

Display Lists in `grid`

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A display list is a record of drawing operations. It is used to redraw graphics output when a graphics window is resized, when graphics output is copied from one device to another, and when graphics output is edited (via `grid.edit`).

There are two display lists that can be used when working with `grid`. R's graphics engine maintains a display list and `grid` maintains its own display list. The former is maintained at the C code level and records both base graphics output and `grid` graphics output. The latter is maintained at the R code level and only records `grid` output.

In standard usage, the graphics engine's display list is used to redraw when a window is resized and when copying between devices. `grid`'s display list is used for redrawing when editing `grid` output.

There are two main problems with this standard usage:

1. The graphics engine display list only records graphics output; none of the calculations leading up to producing the output are recorded. This particularly impacts on plots which perform calculations based on the physical dimensions of the device – an example is the `legend` function which performs calculations in order to arrange the elements of the legend. The effect can be seen from any example which uses the `legend` function. Try running `example(legend)` then resize the device (make it quite tall and thin or quite wide and fat); the legend will start to look pretty sick.

NOTE: that this is a problem with the graphics engine display list – it is not specific to `grid`. In fact, much of `grid`'s behaviour is protected from this problem because things like `grid` units are “declarative” and will be reevaluated on each redraw. However, there are situations where `grid` output can be afflicted, in particular, whenever the `convertUnit()` function (or one of its variants) is used (the help file for `convertUnit()` gives an example).

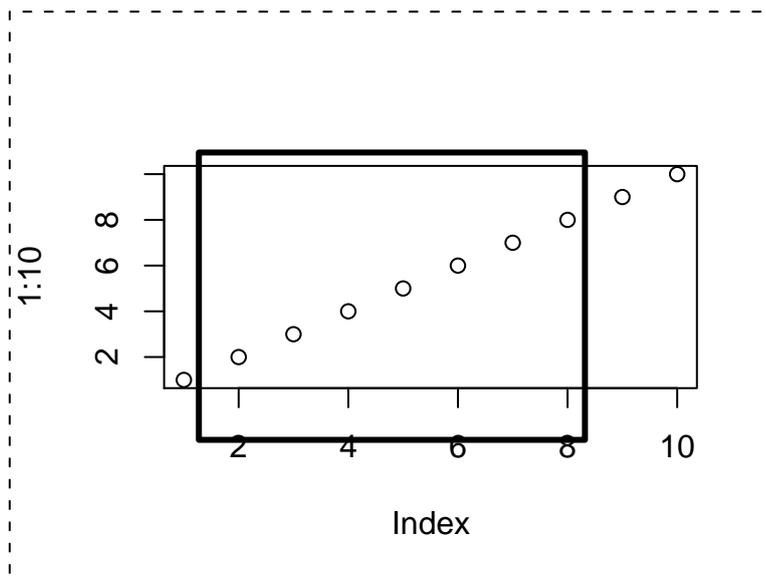
A situation where this problem becomes very relevant for `grid` output is when the `gridBase` package is used. This is a situation where lots of calculations are performed in order to align base and `grid` output, but these calculations are not recorded on the graphics engine display list, so if the device is resized the output will become very yukky.

2. `grid`'s display list does not record base graphics output¹ so if both base and `grid`

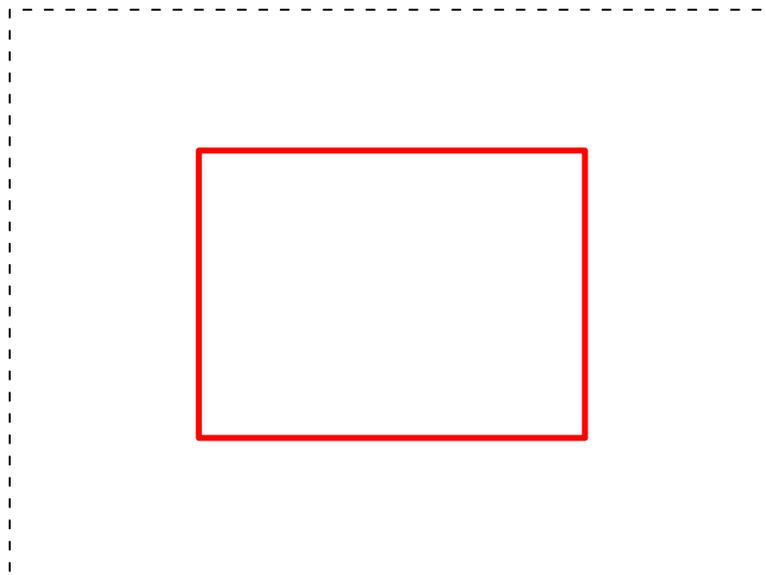
¹This is not quite true; it is possible to include base graphics output on the `grid` display list as we will see later.

output appear on the same device then the result of editing will not redraw the base output. The following code provides a simple example:

```
> plot(1:10)
> par(new = TRUE)
> grid.rect(width = 0.5, height = 0.5, gp = gpar(lwd = 3),
+   name = "gr")
```



```
> grid.edit("gr", gp = gpar(col = "red", lwd = 3))
```



After the `grid.edit`, the rectangle has been redrawn, but the base plot has not.

Avoiding the graphics engine display list

The problems described above can all be avoided if `grid` is able to control all redrawing of output. There are several parts to this solution:

- It must be possible to avoid using the graphics engine display list. This facility is now provided by the `engine.display.list()` function. The following code will stop `grid` output from being recorded on the graphics engine display list:

```
> engine.display.list(FALSE)
```

- `grid` must be alerted whenever a device has been resized or output is being copied between devices. This is handled in C code; if the graphics engine display list is not being used then `grid` automatically redraws its own display list whenever a resize or copy occurs.
- Calculations must be recorded on `grid`'s display list. If graphics output is based on calculations which will not be consistent when the device is resized (e.g., a call to `convertUnit()`, or calls to the `gridBase` functions), then a device resize will produce inconsistent output unless the calculations are recorded somehow on `grid`'s display list. This appears to be exactly the same problem as we had with the graphics engine display list; the difference is that there *is* a way to record calculations on `grid`'s display list.

When a `grid` grob is drawn the `drawDetails` method for that grob will be called; if calculations are put within a `drawDetails` method, then the calculations will be performed every time the grob is drawn.

All of this means that it is possible, for example, to use `convertUnit()` and have the result consistent across device resizes or copies². This next piece of code is an example where the output becomes inconsistent when the device is resized. We specify a width for the rectangle in inches, but convert it (gratuitously) to NPC coordinates – when the device is resized, the NPC coordinates will no longer correspond to 1”.

```
> grid.rect(width = convertWidth(unit(1, "inches"),  
+      "npc"))
```

This second piece of code demonstrates that it is not enough simply to use `grid`'s display list; the calculations are still not being recorded so the inconsistency will still occur.

```
> engine.display.list(FALSE)  
> grid.rect(width = convertWidth(unit(1, "inches"),  
+      "npc"))
```

Finally, the next piece of code demonstrates that, if we only use `grid`'s display list *and* we place the calculations within a `drawDetails` method, then the output remains consistent across device resizes and copies³.

²In each of the examples that follow, you should execute the example code, resize the device to see any inconsistency, then close the device before trying the next example.

³In order to avoid drawing the rectangle multiple times, we have draw the rectangle but not record it on the display list (`recording=FALSE`; only the "myrect" grob is recorded on the display list).

```

> engine.display.list(FALSE)
> drawDetails.myrect <- function(x, x.wrapped, recording) {
+   gr <- rectGrob(width = convertWidth(unit(1,
+     "inches"), "npc"))
+   grid.draw(gr, recording = FALSE)
+ }
> grid.draw(grob(cl = "myrect"))

```

A more impressive use of this facility can be obtained from an example using `gridBase` to combine base and `grid` graphics output. Here I replicate the last example from the “`gridBase`” vignette – a set of base pie charts within `grid` viewports within a base plot. In this case, I can produce all of the grobs required in the normal manner – their locations and sizes are not based on special calculations⁴.

```

> if ("gridBase" %in% .packages(all.available = TRUE)) {
+   library(gridBase)
+   x <- c(0.88, 1, 0.67, 0.34)
+   y <- c(0.87, 0.43, 0.04, 0.94)
+   z <- matrix(runif(4 * 2), ncol = 2)
+   maxpiesize <- unit(1, "inches")
+   totals <- apply(z, 1, sum)
+   sizemult <- totals/max(totals)
+   gs <- segmentsGrob(x0 = unit(c(rep(0, 4),
+     x), rep(c("npc", "native"), each = 4)),
+     x1 = unit(c(x, x), rep("native", 8)),
+     y0 = unit(c(y, rep(0, 4)), rep(c("native",
+     "npc"), each = 4)), y1 = unit(c(y,
+     y), rep("native", 8)), gp = gpar(lty = "dashed",
+     col = "grey"))
+   gr <- rectGrob(gp = gpar(col = "grey", fill = "white",
+     lty = "dashed"))
+ }

```

What is important is that I place the calls to the `gridBase` functions within the `drawDetails` method so that they are performed every time the grob is drawn *and* the calls to the base graphics functions are in here too so that they are called for every redraw.

```

> drawDetails.pieplot <- function(grob, grob.wrapped,
+   recording) {
+   plot(x, y, xlim = c(-0.2, 1.2), ylim = c(-0.2,
+     1.2), type = "n")
+   vps <- baseViewports()
+   par(new = TRUE)
+   pushViewport(vps$inner, vps$figure, vps$plot,
+     recording = FALSE)
+   grid.draw(grob$gs, recording = FALSE)

```

⁴The example is wrapped inside a check for whether the `gridBase` package is installed so that the code will still “run” on systems without `gridBase`.

```

+   for (i in 1:4) {
+     pushViewport(viewport(x = unit(x[i], "native"),
+       y = unit(y[i], "native"), width = sizemult[i] *
+         maxpiesize, height = sizemult[i] *
+         maxpiesize), recording = FALSE)
+     grid.draw(grob$gr, recording = FALSE)
+     par(plt = gridPLT(), new = TRUE)
+     pie(z[i, ], radius = 1, labels = rep("",
+       2))
+     popViewport(recording = FALSE)
+   }
+   popViewport(3, recording = FALSE)
+ }

```

The “pieplot” is created by assembling the component grobs into a collective grob of the appropriate class; the `drawDetails` method takes care of actually producing the output. An important additional step here is that I turn off the graphics engine display list for the base graphics also (otherwise I would get multiple copies of the base graphics output).

```

> if ("gridBase" %in% .packages()) {
+   engine.display.list(FALSE)
+   dev.control(displaylist = "inhibit")
+   grid.draw(grob(gs = gs, gr = gr, cl = "pieplot"))
+ }

```

The output from this example can be resized safely; `grid` handles all of the redrawing, and performs all of the actions within the `drawDetails` method for each redraw, including redrawing the base graphics output!

As a final example, we will harness the `grid` display list purely to achieve consistency in base graphics output. The following reproduces the last example from the `legend()` help page, but produces output which can be resized without the legend going crazy.

```

> drawDetails.mylegend <- function(grob, grob.wrapped,
+   recording) {
+   x <- 0:64/64
+   y <- sin(3 * pi * x)
+   plot(x, y, type = "l", col = "blue", main = "points with bg & legend(*, pt.bg)")
+   points(x, y, pch = 21, bg = "white")
+   legend(0.4, 1, "sin(c x)", pch = 21, pt.bg = "white",
+     lty = 1, col = "blue")
+ }
> engine.display.list(FALSE)
> dev.control(displaylist = "inhibit")
> grid.draw(grob(cl = "mylegend"))

```

Disadvantages to using grid for all redraws

The main problem here is that redrawing `grid`'s display list is slower than redrawing the graphics engine display list. This is just the price that must be paid in order to obtain the advantages of using `grid`'s display list.