Introduction to `SpaDES`

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1 Spatial Discrete Event Simulation (SpaDES)

Requirements This packages 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
```

```
Note: no visible binding for global variable 'to'
Note: no visible global function definition for 'J'
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Note: no visible binding for global variable 'to'
```

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

2 SpaDES modules

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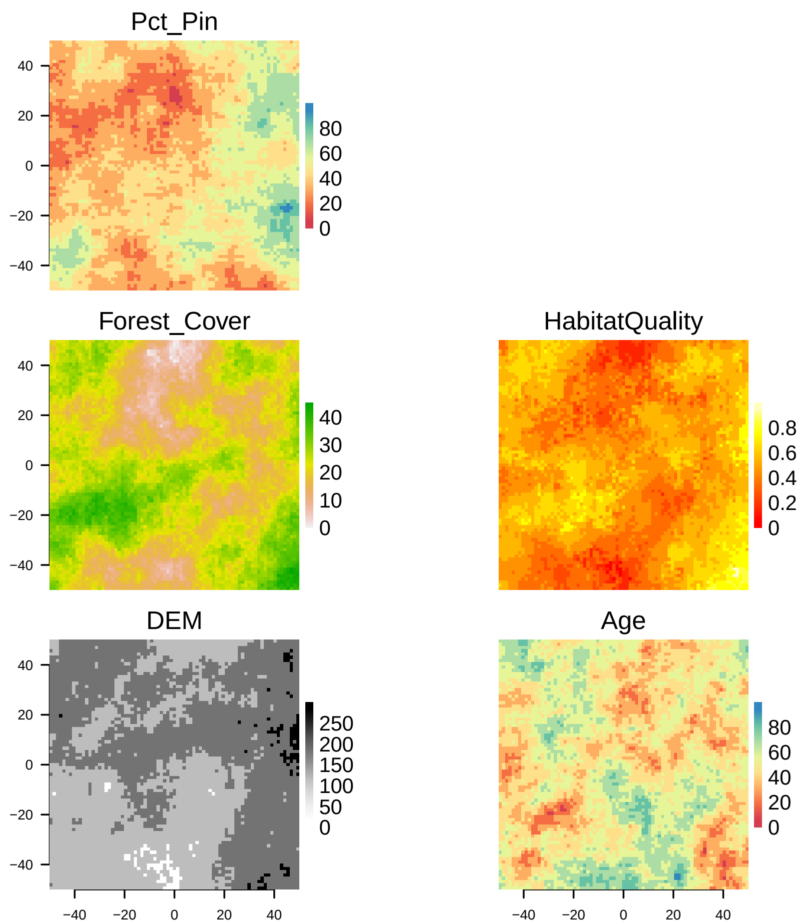
3 Working with maps

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_Pin")
> 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)])
```


Pct_Pin
Forest_Cover
HabitatQuality
DEM
Age

4 Simulating "agents"

4.1 Spatial agents

4.1.1 Point agents

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

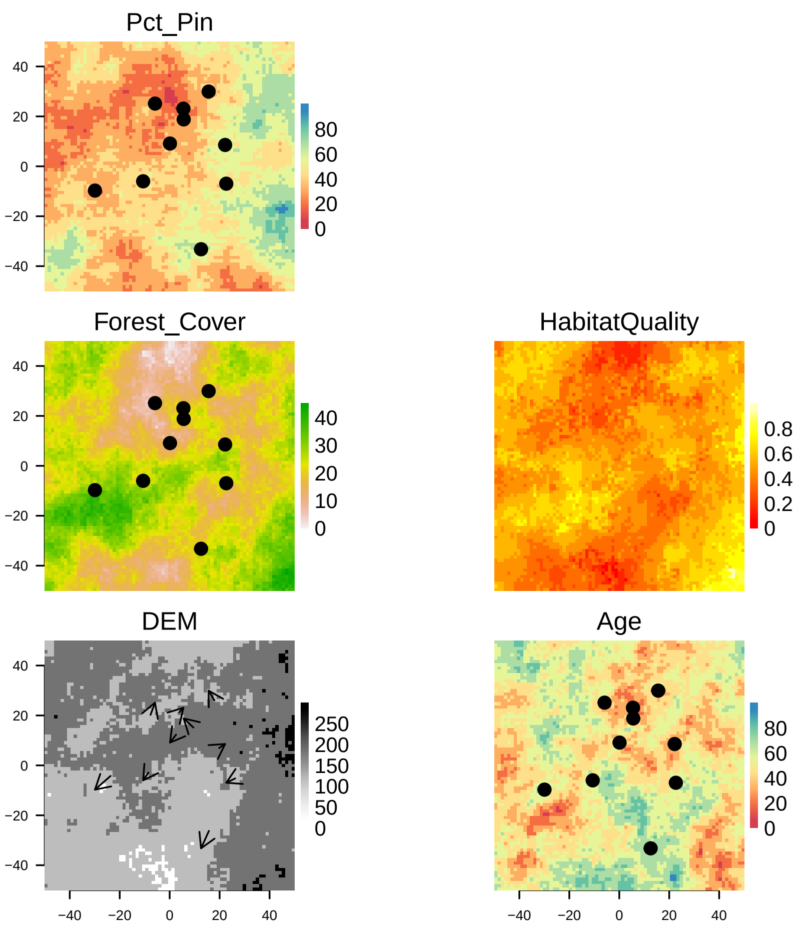
Use a `SpatialPointsDataFrame` with additional columns as needed.

Non-mobile point agents e.g., plants

Mobile point agents e.g., animals use a `SpatialPointsDataFrame`, with additonal 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 l
> prevY <- runif(N, ymin(habitat)+(nrow(habitat)*0.2), ymax(habitat)-(nrow(habitat)*0.2)) # previous Y l
> # 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
217.16423 214.35058 313.08274  20.10693 329.57014 204.27571  42.89194  56.16321
     Igor      Jane
244.11175 228.76567

> coordinates(caribou)

                 x          y
Alice    0.1294032   9.115847
Bob    -10.6222364  -6.001149
Clark    5.6244262  18.800759
Daisy   -5.8734923  25.134108
Eric    15.5981518  29.945377
Franz   12.5689870 -33.224213
Gabby    5.4981422  23.091096
Hayley  22.2043170   8.558081
Igor    22.6617411  -6.961075
Jane   -29.9194073  -9.720533

> ## 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")
```

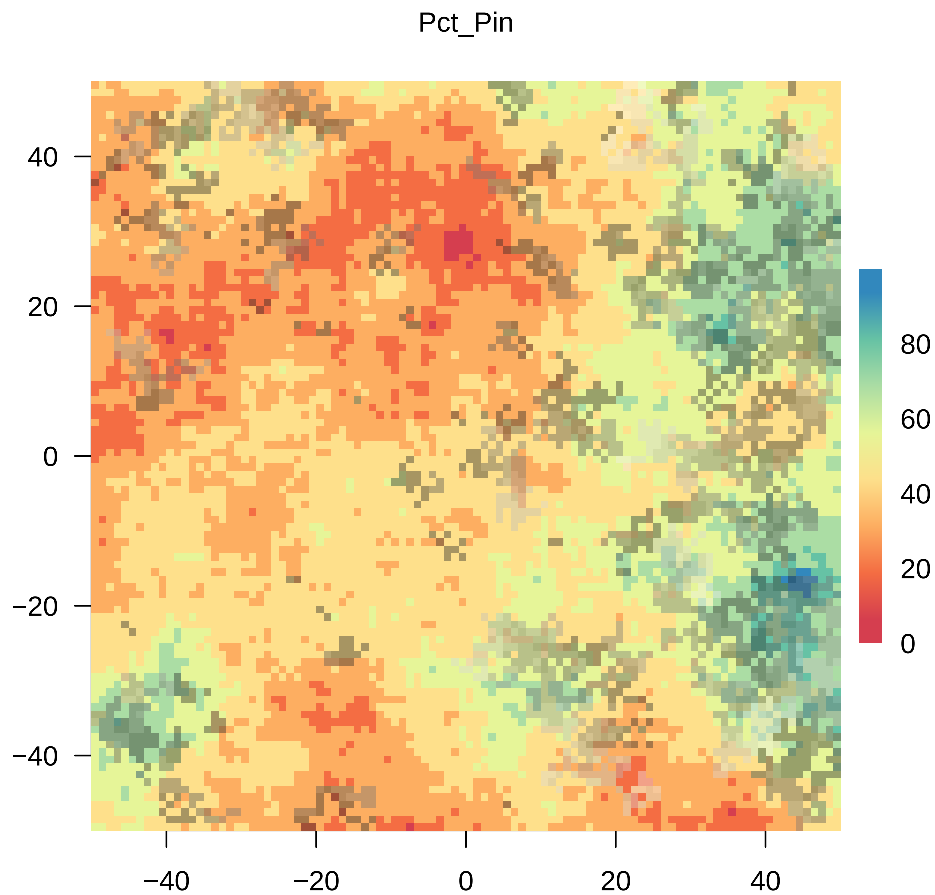


5 A simple fire model

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

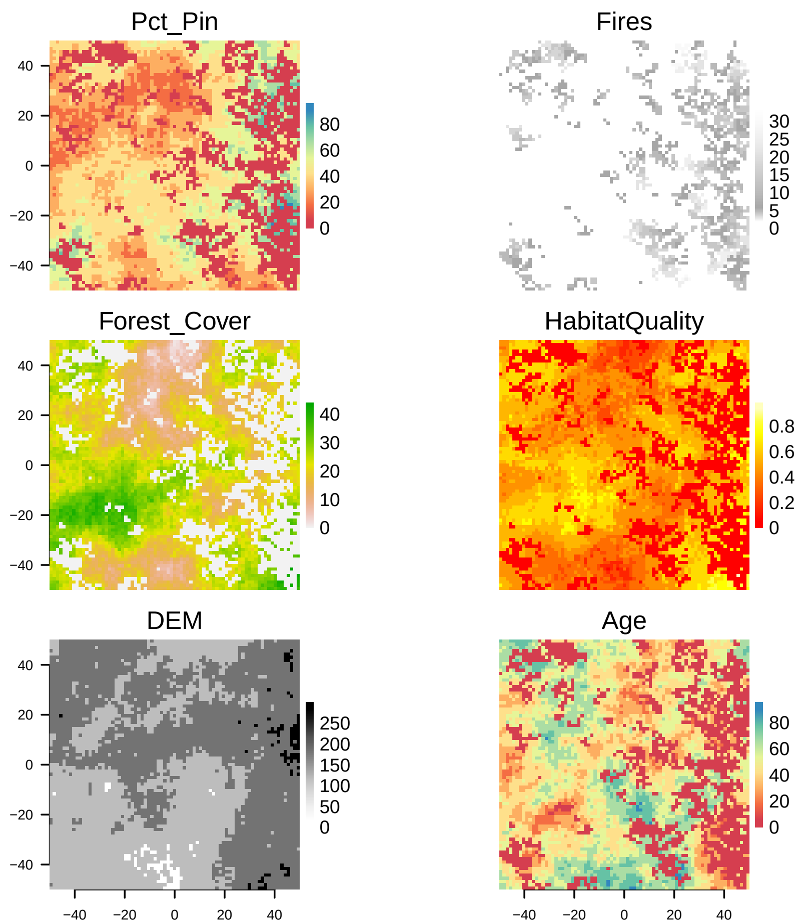
```
> # Show the burning more strongly over abundant pine
> fire<-reclassify(habitat[["Fires"]],rcl= cbind(0:1,c(0,100),0:1))
> pine<-reclassify(habitat[["Pct_Pin"]],rcl= cbind(0:9*10,1:10*10,0:9))
> PineByFire<-crosstab(fire,pine,long=T)
> colnames(PineByFire)<-c("fire","pine","freq")
> PineByFire$pine <- as.numeric(as.character(PineByFire$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
-45.318  -19.024   -1.776   10.046   34.105
```

```
Coefficients:
             Estimate Std. Error z value Pr(>|z|)    
(Intercept)  7.131320   0.018632  382.75   <2e-16 ***
fire1       -1.654289   0.041623  -39.74   <2e-16 ***
pine        -0.134100   0.004242  -31.61   <2e-16 ***
fire1:pine   0.155818   0.007999   19.48   <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: 11729.5  on 19  degrees of freedom
Residual deviance:  8360.1  on 16  degrees of freedom
AIC: 8507.9

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 depedent correlated random walk, simulate the movement of caribou across a heterogeneous 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)
+
+ }
```