives a detailed information about the presence time of each node, by stack level.

ToDo: needs serious revision

ToDo: test na removal in `rrle`

ToDo: use `sprof02` or `sprof03`?

ToDo: handle NA as special case

```
profile_nodes <- profiles_matrix(sprof02)
profile_nodes_rle <- rrle(profile_nodes, collapseNA=FALSE)
#!NA needs special case in run length handling.

strx(profile_nodes_rle, list.len=5)
```

```
##strx: profile_nodes_rle
List of 12
 $ :List of 2
  ..$ lengths: int [1:365] 1 1 1 3 3 1 7 1 ...
  ..$ values : int [1:365] NA NA NA 22 39 37 30 4 ...
  ..- attr(*, "class")= chr "rle"
```

```

6      . . . . . . . .
7      . . . . . . . .
8      . . . . . . . .
9      . . . . . . . .
10     . . . . . . . .
11     . . . . . . . .
12     . . . . . . . .
Sum 40 17 7 4 2 6 1 77

```

```

amt <- nodesrunlength(sprof02)
# print.table(as.table(amt[,1:9]), zero.print = ".")
## ??? print.table changes format when col.10 is present.

```

But `print.xtable` has no `zero.print` ...

```

#special sanitizing for xtable
xr <- rownames(amt)
#for (i in (1:length(xr))) {xr[i] <- sub(xr[i], "\\[", "$[", fixed=TRUE)}
#xr <- paste("$", xr, "$")
xr <- gsub("[", "{[", xr, fixed=TRUE)
xr <- gsub("_", "\\_", xr, fixed=TRUE)
xr <- gsub("^", "\\^", xr, fixed=TRUE)
rownames(amt) <- xr
prxt(amt,
  caption="Marginal statistics on nodes by run length, sorted by total time used, count > 1 only",
  label="tab:pramt1",
  digits=c(rep(0,dim(amt)[2]) ,2),
  zero.print=" . ") #dim(amt)[2]-1, +1 for rownames

```

Table 9: Marginal statistics on nodes by run length, sorted by total time used, count > 1 only

	1	2	3	4	5	6	7	nr_runs	total_time	avg_time
eval	86	34	14	8	4	12	2	160	334	2.09
model.frame	40	17	7	4	2	6	1	77	164	2.13
model.frame.default	40	17	7	4	2	6	1	77	164	2.13
na.omit	46	10	5	4	1	4	1	71	133	1.87
lm.fit	46	18	3	1	1	1	1	71	113	1.59
na.omit.data.frame	43	7	4	5	.	4	.	63	113	1.79
{[]	59	4	3	4	.	1	.	71	98	1.38
{[].data.frame	59	4	3	4	.	1	.	71	98	1.38
model.matrix	55	4	2	.	.	.	.	61	69	1.13
model.matrix.default	55	4	2	.	.	.	.	61	69	1.13
model.response	35	3	3	.	.	1	.	42	56	1.33
as.character	34	3	1	.	.	.	.	38	43	1.13
structure	21	1	.	1	.	1	.	24	33	1.38
lapply	26	.	.	1	.	.	.	27	30	1.11
.getXlevels	17	1	1	1	.	.	.	20	26	1.30
anyDuplicated	10	.	.	2	1	.	.	13	23	1.77

ToDo: rescale to application scale

ToDo: replace sum by weighted sum

ToDo: allow sorting, e.g. by marginals

ToDo: [needs to be hidden for `print.xtable`

ToDo: handle gaps in run length = NA counts

as.list	16	1	.	.	1	.	.	18	23	1.28
vapply	13	1	1	.	1	.	.	16	23	1.44
anyDuplicated.default	9	.	.	2	1	.	.	12	22	1.83
as.list.data.frame	15	1	.	.	1	.	.	17	22	1.29
sapply	14	.	.	.	.	.	.	14	14	1.00
match	12	.	.	.	.	.	.	12	12	1.00
{ } { }	3	.	.	.	1	.	.	4	8	2.00
{ } { }.data.frame	3	.	.	.	1	.	.	4	8	2.00
FUN	7	.	.	.	.	.	.	7	7	1.00
rep.int	7	.	.	.	.	.	.	7	7	1.00
<Anonymous>	1	.	.	.	1	.	.	2	6	3.00
.deparseOpts	4	.	.	.	.	.	.	4	4	1.00
%in%	4	.	.	.	.	.	.	4	4	1.00
simplify2array	4	.	.	.	.	.	.	4	4	1.00
unique	4	.	.	.	.	.	.	4	4	1.00
list	3	.	.	.	.	.	.	3	3	1.00
deparse	2	.	.	.	.	.	.	2	2	1.00
mode	2	.	.	.	.	.	.	2	2	1.00
names	2	.	.	.	.	.	.	2	2	1.00
pmatch	2	.	.	.	.	.	.	2	2	1.00
!	1	.	.	.	.	.	.	1	1	1.00
..getNamespace	1	.	.	.	.	.	.	1	1	1.00
\$	1	.	.	.	.	.	.	1	1	1.00
as.list.default	1	.	.	.	.	.	.	1	1	1.00
as.name	1	.	.	.	.	.	.	1	1	1.00
coef	1	.	.	.	.	.	.	1	1	1.00
lazyLoadDBfetch	1	.	.	.	.	.	.	1	1	1.00
mean	1	.	.	.	.	.	.	1	1	1.00
mean.default	1	.	.	.	.	.	.	1	1	1.00
NCOL	1	.	.	.	.	.	.	1	1	1.00
paste	1	.	.	.	.	.	.	1	1	1.00
terms	1	.	.	.	.	.	.	1	1	1.00
terms.formula	1	.	.	.	.	.	.	1	1	1.00
unlist	1	.	.	.	.	.	.	1	1	1.00

ToDo: add current level

ToDo: generate a coplot representation

ToDo: remove counts per level?

ToDo: hack. keep length in nodesrun-length

See table 9

We can add this information to our base and use it to enhance graphical displays. See: nodes marked by run length and run count, fig. 14 on page 47.

`eval` is the base of all evaluation in R, so we should not be surprised to find it at the top of the list. The next two entries, `model.frame` and `model.frame.default` are seen 77 times. We know that in our example we had a loop with 100 repetitions, so a frequency of 100 would not be surprising. A closer look shows that both functions occur as isolated events 40 times, but frequency decreases with run length until we see another high at run length 6. We are sampling, and of course sampling can miss some function calls. But this pattern is what if occurs if we do not miss a function call, but we miss a gap. So several function calls appear as some longer runs.

We can improve the hit rate by increasing the sampling rate. But of course this is at the expense of using more space for the log files, and increased time for the overhead. In our case, 1 ms seems to be a good compromise, but 0.1 ms might be another feasible choice.

As we walk down the list, `na.omit` is next, followed closely by `na.omit.data.frame`. In our problem, there are no missing data. But R does not have something like a “vanilla mode”. The overhead used for the handling of potentially missing values would need a restructuring of the linear model algorithm, e.g. by introducing a “has.na” flag.

Walking further down, we see other candidates such as `as.character` that may be avoidable in this problem.

```

Input
nr <- nodesrunlength(sprof02, clean=FALSE)
#nr <- rbind(nr,0) ## hack. keep length in nodesrunlength
rownames(nr) <- sprof02$nodes$name
sprof02$nodes <- cbind(sprof02$nodes, nr)
rownames(sprof02$nodes) <- sprof02$nodes$name

```

ToDo: table: node
#runs min median
run length max

3. GRAPH PACKAGE

What we have achieved so far can be seen from the graph representations.

```

Input
library(graph)
search()

```

```

Output
[1] ".GlobalEnv"      "package:Rgraphviz"
[3] "package:graph"    "package:sna"
[5] "package:grid"     "package:wordcloud"
[7] "package:RColorBrewer" "package:Rcpp"
[9] "package:xtable"    "package:sprof"
[11] "package:stats"     "package:graphics"
[13] "package:grDevices" "package:utils"
[15] "package:datasets"  "package:methods"
[17] "Autoloads"         "package:base"

```

```

Input
#12 6
oldpar <- par(mfrow=c(1,2))
plotviz(as(adjacency(sprof01), "graphNEL"),
        sub=sprof01$info$id)
plotviz(as(adjacency(sprof02), "graphNEL"),
        sub=sprof02$info$id)
par(oldpar)

```

See fig. 10 on the following page for a comparison before and after trimming. The scaffold effect are removed from the picture on the right side. This cuts off the

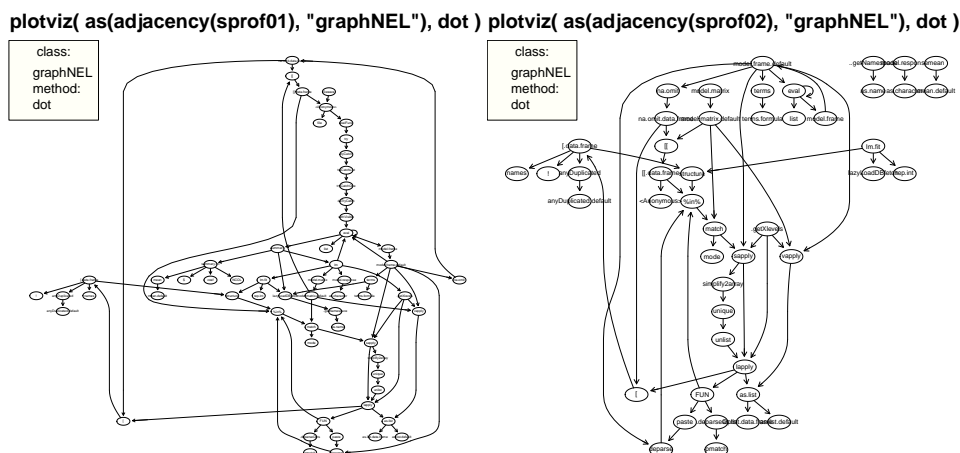


FIGURE 10. Sprof graph, before and after trimming.

uninformative spine, and induces minor changes in the body of the graph. You can do additional trimming, if you want.

R is function based, and control structures in general are implemented as functions. In a graph representation, they appear as nodes, concentrating and seeding to unrelated paths. We can detect these on the stack level and replace them by surrogates, introducing new nodes. This is a case for surgery.

ToDo: fix null name

We used a prepared sanitised version of our data set.

Input

```
sprof04 <- readRprof("RprofsRegressionExpl03.out", id="sprof04")
```

Input

```
#12 6
oldpar <- par(mfrow=c(1,2))
plotviz(as(adjacency(sprof02), "graphNEL"),
        sub=sprof02$info$id)
plotviz(as(adjacency(sprof04), "graphNEL"),
        sub=as.character(sprof04$info$id))
par(oldpar)
```

ToDo: cut top levels

Now the structure becomes obvious. Cutting off may be taken two levels deeper. This would completely separate the `lm()` branch from the `summary.lm()`. In the `lm()` branch, there are tree nodes (`lapply()`, `%in%` and `[.data.frame]`) that are a cases for additional surgery to avoid focusing affects in the graph display. It is your choice to remove them, or live with them.

We know how to create standard graph displays from this. The next step is to encode additional information we have from the profiles as attribute to the graph.

The derived edge frequency is the first bit of information. Implicitly, it can be used as weight in the graph placement routines. We make this explicit by giving a choice


```
plotviz( as(adjacency(sprof02), "graphNEL"), dot ) plotviz( as(adjacency(sprof04), "graphNEL"), dot )
```

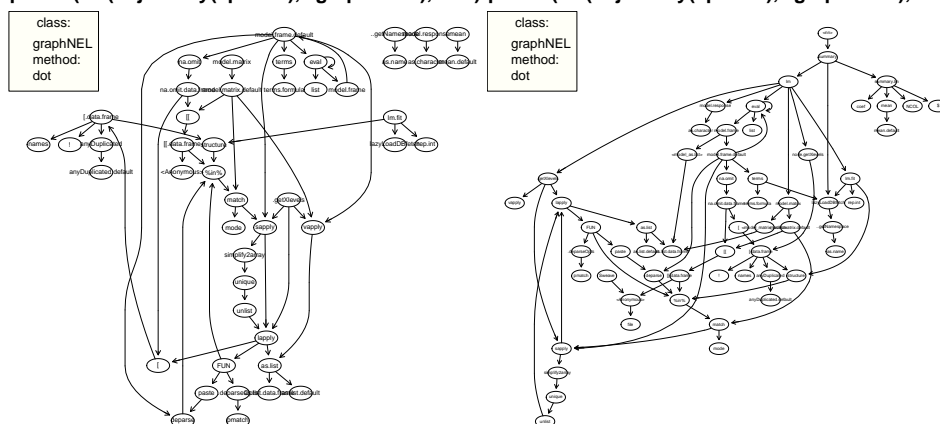


FIGURE 11. Sprof graph, after trimming, and after trimming and some sanitizing.

whether to use it or not. Irrespective of this choice, we encode reference counts as line width of the edges.

This function is not included in the package to avoid dependency of *sprof* on *graph* and other graph packages.

library(graph) Input
search()

Output	Output
[1] ".GlobalEnv"	"package:Rgraphviz"
[3] "package:graph"	"package:sna"
[5] "package:grid"	"package:wordcloud"
[7] "package:RColorBrewer"	"package:Rcpp"
[9] "package:xtable"	"package:sprof"
[11] "package:stats"	"package:graphics"
[13] "package:grDevices"	"package:utils"
[15] "package:datasets"	"package:methods"
[17] "Autoloads"	"package:base"

library(Rgraphviz) Input
search()

Output	Output
[1] ".GlobalEnv"	"package:Rgraphviz"
[3] "package:graph"	"package:sna"
[5] "package:grid"	"package:wordcloud"
[7] "package:RColorBrewer"	"package:Rcpp"
[9] "package:xtable"	"package:sprof"
[11] "package:stats"	"package:graphics"

```
[13] "package:grDevices" "package:utils"
[15] "package:datasets"  "package:methods"
[17] "Autoloader"         "package:base"
```

Input

This is a common routine for the *grpah* and *Rgraphviz* package.

Input

```
as_graphNEL_sprof <- function(sprof, weight=TRUE){

  a04<-adjacency(sprof)

  rnames <- rownames(a04)

  if (!weight) {
    dimold <- dim(a04);a04 <- as.numeric(a04); dim(a04) <- dimold
    rownames(a04)<- rnames; colnames(a04)<- rnames;
  } #! define lwd first

  el04 <- edgematrix(a04)
  el04$lwd <- rkindex(el04$count, maxindex=6, ties.method="min")

  a04NEL <- as(a04,"graphNEL")
  nodeDataDefaults(a04NEL, "shape") <- "ellipse"
  nodeDataDefaults(a04NEL, "cex") <- 0.6
  nodeDataDefaults(a04NEL, "weight") <- 1
  nodeDataDefaults(a04NEL, "fill") <- "green"
  nodeDataDefaults(a04NEL, "col") <- "yellow"

  a04NEL <- layoutGraph(a04NEL)

  nodeRenderInfo(a04NEL) <- list(shape="ellipse")
  nodeRenderInfo(a04NEL) <- list(cex=0.6, shape="ellipse")
  nodeRenderInfo(a04NEL) <- list(weight=1)
  #nodeRenderInfo(a04NEL) <- list(color="yellow")
  nodeRenderInfo(a04NEL) <- list(fill="yellow", col="blue")

  edgeDataDefaults(a04NEL,"lwd") <- 1
  edgeDataDefaults(a04NEL,"col") <- "grey"

  #nodeRenderInfo(a04NEL) <- list(weight=1)

  #edgeRenderInfo(a04NEL) <- list(lwd=el04$lwd)
  #edgeRenderInfo(a04NEL)$lwd <- el04$lwd
  for (i in 1:length(el04$lwd))
  {edgeRenderInfo(a04NEL)$lwd[i] <- el04$lwd[i]}
  a04NEL
}
```

Input

```

plot_graphNEL_sprof <- function(graphNEL)
{
  main1 <- deparse(substitute(graphNEL))

  if (inherits(graphNEL, "sprof")) {
    main1 <- graphNEL$info$id
    graphNEL <-
      as_graphNEL_sprof(graphNEL, weight=FALSE)
  }

  renderGraph(graphNEL)
  #title(main=paste0( "Rgraphviz/graph( ",main1, " )"))
  title(main=main1)
  #title(main="nodes time", sub=sprof04$info$id)
  #legend("bottomright",legend= c("node color: self.time, pwr=0.5", "node
  #lwd: total.time, pwr=0.5"), bty="n")

  legend("topleft",
        legend=class(graphNEL),
        title="plot_graphNEL_sprof class:"
        )
}

```

```

a04NEL <- as_graphNEL_sprof(sprof04)
plot_graphNEL_sprof(a04NEL)

```

Rgraphviz/graph basic plot: see fig. 12 on the next page.

To use attributes on nodes and edges, we need **Rgraphviz**.

ToDo: merge with
as_graphNEL_sprof

```

library(graph)
# see help(nodeRenderInfo) for attributes.
#6 6
a04NELO <- as_graphNEL_sprof(sprof04, weight=FALSE)
#nDD0 <- (nodeRenderInfo(a04NELO))
#a04NELO <- layoutGraph(a04NELO)
#nDD1 <- (nodeRenderInfo(a04NELO))# fill & col corrupted
nodeDataDefaults(a04NELO, "shape") <- "ellipse"
#nodeDataDefaults(a04NELO, "cex") <- 1.0
#nodeDataDefaults(a04NELO, "weigh") <- 1
#nodeDataDefaults(a04NELO, "fill") <- "green"
#nodeDataDefaults(a04NELO, "col") <- "yellow"
nDD2 <- (nodeRenderInfo(a04NELO))
a04NELO <- layoutGraph(a04NELO)
# node attributes
#sprof04$nodes$self.time -> fill
fill_list <- heat.colors(12)[
  rkindex(-sprof04$nodes$self.time,
    pwr=0.5, maxindex=12, ties.method="min")]

```

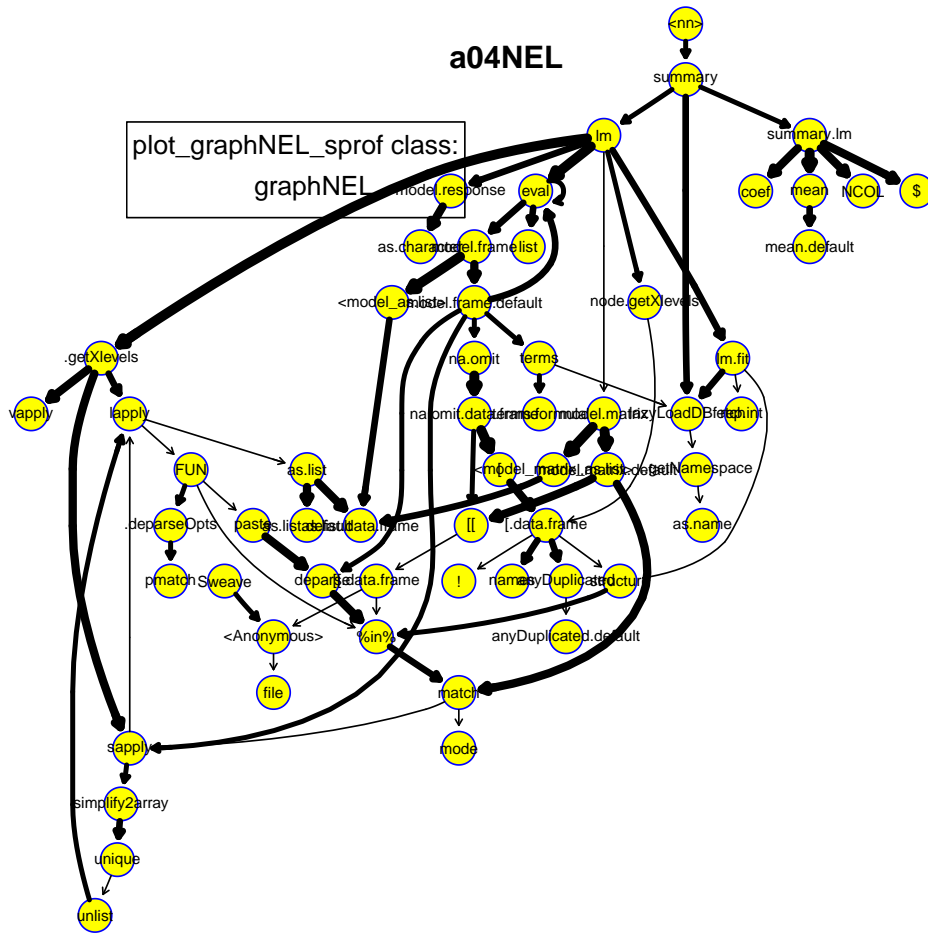


FIGURE 12. Rgraphviz/graph basic plot

```

names(fill_list) <- sprof04$nodes$name
#sprof04$nodes$total.time -> lwd
lwd_list <- rkindex(sprof04$nodes$total.time,
  pwr=0.5, maxindex=6, ties.method="min")
names(lwd_list) <- sprof04$nodes$name
#strx(nodeRenderInfo(a04NEL0))
nodeRenderInfo(a04NEL0) <- list(lwd=lwd_list,
  fill=fill_list,
  col="#0000FF80",
  shape="ellipse",
  weight=1)
#strx(nodeRenderInfo(a04NEL0))

# edge attributes
# strx(edgeRenderInfo(a04NEL0))
edgeRenderInfo(a04NEL0) <- list(col= "#80808080")

```

nodes (time)

class:
graphNEL

node color: self.time, pwr=0.5
 node lwd: total.time, pwr=0.5
 edge lwd: frequency

sprof04

Rgraphviz/graph plot with attributes: see fig. 13. This plot gives us the traditional view, highlighting nodes and edges with overall time presence.

Input

```
detach(package:Rgraphviz)
```

We should not overload the plot. We could use colour encoding for the edges, but this would conflict visually with the colour encoding of the nodes. We could use different colours for classes of nodes, but then we would need an additional display to explain the shape information.

But within the choice of attributes used, we still can select the information shown. To close this round, instead of showing the node information from the rough summary, we can show the information from the run length discussed in section 2.4 on page 35.

Input

```
#6 6
amt04 <- nodesrunlength(sprof04)
library(graph)
library(Rgraphviz)
# see help(nodeRenderInfo) for attributes.

a04NEL0rle <- as_graphNEL_sprof(sprof04, weight=FALSE)
#nDD0 <- (nodeRenderInfo(a04NEL0rle))
#a04NEL0rle <- layoutGraph(a04NEL0rle)
#nDD1 <- (nodeRenderInfo(a04NEL0rle))# fill & col corrupted
nodeDataDefaults(a04NEL0rle, "shape") <- "ellipse"
#nodeDataDefaults(a04NEL0rle, "cex") <- 1.0
#nodeDataDefaults(a04NEL0rle, "weight") <- 1
#nodeDataDefaults(a04NEL0rle, "fill") <- "green"
#nodeDataDefaults(a04NEL0rle, "col") <- "yellow"
nDD2 <- (nodeRenderInfo(a04NEL0rle))
a04NEL0rle <- layoutGraph(a04NEL0rle)
# node attributes
#sprof04$nodes$self.time -> fill
fill_list <- heat.colors(12)[rindex(-amt04[, "avg_time"], pwr=0.5, maxindex=12, ties.method="min")]
names(fill_list) <- sprof04$nodes$name
#sprof04$nodes$total.time -> lwd
lwd_list <- rindex(amt04[, "nr_runs"], pwr=0.5, maxindex=6, ties.method="min")
names(lwd_list) <- sprof04$nodes$name
#strx(nodeRenderInfo(a04NEL0rle))
nodeRenderInfo(a04NEL0rle) <- list(lwd=lwd_list,
                                fill=fill_list,
                                col="#0000FF80",
                                shape="ellipse",
                                weight=1)
#strx(nodeRenderInfo(a04NEL0rle))

# edge attributes
# strx(edgeRenderInfo(a04NEL0rle))
edgeRenderInfo(a04NEL0rle) <- list(col= "#80808080")
# strx(edgeRenderInfo(a04NEL0rle))

renderGraph(a04NEL0rle)
title(main="nodes (run length)", sub=sprof04$info$id, col.sub=grey(0.5))
```

```
legend("bottomright",
      legend= c("node lwd: nr runs, pwr=0.5",
                "node color: avg time, pwr=0.5",
                "edge lwd: frequency"),
      bty="n", text.font=3)
legend("topleft",
      legend=class(a04NELorle),
      title="class:")
)
detach(package:Rgraphviz)
```

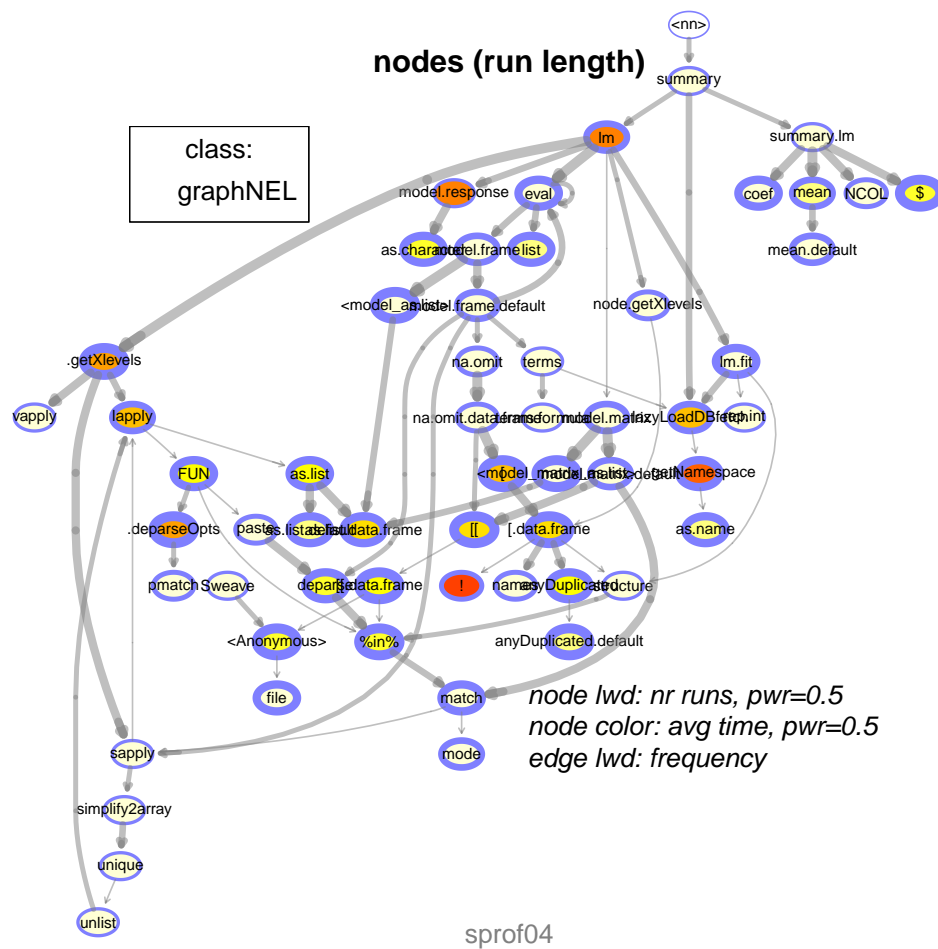


FIGURE 14. nodes (run length)

Nodes marked by run length and run count: see fig. 14. This plot gives us a more informative view, highlighting nodes by number of runs and average run length and edges with overall time presence.

4. STANDARD OUTPUT

For a reference, here are the standard functions.

Input

```
sprof <- sprof01
```

4.1. **Print.** We omit the (lengthy) print output here and just give the commands as a reference.

Input

```
print_nodes(sprof)
```

Input

```
print_stacks(sprof)
```

Input

```
print_profiles(sprof)
```

The `print()` method for `sprof` objects concatenates these three functions.

4.2. **Summary.**

Input

```
summary_nodes(sprof)
```

Input

```
summary_stacks(sprof)
```

Input

```
summary_profiles(sprof)
```

The `summary()` method for `sprof` objects concatenates these three functions.

ToDo: Clarify: "print prints its argument and returns it invisibly (via `invisible(x)`)."

Return the argument, or some print representation?

ToDo: is there a `print=FALSE` variant to postpone printing to e.g. `xtable`?

4.3. **Plot.** Examples are given in the reference manual for *sprof*.

`plot_nodes(sprof)` Input

`plot_stacks(sprof)` Input

`plot_profiles(sprof)` Input

The `plot.sprof()` method for *sprof* objects concatenates these three functions.

5. MORE GRAPHS

Note: This section is collecting experiments with various graph packages. It is only of interest for you, if you have a preference for some graphic package and want to look up a wrapper here. On the other side: contributions and suggestions are welcome.

Graph layout is a theme of its own. Proposals are readily available, as are their implementation. For some of them, there are R interfaces or re-implementations in R. Their usefulness in our context has to be explored, and the answers will vary with personal preferences.

For some graph layout packages we illustrate an interface here and show a sample result. We use the original profile data here. This is a nasty graph with some R stack peculiarities. The corresponding results for the trimmed profile data are shown in the next section section 6 on page 76. This is a more realistic example of the kind of graphs you will have to work with.

5.1. **Example: regression.** In this section, we use the recent version of our example, *sprof02* for demonstration. You can re-run it, using your *sprof* data by modifying this instruction by replacing *sprof02* with your profile information.

`sprof <- sprof02` Input

To interface *sprof* to a graph handling package, `adjacency()` can extract the adjacency matrix from the profile.

There are various packages for finding a graph layout, and the choice is open to your preferences. The R packages for most of these are just wrapper

`sprofadj02 <- adjacency(sprof)` Input

This is a format any graph package can handle (maybe). To be on the save side, we provide an (extended) edge list. The added component *lwd* is a proposal for the line width in the graph rendering.

ToDo: by graph package: preferred input format?

ToDo: use attributes. Edge with should be easy.

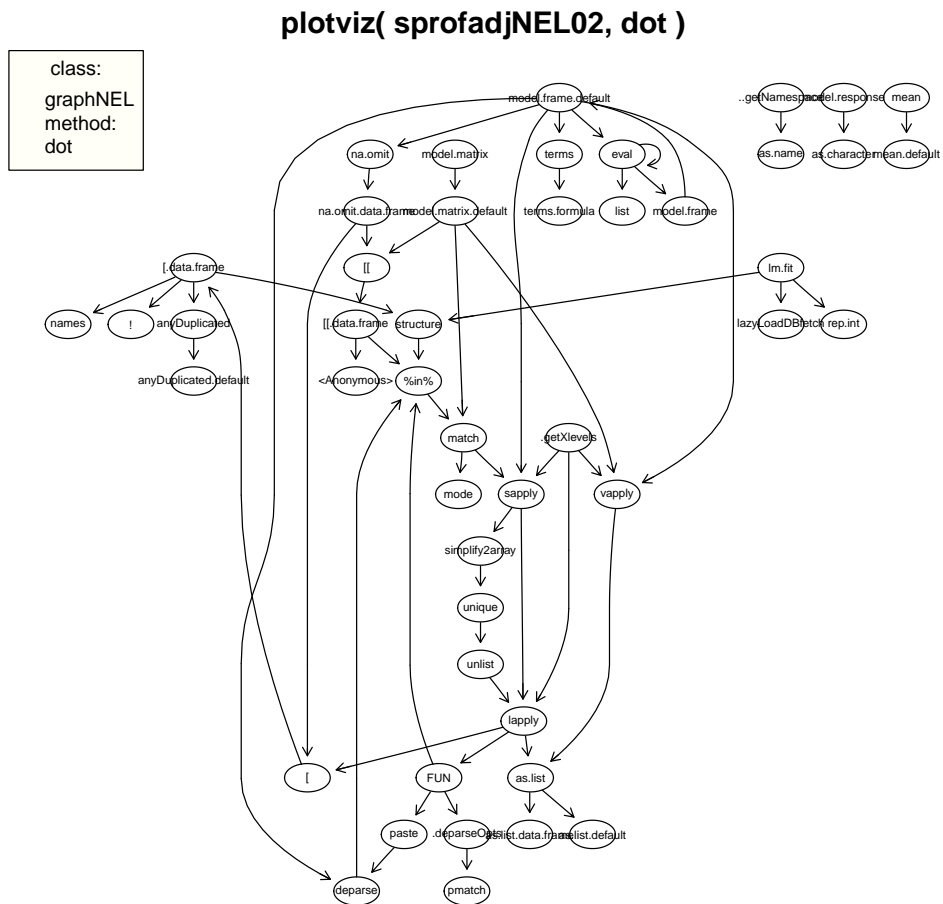
ToDo: include information from stack connectivity.

Input

```
sprofedge102 <- edgematrix(sprofadj02)
sprofedge102$lwd <- rkindex(sprofedge102$count, maxindex=12, ties.method="min")
```

5.1.1. *graph* package.

Input



5.1.2. *igraph package*. Attributes for igraphs are documented in `help(igraph.plotting)`.

Layouts available for *igraph*:

```
layout.auto(graph, dim=2, ...)
layout.random(graph, params, dim=2)
layout.circle(graph, params)
layout.sphere(graph, params)
layout.fruchterman.reingold(graph, ..., dim=2, params)
layout.kamada.kawai(graph, ..., dim=2, params)
layout.spring(graph, ..., params)
layout.reingold.tilford(graph, ..., params)
layout.fruchterman.reingold.grid(graph, ..., params)
layout.lgl(graph, ..., params)
layout.graphopt(graph, ..., params=list())
layout.svd(graph, d=shortest.paths(graph), ...)
layout.norm(layout, xmin = NULL, xmax = NULL, ymin = NULL, ymax = NULL,
zmin = NULL, zmax = NULL)
```

Input

```
library(igraph)
search()
```

	Output
[1] ".GlobalEnv"	"package:igraph"
[3] "package:sna"	"package:grid"
[5] "package:wordcloud"	"package:RColorBrewer"
[7] "package:Rcpp"	"package:xtable"
[9] "package:sprof"	"package:stats"
[11] "package:graphics"	"package:grDevices"
[13] "package:utils"	"package:datasets"
[15] "package:methods"	"Autoloads"
[17] "package:base"	

Input

```
as_igraph_sprof <- function(sprof, layoutfun, params=NULL,...){
  adj <- adjacency(sprof)
  adj[adj!=0] <- 1
  sprof_igraph <- graph.adjacency(adj)
  sprof_igraph <- set.graph.attribute(sprof_igraph, "layout",
    layoutfun(sprof_igraph,params=params,...),...)
  V(sprof_igraph)$color <- "yellow"
  E(sprof_igraph)$color <- "#0000FF20"
  E(sprof_igraph)$width <- c(1,2)
  return(sprof_igraph)
```

```
}

```

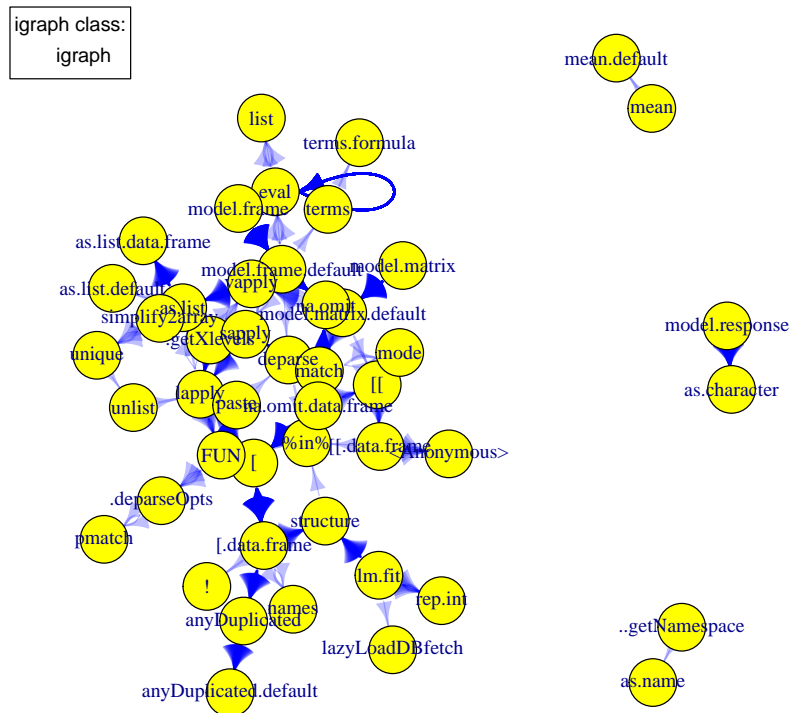
Input

```
sprof_igraph <- graph.adjacency(adjacency(sprof))
sprof_igraph <- set.graph.attribute(sprof_igraph, "layout", layout.kamada.kawai(sprof_igraph))
V(sprof_igraph)$color <- "yellow"
#E(sprof_igraph)$width <- c(1,2)
E(sprof_igraph)$color <- "#0000FF40"
E(sprof_igraph)$width <- c(1,2)
# see
```

Input

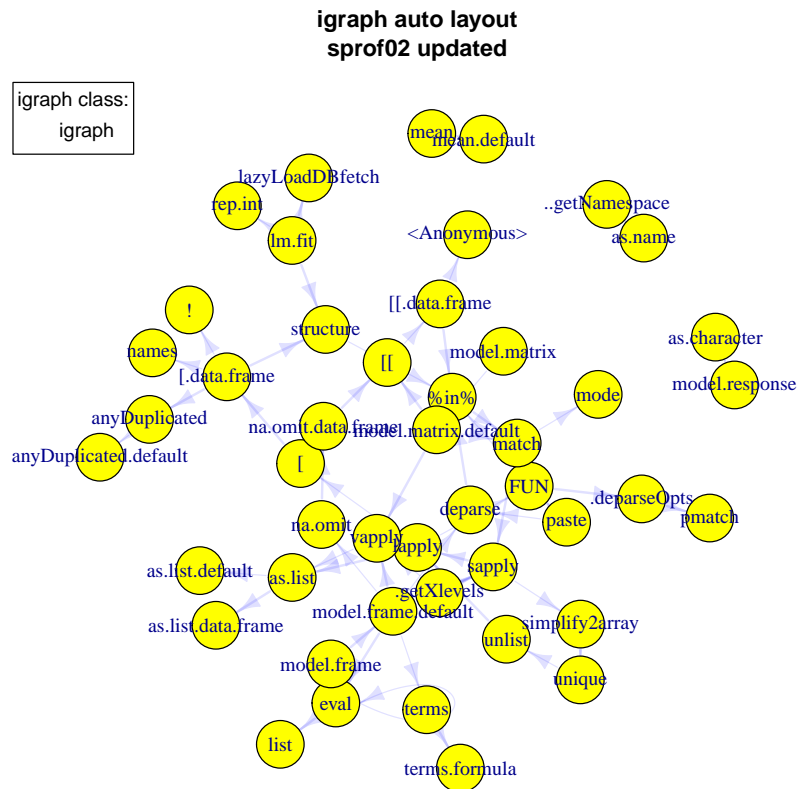
```
plot(sprof_igraph, main=paste0("igraph kamada.kawai layout\n", sprof$info$id))
  legend("topleft",
        legend=class(sprof_igraph),
        title="igraph class:"
  )
```

igraph kamada.kawai layout
sprof02 updated



Experiments with various layouts for *igraph* follow.

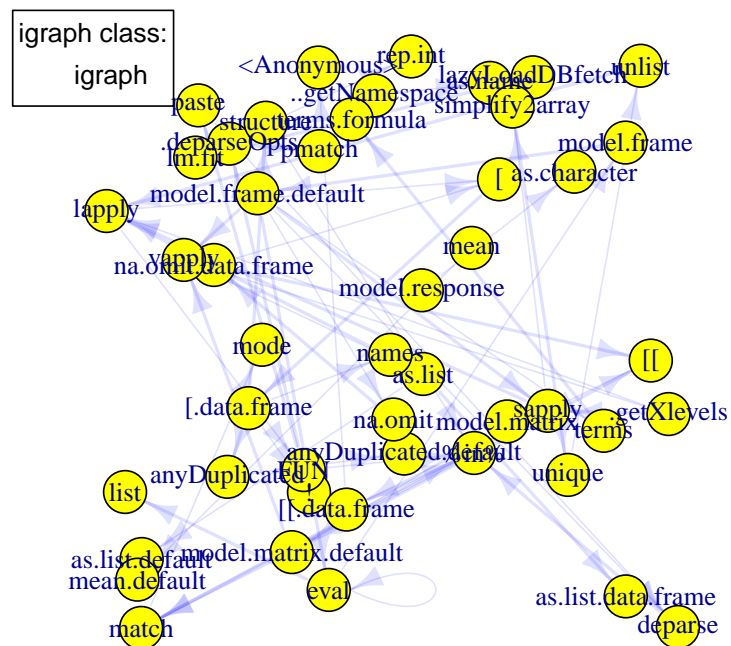
Input



Input

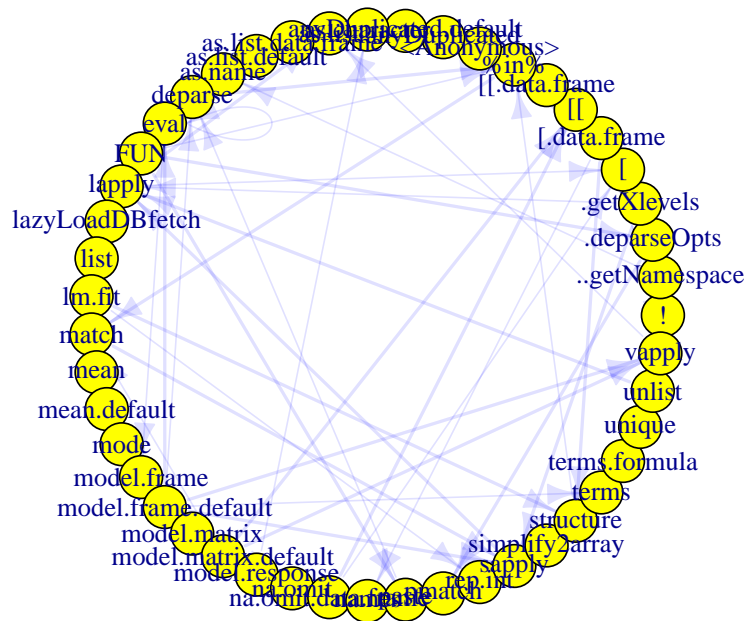
```
#6 6
sprof_ig_random <- as_igraph_sprof(sprof, layout.random)
plot(sprof_ig_random, main=paste0("igraph random layout\n", sprof$info$id))
  legend("topleft",
        legend=class(sprof_ig_random),
        title="igraph class:"
  )
```

igraph random layout sprof02 updated



```
#6 6
sprof_ig_auto <- as_igraph_sprof(sprof, layout.circle)
plot(sprof_ig_auto, main=paste0("igraph circle layout\n", sprof$info$id))
```

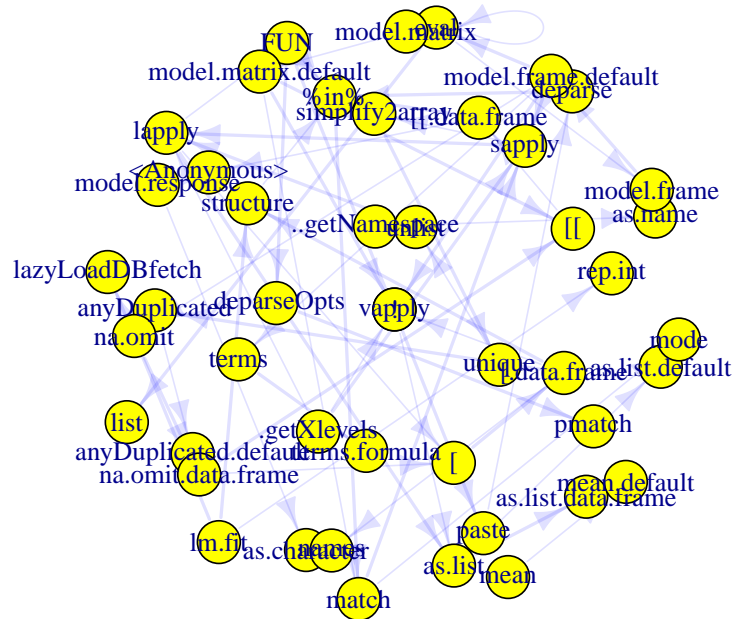
igraph circle layout
sprof02 updated



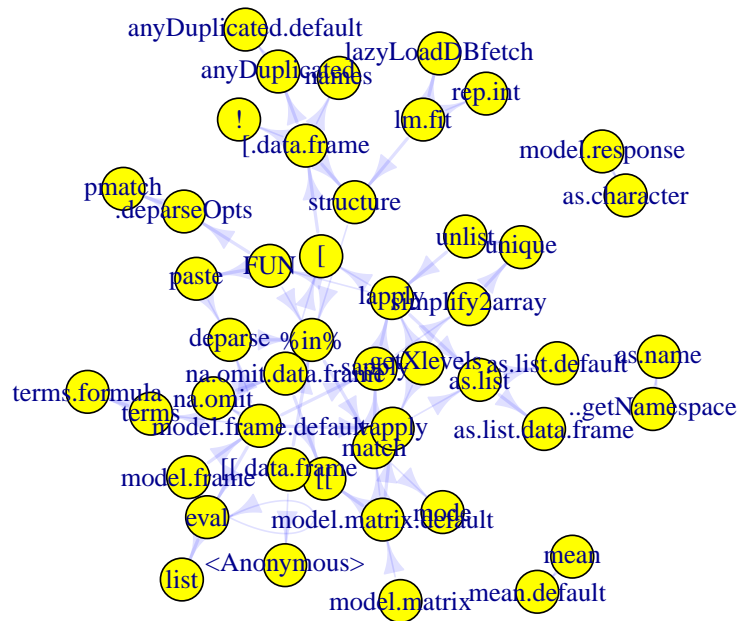
#6 6

```
sprof_ig_auto <- as_igraph_sprof(sprof, layout.sphere)
plot(sprof_ig_auto, main=paste0("igraph sphere layout\n", sprof$info$id))
```

igraph sphere layout
sprof02 updated

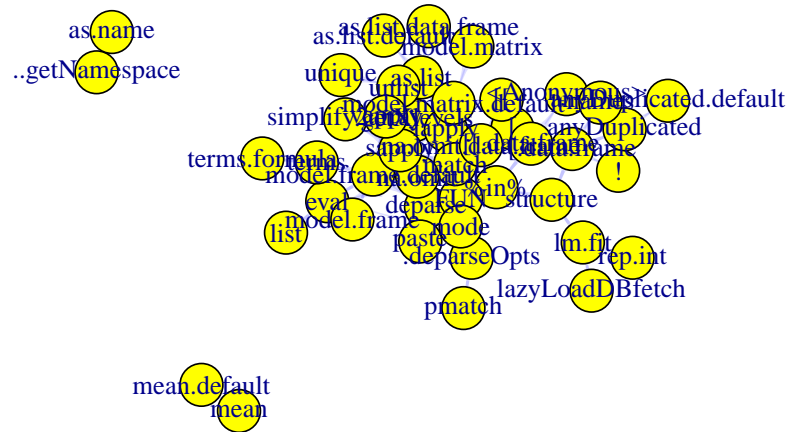


Input

sprof02 updated

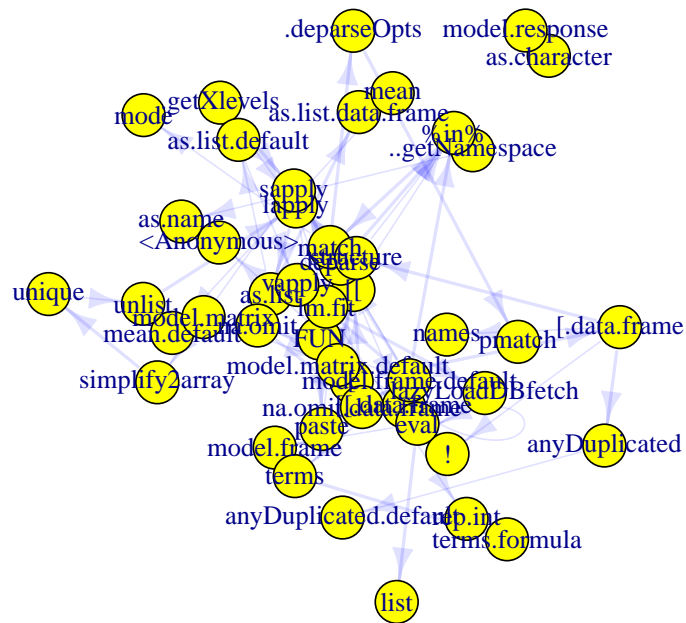
Input

model.response



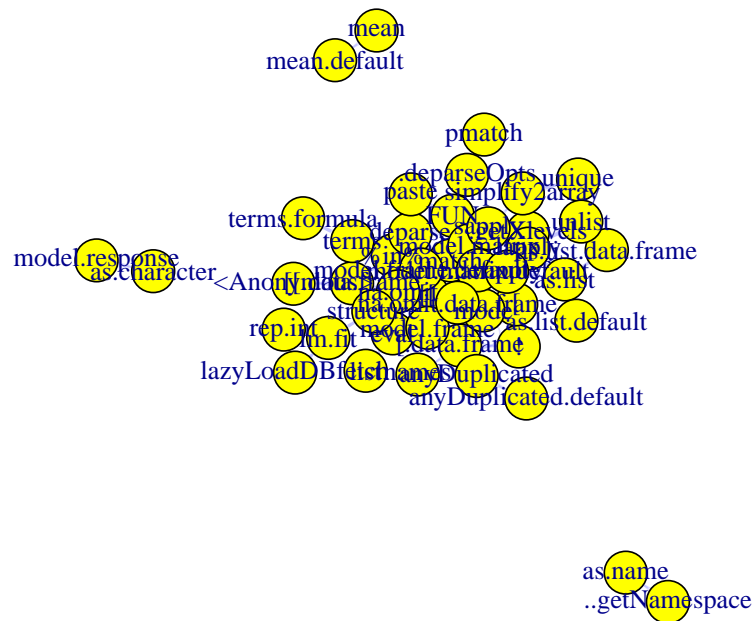
Input

igraph spring layout
sprof02 updated



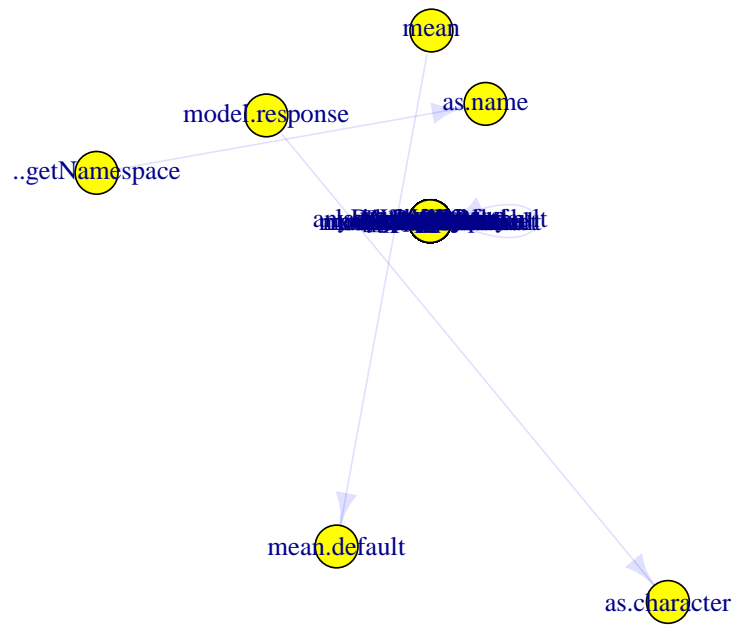
#6 6

igraph fruchterman.reingold.grid layout
sprof02 updated



```
#6 6
sprof_ig_auto <- as_igraph_sprof(sprof, layout.lgl)
plot(sprof_ig_auto, main=paste0("igraph lgl layout\n", sprof$info$id))
```

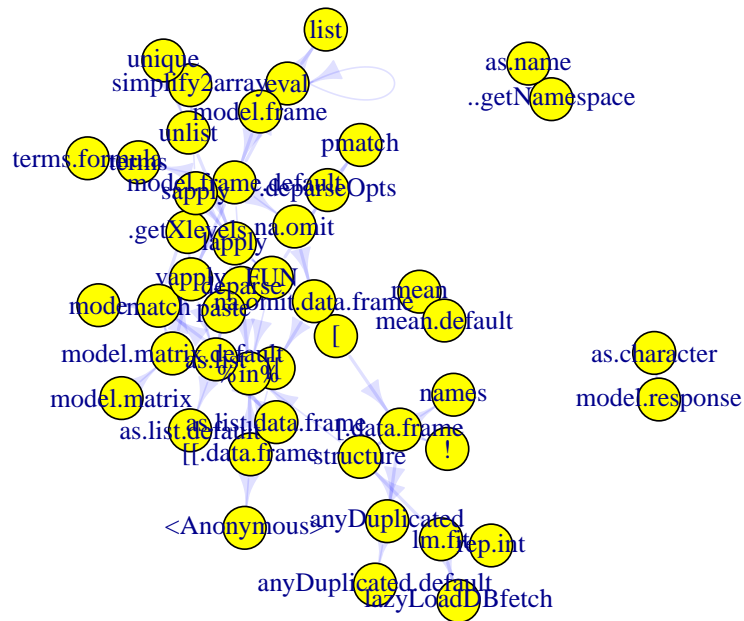
igraph lgl layout sprof02 updated



#6 6

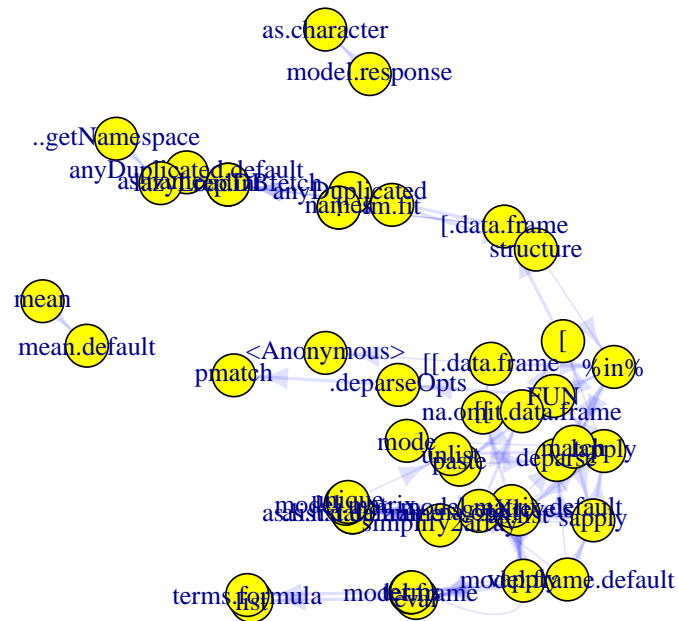
```
sprof_ig_auto <- as_igraph_sprof(sprof, layout.graphopt)
plot(sprof_ig_auto, main=paste0("igraph graphopt layout\n", sprof$info$id))
```

igraph graphopt layout
sprof02 updated



#6 6

igraph svd layout
sprof02 updated



5.1.3. *network* package.

```
library(network)
search()
```

Input

```

[1] ".GlobalEnv"      "package:network"
[3] "package:igraph"  "package:sna"
[5] "package:grid"    "package:wordcloud"
[7] "package:RColorBrewer" "package:Rcpp"
[9] "package:xtable"   "package:sprof"
[11] "package:stats"    "package:graphics"
[13] "package:grDevices" "package:utils"
[15] "package:datasets" "package:methods"
[17] "Autoloads"        "package:base"

```

Output

ToDo: propagate

```

as_network_sprof <- function(sprof) {
  sprofadj02 <- adjacency(sprof)
  nwsprofadj <- as.network(sprofadj02)
  network.vertex.names(nwsprofadj) <-
    rownames(sprofadj02) # not honoured by plot
  return(nwsprofadj)
}

```

Input

```

plot_network_sprof <- function(nwsprof, mode = "fruchtermanreingold", ...) {
  classnwsprof <- class(nwsprof)
  main1 <- deparse(substitute(nwsprof))
  if (inherits(nwsprof, "sprof")) nwsprof <-
    as_network_sprof(nwsprof)

  plot(nwsprof,
    label=network.vertex.names(nwsprof),
    main=paste0(main1, ": network layout\n", mode),
    mode = mode,
    edge.len=2,
    edge.col="#80808080",
    sub= main1,
    cex.main=1.5, ...)

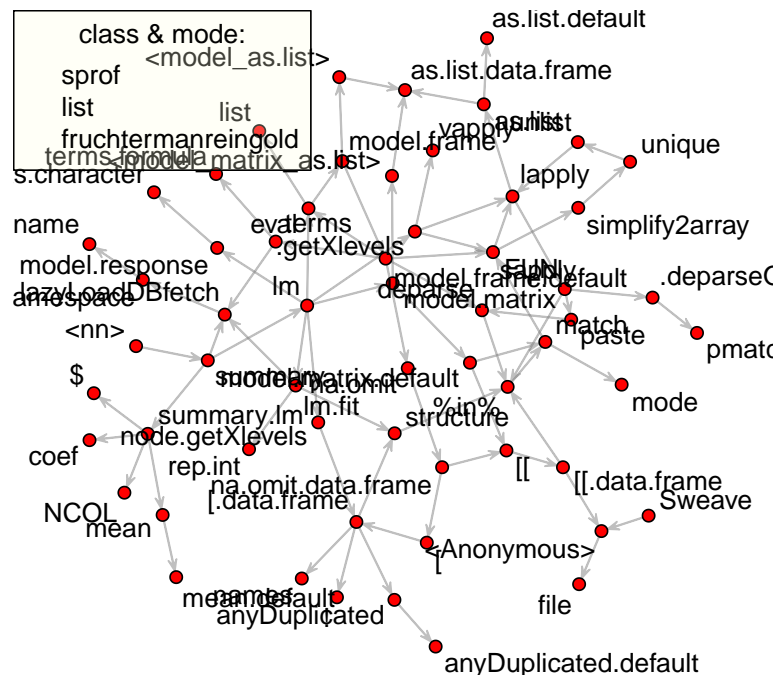
  legend("topleft",
    legend=c(classnwsprof, mode),
    title="class & mode:",
    bg="#FFFFFFE040",
    seg.len=0
  )
}

```

Input

```
plot_network_sprof(sprof04)
```

sporf04: network layout fruchtermanreingold



sprof04

Input

```

nwsprofadj <- as.network(sprofadj02) # names is not imported
#network.vertex.names(nwsprofadj) <- rownames(sprofadj02) # not honoured by plot
plot(nwsprofadj, label=rownames(sprofadj02), main="sprof02: network layout", cex.main=2)

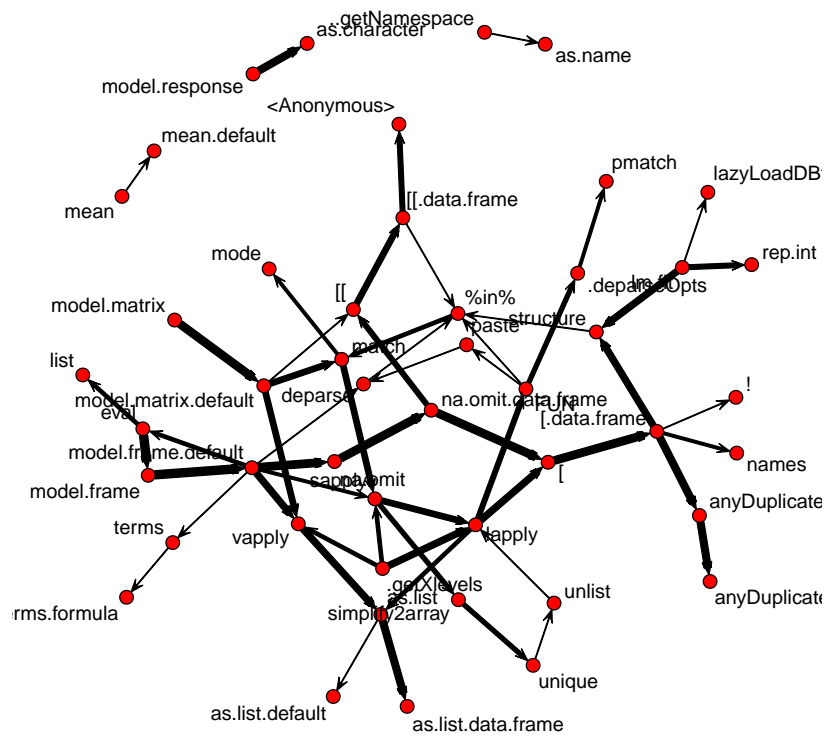
```


ToDo: maximum
edge.lwd?

Input

```
edge.lwd<- sprofadj02
edge.lwd[edge.lwd>0]<- rkindex(edge.lwd[edge.lwd>0], maxindex=12, ties.method="min")
plot(nwsprofadj, label=rownames(sprofadj02), main="sprof02: network layout", cex.main=2, edge.lwd=e
detach("package:network")
```

sprof02: network layout



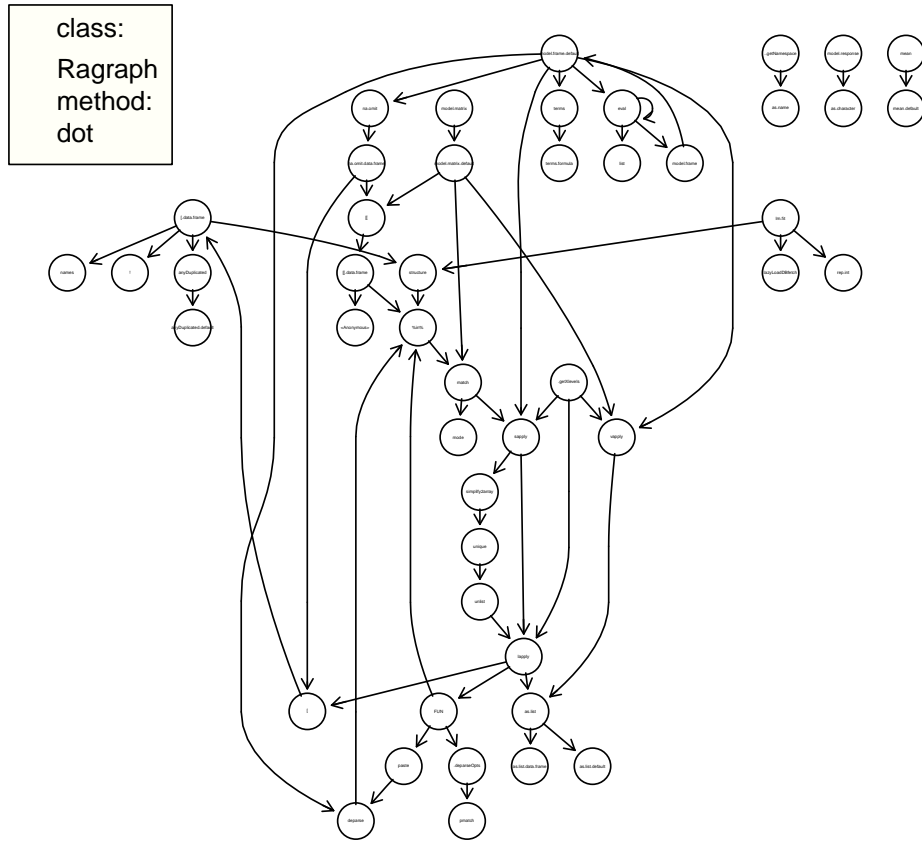
5.1.4. *Rgraphviz package.*

<pre>library(Rgraphviz) search()</pre>	<i>Input</i>
<pre>[1] ".GlobalEnv" [3] "package:graph" [5] "package:sna" [7] "package:wordcloud" [9] "package:Rcpp" [11] "package:sprof" [13] "package:graphics" [15] "package:utils" [17] "package:methods" [19] "package:base"</pre>	<i>Output</i>
<pre>sprofadjRag02 <- agopen(sprofadjNELO2, name="Rprof Example")</pre>	<i>Input</i>

6 6 *Input*

plotviz(sprofadjRag02, sub=sprof\$info\$id)

plotviz(sprofadjRag02, dot)

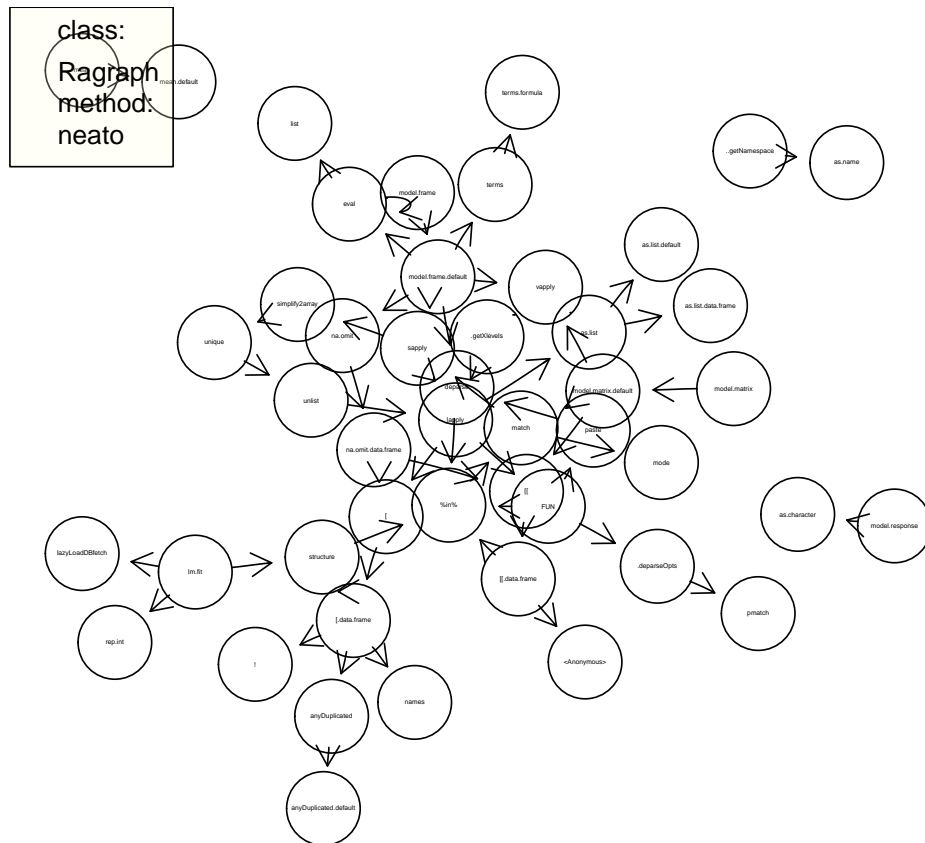


Input

#6 6

```
plotviz(sprofadjRag02,"neato",
        sub=sprof$info$id)
```

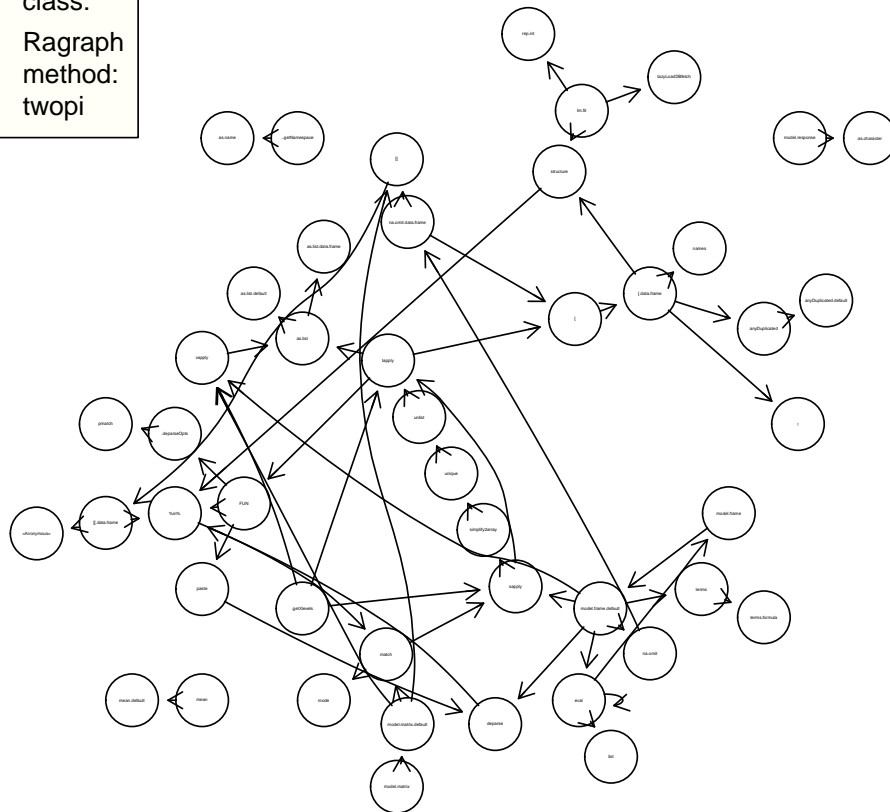
plotviz(sprofadjRag02, neato)



#6 6

```
plotviz( sprofadjRag02, twopi )
```

```
class:
Ragraph
method:
twopi
```

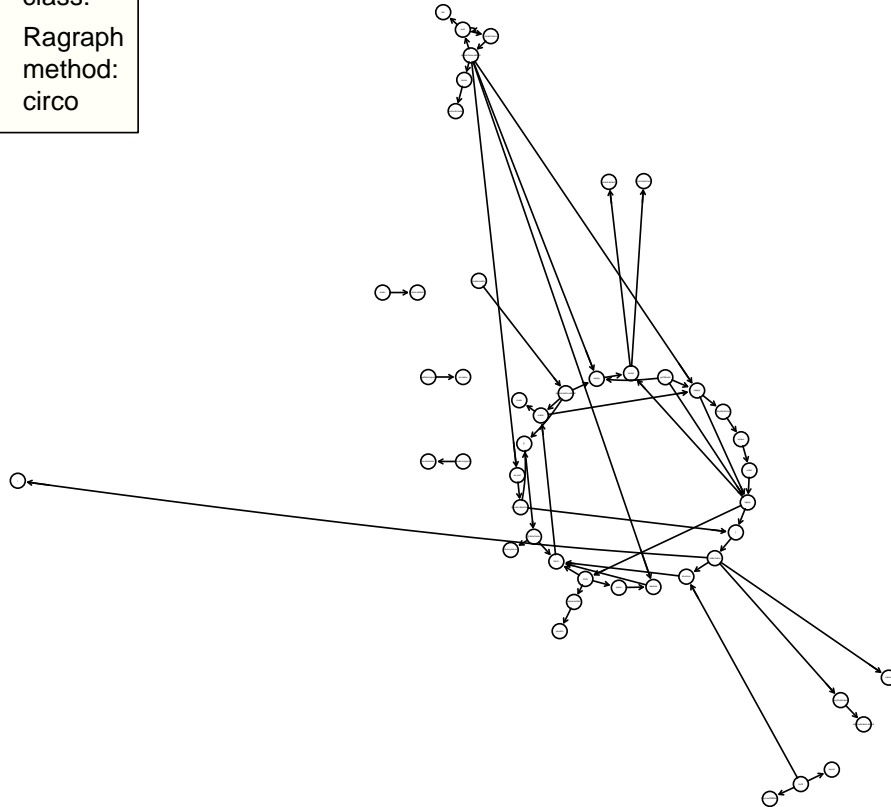


Input

```
#6 6  
plotviz(sprofadjRag02,"circo",  
        sub=sprof$info$id)
```

plotviz(sprofadjRag02, circo)

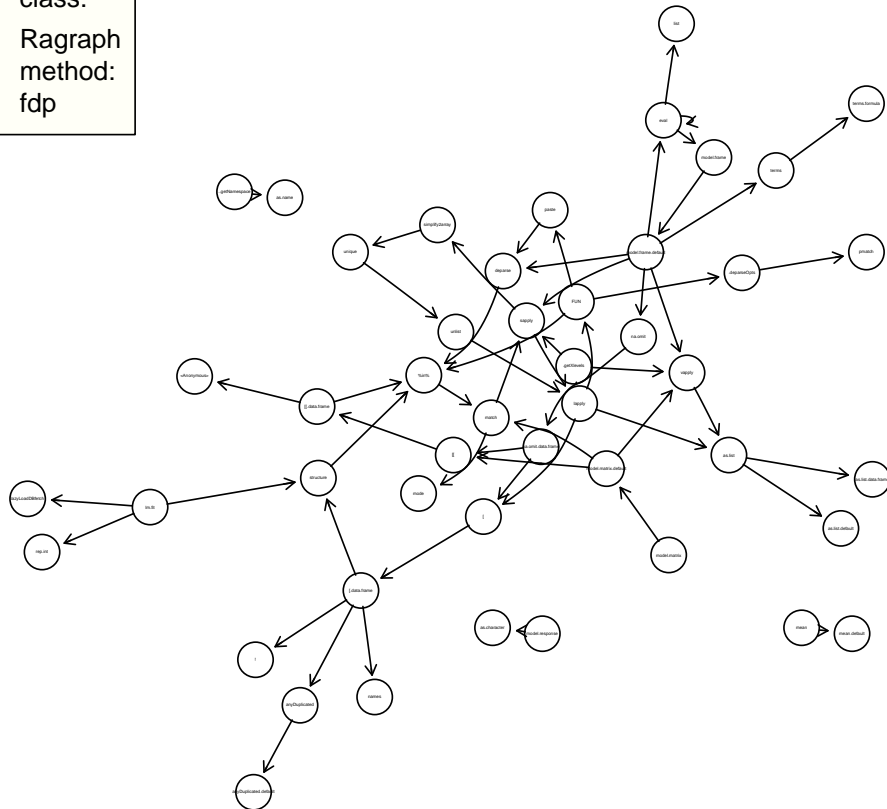
class: Ragraph method: circo



```
#6 6
plotviz(sprofadjRag02,"fdp",
        sub=sprof$info$id)
```

plotviz(sprofadjRag02, fdp)

class:
Ragraph
method:
fdp



6. TRIMMED EXAMPLE: REGRESSION

In this section, we use the reduced version of our example, *sprof04* for demonstration. Except for the change of the data set, this is just a copy of the previous chapter, collecting the various layouts for easy reference.

Note: This section will be replaced by the template section. For internal use only. Skip it.

Some experiments may have found their way to this chapter. They will be expelled.

You can re-run it, using your *sprof* data by modifying this instruction:

```
sprof <- sprof04
```

To interface *sprof* to a graph handling package, *until()* can extract the adjacency matrix from the profile.

```
sprofadj02 <- adjacency(sprof)  
adjname <- colnames(sprofadj02)  
adjname[adjname==""] <- "<NULL>"  
colnames(sprofadj02) <- adjname  
rownames(sprofadj02) <- adjname
```

This is a format any graph package can handle (maybe).

6.0.5. *graph* package.

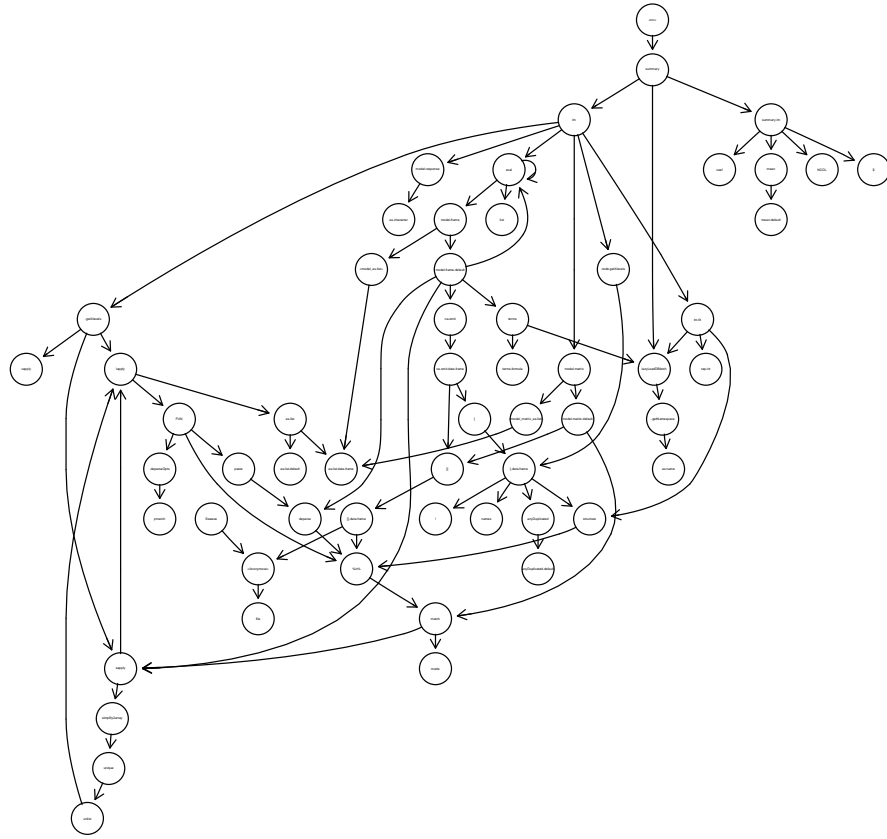
```
library(graph)
search()
```

	Output
[1] ".GlobalEnv"	"package:Rgraphviz"
[3] "package:graph"	"package:igraph"
[5] "package:sna"	"package:grid"
[7] "package:wordcloud"	"package:RColorBrewer"
[9] "package:Rcpp"	"package:xtable"
[11] "package:sprof"	"package:stats"
[13] "package:graphics"	"package:grDevices"
[15] "package:utils"	"package:datasets"
[17] "package:methods"	"Autoloads"
[19] "package:base"	

Some tests for scaling ...

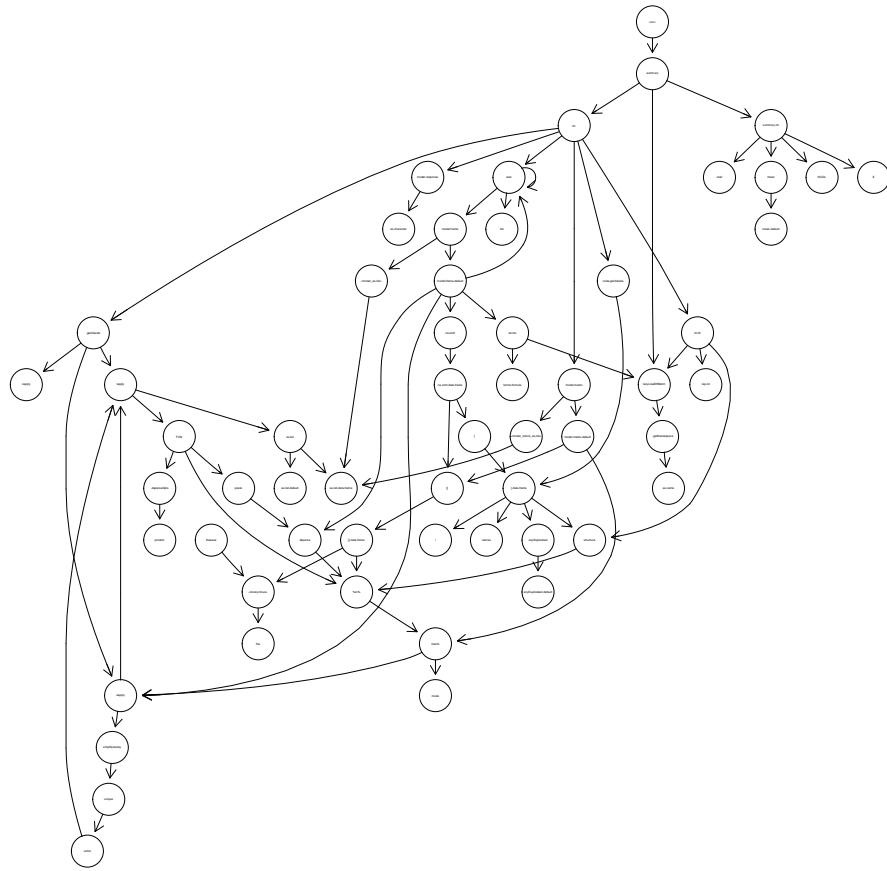
```
sprofadjNEL02 <- as(sprofadj02, "graphNEL")
```

```
#8
plot(sprofadjNEL02, main="sprof04: graph layout",)
#detach("package:graph")
```

sprof04: graph layout

```
#18
plot(sprofadjNEL02, main="sprof04: graph layout",)
#detach("package:graph")
```

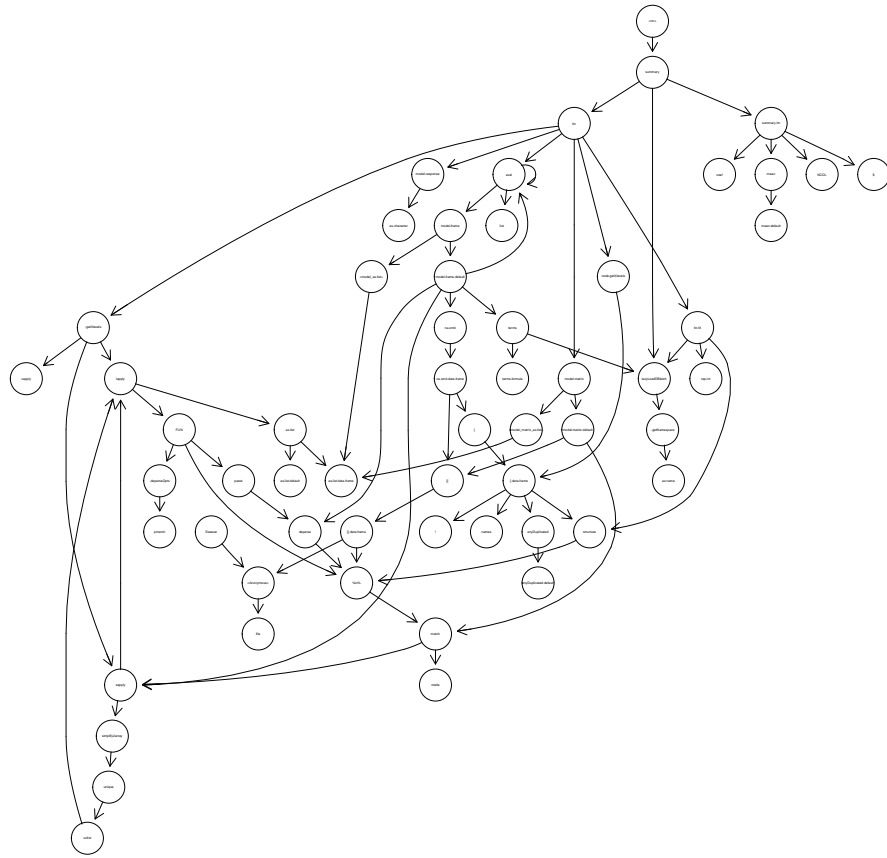
sprof04: graph layout



Input

```
#12
plot(sprofadjNEL02, main="sprof04: graph layout")
#detach("package:graph")
```

sprof04: graph layout



6.0.6. *igraph* package.

```
library(igraph)
search()
```

Input

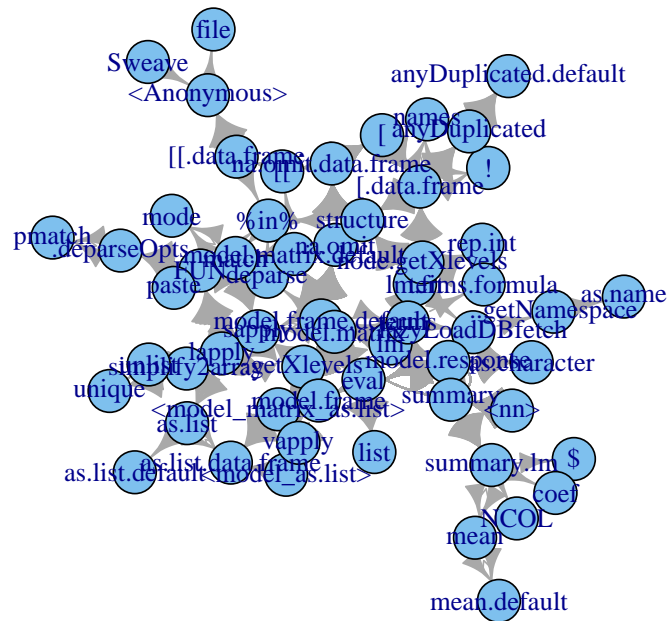
	Output
[1] ".GlobalEnv"	"package:Rgraphviz"
[3] "package:graph"	"package:igraph"
[5] "package:sna"	"package:grid"
[7] "package:wordcloud"	"package:RColorBrewer"
[9] "package:Rcpp"	"package:xtable"
[11] "package:sprof"	"package:stats"
[13] "package:graphics"	"package:grDevices"
[15] "package:utils"	"package:datasets"
[17] "package:methods"	"Autoloads"
[19] "package:base"	

```
sprof_igraph <- graph.adjacency(sprofadj02)
```

Input

```
#6
#plot(sprof_igraph, main="sprof04: igraph layout", cex.main=2)
plot(sprof_igraph, main="sprof04: igraph layout: trimmed data")
detach("package:igraph")
```

sprof04: igraph layout: trimmed data



6.0.7. *network* package.

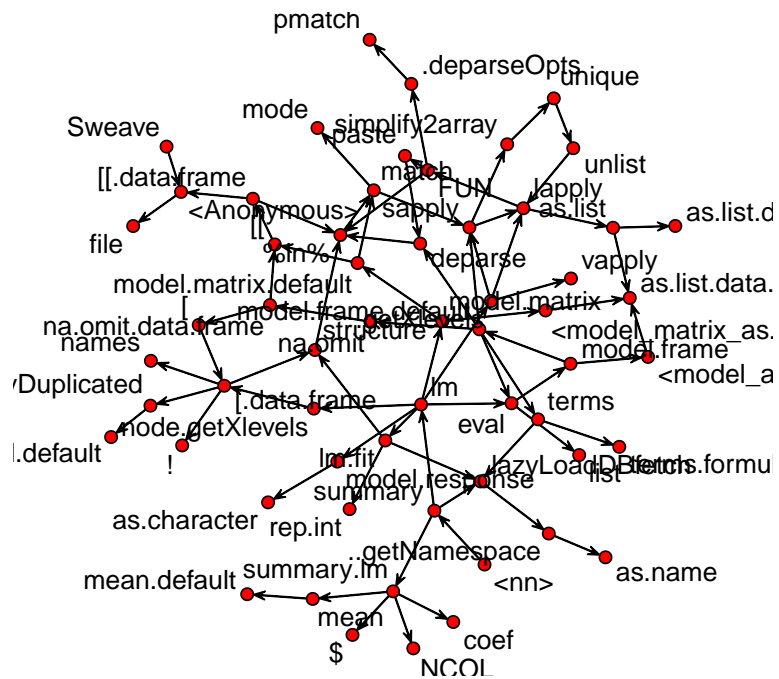
```
library(network)
search()
```

Input

	Output
[1] ".GlobalEnv"	"package:network"
[3] "package:Rgraphviz"	"package:graph"
[5] "package:sna"	"package:grid"
[7] "package:wordcloud"	"package:RColorBrewer"
[9] "package:Rcpp"	"package:xtable"
[11] "package:sprof"	"package:stats"
[13] "package:graphics"	"package:grDevices"
[15] "package:utils"	"package:datasets"
[17] "package:methods"	"Autoloads"
[19] "package:base"	

Input

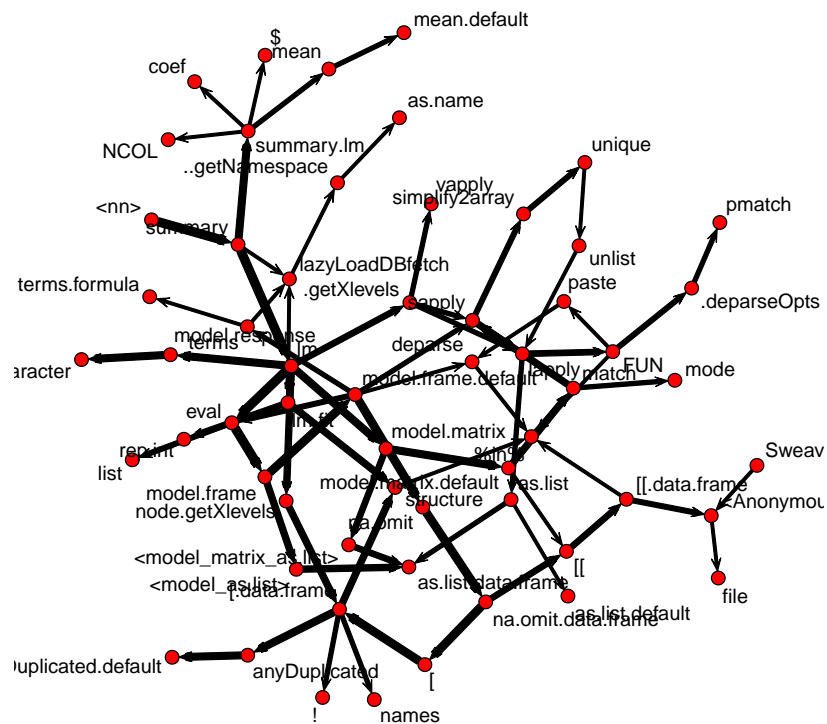
```
#6
nwsprofadj <- as.network(sprofadj02) # names is not imported
network.vertex.names(nwsprofadj) <- rownames(sprofadj02) # not honoured by plot
plot(nwsprofadj, label=rownames(sprofadj02),
     main="sprof04: network layout: trimmed data", cex.main=2)
```

sprof04: network layout: trimmed dat

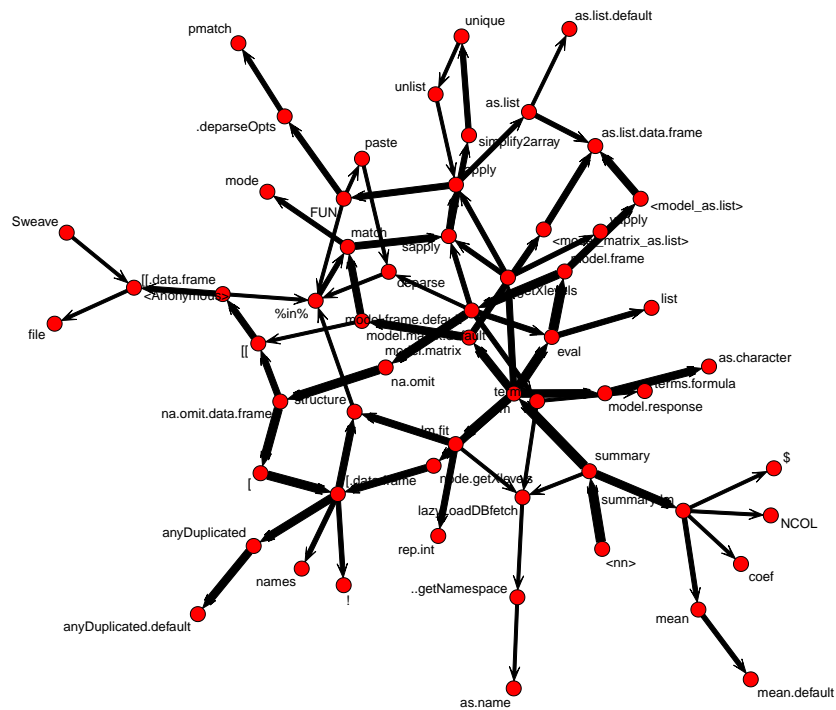
Input

```
#8
edge.lwd<-sprofadj02
edge.lwd[edge.lwd>0]<- rkindex(edge.lwd[edge.lwd>0], maxindex=12,
  ties.method="max")
plot(nwsprofadj, label=rownames(sprofadj02),
  main="sprof04: network layout: trimmed data",
  cex.main=2, edge.lwd=edge.lwd)
```

sprof04: network layout: trimmed data



#12

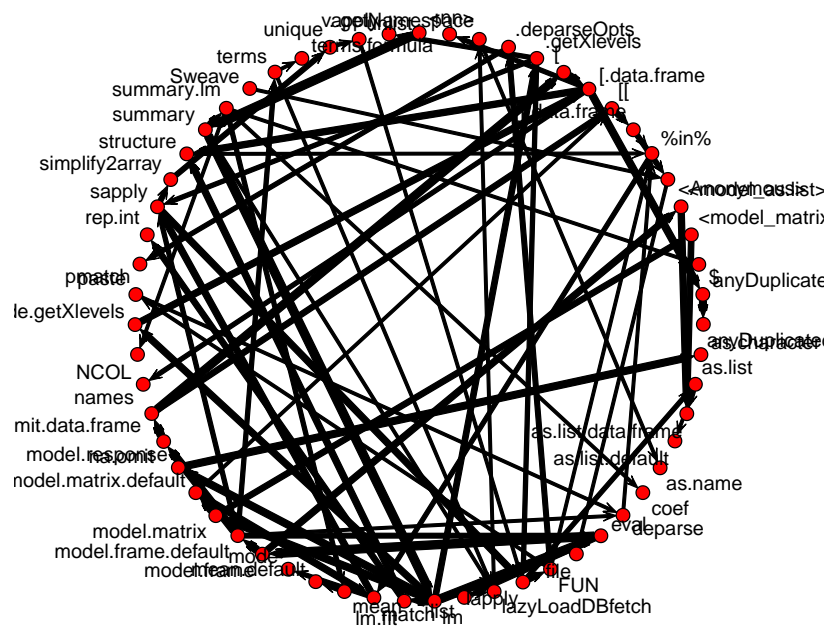
**sprof04: network kamadakawai layout:
trimmed data**

```

Input
plot(nwsprofadj, label=rownames(sprofadj02),
     main="sprof04: network circle layout: \n trimmed data",
     mode="circle",
     cex.main=2, edge.lwd=edge.lwd)

```

sprof04: network circle layout: trimmed data



```

Input
plot(nwsprofadj, label=rownames(sprofadj02),
     main="sprof04: network fruchtermanreingold layout: \n trimmed data",
     mode="fruchtermanreingold",
     cex.main=2, edge.lwd=edge.lwd)
detach("package:network")

```


6.0.8. *Rgraphviz* package.

Input

```
library(Rgraphviz)
search()
```

Output

```
[1] ".GlobalEnv"      "package:Rgraphviz"
[3] "package:graph"    "package:sna"
[5] "package:grid"     "package:wordcloud"
[7] "package:RColorBrewer" "package:Rcpp"
[9] "package:xtable"   "package:sprof"
[11] "package:stats"    "package:graphics"
[13] "package:grDevices" "package:utils"
[15] "package:datasets" "package:methods"
[17] "Autoloads"        "package:base"
```

Input

```
sprofadjRag02 <- agopen(sprofadjNELO2, name="Rprof Example")
```

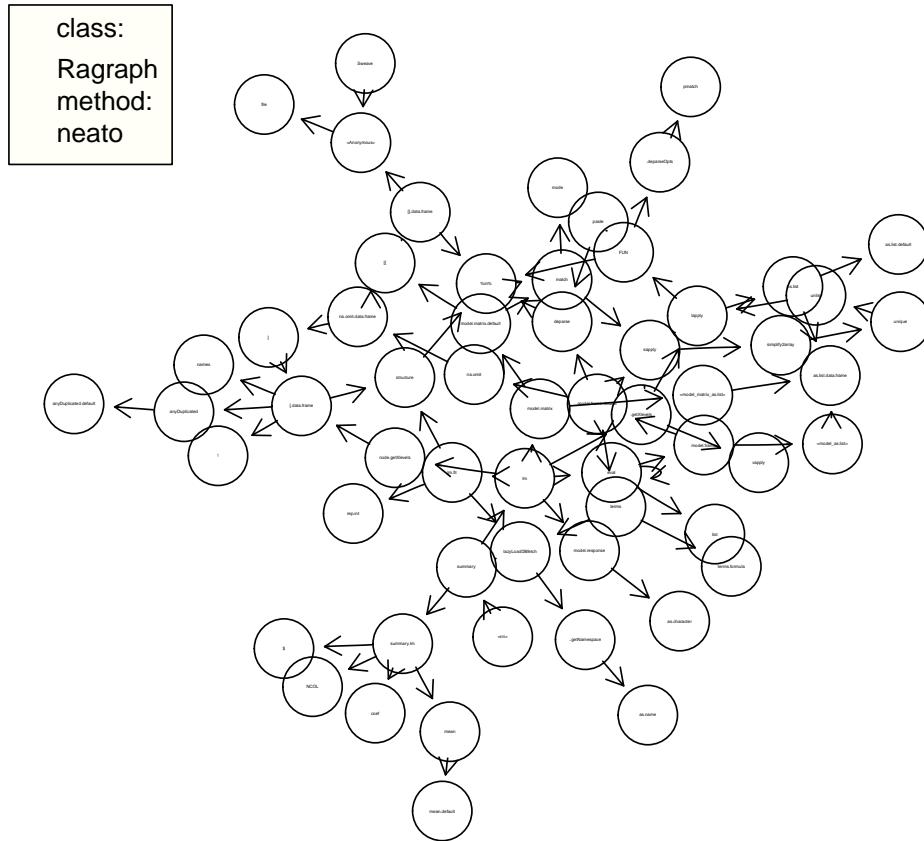
Input

```
#6 6
plotviz(sprofadjRag02, sub=as.character(sprof$info$id))
```

#6 *Input*

```
plotviz(x=sprofadjRag02,y="neato")
```

plotviz(sprofadjRag02, neato)



#6

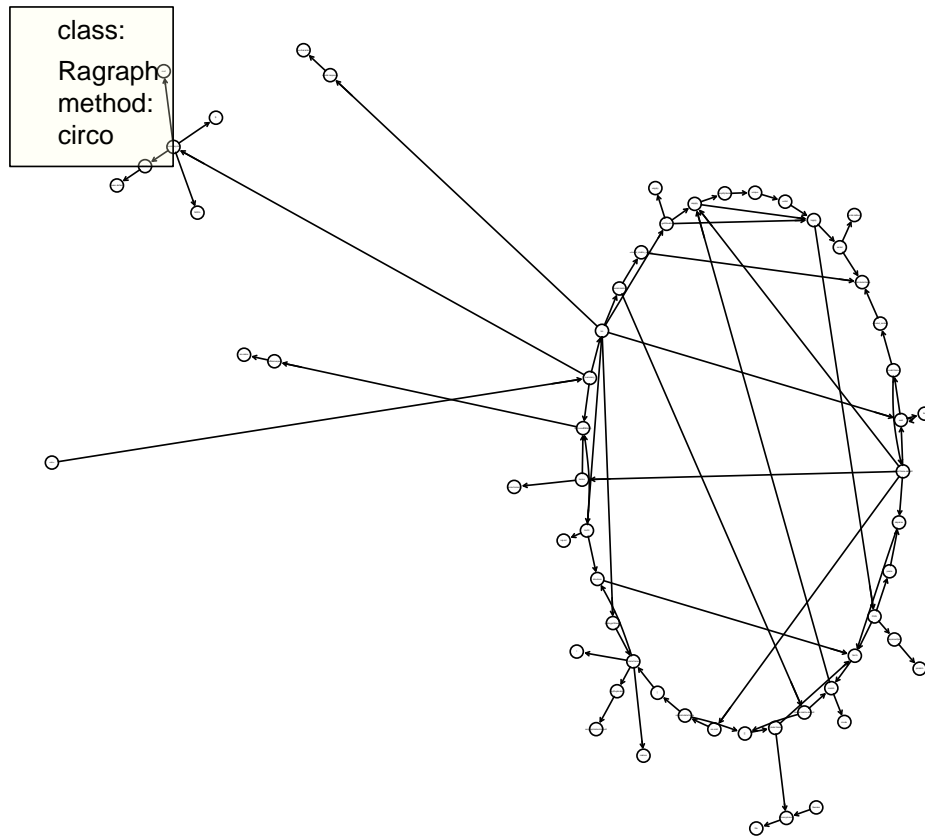
```
plotviz( sprofadjRag02, twopi )
```

[illegible]

#6 *Input*

```
plotviz(sprofadjRag02,y="circo")
```

plotviz(sprofadjRag02, circo)

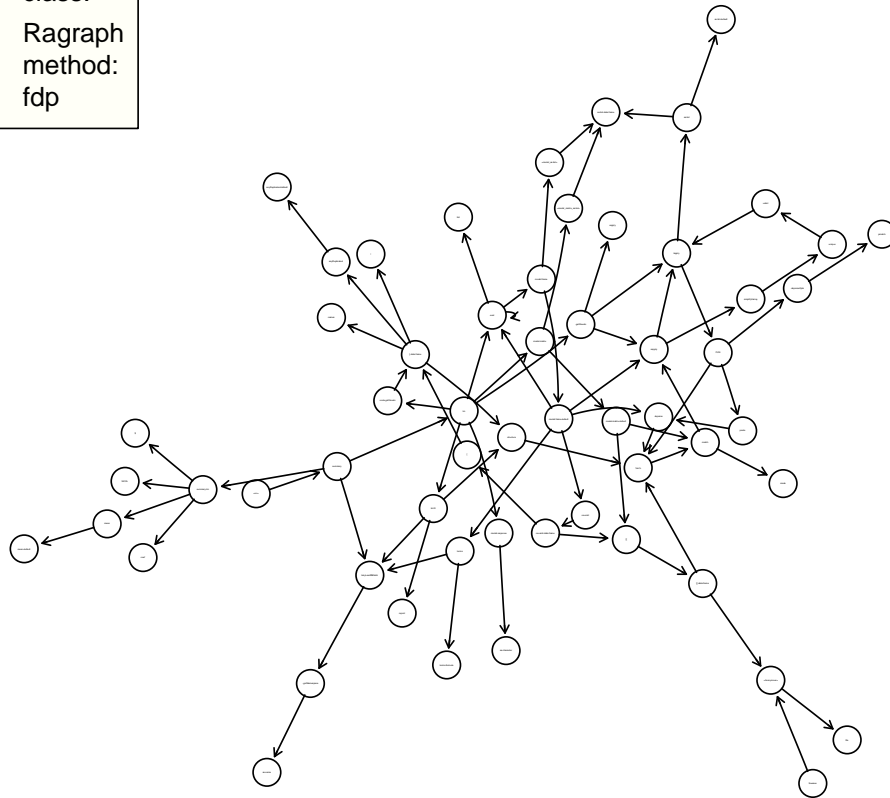


Input

```
#6
plotviz(sprofadjRag02, y="fdp")
```

plotviz(sprofadjRag02, fdp)

class: Ragraph method: fdp



7. TEMPLATE

- Run a profiling routine to profile your functions. You can do it on the fly
- Read in the profile
- Get a survey
- Trim base level and burn-in/fade-out
- Get a revised survey
- Use a graph display
- Think!

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R session info:

- R version 3.0.1 (2013-05-16), x86_64-apple-darwin10.8.0
- Locale: en_GB.UTF-8/en_GB.UTF-8/en_GB.UTF-8/C/en_GB.UTF-8/en_GB.UTF-8
- Base packages: base, datasets, graphics, grDevices, grid, methods, stats, utils
- Other packages: graph 1.38.3, RColorBrewer 1.0-5, Rcpp 0.10.3, Rgraphviz 2.4.0, sna 2.3-1, sprof 0.0-6, wordcloud 2.4, xtable 1.7-1
- Loaded via a namespace (and not attached): BiocGenerics 0.6.0, igraph 0.6.5-2, network 1.7.2, parallel 3.0.1, slam 0.1-28, stats4 3.0.1, tools 3.0.1

L^AT_EX information: textwidth: 4.9823in linewidth:4.9823in

textheight: 8.0824in

Svn repository information:

```
$HeadURL: svnssh://gsawitzki@svn.r-forge.r-project.org/svnroot/sintro/pkg/sprof/vignettes/sprofiling.Rnw +
$Source: /u/math/j40/cvsroot/lectures/src/insider/profile/Rnw/profile.Rnw,v $
$Id: sprofiling.Rnw 207 2013-08-12 18:56:45Z gsawitzki $
$Revision: 207 $
$Date: 2013-08-12 20:56:45 0200(Mon, 12 Aug 2013)+
$name: $
$Author: gsawitzki $
```

8. XXX – LOST & FOUND

```

                                Input
nodefreq <- rep(0,length(sprof01$nodes$name))
for (i in (1:length(sprof01$stacks$nodes))){
  nodefreq <- nodefreq +
    table( factor(sprof01$stacks$nodes[[i]],
                  levels <- 1:length(sprof01$nodes$name),
                  ordered=FALSE))
}
names(nodefreq) <- sprof01$nodes$name

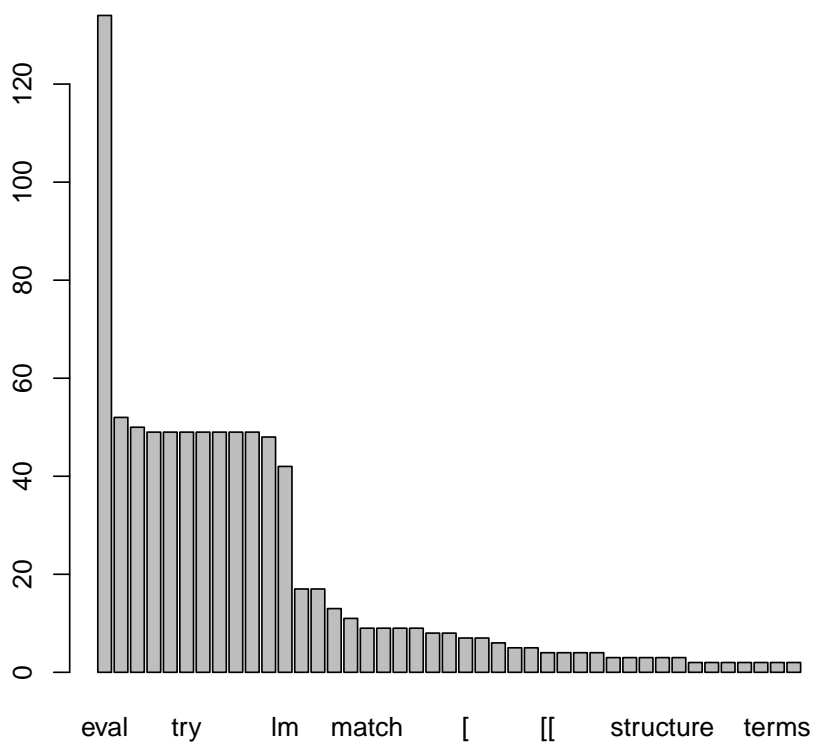
```

Top frequent nodes.

```

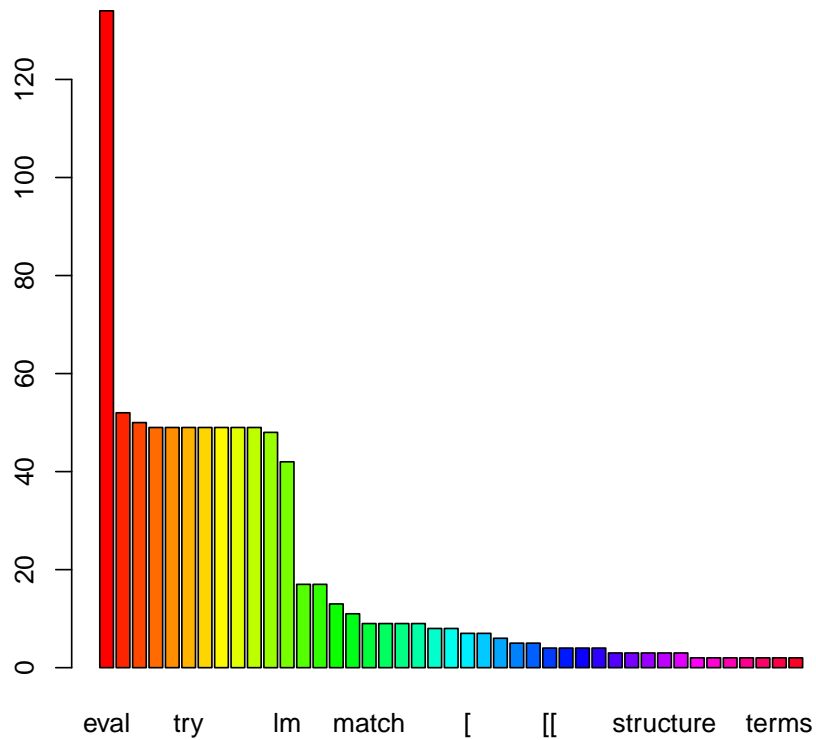
                                Input
ndf <- nodefreq[nodefreq>1]
ondf <- order(ndf,decreasing=TRUE)
barplot(ndf[ondf])

```



Input

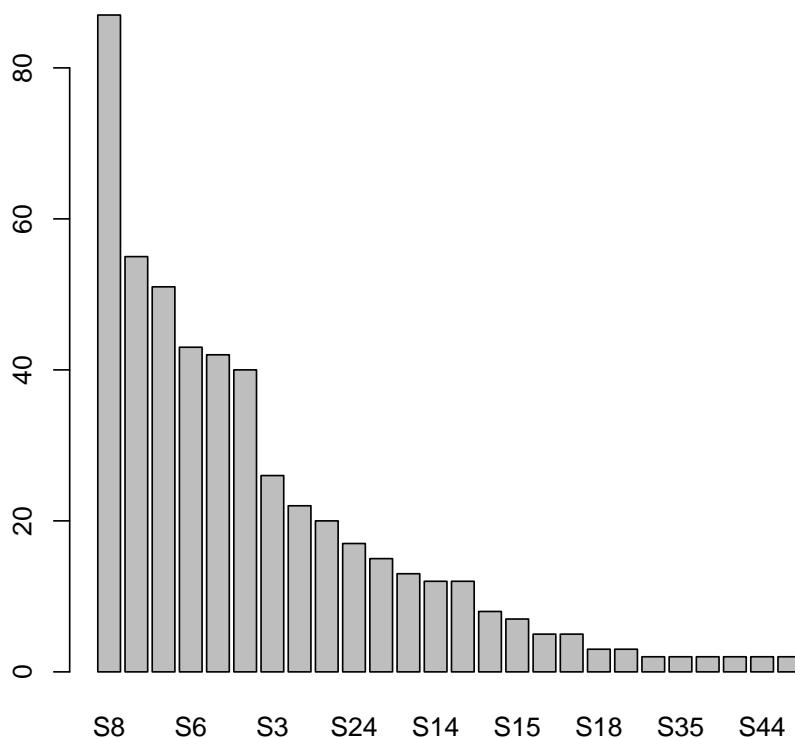
```
barplot(ndf[ondf], col=rainbow(length(ondf)))
```



Top frequent stacks.

Input

```
x <- sprof01
xsrc <- as.matrix(x$stacks$refcount)
rownames(xsrc) <- rownames(xsrc, do.NULL=FALSE, prefix="S")
#stf <- x$stacks$refcount[x$stacks$refcount>1]
#names(stf) <- x$stacks$shortname[x$stacks$refcount>1]
stf <- xsrc[xsrc>1]
names(stf) <- rownames(xsrc)[xsrc>1]
ostf <- order(stf,decreasing=TRUE)
barplot(stf[ostf])
```



```

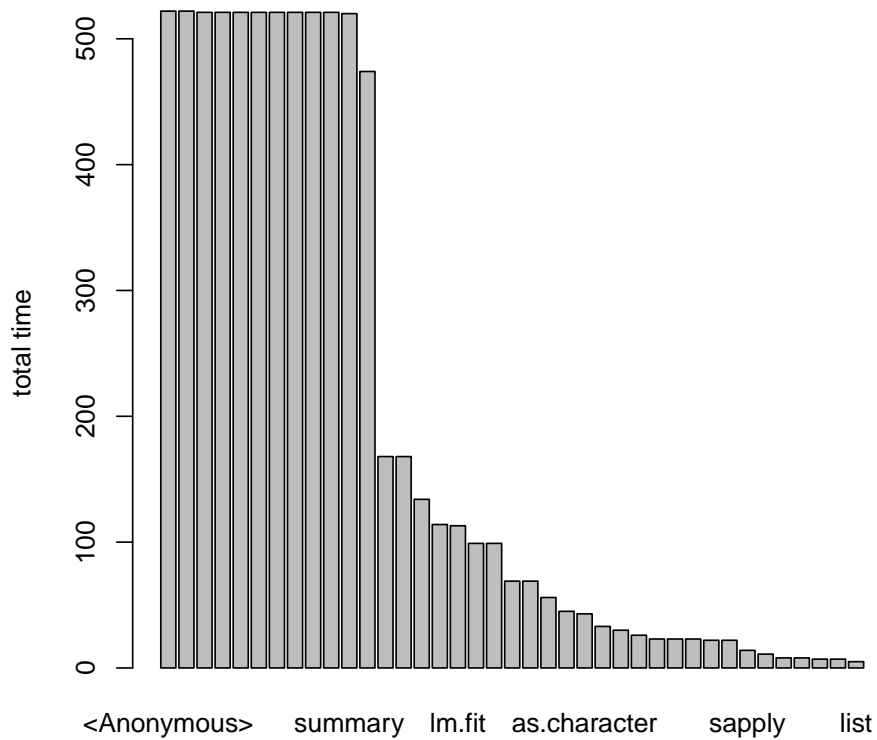
# xtable cannot handle posix, so we use print output here
# str(profile_nodes_rle, max.level=2, vec.len=3, nchar.max=40, list.len=6)
strx(sprof01$info)

```

```
##strx: sprof01$info
'data.frame':      1 obs. of  8 variables:
 $ id : chr "sprof01"
 $ date : POSIXct, format: "2013-08-13 21:33:38"
 $ nrnodes : int 62
 $ nrstacks : int 50
 $ nrrecords: int 522
 $ firstline: Factor w/ 1 level "sample.interval=1000": 1
 $ ctllines : Factor w/ 1 level "sample.interval=1000": 1
 $ ctllinenr: num 1
```

Selections are recorded as selection vectors, with reference to the original order. This needs some caution to align them with the order choices.

Nodes, by total time



On the first look, information on the profile level is not informative. Profile records are just recordings of some step, taken at regular intervals. We get a minimal information, if we encode the stacks in colour.

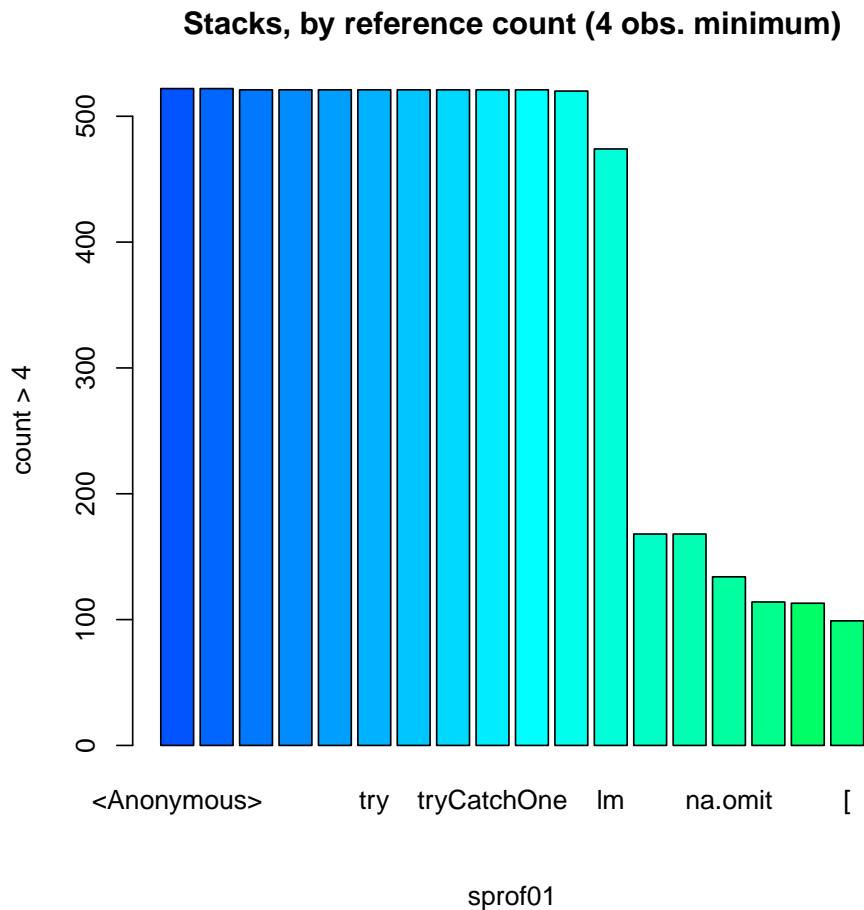
ToDo: use stack colours

We now do a step down analysis. Aggregating the information from the profiling events, we have the frequency of stack references. On the stack level, we encode the frequency in colour, and linking propagates this to the profile level.

ToDo: use as_rkindex

Input

```
stackfreqscore <- rank(sprof01$stacks$refcount,ties.method="random")
stacksperm <- order(sprof01$stacks$refcount,decreasing=TRUE)
stacksnrobsok <- sprof01$stacks$refcount > 4
stackfreqscore4<- stackfreqscore[stacksperm][stacksnrobsok[stacksperm]]
barplot(sp[stacksnrobsok[stacksperm]],
        main="Stacks, by reference count (4 obs. minimum)", ylab="count > 4",
        col=rainbow(80)[stackfreqscore4], sub=sprof01$info$id)
```



Input

```
prxt(sprof01$nodes,
```

```
  caption="nodes",
  label="tab:prSREnodes",
  max.level=2, vec.len=3,nchar.max=40,
  digits=c(0,0,0,2,0,2,0))
```

Table 10: nodes

	name	self.time	self.pct	total.time	total.pct	icol
1	!	2	0.38	2	0.03	48
2	..getNamespace	0	0.00	1	0.01	59
3	.deparseOpts	2	0.38	4	0.05	42
4	.getXlevels	0	0.00	26	0.34	28
5	[	0	0.00	99	1.29	19
6	[.data.frame	57	10.92	99	1.29	20
7	[[	0	0.00	8	0.10	36
8	[[.data.frame	1	0.19	8	0.10	35
9	%in%	1	0.19	4	0.05	41
10	<Anonymous>	6	1.15	522	6.79	3
< cut >	\vdots	:	:	:	:	:
53	terms	0	0.00	2	0.03	49
54	terms.formula	1	0.19	1	0.01	58
55	try	0	0.00	521	6.78	9
56	tryCatch	0	0.00	521	6.78	5
57	tryCatchList	0	0.00	521	6.78	11
58	tryCatchOne	0	0.00	521	6.78	6
59	unique	3	0.57	4	0.05	43
60	unlist	0	0.00	1	0.01	61
61	vapply	3	0.57	23	0.30	29
62	withVisible	0	0.00	521	6.78	10

Input

```
#str(sprof01$stacks, max.level=2, vec.len=6,
#      nchar.max=40, list.len=20,width=70, strict.width="wrap"
strx(sprof01$stacks)
```

Output

```
##strx: sprof01$stacks
'data.frame':      50 obs. of  7 variables:
 $ nodes :List of 50
 ..$ : int 52 10 23 55 56 57 58 21 ...
 ..$ : int 52 10 23 55 56 57 58 21 ...
 ..$ : int 52 10 23 55 56 57 58 21 ...
 ..$ : int 52 10 23 55 56 57 58 21 ...
 ..$ : int 52 10 23 55 56 57 58 21 ...
 ..$ : int 52 10 23 55 56 57 58 21 ...
 ..$ : int 52 10 23 55 56 57 58 21 ...
 ..$ : int 52 10 23 55 56 57 58 21 ...
 ..$ : int 52 10 23 55 56 57 58 21 ...
 ..$ : int 52 10 23 55 56 57 58 21 ...
 ..$ : int 52 10 23 55 56 57 58 21 ...
 ..$ : int 52 10 23 55 56 57 58 21 ...
 .. [list output truncated]
 $ shortname : Factor w/ 50 levels
   "S<A>eFttCtCLtC0dTCwVeesleem.m..n.n...[|" | __truncated__,...: 27 17
   19 1 35 36 37 30 ...
 $ refcount : num 1 5 26 55 13 43 51 87 ...
 $ stacklength : int 19 20 19 21 14 15 15 14 ...
 $ stackheadnodes: int 52 52 52 52 52 52 52 52 ...
 $ stackleafnodes: int 27 28 41 6 39 14 38 30 ...
 $ stackssrc : Factor w/ 50 levels "!" [.data.frame [
   na.omit.data.frame na." | __truncated__,...: 27 28 39 5 37 13 36 30
   ...
```

A summary is provided on request.

Input

```
sumsprof01 <- summary.sprof(sprof01)
```

Output

```
$id
[1] "Profile Summary Tue Aug 13 21:34:06 2013"

$len
[1] 522

$uniquestacks
[1] 50

$nr_runs
[1] 396

$nrstacks
[1] 50
```



```
$stacklength
```

```
[1] 3 25
```

```
$nrnodesperlevel
```

```
[1] 1 1 2 1 1 1 1 1 1 1 1 1 3 10 11 9 9 15 8 7 5 7
[23] 2 1 1
```

	shortname	root	leaf	self.time	self.pct
!	!	-	LEAF	2	0.383142
..getNamespace	..gN	-	-	0	0.000000
.deparseOpts	.dpO	-	LEAF	2	0.383142
.getXlevels	.gtX	-	-	0	0.000000
[	[	-	-	0	0.000000
[.data.frame	[.d.	-	LEAF	57	10.919540
[[	[[	-	-	0	0.000000
[[.data.frame	[[..	-	LEAF	1	0.191571
%in%	%in%	-	LEAF	1	0.191571
<Anonymous>	<An>	-	LEAF	6	1.149425
\$	\$	-	LEAF	1	0.191571
anyDuplicated	anyD	-	LEAF	1	0.191571
anyDuplicated.default	anD.	-	LEAF	22	4.214559
as.character	as.c	-	LEAF	43	8.237548
as.list	as.l	-	-	0	0.000000
as.list.data.frame	a...	-	LEAF	22	4.214559
as.list.default	as..	-	LEAF	1	0.191571
as.name	as.n	-	LEAF	1	0.191571
coef	coef	-	LEAF	1	0.191571
deparse	dprs	-	LEAF	1	0.191571
doTryCatch	dTrC	-	-	0	0.000000
eval	eval	-	LEAF	1	0.191571
evalFunc	evlF	-	-	0	0.000000
file	file	-	LEAF	1	0.191571
FUN	FUN	-	LEAF	1	0.191571
lapply	lppl	-	LEAF	2	0.383142
lazyLoadDBfetch	lLDB	-	LEAF	2	0.383142
list	list	-	LEAF	5	0.957854
lm	lm	-	LEAF	42	8.045977
lm.fit	lm.f	-	LEAF	87	16.666667
match	mtch	-	LEAF	1	0.191571
mean	mean	-	-	0	0.000000
mean.default	mn.d	-	LEAF	2	0.383142
mode	mode	-	LEAF	2	0.383142
model.frame	mdl.f	-	-	0	0.000000
model.frame.default	mdl.f.	-	LEAF	12	2.298851
model.matrix	mdl.m	-	-	0	0.000000
model.matrix.default	mdl.m.	-	LEAF	51	9.770115
model.response	mdl.r	-	LEAF	13	2.490421
na.omit	n.mt	-	LEAF	20	3.831418
na.omit.data.frame	n...	-	LEAF	26	4.980843
names	nams	-	LEAF	2	0.383142
NCOL	NCOL	-	LEAF	1	0.191571
paste	past	-	-	0	0.000000
pmatch	pmtc	-	LEAF	2	0.383142

rep.int	rp.n	- LEAF	7	1.340996
sapply	sppl	- LEAF	1	0.191571
simplify2array	smp2	- -	0	0.000000
structure	strc	- LEAF	32	6.130268
summary	smmr	- -	0	0.000000
summary.lm	smm.	- LEAF	40	7.662835
Sweave	Swev	ROOT -	0	0.000000
terms	trms	- -	0	0.000000
terms.formula	trm.	- LEAF	1	0.191571
try	try	- -	0	0.000000
tryCatch	tryC	- -	0	0.000000
tryCatchList	trCL	- -	0	0.000000
tryCatchOne	trCO	- -	0	0.000000
unique	uniq	- LEAF	3	0.574713
unlist	unls	- -	0	0.000000
vapply	vppl	- LEAF	3	0.574713
withVisible	wthV	- -	0	0.000000
	total.time	total.pct		
!	2	0.383142		
..getNamespace	1	0.191571		
.deparseOpts	4	0.766284		
.getXlevels	26	4.980843		
[	99	18.965517		
[.data.frame	99	18.965517		
[[	8	1.532567		
[[.data.frame	8	1.532567		
%in%	4	0.766284		
<Anonymous>	522	100.000000		
\$	1	0.191571		
anyDuplicated	23	4.406130		
anyDuplicated.default	22	4.214559		
as.character	43	8.237548		
as.list	23	4.406130		
as.list.data.frame	22	4.214559		
as.list.default	1	0.191571		
as.name	1	0.191571		
coef	1	0.191571		
deparse	2	0.383142		
doTryCatch	521	99.808429		
eval	521	99.808429		
evalFunc	521	99.808429		
file	1	0.191571		
FUN	7	1.340996		
lapply	30	5.747126		
lazyLoadDBfetch	3	0.574713		
list	5	0.957854		
lm	474	90.804598		
lm.fit	113	21.647510		
match	11	2.107280		
mean	2	0.383142		
mean.default	2	0.383142		
mode	2	0.383142		
model.frame	168	32.183908		

model.frame.default	168	32.183908
model.matrix	69	13.218391
model.matrix.default	69	13.218391
model.response	56	10.727969
na.omit	134	25.670498
na.omit.data.frame	114	21.839080
names	2	0.383142
NCOL	1	0.191571
paste	1	0.191571
pmatch	2	0.383142
rep.int	7	1.340996
sapply	14	2.681992
simplify2array	4	0.766284
structure	33	6.321839
summary	520	99.616858
summary.lm	45	8.620690
Sweave	522	100.000000
terms	2	0.383142
terms.formula	1	0.191571
try	521	99.808429
tryCatch	521	99.808429
tryCatchList	521	99.808429
tryCatchOne	521	99.808429
unique	4	0.766284
unlist	1	0.191571
vapply	23	4.406130
withVisible	521	99.808429

Input

```
#str(profile_nodes_rle, max.level=2, vec.len=3, nchar.max=40, list.len=6)
strx(sumsprof01)
```

Output

```
##strx: sumsprof01
'data.frame':      62 obs. of  7 variables:
 $ shortname : Factor w/ 62 levels "!", "..gN", ".dp0", ...: 1 2 3 4 5 6 7
   8 ...
 $ root : Factor w/ 2 levels "-", "ROOT": 1 1 1 1 1 1 1 ...
 $ leaf : Factor w/ 2 levels "-", "LEAF": 2 1 2 1 1 2 1 2 ...
 $ self.time : num 2 0 2 0 0 57 0 1 ...
 $ self.pct : num 0.383 0 0.383 0 ...
 $ total.time: num 2 1 4 26 99 99 8 8 ...
 $ total.pct : num 0.383 0.192 0.766 4.981 ...
```

Input

```
#str(sumsprof01, max.level=2, vec.len=3,
#      nchar.max=40, list.len=6,
#      width=70, strict.width="wrap")
```

The classical approach hides the work that has been done. Actually it breaks down the data to record items. This figure is not reported anywhere. In our case, it can be reconstructed. The profile data have 8456 words in 524 lines.

In our approach, we break down the information. Two lines of control information are split off. We have 522 lines of profile with 50 unique stacks, referencing 62 nodes. Instead of reducing it to a summary, we keep the full information. Information is always kept on its original level.

On the profiles level, we know the sample interval length, and the id of the stack recorded. On the stack level, for each stack we have a reference count, with the sample interval lengths used as weights. This reference count is added up for each node in the stack to give the node timings.

Cheap statistics are collected as they come by. For example, from the stacks table it is cheap to identify root and leaf nodes, and this mark is propagated to the nodes table. These are some attempts to recover the factor structures.

Input

```

xfi <- levels(sprof02$nodes$name)
profile_nodes_rlefac <- lapply(profile_nodes_rle,
  function(xl) {xl$values <- factor(xl$values,
    levels=1:62,
    labels=xfi); xl}) # seems ok
profile_nodes_rletfac <- lapply(profile_nodes_rle,
  function(x) table(x,dnn=c("run length","node")) ) #factors lost again
colnames(profile_nodes_rletfac[[1]]) <-
  sprof02$nodes$name[ as.integer(colnames(profile_nodes_rletfac[[1]]))]
profile_nodes_rletfac1 <- lapply(profile_nodes_rletfac,
  function(xl) {colnames(xl) <-
    sprof02$nodes$name[ as.integer(colnames(xl))];
    xl} )
invisible(lapply(profile_nodes_rletfac1,
  function(x) print.table(t(x),zero.print = ".") ))

```

Output

```

      run length
node   1  2  3  4  5  6  7
<NA>   1  .  .  .  .  .  .
<NA>  17  1  1  1  .  .  .
<NA>   1  .  .  .  .  .  .
<NA>   1  .  .  .  .  .  .
<NA>  40 17  7  4  2  6  1
<NA>  46 18  3  1  1  1  1
<NA>   1  .  .  .  .  .  .
<NA>  55  4  2  .  .  .  .
<NA>  35  3  3  .  .  1  .
<NA>   1  .  .  .  .  .  .

      run length
node           1  2  3  4  5  6  7
as.character    34  3  1  .  .  .  .
as.name          1  .  .  .  .  .  .
eval            40 17  7  4  2  6  1
lapply           16  .  .  1  .  .  .
lazyLoadDBfetch   1  .  .  .  .  .  .
mean.default      1  .  .  .  .  .  .
model.matrix.default 55  4  2  .  .  .  .

```

```

rep.int          7 . . . . .
sapply           3 . . . . .
structure        10 1 . . . 1 .
vapply           . . 1 . . . .

run length
node             1 2 3 4 5 6 7
[                14 . . 1 . . .
[[               1 . . . . . .
%in%             1 . . . . . .
as.list          2 . . . . . .
lapply           2 . . . . . .
match            9 . . . . . .
model.frame      40 17 7 4 2 6 1
simplify2array   1 . . . . . .
vapply           6 1 . . . . .

run length
node             1 2 3 4 5 6 7
[.data.frame     14 . . 1 . . .
[[.data.frame    1 . . . . . .
as.list          7 1 . . . . .
as.list.data.frame 2 . . . . . .
FUN              1 . . . . . .
match            1 . . . . . .
model.frame.default 40 17 7 4 2 6 1
sapply           9 . . . . . .
unique           1 . . . . . .

run length
node             1 2 3 4 5 6 7
.deparseOpts     1 . . . . . .
<Anonymous>      1 . . . . . .
anyDuplicated     1 . . . . . .
as.list.data.frame 6 1 . . . . .
as.list.default   1 . . . . . .
deparse          1 . . . . . .
eval             3 . . . . . .
lapply           5 . . . . . .
na.omit          46 10 5 4 1 4 1
sapply           2 . . . . . .
simplify2array    3 . . . . . .
structure        11 . . 1 . . .
terms            1 . . . . . .
unlist           1 . . . . . .
vapply           7 . . . 1 . .

run length
node             1 2 3 4 5 6
as.list          7 . . . 1 .
eval             3 . . . . .
FUN              5 . . . . .
lapply           3 . . . . .
na.omit.data.frame 43 7 4 5 . 4
terms.formula    1 . . . . .
unique           3 . . . . .

run length

```

```

node          1  2  3  4  5  6
.deparseOpts    3  .  .  .  .  .
[             45  4  3  3  .  1
[[            2  .  .  .  1  .
%in%           1  .  .  .  .  .
as.list.data.frame 7  .  .  .  1  .
FUN            1  .  .  .  .  .
list           3  .  .  .  .  .

```

```

run length
node          1  2  3  4  5  6
[.data.frame 45  4  3  3  .  1
[ [.data.frame 2  .  .  .  1  .
match         1  .  .  .  .  .
paste         1  .  .  .  .  .
pmatch        2  .  .  .  .  .

```

```

run length
node          1  4  5
!             1  .  .
%in%          1  .  .
<Anonymous>   .  .  1
anyDuplicated 9  2  1
deparse        1  .  .
mode           1  .  .
names          2  .  .

```

```

run length
node          1  4  5
%in%          1  .  .
anyDuplicated.default 9  2  1

```

```

run length

```

```

node 1

```

```

match 1

```

```

run length

```

```

node 1

```

```

mode 1

```

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