microbenchmark

A package to accurately time R expressions

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Image courtesy of William Warby

SURGEON GENERAL'S WARNING: Microbenchmarks can lead to a distorted view of reality and massive loss of productivity.

Want to benchmark “regular” R code?

Check out the `rbenchmark` package by Wacek Kusnierczyk on CRAN.

So why another timing package?

Isn't this enough

```
> system.time(function_under_test())
     user  system elapsed
   12.236   0.520  13.092
```

or possibly

```
> system.time(replicate(100, function_under_test())) / 100
   user  system elapsed
  0.820   0.145   0.965
```

Not really...

```
> f_nothing <- function() NULL
> f_something <- function() 1 + 1
> n <- 1000000L
> (tr1 <- system.time(replicate(n, f_nothing())) / n)
     user    system   elapsed
3.372e-06 5.600e-08 3.429e-06
> (tr2 <- system.time(replicate(n, f_something())) / n)
     user    system   elapsed
5.488e-06 5.200e-08 5.543e-06
> (tr3 <- system.time(replicate(n, NULL)) / n)
     user    system   elapsed
1.176e-06 7.600e-08 1.252e-06
> (tr4 <- system.time(replicate(n, 1 + 1)) / n)
     user    system   elapsed
3.912e-06 0.000e+00 3.913e-06
```

Not really...

```
> s <- seq_len(n)
> (tf1 <- system.time(for(i in s) f_nothing()) / n)
    user   system  elapsed
2.88e-07 1.60e-08 3.05e-07
> (tf2 <- system.time(for(i in s) f_something()) / n)
    user   system  elapsed
5.65e-07 0.00e+00 5.67e-07
> (tf3 <- system.time(for(i in s) NULL) / n)
   user  system elapsed
6.8e-08 0.0e+00 6.8e-08
> (tf4 <- system.time(for(i in s) 1 + 1) / n)
    user   system  elapsed
3.20e-07 0.00e+00 3.19e-07
```

Which timings are “correct”?

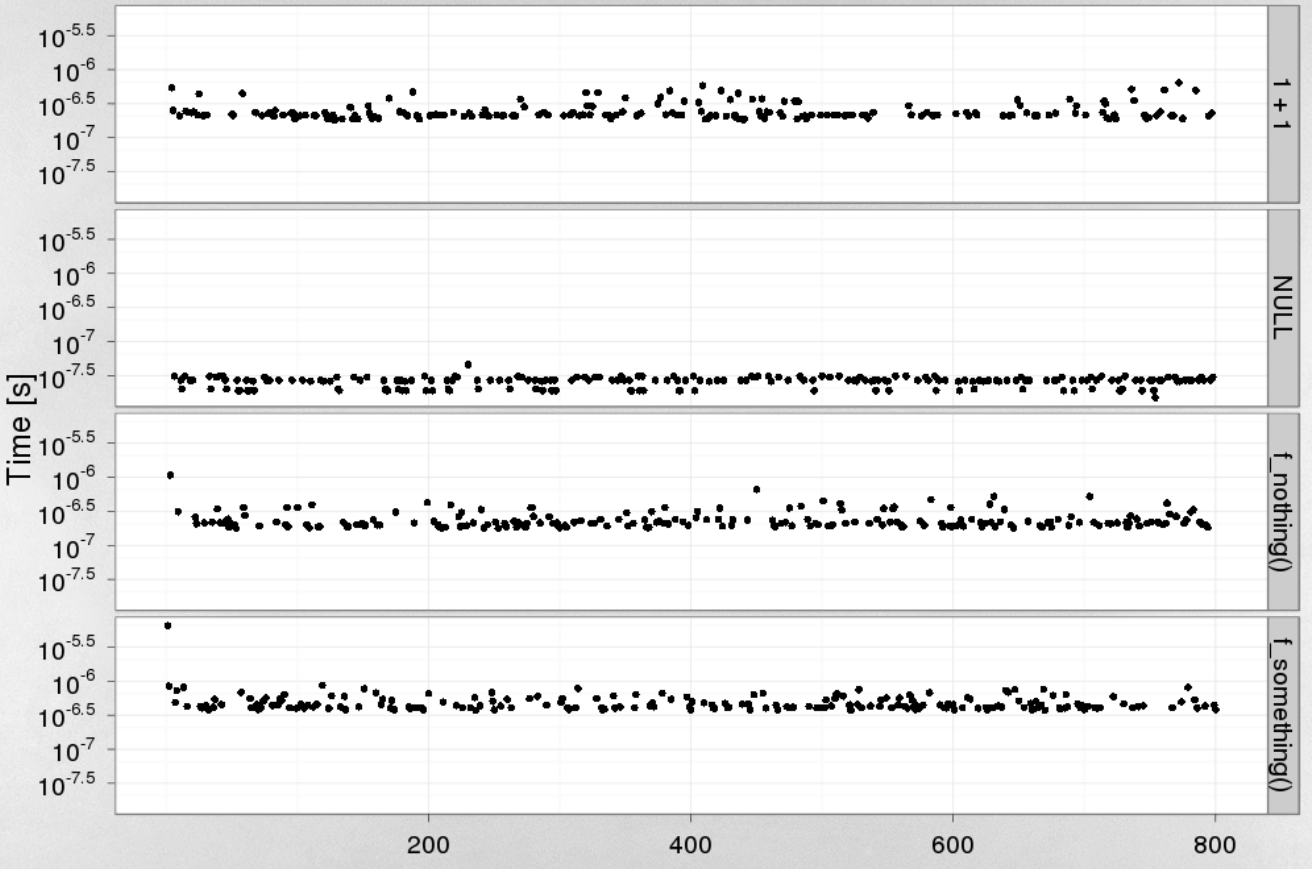
```
> cast(expr ~ method, data=r, value="time")
           expr replicate      for
1         1 + 1 3.912e-06 3.20e-07
2          NULL 1.176e-06 6.80e-08
3   f_nothing() 3.372e-06 2.88e-07
4 f_something() 5.488e-06 5.65e-07
```

Table contains the *elapsed* time in seconds.

Lets check...

```
> res <- microbenchmark(f_nothing(), f_something(), NULL, 1 + 1,
+                       times=200L)
>
> print(res, unit="s")
Unit: seconds
          expr      min       lq   median        uq       max
1        1 + 1 1.84e-07 2.10e-07 2.14e-07 2.400e-07 6.420e-07
2         NULL 1.50e-08 2.60e-08 2.70e-08 2.700e-08 4.600e-08
3   f_nothing() 1.80e-07 1.96e-07 2.14e-07 2.410e-07 1.077e-06
4 f_something() 3.75e-07 4.05e-07 4.32e-07 5.365e-07 6.498e-06
```

Lets check...


Time [s]
$10^{-5.5}$
10^{-6}
$10^{-6.5}$
10^{-7}
$10^{-7.5}$
1 + 1
NULL
f_nothing()
f_something()
200
400
600
800

Lets check...

```
> cast(expr ~ method, data=rr, value="time")
           expr replicate      for microbenchmark
1         1 + 1 3.912e-06 3.20e-07    2.50830e-07
2          NULL 1.176e-06 6.80e-08    2.59200e-08
3   f_nothing() 3.372e-06 2.88e-07    2.44625e-07
4 f_something() 5.488e-06 5.65e-07    5.08955e-07
```

How it works

`proc.time()` / `system.time()`

On Unix/Linux: `getrusage()`, `gettimeofday()`, `times()`

On Windows: `GetTickCount()`, `GetProcessTimes()`

How it works

`proc.time()` / `system.time()`

On Unix/Linux: `getrusage()`, `gettimeofday()`, `times()`
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`microbenchmark()`

On Unix/Linux: `clock_gettime()`, `gethrtime()`
On MacOS X: `mach_timebase_info()`
On Windows: `QueryPerformanceCounter()`, `QueryPerformanceFrequency()`

Challenges

Timing is extremely accurate

We can measure/see

- CPU frequency scaling / throttling and core hopping
- Overhead of C function calls

Precision of clock is unknown

- Clock might drift
- Timing might be zero
- Might observe discrete values

Clock only measures elapsed time

Don't know where time is spent. Might not even be spent in R process.

Countermeasures in `microbenchmark`

Automatic

- Configurable warm-up phase to wake CPU (`warmup` setting in `control`).
- Configurable order of execution (`random`, `inorder`, `block`)
- Estimate minimal overhead in warm-up phase and subtract from all timings.
- Warn if timings underflow (lower than estimated overhead).
- Explicitly avoid inlining of functions in C code.

Users responsibility

- Ensure R session is a representative state
- Possibly call `gc()` or allocate some large objects
- Consider side-effects

Suggestions - Windows

Recommendations

- Bind R process to a CPU (use Task Manager)
- Set an appropriate power scheme to disable CPU frequency scaling (usually Office/Desktop)
- Install Intel/AMD CPU drivers

Windows XP

Precision of clock is usually lacking because of missing HPET.

Suggestions - MacOS X

Problems

- ▷ No clean way to temporarily disable CPU frequency scaling (must uninstall kexts!)
- ▷ No command line utility to set CPU affinity

Solution

`microbenchmark` tries hard to spin up CPU before actual timing. No solution for CPU hopping.

Suggestions - Linux

Recommendations

- Bind R process to a CPU (`taskset`)
- Disable frequency scaling:

```
for cpu in /sys/devices/system/cpu/cpu[0-9]* ; do
  echo performance > $cpu/cpufreq/scaling_governor
done
```

or if you have the `cpufrequtils` installed

```
cpufreq-set -c $core -g performance
```

Older systems

No HPET on older x86 Chipsets results in loss of precision.

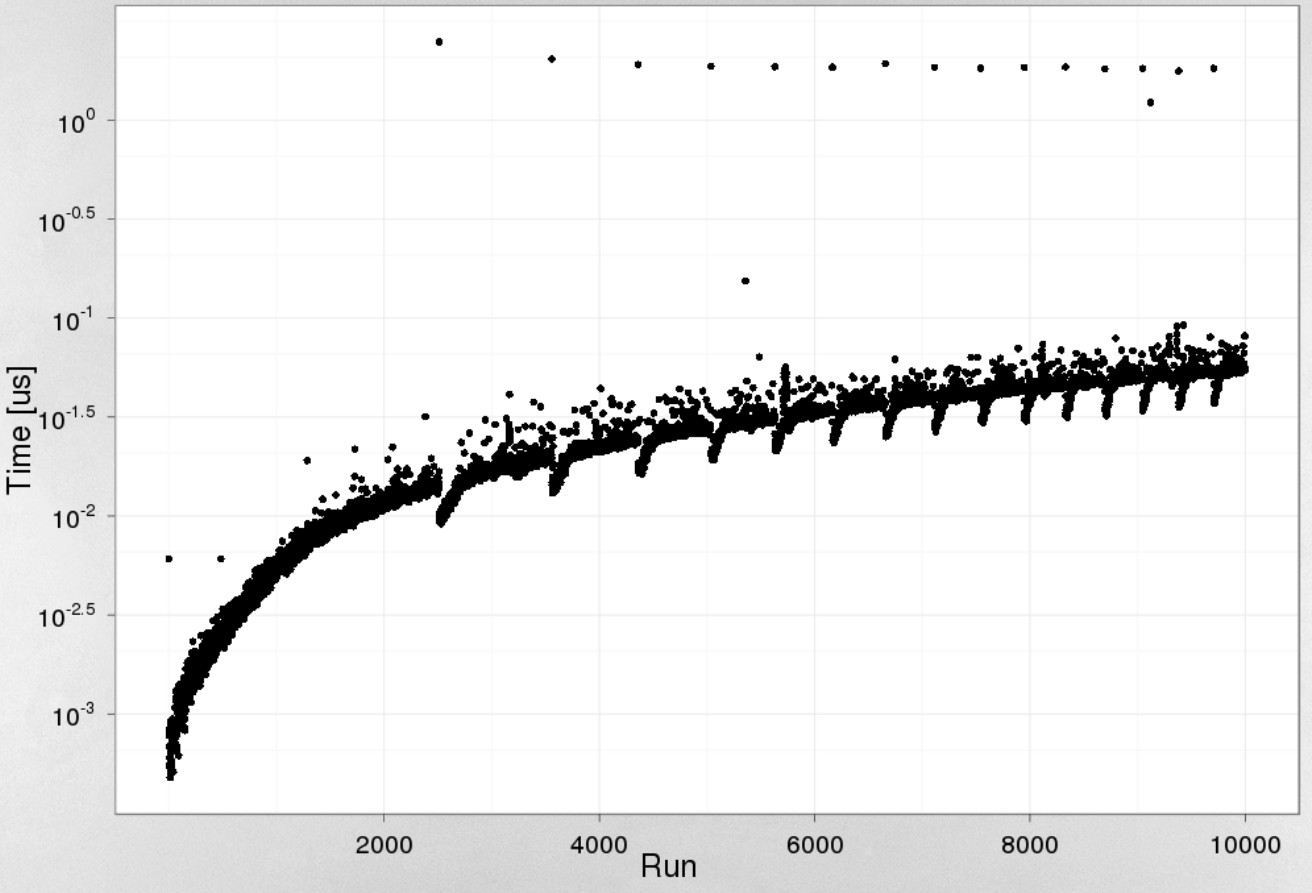
More examples - .Call

```
> r_do_nothing <- function(x) x
> do_nothing <- getNativeSymbolInfo("do_nothing")
>
> res <- microbenchmark(r=r_do_nothing(NULL),
+                       symbol=.Call(do_nothing, NULL),
+                       string=.Call("do_nothing", NULL),
+                       times=100L,
+                       control=list(warmup=2^16))
> print(res, unit="eps")
Unit: evaluations per second
    expr       min        lq    median        uq     max
1      r 775193.80 1509441.7 1564960.6 2998831.0 3597122
2 string  18906.81  115048.7  118210.3  120802.1  129584
3 symbol  81699.35  991080.3 1041124.7 1686340.6 2016129
```

More examples - side effects

```
> x <- NULL
> res <- microbenchmark(x <- c(x, 1), times=10000L)
> print(res)
Unit: nanoseconds
          expr min    lq median      uq     max
1 x <- c(x, 1) 477 13492  27128 40552.5 2483183
```

More examples - side effects



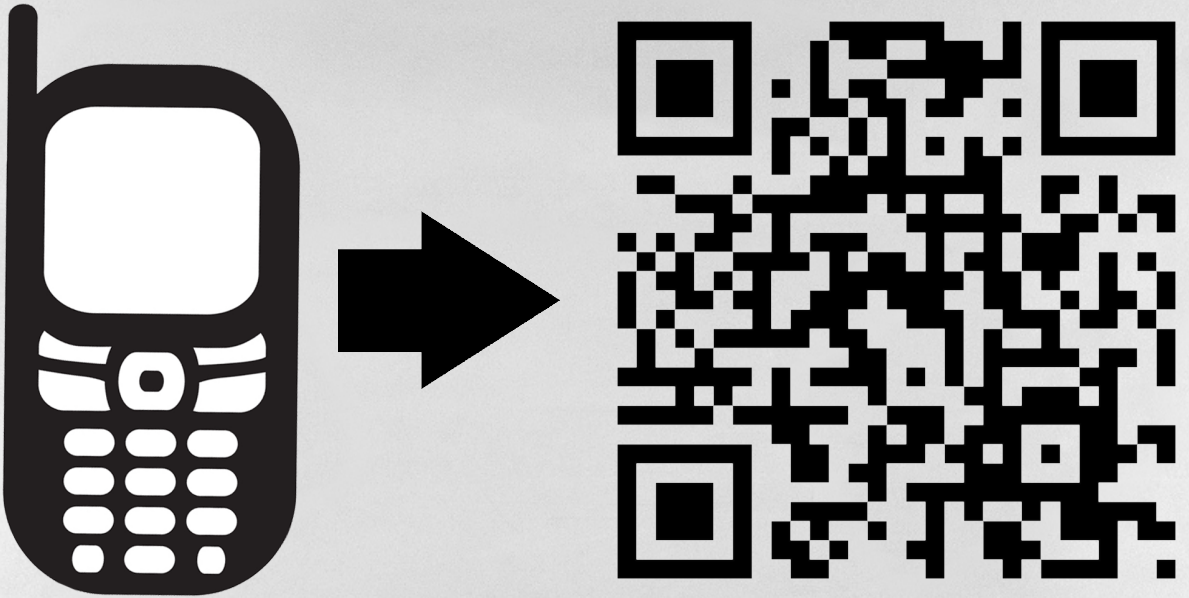
Conclusion and Outlook

Other real-world uses

- Cost of S3, S4 and `proto` method calls
- Overhead of `.C` vs. `.Call` vs pure R function
- Measure influence of compiler and compiler flags on speed of interpreter (Warning: microbenchmark!)

Planned features

- More plotting functions (currently only boxplots)
- Possibly use OS API to set Process Affinity
- Better and more diagnostic messages
- Estimate clock granularity and overhead more accurately



http://ptr.p-value.net/usr11