BirthDeath model

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library(ape)

## Warning: package 'ape' was built under R version 3.4.4

library(BioGeoBEARS)

## Warning: package 'BioGeoBEARS' was built under R version 3.4.4

## Loading required package: rexpokit

## Warning: package 'rexpokit' was built under R version 3.4.4

## Loading required package: cladoRcpp

## Warning: package 'cladoRcpp' was built under R version 3.4.4

## Loading required package: phylobase

## Warning: package 'phylobase' was built under R version 3.4.4

##   
## Attaching package: 'phylobase'

## The following object is masked from 'package:ape':  
##   
## edges

#load tree data into R  
phy <- read.nexus("http://www.r-phylo.org/w/images/0/02/Geospiza.nex")  
birthdeath(phy)

##   
## Estimation of Speciation and Extinction Rates  
## with Birth-Death Models  
##   
## Phylogenetic tree: phy   
## Number of tips: 14   
## Deviance: -44.72209   
## Log-likelihood: 22.36105   
## Parameter estimates:  
## d / b = 0.6147299 StdErr = 0.4413613   
## b - d = 1.418635 StdErr = 1.273316   
## (b: speciation rate, d: extinction rate)  
## Profile likelihood 95% confidence intervals:  
## d / b: [0.0456687, 0.8435001]  
## b - d: [0.6685375, 2.728088]

#parameters: Birth\_rate = lambda, Death\_rate = mu, Net Diversification Rate (r) = Birth\_rate - Death\_rate, Relative Extinction Rate (a)= Death\_rate / Birth\_rate  
lambda <- 5  
mu <- 2  
a = mu / lambda  
r = lambda - mu  
  
  
  
#The number of speices in the tree  
N = length(phy$tip.label)  
#branching time of each species  
x <- c(NA, branching.times(phy))  
  
  
  
  
#log likelihood function  
  
log\_likelihood <- function(lambda, mu, phy) {  
   
 #creat an empty vector for Lnl  
   
 a = mu / lambda  
 r = lambda - mu  
 N = length(phy$tip.label)  
 x <- c(NA, branching.times(phy))  
   
 #Set up the condition for the function   
 #If the speciation rate is smaller than 0 or the extinction rate is larger than 1, then return to a very small number   
   
 if (r < 0 || a > 1){  
 Lnl = exp(0.001)  
 } else{  
 #If the speciation rate is larger than 0 or the extinction rate is smaller than 1, then do the log likelihood calculation  
 #  
   
   
 Lnl = lfactorial(N - 1) + (N - 2) \* log(r) + r \* sum(x[3:N]) + N \* log(1 - a) - 2 \* sum(log(exp(r \* x[2:N]) - a))  
 }  
   
print(paste("lambda=",lambda,"mu=", mu, "Lnl=",Lnl))   
   
   
  
   
   
 return(Lnl)  
   
}  
  
  
  
#optimise the birth and death rate  
#Find value of lambda and mu by maximizing the log\_likelihood given the tree.  
optim(c(lambda,mu), fn = function(p)log\_likelihood(lambda = p[1],mu=p[2],phy = phy), method=c("L-BFGS-B"),lower = 0, control = list(fnscale = -1))

## [1] "lambda= 5 mu= 2 Lnl= 21.2901584555853"  
## [1] "lambda= 5.001 mu= 2 Lnl= 21.2888265751282"  
## [1] "lambda= 4.999 mu= 2 Lnl= 21.2914896624875"  
## [1] "lambda= 5 mu= 2.001 Lnl= 21.29099839997"  
## [1] "lambda= 5 mu= 1.999 Lnl= 21.2893181450283"  
## [1] "lambda= 4.15426815860261 mu= 2.53360814503396 Lnl= 22.2996844333347"  
## [1] "lambda= 4.15526815860261 mu= 2.53360814503396 Lnl= 22.2993359501745"  
## [1] "lambda= 4.15326815860261 mu= 2.53360814503396 Lnl= 22.3000319211305"  
## [1] "lambda= 4.15426815860261 mu= 2.53460814503396 Lnl= 22.2998585876907"  
## [1] "lambda= 4.15426815860261 mu= 2.53260814503396 Lnl= 22.2995098603165"  
## [1] "lambda= 3.85438042377955 mu= 2.67237694541218 Lnl= 22.3522809115296"  
## [1] "lambda= 3.85538042377955 mu= 2.67237694541218 Lnl= 22.3523363040087"  
## [1] "lambda= 3.85338042377956 mu= 2.67237694541218 Lnl= 22.3522243783031"  
## [1] "lambda= 3.85438042377955 mu= 2.67337694541218 Lnl= 22.3522143223343"  
## [1] "lambda= 3.85438042377955 mu= 2.67137694541218 Lnl= 22.3523470747694"  
## [1] "lambda= 3.89460778184851 mu= 2.6319027784487 Lnl= 22.3549422321727"  
## [1] "lambda= 3.89560778184851 mu= 2.6319027784487 Lnl= 22.3549271079119"  
## [1] "lambda= 3.89360778184851 mu= 2.6319027784487 Lnl= 22.3549562386173"  
## [1] "lambda= 3.89460778184851 mu= 2.6329027784487 Lnl= 22.354917819668"  
## [1] "lambda= 3.89460778184851 mu= 2.6309027784487 Lnl= 22.3549662193681"  
## [1] "lambda= 3.88695952928561 mu= 2.60978231866492 Lnl= 22.3555567616735"  
## [1] "lambda= 3.88795952928561 mu= 2.60978231866492 Lnl= 22.3555365162929"  
## [1] "lambda= 3.88595952928561 mu= 2.60978231866492 Lnl= 22.3555758876669"  
## [1] "lambda= 3.88695952928561 mu= 2.61078231866492 Lnl= 22.3555370291707"  
## [1] "lambda= 3.88695952928561 mu= 2.60878231866492 Lnl= 22.3555760688304"  
## [1] "lambda= 3.85636651903401 mu= 2.52130047952981 Lnl= 22.3573714641392"  
## [1] "lambda= 3.85736651903401 mu= 2.52130047952981 Lnl= 22.3573307755608"  
## [1] "lambda= 3.85536651903401 mu= 2.52130047952981 Lnl= 22.3574110270282"  
## [1] "lambda= 3.85636651903401 mu= 2.52230047952981 Lnl= 22.357370430923"  
## [1] "lambda= 3.85636651903401 mu= 2.52030047952981 Lnl= 22.3573720719081"  
## [1] "lambda= 3.74203772726034 mu= 2.32679151706623 Lnl= 22.3604662861495"  
## [1] "lambda= 3.74303772726034 mu= 2.32679151706623 Lnl= 22.3604351261566"  
## [1] "lambda= 3.74103772726034 mu= 2.32679151706623 Lnl= 22.3604962820977"  
## [1] "lambda= 3.74203772726034 mu= 2.32779151706623 Lnl= 22.3604767944498"  
## [1] "lambda= 3.74203772726034 mu= 2.32579151706623 Lnl= 22.3604553514457"  
## [1] "lambda= 3.67785884538036 mu= 2.25767439784831 Lnl= 22.3610445498194"  
## [1] "lambda= 3.67885884538036 mu= 2.25767439784831 Lnl= 22.3610453905016"  
## [1] "lambda= 3.67685884538036 mu= 2.25767439784831 Lnl= 22.3610425177642"  
## [1] "lambda= 3.67785884538036 mu= 2.25867439784831 Lnl= 22.3610441075963"  
## [1] "lambda= 3.67785884538036 mu= 2.25667439784831 Lnl= 22.361044564833"  
## [1] "lambda= 3.68223075019712 mu= 2.26348077664862 Lnl= 22.3610469851299"  
## [1] "lambda= 3.68323075019712 mu= 2.26348077664862 Lnl= 22.3610462962408"  
## [1] "lambda= 3.68123075019712 mu= 2.26348077664862 Lnl= 22.3610464844366"  
## [1] "lambda= 3.68223075019712 mu= 2.26448077664862 Lnl= 22.3610468290024"  
## [1] "lambda= 3.68223075019712 mu= 2.26248077664862 Lnl= 22.3610467140956"  
## [1] "lambda= 3.6821920097541 mu= 2.26354544672178 Lnl= 22.3610469891235"  
## [1] "lambda= 3.6831920097541 mu= 2.26354544672178 Lnl= 22.361046387217"  
## [1] "lambda= 3.6811920097541 mu= 2.26354544672178 Lnl= 22.3610464014197"  
## [1] "lambda= 3.6821920097541 mu= 2.26454544672178 Lnl= 22.3610467808631"  
## [1] "lambda= 3.6821920097541 mu= 2.26254544672178 Lnl= 22.3610467702211"

## $par  
## [1] 3.682192 2.263545  
##   
## $value  
## [1] 22.36105  
##   
## $counts  
## function gradient   
## 10 10   
##   
## $convergence  
## [1] 0  
##   
## $message  
## [1] "CONVERGENCE: REL\_REDUCTION\_OF\_F <= FACTR\*EPSMCH"