

# DOBAD Package: simulation of BDI process conditional on discrete observations

Charles Doss

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## Part I

# Simulation of a Linear BDI Process, Conditional on Observing it at Discrete Times

We are demonstrating the use of the `DOBAD` package's function for conditionally simulating a birth-death process, using the methods of Doss et al. (2010). Call the process  $\{X(t)\}_{t \in \mathbb{R}}$ ; we will simulate it conditional upon seeing data which is the value of the process at a finite number of discrete time points. That is, for times  $0 = t_0, t_1, \dots, t_n$ , we see the state of the process,  $X(t_i)$ . Thus the data  $D$  is 2 parts: a vector of the times  $t_i$ ,  $i = 0, \dots, n$  and a vector of states at each of those times,  $s_i$ , for  $i = 0, \dots, n$  (where  $X(t_i) = s_i$ ).

```
> library(DOBAD)
```

Generate a chain, the “truth” that we would not observe in practice:

```
> L <- 0.3
> m <- 0.5
> nu <- 0.4
> set.seed(112)
> unobservedChain <- birth.death.simulant(t = 5, X0 = 11, lambda = 0.3,
+     mu = 0.5, nu = 0.4)
> unobservedChain
```

An object of class "BDMC"

Slot "states":

```
[1] 11 12 11 10 9 10 11 10 11 10 9 10 9 10 9 10 9 8 7 8 9 10 9 8 7
[26] 8 9 8 7 6 5 6 7 8 7 8 7 8 7 8 7 6 5 4
```

Slot "times":

```
[1] 0.0000000 0.1304171 0.1378384 0.1874095 0.3413327 0.4836734 0.5151733
[8] 0.5570117 0.7665553 0.9320789 1.0212908 1.1413929 1.1998740 1.2975232
[15] 1.3406924 1.3665537 1.3994869 1.6049192 1.6333970 1.7129540 1.7668332
[22] 1.8285686 1.8363130 1.9739581 1.9851389 2.0814101 2.0854210 2.3046697
[29] 2.4094295 2.5627537 2.6068091 3.1822596 3.3482861 3.3844540 3.4134403
[36] 3.4503969 3.4519932 3.9011731 4.1374942 4.2672352 4.3789622 4.5547798
[43] 4.6734574 4.7213272
```

Slot "T":

```
[1] 5
```

Then fix some “observation times” and “observe” the chain:

```
> times <- c(0, 0.21, 0.62, 0.73, 1.44, 1.95, 3.56, 4.17)
> obsData <- getPartialData(times, unobservedChain)
> obsData
```

An object of class "CTMC\_PO\_1"

Slot "states":

```
[1] 11 10 10 10 9 9 7 7
```

Slot "times":

```
[1] 0.00 0.21 0.62 0.73 1.44 1.95 3.56 4.17
```

Now, we do a conditional simulation:

```
> nsims <- 5
> condSims <- sim.condBD(N = nsims, bd.PO = obsData, L = L, m = m,
+   nu = nu)
> condSims[1]
```

```
[[1]]
```

An object of class "BDMC"

Slot "states":

```
[1] 11 10 9 10 11 10 11 10 9 10 9 10 9 8 7 8 9 8 7 6 7
```

Slot "times":

```
[1] 0.00000000 0.05224893 0.44767799 0.57874166 0.76491147 0.86669301
[7] 0.99362847 1.17552882 1.41615881 1.64403070 1.68311572 1.75535090
[13] 1.91845847 2.06208393 2.10971694 2.29007387 2.31764070 2.59837720
[19] 2.70438486 3.88598190 4.08667118
```

Slot "T":

```
[1] 4.17
```

```
> condSims[4]
```

```
[[1]]
```

An object of class "BDMC"

Slot "states":

```
[1] 11 10 9 10 11 10 9 8 9 10 11 10 11 10 9 8 7 8 7 6 7 8 7 8 7
[26] 8 7 8 7
```

Slot "times":

```
[1] 0.00000000 0.02210702 0.44783042 0.46187799 0.64255612 0.69685008
[7] 0.77231358 0.85598923 1.42694811 1.44175639 1.46869934 1.63690122
[13] 1.66096808 1.77043653 1.80831279 2.17136625 2.45274890 2.55077418
[19] 2.59310847 2.60258622 2.71888487 2.74860598 2.96281893 2.98744978
[25] 3.08537681 3.70667131 3.89807045 4.01906935 4.09732896
```

Slot "T":

```
[1] 4.17
```

## References

Doss, C., Suchard, M., Holmes, I., Kato-Maeda, M., and Minin, V. (2010). Great Expectations: EM Algorithms for Discretely Observed Linear Birth-Death-Immigration Processes. *Arxiv preprint arXiv:1009.0893*.