USING COMPILED CODE IN POMP

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CONTENTS

1. A TWO-DIMENSIONAL ORNSTEIN-UHLENBECK PROCESS.

Let's look again at our example of the discrete-time 2-D Ornstein-Uhlenbeck process with normal measurement error. Recall that the unobserved Ornstein-Uhlenbeck (OU) process $X_t \in \mathbb{R}^2$ satisfies

$$X_t = A \, X_{t-1} + \xi_t.$$

The observation process is

$$Y_t = B \, X_t + \varepsilon_t.$$

In these equations, A and and B are 2×2 constant matrices; ξ_t and ε_t are mutually-independent families of i.i.d. bivariate normal random variables. We let $\sigma\sigma^T$ be the variance-covariance matrix of ξ_t, where σ is lower-triangular; likewise, we let $\tau\tau^T$ be that of ε_t.

Since many of the methods we will use require us to simulate the process and/or measurement models many times, it is a good idea to use native (compiled) codes for the computational heavy lifting. The package includes some C codes that were written to implement the OU example. Read the source (file 'ou2.c') for details.

2. THE .C INTERFACE

```
> ou2.rprocess <- function(xstart, times, params,
+       ...) {
+     nvar <- nrow(xstart)
+     npar <- nrow(params)
+     nrep <- ncol(xstart)
+     ntimes <- length(times)
+     parindex <- match(c("alpha.1", "alpha.2",
+         "alpha.3", "alpha.4", "sigma.1", "sigma.2",
+         "sigma.3"), rownames(params)) - 1
+     array(.C("ou2_adv", X = double(nvar * nrep *
+         ntimes), xstart = as.double(xstart), par = as.double(params),
+         times = as.double(times), n = as.integer(c(nvar,
+             npar, nrep, ntimes)), parindex = as.integer(parindex),
+         DUP = FALSE, NAOK = TRUE, PACKAGE = "pomp")$X,
```

```
+             dim = c(nvar, nrep, ntimes), dimnames = list(rownames(xstart),
+                 NULL, NULL))
+ }
> ou2.dprocess <- function(x, times, params, log,
+     ...) {
+     nvar <- nrow(x)
+     npar <- nrow(params)
+     nrep <- ncol(x)
+     ntimes <- length(times)
+     parindex <- match(c("alpha.1", "alpha.2",
+         "alpha.3", "alpha.4", "sigma.1", "sigma.2",
+         "sigma.3"), rownames(params)) - 1
+     array(.C("ou2_pdf", d = double(nrep * (ntimes -
+         1)), X = as.double(x), par = as.double(params),
+         times = as.double(times), n = as.integer(c(nvar,
+             npar, nrep, ntimes)), parindex = as.integer(parindex),
+         give_log = as.integer(log), DUP = FALSE,
+         NAOK = TRUE, PACKAGE = "pomp")$d, dim = c(nrep,
+         ntimes - 1))
+ }
> bvnorm.dmeasure <- function(y, x, times, params,
+     log = TRUE, ...) {
+     measindex <- match(c("tau"), rownames(params)) -
+         1
+     nvar <- dim(x)[1]
+     nrep <- dim(x)[2]
+     ntimes <- dim(x)[3]
+     npar <- nrow(params)
+     nobs <- 2
+     array(.C("normal_dmeasure", n = as.integer(c(nvar,
+         npar, nrep, ntimes, nobs)), X = as.double(x),
+         par = as.double(params), index = as.integer(measindex),
+         Y = as.double(y), f = double(nrep * ntimes),
+         give_log = as.integer(log), DUP = FALSE,
+         NAOK = TRUE, PACKAGE = "pomp")$f, dim = c(nrep,
+         ntimes))
+ }
> bvnorm.rmeasure <- function(x, times, params,
+     ...) {
+     nvar <- dim(x)[1]
+     nrep <- dim(x)[2]
+     ntimes <- dim(x)[3]
+     npar <- dim(params)[1]
+     nobs <- 2
+     measindex <- match(c("tau"), rownames(params)) -
+         1
+     array(.C("normal_rmeasure", n = as.integer(c(nvar,
+         npar, nrep, ntimes, nobs)), X = as.double(x),
+         par = as.double(params), index = as.integer(measindex),
+         obs = double(nobs * nrep * ntimes), DUP = FALSE,
+         NAOK = TRUE, PACKAGE = "pomp")$obs, dim = c(nobs,
+         nrep, ntimes), dimnames = list(c("y1",
```

```
+         "y2"), NULL, NULL))
+ }
> ou2 <- pomp(times = seq(1, 100), data = rbind(y1 = rep(0,
+     100), y2 = rep(0, 100)), t0 = 0, rprocess = ou2.rprocess,
+     dprocess = ou2.dprocess, rmeasure = bvnorm.rmeasure,
+     dmeasure = bvnorm.dmeasure)
```

We'll specify some parameters:

```
> p <- c(alpha.1 = 0.9, alpha.2 = 0, alpha.3 = 0,
+     alpha.4 = 0.99, sigma.1 = 1, sigma.2 = 0,
+     sigma.3 = 2, tau = 1, x1.0 = 50, x2.0 = -50)

> tic <- Sys.time()
> ou2 <- simulate(ou2, params = p, nsim = 1000,
+     seed = 800733088)[[1]]
> toc <- Sys.time()
> print(toc - tic)

Time difference of 2.501312 secs
```

3. The .Call interface

The following wrapper functions make use of the above compiled codes.

```
> ou2.rprocess <- function(xstart, times, params,
+     ...) .Call("ou2_simulator", xstart, times,
+     params)
> ou2.dprocess <- function(x, times, params, log = FALSE,
+     ...) .Call("ou2_density", x, as.numeric(times),
+     params, log)
> bvnorm.dmeasure <- function(y, x, times, params,
+     log = FALSE, ...) .Call("bivariate_normal_dmeasure",
+     y, x, as.numeric(times), params, log)
> bvnorm.rmeasure <- function(x, times, params,
+     ...) .Call("bivariate_normal_rmeasure", x,
+     as.numeric(times), params)
```

To take advantage of the compiled functions, we need to reconstruct the pomp object.

```
> ou2 <- pomp(times = seq(1, 100), data = rbind(y1 = rep(0,
+     100), y2 = rep(0, 100)), t0 = 0, rprocess = ou2.rprocess,
+     dprocess = ou2.dprocess, rmeasure = bvnorm.rmeasure,
+     dmeasure = bvnorm.dmeasure, ivpnames = c("x1.0",
+         "x2.0"), parnames = c("alpha.1", "alpha.2",
+         "alpha.3", "alpha.4", "sigma.1", "sigma.2",
+         "sigma.3", "tau"))
```

Notice that we have added two objects, ivpnames and parnames to the pomp object. These character vectors are placed into the userdata slot of the pomp object and will be passed to each of the process and measurement model functions. They will come in handy later when we do particle filtering.

We'll fill the data slot with simulated data:

ou2
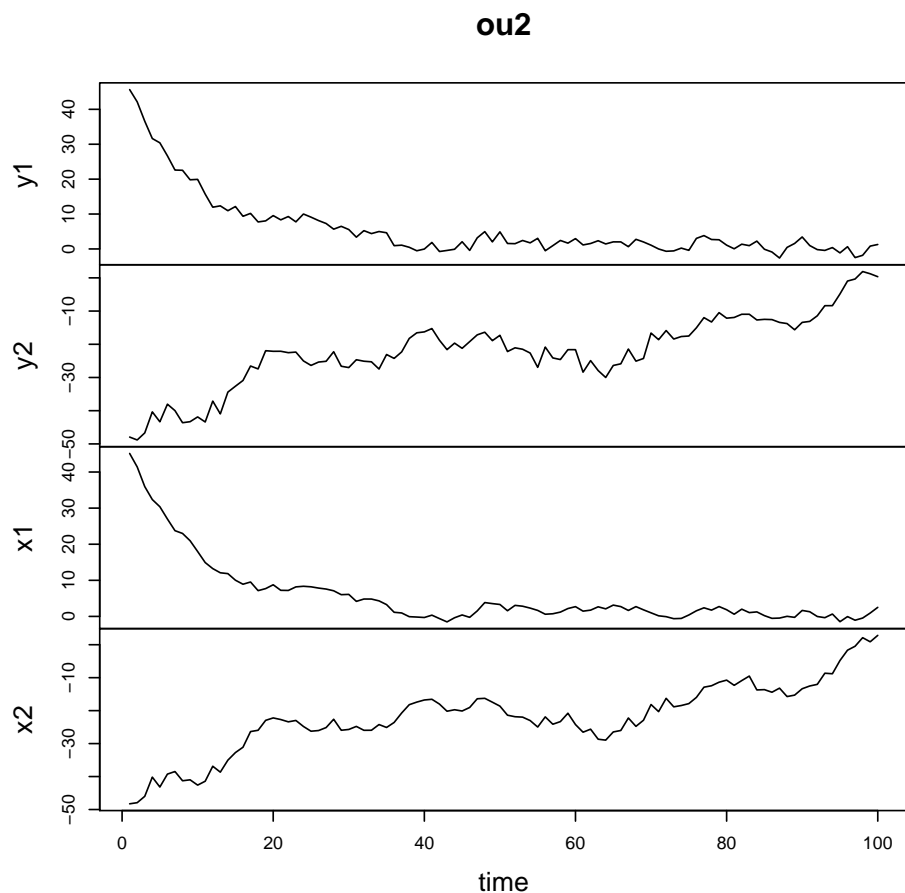

FIGURE 1. One realization of the two-dimensional OU process.

```
> tic <- Sys.time()
> ou2 <- simulate(ou2, params = p, nsim = 1000,
+     seed = 800733088)[[1]]
> toc <- Sys.time()
> print(toc - tic)
```

```
Time difference of 2.481526 secs
```

Fig. 1 plots the data.

The pomp object we just created is included in the package: use data(ou2) to retrieve it.

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