Analysing termite favouritism in annular arenas*

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Tracking algorithm:

Available at: https://github.com/dmrib/trackingtermites
Wrote the final code: Danilo Ribeiro
Wrote the first working code: Sidiney Alves
Supervised coding: Og DeSouza

1 Overall rationale

- Here we inspect whether termites walking in annular arenas would preferentially contact some of their nestmates over others along a *c.a.* 30 min period.
- our tracking algorithm (available at GitHub https://github.com/dmrib/trackingtermites) was able to (i) identify each one of the termite individuals in the arena, (ii) track their positions along the whole footage, and (iii) tally the number of time-steps each individual termite acted as a target of a one-to-one interaction. That is to say, when a given termite walked towards another and met it, this second termite was recorded as a "target". We then recorded the duration of this encounter in terms of time-steps. Then we analysed the proportion of time-steps (relative to the duration of the whole footage) *each* termite acted as a target. In the absence of favouritism, the proportion of time-steps each member of the group acted as a target would not differ among group members (that is our null hypothesis). That is, for a given footage duration, target time-steps would be even distributed among all members of the group. On the other hand, if *some* of the termites in the group would be "preferred targets" over others, they would spend more time-steps acting as targets than other members of the group. In doing so, for a given footage duration, target time-steps would be unevenly distributed among all members of the group.

*This is part of the paper: Paiva *et al.*(in review) Scale-free movement patterns in termites emerge from social interactions and preferential attachments. *submitted to PNAS*.

- To do so, we filmed and tracked each individual termite in the confined group, tallying the number of time-steps this focal termite spent contacting a given target termite along the whole footage.
- This has produced a dataset such as:

```
Tallyied time-steps for a group of 3 individuals.
-------------------------------------------------
  trajectory focalTermite targetTermite steps
1  traj00006    termite01     termite02   640
2  traj00006    termite01     termite03   676
3  traj00006    termite02     termite01   635
4  traj00006    termite02     termite03   500
5  traj00006    termite03     termite01   702
6  traj00006    termite03     termite02   502
-------------------------------------------------
```

- then, for each individual we averaged number of time-steps it acted as a target of an interaction along the whole footage, producing a result such as:

```
Averaged time-steps a termite spent as a target.
------------------------------------------------
  targetTermite steps
1     termite01 668.5
2     termite02 571.0
3     termite03 588.0
------------------------------------------------
```

- then we ran a Chi-square test to verify whether the proportion of time-steps spent as a target would vary among termite individuals. That is to say, we inspected whether these proportions would depart from an uniform distribution and, if so, to point to the existence of 'favourite targets'.
- in case the Chi-square test did point to significant differences, we counted the number of 'favourites' within that given group. These 'favourites' were defined as as being the termites whose average number of time-steps spent as a target was larger than the global average of targeting time-steps in the whole footage.
- The number of preferred target-termites in each arena (y-var) was then regressed against the number of termites therein confined (x-var), in order to inspect how preferential attachments would correlate with group size. Analysis consisted in contrasting the model thereby obtained with a model with zero intercept and slope = 1, that is, a model in which favouritism was absent. Modelling was performed in R, under Generalised Linear Modelling and normal error distribution, followed by residual analysis. Contrasts were made using Akaike Information Criterion (AIC).

2 Loading and preparing data

```
> setwd("./")
> dt<-read.table("../dat/newdata.dat",sep=",") # termite1 changed to termite01, etc
> names(dt)[1] <- "trajectory"
> names(dt)[2]<- "focalTermite"
> names(dt)[3]<- "targetTermite"
> names(dt)[4]<- "steps"
> summary(dt)

     trajectory      focalTermite    targetTermite     steps
 traj00013:240    termite01: 67    termite01: 67   Min.   :   1.0
 traj00130:240    termite02: 67    termite02: 67   1st Qu.: 309.0
 traj00007: 56    termite03: 67    termite03: 67   Median : 626.0
 traj00100: 56    termite04: 63    termite04: 63   Mean   : 858.4
 traj00145: 56    termite05: 51    termite05: 51   3rd Qu.:1032.0
 traj00012: 12    termite06: 51    termite06: 51   Max.   :8963.0
 (Other)  : 48   (Other)   :342   (Other)   :342
```

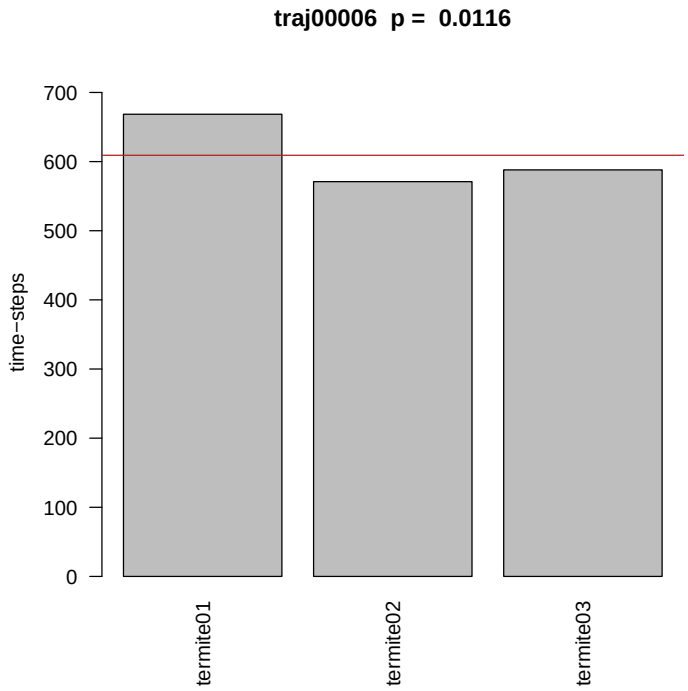
3 Preferences per trajectory

Preparing functions:

```
> interact <- function(traj){ # interactions with target termite
+   ss <- subset(dt,trajectory==traj)
+   ss <- droplevels(ss)
+   ##
+   ## the total number of steps here considers readings
+   ## from termite01 > termite02 as well as termite02 > termite01.
+   ## We should make it as the mean of both cases.
+   totSteps <- sum(ss$steps)
+   interactions <- aggregate(ss$steps,list(ss$targetTermite),mean)
+   names(interactions)[1] <- "targetTermite"
+   names(interactions)[2] <- "steps"
+   return(interactions)
+ }
> pl<-function(interactions)
+   {pval <- round(chisq.test(interactions[2])$p.value,4)
+   expected <- chisq.test(interactions[2])$expected
+   barplot(interactions$steps,
+         names.arg = interactions$targetTermite,
+         las=2,
+         main=paste(traj, " p = ",pval ),
+         ylab="time-steps",
+         #xlab="termite ID",
+         ylim=c(0,1.1*max(interactions[2]))
+         )
+ abline(h=expected[1],col="red")
+ }
> summtraj <- function(resultChi){
+   expected <- resultChi$expected
+   observed <- resultChi$observed
+   favourites <- sum(observed>expected)
+   total <- length(resultChi$observed)
+   totSteps <- sum(resultChi$observed)
+   chi <- resultChi$statistic
+   pval <- resultChi$p.value
+   return(list(total = total,
+               favourites = favourites,
+               totSteps = totSteps,
+               chisquare = chi[[1]],
+               pvalue = pval))
+ }
>
```

4 Trajectory 00006

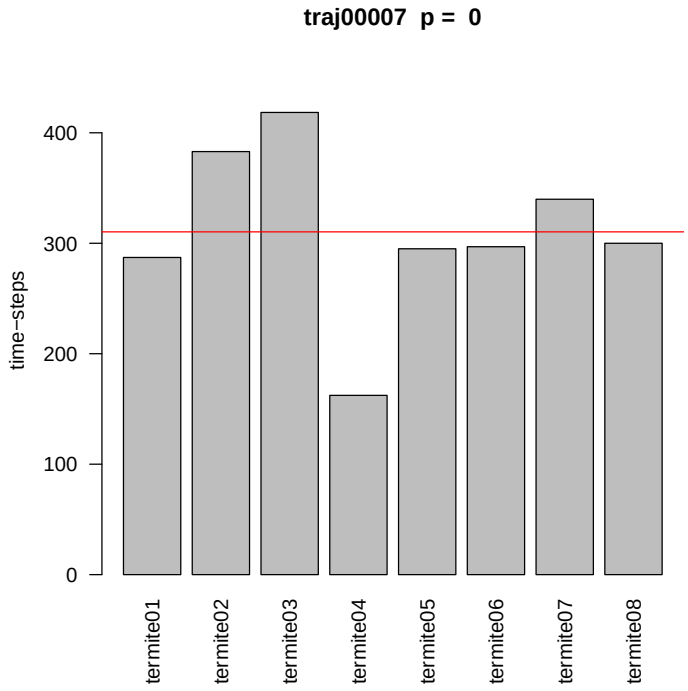
```
> traj <- "traj00006"
> ii <- interact(traj)
> ii

  targetTermite steps
1     termite01 668.5
2     termite02 571.0
3     termite03 588.0

> resultChi <- chisq.test(ii[2])
> resultTraj00006 <-summtraj(resultChi)
> resultTraj00006

$total
[1] 3

$favourites
[1] 1

$totSteps
[1] 1827.5

$chisquare
[1] 8.905882

$pvalue
[1] 0.01164427

> pl(ii)
> svg(filename = "graphs/fig-traj00006.svg")
> pl(ii)
> dev.off()

pdf
  2
```



5 Trajectory 00007

```
> traj <- "traj00007"
> ii <- interact(traj)
> resultChi <- chisq.test(ii[2])
> resultTraj00007 <-summtraj(resultChi)
> resultTraj00007

$total
[1] 8

$favourites
[1] 3

$totSteps
[1] 2482.571

$chisquare
[1] 131.5284

$pvalue
```

```
[1] 3.012616e-25

> pl(ii)
> svg(filename = "graphs/fig-traj00007.svg")
> pl(ii)
> dev.off()

pdf
  2
```



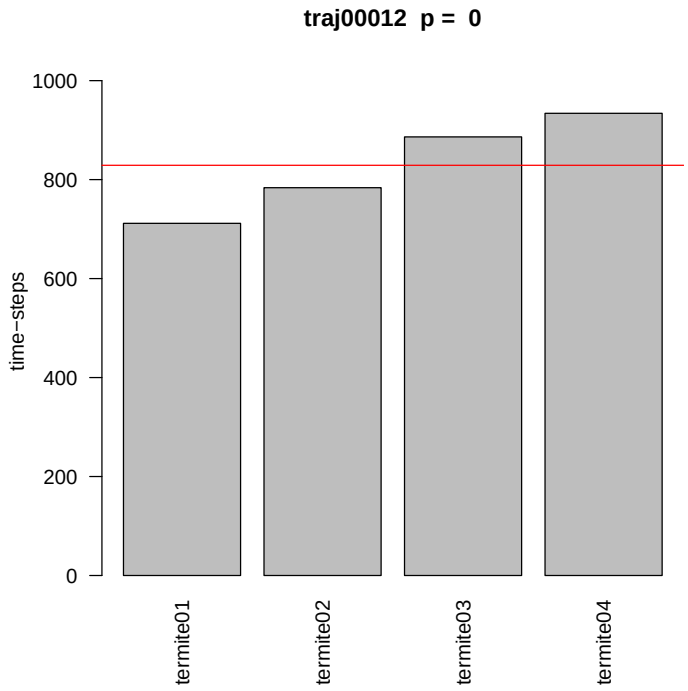
6 Trajectory 00012

```
> traj <- "traj00012"
> ii <- interact(traj)
> resultChi <- chisq.test(ii[2])
> resultTraj00012 <-summtraj(resultChi)
> resultTraj00012

$total
[1] 4

$favourites
```

```
[1] 2

$totSteps
[1] 3315.667

$chisquare
[1] 36.35384

$pvalue
[1] 6.303287e-08
```

```
> pl(ii)
> svg(filename = "graphs/fig-traj00012.svg")
> pl(ii)
> dev.off()
```

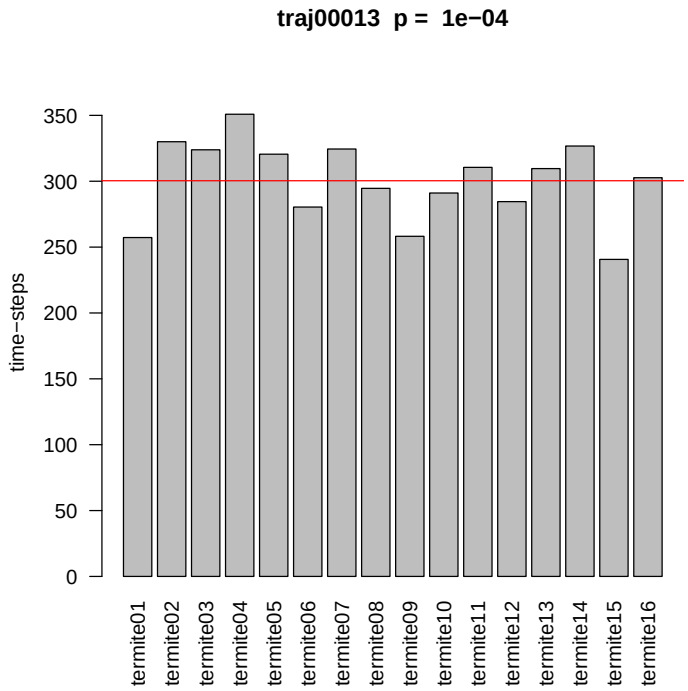
```
pdf
  2
```



7 Trajectory 00013

```
> traj <- "traj00013"
> ii <- interact(traj)
```

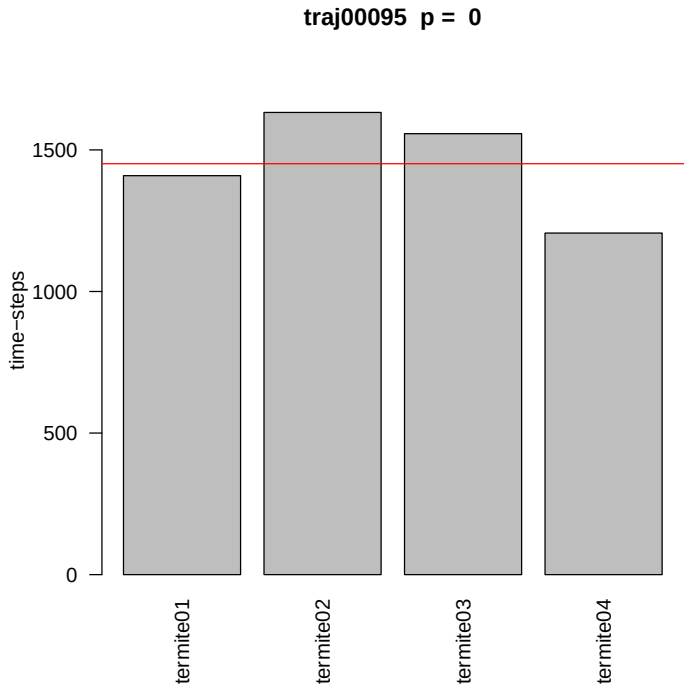
```
> resultChi <- chisq.test(ii[2])
> resultTraj00013 <-summtraj(resultChi)
> resultTraj00013

$total
[1] 16

$favourites
[1] 9

$totSteps
[1] 4806

$chisquare
[1] 46.02939

$pvalue
[1] 5.260081e-05

> pl(ii)
> svg(filename = "graphs/fig-traj00013.svg")
> pl(ii)
> dev.off()

pdf
  2
```



8 Trajectory 00095

```
> traj <- "traj00095"
> ii <- interact(traj)
> resultChi <- chisq.test(ii[2])
> resultTraj00095 <-summtraj(resultChi)
> resultTraj00095

$total
[1] 4

$favourites
[1] 2

$totSteps
[1] 5805

$chisquare
[1] 72.91237

$pvalue
```

```
[1] 1.014982e-15

> pl(ii)
> svg(filename = "graphs/fig-traj00095.svg")
> pl(ii)
> dev.off()

pdf
  2
```



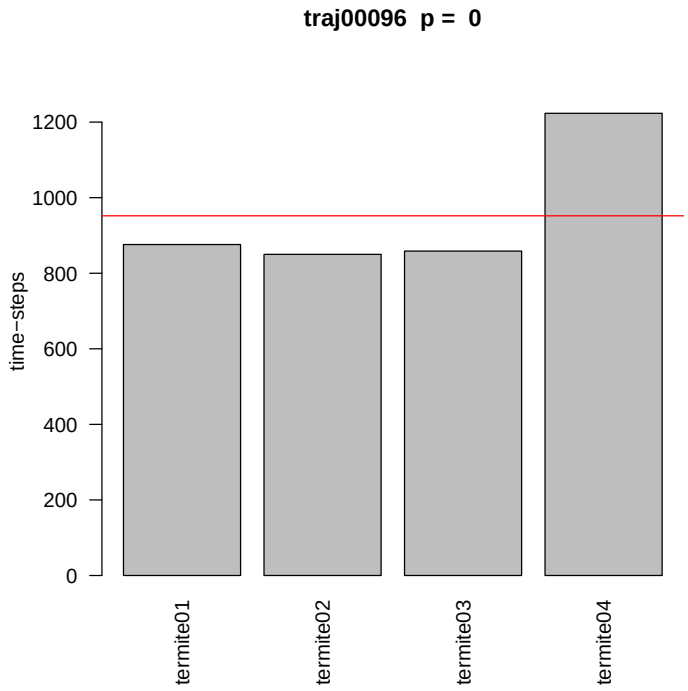
9 Trajectory 00096

```
> traj <- "traj00096"
> ii <- interact(traj)
> resultChi <- chisq.test(ii[2])
> resultTraj00096 <-summtraj(resultChi)
> resultTraj00096

$total
[1] 4

$favourites
```

```
[1] 1

$totSteps
[1] 3808

$chisquare
[1] 103.4799

$pvalue
[1] 2.774122e-22
```

```
> pl(ii)
> svg(filename = "graphs/fig-traj00096.svg")
> pl(ii)
> dev.off()
```

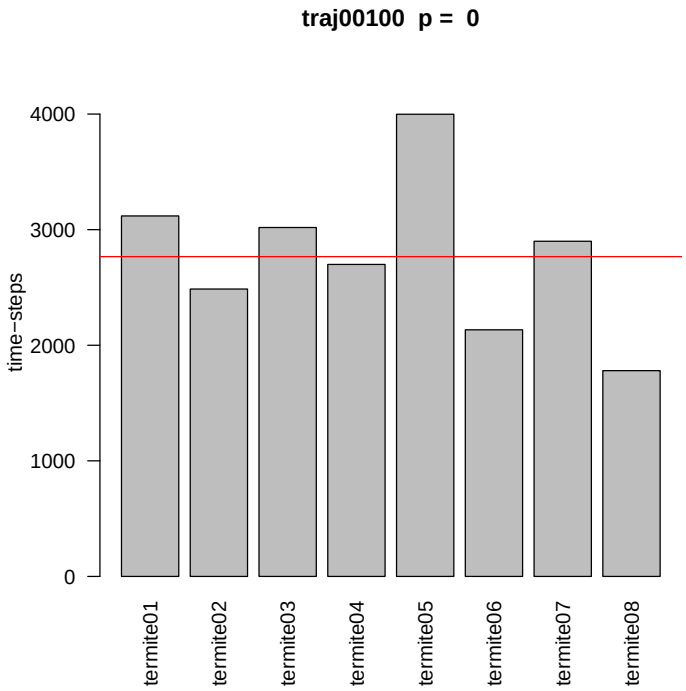
```
pdf
  2
```



10 Trajectory 00100

```
> traj <- "traj00100"
> ii <- interact(traj)
```

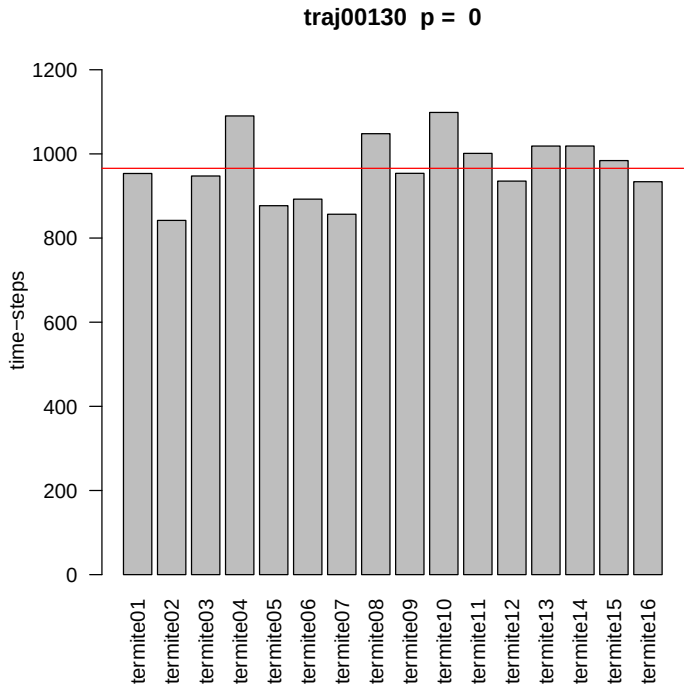
```
> resultChi <- chisq.test(ii[2])
> resultTraj00100 <-summtraj(resultChi)
> resultTraj00100

$total
[1] 8

$favourites
[1] 4

$totSteps
[1] 22134.86

$chisquare
[1] 1149.136

$pvalue
[1] 7.031052e-244

> pl(ii)
> svg(filename = "graphs/fig-traj00100.svg")
> pl(ii)
> dev.off()

pdf
  2
```



11 Trajectory 00130

```
> traj <- "traj00130"
> ii <- interact(traj)
> resultChi <- chisq.test(ii[2])
> resultTraj00130 <-summtraj(resultChi)
> resultTraj00130

$total
[1] 16

$favourites
[1] 7

$totSteps
[1] 15451.27

$chisquare
[1] 93.37328

$pvalue
```

```
[1] 2.319141e-13

> pl(ii)
> svg(filename = "graphs/fig-traj00130.svg")
> pl(ii)
> dev.off()

pdf
  2
```



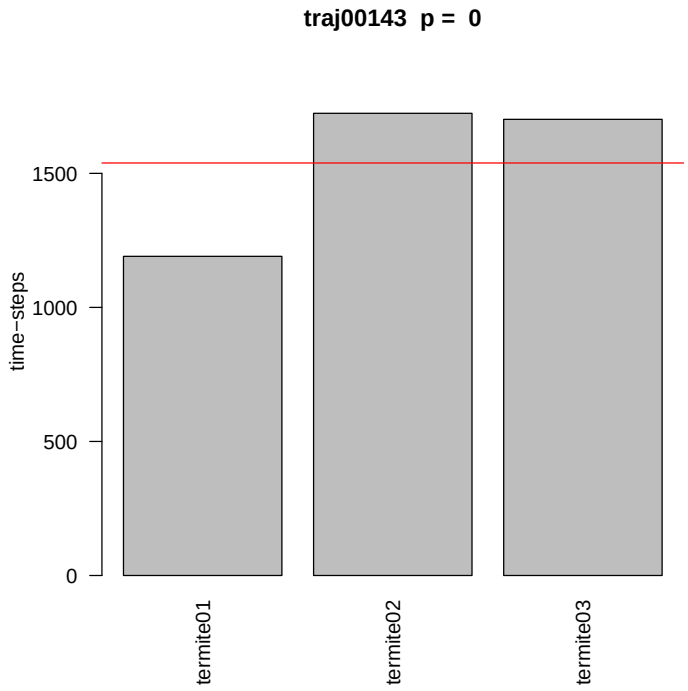
12 Trajectory 00143

```
> traj <- "traj00143"
> ii <- interact(traj)
> resultChi <- chisq.test(ii[2])
> resultTraj00143 <-summtraj(resultChi)
> resultTraj00143

$total
[1] 3

$favourites
```

```
[1] 2

$totSteps
[1] 4616

$chisquare
[1] 118.3383

$pvalue
[1] 2.009875e-26
```

```
> pl(ii)
> svg(filename = "graphs/fig-traj00143.svg")
> pl(ii)
> dev.off()
```

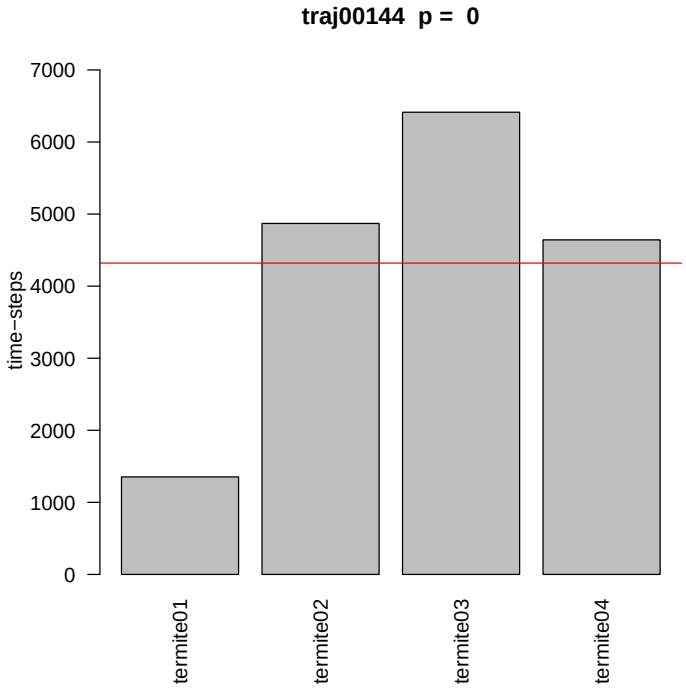
```
pdf
  2
```



13 Trajectory 00144

```
> traj <- "traj00144"
> ii <- interact(traj)
```

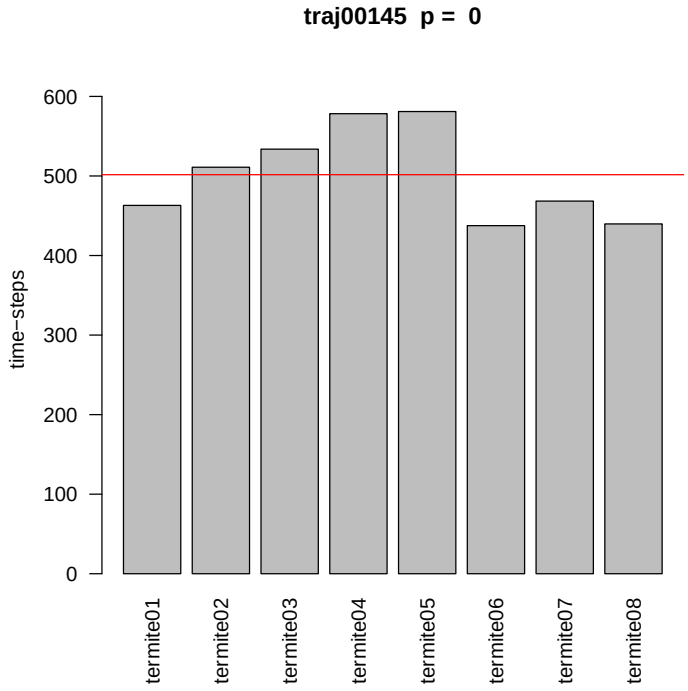
```
> resultChi <- chisq.test(ii[2])
> resultTraj00144 <-summtraj(resultChi)
> resultTraj00144

$total
[1] 4

$favourites
[1] 3

$totSteps
[1] 17279.33

$chisquare
[1] 3145.936

$pvalue
[1] 0

> pl(ii)
> svg(filename = "graphs/fig-traj00144.svg")
> pl(ii)
> dev.off()

pdf
  2
```



14 Trajectory 00145

```
> traj <- "traj00145"
> ii <- interact(traj)
> resultChi <- chisq.test(ii[2])
> resultTraj00145 <-summtraj(resultChi)
> resultTraj00145

$total
[1] 8

$favourites
[1] 4

$totSteps
[1] 4012.714

$chisquare
[1] 47.49812

$pvalue
```

```
[1] 4.462514e-08

> pl(ii)
> svg(filename = "graphs/fig-traj00145.svg")
> pl(ii)
> dev.off()

pdf
  2
```



15 Big summary

```
> traj <- sort(unique(dt$trajectory))
> groupSize <- c(resultTraj00006$total,
+                resultTraj00007$total,
+                resultTraj00012$total,
+                resultTraj00013$total,
+                resultTraj00095$total,
+                resultTraj00096$total,
+                resultTraj00100$total,
+                resultTraj00130$total,
+                resultTraj00143$total,
```

```
+                resultTraj00144$total,
+                resultTraj00145$total
+                )
> favourites <- c(resultTraj00006$favourites,
+                 resultTraj00007$favourites,
+                 resultTraj00012$favourites,
+                 resultTraj00013$favourites,
+                 resultTraj00095$favourites,
+                 resultTraj00096$favourites,
+                 resultTraj00100$favourites,
+                 resultTraj00130$favourites,
+                 resultTraj00143$favourites,
+                 resultTraj00144$favourites,
+                 resultTraj00145$favourites
+                 )
> steps <- c(resultTraj00006$totSteps,
+                 resultTraj00007$totSteps,
+                 resultTraj00012$totSteps,
+                 resultTraj00013$totSteps,
+                 resultTraj00095$totSteps,
+                 resultTraj00096$totSteps,
+                 resultTraj00100$totSteps,
+                 resultTraj00130$totSteps,
+                 resultTraj00143$totSteps,
+                 resultTraj00144$totSteps,
+                 resultTraj00145$totSteps
+                 )
> chisq <- c(resultTraj00006$chisquare,
+                 resultTraj00007$chisquare,
+                 resultTraj00012$chisquare,
+                 resultTraj00013$chisquare,
+                 resultTraj00095$chisquare,
+                 resultTraj00096$chisquare,
+                 resultTraj00100$chisquare,
+                 resultTraj00130$chisquare,
+                 resultTraj00143$chisquare,
+                 resultTraj00144$chisquare,
+                 resultTraj00145$chisquare
+                 )
> pval <- c(resultTraj00006$pvalue,
+                 resultTraj00007$pvalue,
+                 resultTraj00012$pvalue,
+                 resultTraj00013$pvalue,
+                 resultTraj00095$pvalue,
+                 resultTraj00096$pvalue,
+                 resultTraj00100$pvalue,
```

```
+                 resultTraj00130$pvalue,
+                 resultTraj00143$pvalue,
+                 resultTraj00144$pvalue,
+                 resultTraj00145$pvalue
+                 )
> summdf <- data.frame(traj,groupSize,fav=favourites, steps=round(steps,0), chisq, pval)
> nestID <- read.table("nestIDtraj.csv", h=T)
> summTab <- merge(nestID,summdf,by="traj")
> library(xtable)
> print(xtable(summTab,
+              display = c("s","s","s","s","s","s","g","g")),
+       math.style.exponents=TRUE
+       )
```

	traj	nest	groupSize	fav	steps	chisq	pval
1	traj00006	nest2017-05-24-KRR-N01	3	1	1828	8.9	0.012
2	traj00007	nest2017-05-24-KRR-N01	8	3	2483	1.3×10^{2}	3×10^{-25}
3	traj00012	nest2017-05-26-LPNS-N01	4	2	3316	36	6.3×10^{-8}
4	traj00013	nest2017-05-29-KRR-N01	16	9	4806	46	5.3×10^{-5}
5	traj00095	nest2017-05-03-KRR-N01	4	2	5805	73	1×10^{-15}
6	traj00096	nest2017-05-03-KRR-N01	4	1	3808	1×10^{2}	2.8×10^{-22}
7	traj00100	nest2017-05-03-KRR-N01	8	4	22135	1.1×10^{3}	7×10^{-244}
8	traj00130	nest2017-05-08-KRR-N02	16	7	15451	93	2.3×10^{-13}
9	traj00143	nest207-06-06-LPNS-N03	3	2	4616	1.2×10^{2}	2×10^{-26}
10	traj00144	nest2017-06-07-KRR-N01	4	3	17279	3.1×10^{3}	0
11	traj00145	nest2016-06-07-KRR-N01	8	4	4013	47	4.5×10^{-8}

```
> write.csv(summTab, file = "summaryFavourites.csv", row.names = FALSE)
> favourites/groupSize
```

[1] 0.3333333 0.3750000 0.5000000 0.5625000 0.5000000 0.2500000 0.5000000 [8] 0.4375000 0.6666667 0.7500000 0.5000000

```
> mean(favourites/groupSize)
```

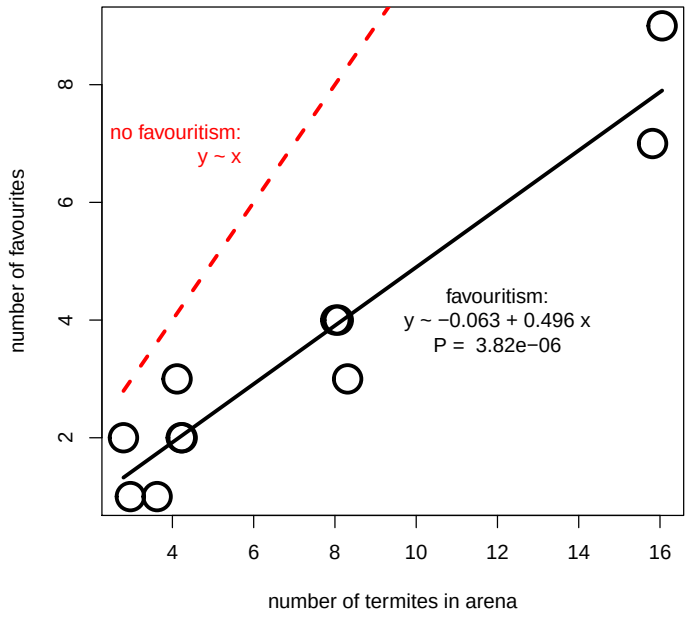
[1] 0.4886364

16 Regression

```
> m1<-glm(favourites~groupSize)
> m0<-glm(favourites~offset(0+groupSize))
> AIC(m0,m1)

   df      AIC
m0  2 54.68087
m1  3 29.40147
```

```
> anova(m0,m1, test="F")

Analysis of Deviance Table

Model 1: favourites ~ offset(0 + groupSize)
Model 2: favourites ~ groupSize
  Resid. Df Resid. Dev Df Deviance      F    Pr(>F)
1        10     64.545
2         9      5.406  1    59.14 98.466 3.816e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> pfav <- anova(m0,m1, test="F")$'Pr(>F)'[2]
> library(scales)
> # digits = 3 is the default but I am setting it here to be explicit,
> # and draw attention to the fact this is different than the formatC
> # solution.
> pfav <- scientific(pfav, digits = 3)
> pfav

[1] "3.82e-06"

> anova(m1,test="F")

Analysis of Deviance Table

Model: gaussian, link: identity

Response: favourites

Terms added sequentially (first to last)


          Df Deviance Resid. Df Resid. Dev      F    Pr(>F)
NULL                         10     62.727
groupSize  1   57.322         9      5.406 95.438 4.344e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> coef(m1)

(Intercept)   groupSize
-0.06323185  0.49609680

> plot(favourites~jitter(groupSize,factor=2)
+      ,lwd = 3
+      ,cex = 3
```

```
+      ,pch = 21
+      ,xlab = "number of termites in arena"
+      ,ylab = "number of favourites"
+      )
> curve(coef(m1)[1]+coef(m1)[2]*x, add=T,lwd=3)
> curve(0+1*x, add = T, col = "red", lwd = 3, lty=2)
> eq0 <- c('y ~ x')
> eq0

[1] "y ~ x"

> text(5.7,7,paste("no favouritism:", eq0,sep='\n'),col="red", adj=1)
> eq1 <- paste('y ~'
+     ,round(coef(m1)[1],3)
+     ,'+'
+     ,round(coef(m1)[2],3)
+     , 'x'
+     )
> eq1

[1] "y ~ -0.063 + 0.496 x"

> pval <- paste('P = ', pfav)
> text(12,4, paste(
+     'favouritism:'
+     ,eq1
+     ,pval
+     ,sep='\n'
+   )
+   )
```



Raw data

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