

Introduction to SpaDES

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1 Spatial Discrete Event Simulation (SpaDES)

Requirements This package makes heavy use of the `raster` and `sp` packages, so familiarity with these packages and their classes and methods is recommended.

```
> ## for now only while testing, etc.
> OS <- tolower(Sys.info()["sysname"])
> hostname <- gsub(Sys.info()["nodename"], pattern=".-VIC-", replace="")
> if (OS=="windows") {
+   if(any(pmatch(c("A105200", "A105192"), hostname, nomatch=FALSE))) {
+     path <- "c:/Eliot/GitHub"
+   } else {
+     path <- "~/GitHub"
+   }
+ } else {
+   path <- "~/Documents/GitHub"
+ }
> #devtools::dev_mode(TRUE)
> devtools::load_all(file.path(path, "SpaDES")) # for development/testing
```

```
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Note: no visible binding for global variable 'to'
```

```
>
> ##
> #library(SpaDES)
```

2 SpaDES modules

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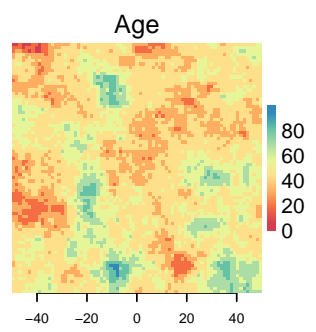
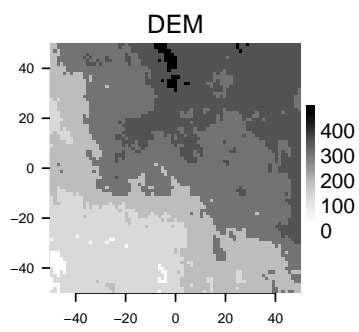
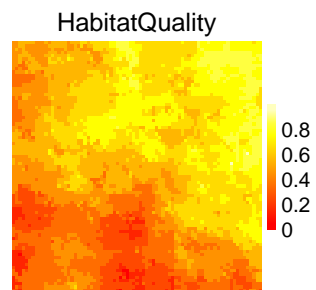
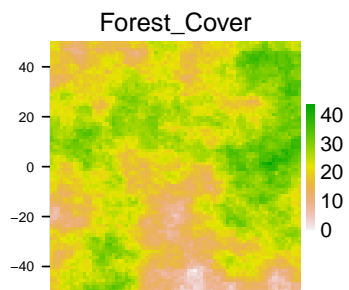
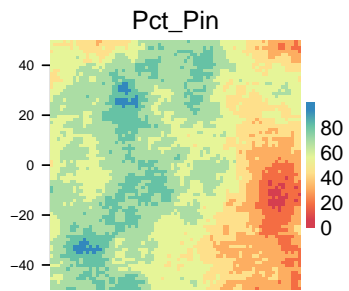
Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

3 Working with maps

A raster map Sample map of habitat quality.

```
> # Give dimensions of dummy raster
> nx = 1e2
> ny = 1e2
> template = raster(nrows=ny, ncols=nx, xmn=-nx/2, xmx=nx/2, ymn=-ny/2, ymx=ny/2)
> # Make dummy maps for testing of models
> DEM = round(GaussMap(template, scale = 300, var = 0.03, speedup=1), 1)*1000
> Age = round(GaussMap(template, scale = 10, var = 0.1, speedup=1), 1)*20
> Forest_Cover = round(GaussMap(template, scale = 50, var = 1, speedup=1), 2)*10
> Pct_Pine = round(GaussMap(template, scale = 50, var = 1, speedup=1), 1)
> # Scale them as needed
> Age = Age/maxValue(Age)*100
> Pct_Pine = Pct_Pine/maxValue(Pct_Pine)*100
> # Make layers that are derived from other layers
> HabitatQuality = (DEM+10 + (Forest_Cover+5)*10)/100
> HabitatQuality = HabitatQuality/maxValue(HabitatQuality)
> # Stack them into a single stack for plotting
> habitat = stack(list(DEM, Age, Forest_Cover, HabitatQuality, Pct_Pine))
> names(habitat) = c("DEM", "Age", "Forest_Cover", "HabitatQuality", "Pct_Pine")
> library(RColorBrewer)
> cols = list(
+   transparent.red=c("#00000000", paste(brewer.pal(8, "Greys"), "66", sep="")[8:1]),
+   grey = brewer.pal(9, "Greys"),
+   spectral = brewer.pal(8, "Spectral"),
+   terrain = rev(terrain.colors(100)),
+   heat = heat.colors(10),
+   topo = topo.colors(10)
+ )
> simPlot(habitat, col = cols[c(2:5, 3)])
```



4 Simulating “agents”

4.1 Spatial agents

4.1.1 Point agents

Agents represented by a single set of coordinates indicating their current position.

Use a `SpatialPointsDataFrame` with additional columns as needed.

Non-mobile point agents e.g., plants

Mobile point agents e.g., animals use a `SpatialPointsDataFrame`, with additional columns for agents' previous `n` positions, and any other columns such as age, sex, group membership, etc.

```
> N <- 1e1 # number of agents
> # caribou data vectors
> IDs <- c("Alice", "Bob", "Clark", "Daisy", "Eric",
+         "Franz", "Gabby", "Hayley", "Igor", "Jane")
> sex <- c("female", "male", "male", "female", "male",
+         "male", "female", "female", "male", "female")
> age <- round(rnorm(N, mean=8, sd=3))
> prevX <- runif(N, xmin(habitat)+(ncol(habitat)*0.2), xmax(habitat)-(ncol(habitat)*0.2)) # previous X
> prevY <- runif(N, ymin(habitat)+(nrow(habitat)*0.2), ymax(habitat)-(nrow(habitat)*0.2)) # previous Y
> # create the caribou agent object
> caribou <- SpatialPointsDataFrame(coords=cbind(x=rnorm(N, prevX, ncol(habitat)/20),
+         y=rnorm(N, prevY, ncol(habitat)/20)),
+         data=data.frame(prevX, prevY, sex, age))
> row.names(caribou) <- IDs # alternatively, add IDs as column in data.frame above
> heading(SpatialPoints(cbind(x=prevX,y=prevY)),caribou)
```

	Alice	Bob	Clark	Daisy	Eric	Franz	Gabby	Hayley
	303.24549	347.11640	84.23531	323.28008	239.18583	195.04528	54.14145	55.02652
	Igor	Jane						
	72.77079	228.10522						

```
> coordinates(caribou)
```

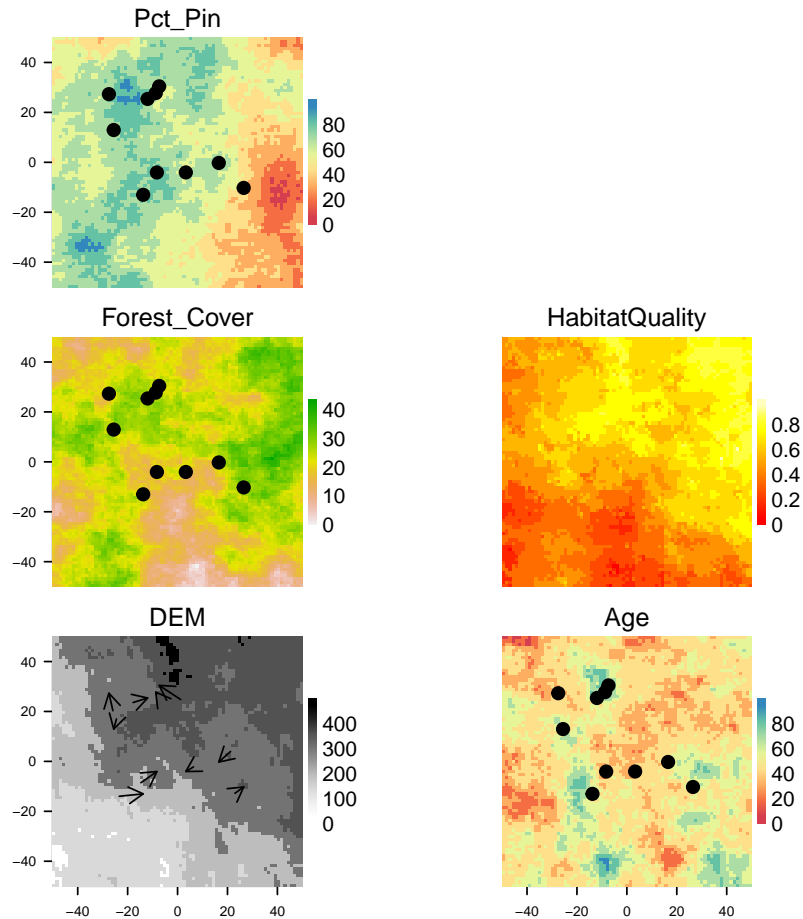
	x	y
Alice	-7.357724	30.4214478
Bob	-27.497599	27.3032919
Clark	-13.771989	-13.0097332
Daisy	-8.736794	27.7304971
Eric	3.314618	-4.0533017
Franz	-25.573490	12.9357876
Gabby	26.495074	-10.2524419
Hayley	-8.279154	-4.0691810
Igor	-12.002937	25.3864274
Jane	16.520854	-0.2535602

```
> ## conventional plotting method - agents don't plot properly when it is a raster stack
> #plot(habitat)
> #plot(caribou, add=TRUE)
```

```

>
> # convenient plotting using simPlot
> simPlot(habitat,col = cols[c(2:5,3)])
> simPlot(caribou,on.which.to.plot=c(2,3,5),pch=19,size=unit(0.1,"inches"))
> drawArrows(from = SpatialPoints(cbind(x=prevX,y=prevY)),
+           to = caribou,
+           on.which.to.plot = "DEM")

```



5 A simple fire model

Burn some of the forest Using the spread function, we can simulate fires, and subsequent changes to the various map layers

```

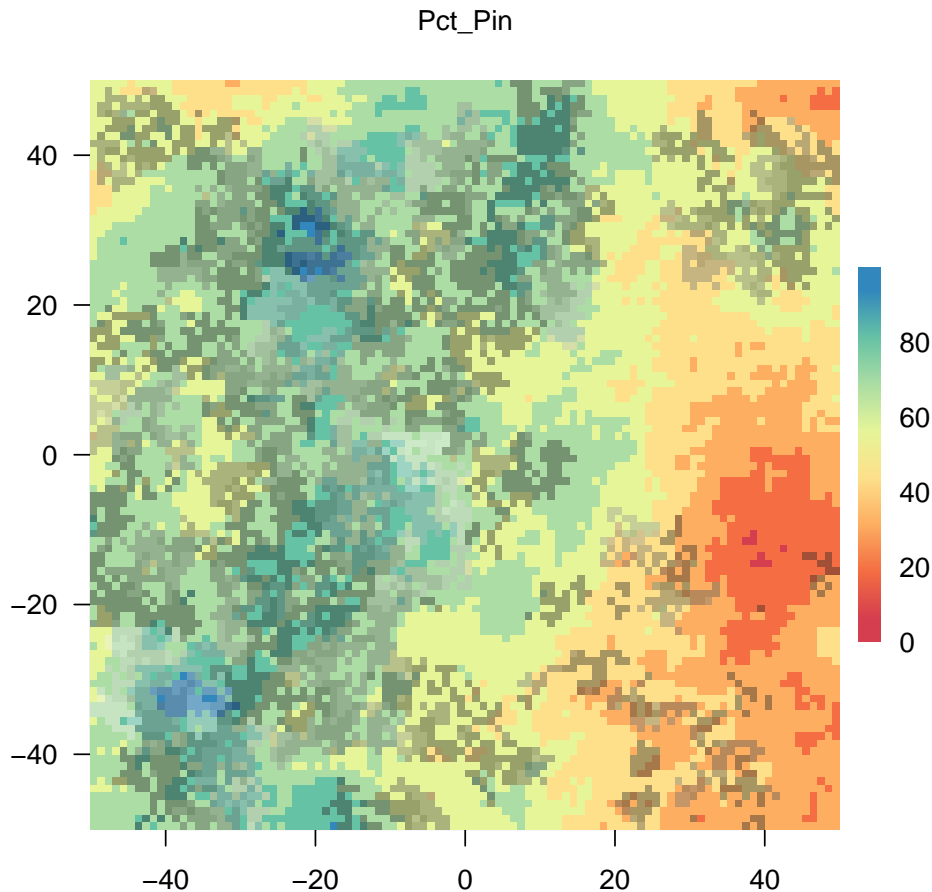
> nFires <- 100 # number of agents
> habitat[["Fires"]] <- spread(habitat[[1]],loci=as.integer(sample(1:ncell(habitat),nFires)),
+                             spreadProb = habitat[["Pct_Pin"]]/(maxValue(habitat[["Pct_Pin"]])*5)+0.1,
+                             persistance=0,
+                             mask = NULL,
+                             maxSize = 1e8,
+                             directions = 8,
+                             iterations=1e6,
+                             mergeDuplicates = T)

```

```

> # Show the burning more strongly over abundant pine
> simPlot(habitat[["Pct_Pin"]],col=cols[[3]])
> simPlot(habitat[["Fires"]],add=T,delete.previous=F,col=cols[[1]])

```



We can see that the fires tend to be in the Pines because we made it that way, using an arbitrary weighting with pine abundance

```

> # Show the burning more strongly over abundant pine
> fire<-reclassify(habitat[["Fires"]],rcl= cbind(0:1,c(0,100),0:1))
> pine<-reclassify(habitat[["Pct_Pin"]],rcl= cbind(0:9*10,1:10*10,0:9))
> PineByFire<-crosstab(fire,pine,long=T)
> colnames(PineByFire)<-c("fire","pine","freq")
> PineByFire$pine <- as.numeric(as.character(PineByFire$pine))
> summary(glm(freq ~ fire*pine, data=PineByFire,family="poisson"))

```

Call:

```
glm(formula = freq ~ fire * pine, family = "poisson", data = PineByFire)
```

Deviance Residuals:

Min	1Q	Median	3Q	Max
-33.511	-14.083	-2.176	8.025	25.961

Coefficients:

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	6.140263	0.026145	234.850	<2e-16 ***
fire1	-1.227184	0.051229	-23.955	<2e-16 ***
pine	0.043298	0.004640	9.332	<2e-16 ***
fire1:pine	0.177246	0.007969	22.242	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for poisson family taken to be 1)

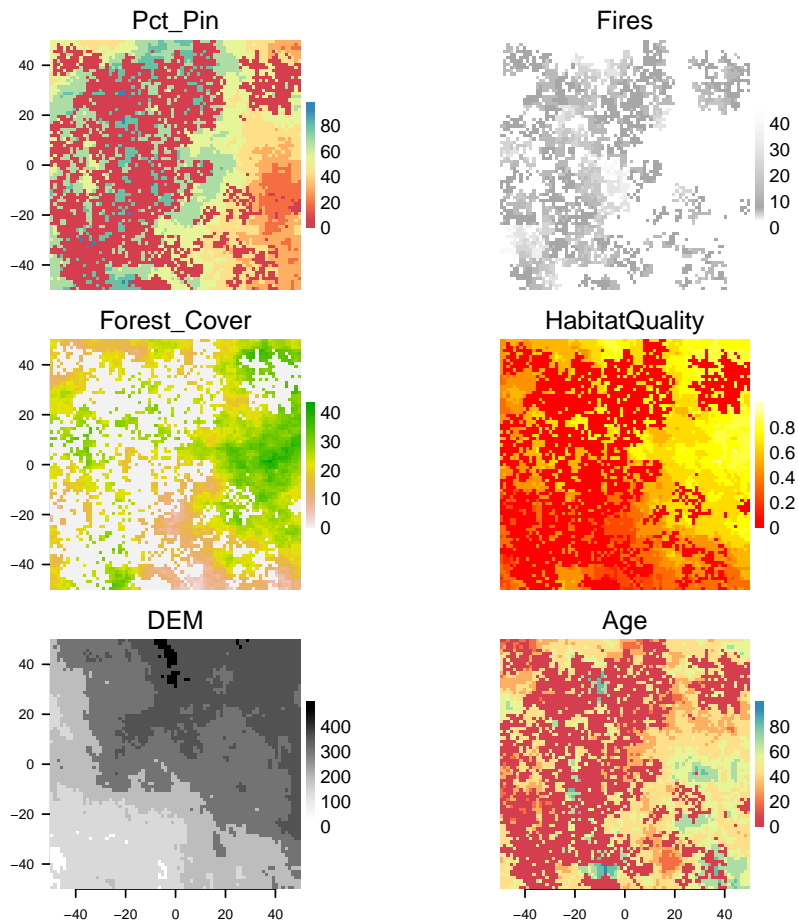
Null deviance: 7155.9 on 18 degrees of freedom
Residual deviance: 5723.9 on 15 degrees of freedom
AIC: 5874.8

Number of Fisher Scoring iterations: 5

Sure enough, there are more fires as the abundance of pine goes up, as seen by the positive interaction term (the negative fire1 term means that there are more pixels without fires than with fires).

Impact some of the forest

```
> habitat[["Age"]][habitat[["Fires"]]>0] <- 0
> habitat[["Forest_Cover"]][habitat[["Fires"]]>0] <- 0
> habitat[["HabitatQuality"]][habitat[["Fires"]]>0] <- 0.1
> habitat[["Pct_Pin"]][habitat[["Fires"]]>0] <- 0
> simPlot(habitat,col = cols[c(2:5,3,1)])
```



6 A simple individual based model (IBM)

Move some agents Using a simple habitat dependent correlated random walk, simulate the movement of caribou across a heterogeneous landscape. Because we had just had fires, and we assume that fires have a detrimental effect on animal movement, we can see the long steps taken in the new, low quality, post-burn sections of the landscape.

```
> simPlot(habitat[["HabitatQuality"]],col = cols[[3]])
> for (i in 1:10) {
+
+   #crop any caribou that went off maps
+   caribou <- crop(caribou,habitat)
+   drawArrows(from =
+               SpatialPoints(cbind(x=caribou$prevX,y=caribou$prevY)),
+               to = caribou,length=0.04,
+               on.which.to.plot = 1)
+
+   # find out what pixels the individuals are on now
+   ex = habitat[["HabitatQuality"]][caribou]
+
+   #step length is a function of current cell's habitat quality
```

```

+ sl = 0.25/ex
+
+ ln = rlnorm(length(ex), sl, 0.02) # log normal step length
+ sd = 30 # could be specified globally in params
+
+ caribou <- crw(caribou, stepLength=ln, stddev=sd, lonlat=FALSE)
+
+ }

```

