Dynamic structural equation models

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```r
library(tinyVAST)
set.seed(101)
```

`tinyVAST` includes features to fit a dynamic structural equation model. We here show this using a bivariate vector autoregressive model for wolf and moose abundance on Isle Royale.

```r
data(isle_royale, package="dsem")

# Convert to long-form
data = expand.grid( "time"=isle_royale[,1], "var"=colnames(isle_royale[,2:3]) )
data$logn = unlist(log(isle_royale[2:3]))

# Define cross-lagged DSEM
dsem = "
  # Link, lag, param_name
  wolves -> wolves, 1, arW
  moose -> wolves, 1, MtoW
  wolves -> moose, 1, WtoM
  moose -> moose, 1, arM
  wolves -> moose, 0, corr
"

# fit model
mytiny = tinyVAST( dsem = dsem,
                 data = data,
                 times = isle_royale[,1],
                 variables = colnames(isle_royale[,2:3]),
                 formula = logn ~ 0 + var,
                 control = tinyVASTcontrol(quiet=TRUE, trace=0) )
#> Warning in nlminb(start = opt$par, objective = obj$fn, gradient = obj$gr, : NA/NaN function evaluati
mytiny
#> $call
#> tinyVAST(formula = logn ~ 0 + var, data = data, dsem = dsem,
#>     times = isle_royale[, 1], variables = colnames(isle_royale[,
#>         2:3]), control = tinyVASTcontrol(quiet = TRUE, trace = 0))
#>
#> $opt
#> $opt$par
#>      alpha_j     alpha_j      beta_z      beta_z      beta_z      beta_z      beta_z      bet
#>   3.32526212  6.44165421  0.89304301  0.01420970 -0.11865018  0.86169482 -0.01539658  0.37749
#>
#> $opt$objective
#> [1] 5.781919
#>
```

```
#> $opt$convergence
#> [1] 0
#>
#> $opt$iterations
#> [1] 93
#>
#> $opt$evaluations
#> function gradient
#>      116       94
#>
#> $opt$message
#> [1] "relative convergence (4)"
#>
#>
#> $sdrep
#> sdreport(.) result
#>               Estimate   Std. Error
#> alpha_j     3.32526212 2.483496e-01
#> alpha_j     6.44165421 2.116034e-01
#> beta_z      0.89304301 8.420632e-02
#> beta_z      0.01420970 1.279152e-01
#> beta_z     -0.11865018 6.477638e-02
#> beta_z      0.86169482 7.080269e-02
#> beta_z     -0.01539658 6.067738e-02
#> beta_z      0.37749042 3.503686e-02
#> beta_z      0.17052360 1.582618e-02
#> log_sigma -12.56122233 1.909999e+04
#> Maximum gradient component: 9.935109e-05
#>
#> $run_time
#> Time difference of 0.2885571 secs
```

And we can specifically inspect the estimated interaction matrix:

	wolves	moose
wolves	0.893	-0.119
moose	0.014	0.862

We can then compare this with package `dsem`

```
library(dsem)

# Keep in wide-form
dsem_data = ts( log(isle_royale[,2:3]), start=1959)
family = c("normal","normal")

# initial first without delta0 (to improve starting values)
mydsem = dsem::dsem( sem = dsem,
             tsdata = dsem_data,
             control = dsem_control(quiet = TRUE),
             getsd = FALSE,
             family = family )
```

```
mydsem
#> $par
#>       beta_z        beta_z        beta_z        beta_z        beta_z        beta_z        beta_z
#>   0.895834720   0.007358847  -0.109332511   0.875012562  -0.017355229   0.378795847  -0.172873038 -1
#>
#> $objective
#> [1] 7.739638
#>
#> $iterations
#> [1] 79
#>
#> $evaluations
#> function gradient
#>       96       80
#>
#> $time_for_MLE
#> Time difference of 0.07060909 secs
#>
#> $max_gradient
#> [1] 7.714655e-07
#>
#> $Convergence_check
#> [1] "There is no evidence that the model is not converged"
#>
#> $number_of_coefficients
#>  Total  Fixed Random
#>    133      9    124
#>
#> $AIC
#> [1] 33.47928
#>
#> $diagnostics
#>       Param starting_value Lower           MLE Upper final_gradient
#> 1    beta_z           0.01  -Inf   0.895834720   Inf   4.785205e-09
#> 2    beta_z           0.01  -Inf   0.007358847   Inf  -5.078683e-09
#> 3    beta_z           0.01  -Inf  -0.109332511   Inf  -2.031211e-08
#> 4    beta_z           0.01  -Inf   0.875012562   Inf  -5.821149e-08
#> 5    beta_z           0.01  -Inf  -0.017355229   Inf  -5.373382e-09
#> 6    beta_z           1.00  -Inf   0.378795847   Inf   2.119351e-09
#> 7    beta_z           1.00  -Inf  -0.172873038   Inf  -7.714655e-07
#> 8 lnsigma_j           0.00  -Inf -15.799262455   Inf   1.628788e-12
#> 9 lnsigma_j           0.00  -Inf -11.977331517   Inf   2.141499e-09
#>
#> $time_for_run
#> Time difference of 0.07218099 secs
```

where we again inspect the estimated interaction matrix:

	wolves	moose
wolves	0.896	-0.109
moose	0.007	0.875