NeutralLandscapes.jl: a library for efficient generation of neutral landscapes with temporal change

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Last revision: *January 7, 2022*

Soon to be a paper, maybe. TK authors, MKB,VB,RS,TP

Introduction

Neutral landscapes are increasingly used in ecological and evolutionary studies to provide a null expectation spatial variation of a given measurement. Originally developed to simulate the spatially autocorrelated data (Gardner *et al.* 1987; Milne 1992), the have seen use in a wide range of disciplines: from landscape genetics (Storfer *et al.* 2007), to landscape and spatial ecology (Tinker *et al.* 2004; Remmel & Fortin 2013), and biogeography (Albert *et al.* 2017).

The two primary packages used to simulate neutral landscapes are `NLMR` in (the `R` language) (Sciaini *et al.* 2018) and `NLMpy` (in Python; Etherington *et al.* 2015). We present `NeutralLandscapes.jl`, a package in `Julia` for neutral landscapes which is faster than both above package. Here we demonstrate that `NeutralLandscapes.jl`, depending on the method, is orders of magnitude faster than previous neutral landscape packages. As biodiversity science becomes increasingly concerned with temporal change and its consequences, its clear there is a gap in methodology in generating neutral landscapes that change over time. In addition we present a novel method for generating landscape change with prescribed levels of spatial and temporal autocorrelation, which is implemented in `NeutralLandscapes.jl`

Software Overview

This software can generate neutral landscapes using several methods, enables masking and works with other julia packages.

fig. 1 shows a replica of Figure 1 from Etherington *et al.* (2015), which shows the capacity of the library to generate different types of neutral landscapes, and then apply masks and categorical classifcation to them.

[Figure 1 about here.]

Interoperability

Ease of use with other julia packages

Mask of neutral variable masked across quebec in 3 lines.

```
using NeutralLandscapes
```

```
using SimpleSDMLayers

quebec = SimpleSDMPredictor(WorldClim, BioClim; left=-90., right=-50., top=75., bottom=40.)
qcmask = fill(true, size(quebec))
qcmask[findall(isnothing, quebec.grid)] .= false

pltsettings = (cbar=:none, frame=:box)

plot(
    heatmap(rand(MidpointDisplacement(0.8), size(layer), mask=qcmask); pltsettings),
    heatmap(rand(PlanarGradient(), size(layer), mask=qcmask); pltsettings),
    heatmap(rand(PerlinNoise((4,4)), size(layer), mask=qcmask); pltsettings),
    heatmap(rand(NearestNeighborCluster(0.5), size(layer), mask=qcmask); pltsettings),
    dpi=400
)
```

[Figure 2 about here.]

Benchmark comparison to `nlmpy` and `NLMR`

It's fast. As the scale and resolution of raster data increases, neutral models must be able to scale to match those data dimensions. Here we provide two benchmark tests. First a comparison of the speed variety of methods from each `NeutralLandscapes.jl`, `NLMR`, and `nlmpy`. Second we compare these performance of each of these software packages as rasters become larger. We show that `Julia` even outperforms the `NLMR` via C++ implemention of a particularly slow neutral landscape method (midpoint displacement).

[Figure 3 about here.]

Generating dynamic neutral landscapes

We implement methods for generating change that are temporally autocorrelated, spatially autocorrelated, or both.

$M_t = M_{t-1} + f(M(t-1))$

Models of change

Directional

Temporally autocorrelation

r: rate, v: variability, U matrix of draws from standard Normal$(0, 1)$

$f_T(M_{ij}) = r + vU_{ij}$

Spatial autocorrelation

r: rate, v: variability, $[Z(\delta)]_{ij}$: the (i, j) entry of the zscore of the δ matrix

$f_S(M_{ij}) = r + v \cdot [Z(\delta)]_{ij}$

Spatiotemporal autocorrelation

$f_{ST}(M_{ij}) = r + v \cdot [Z(\delta)]_{ij}$

Rescaling to mimic real data

Discussion

References

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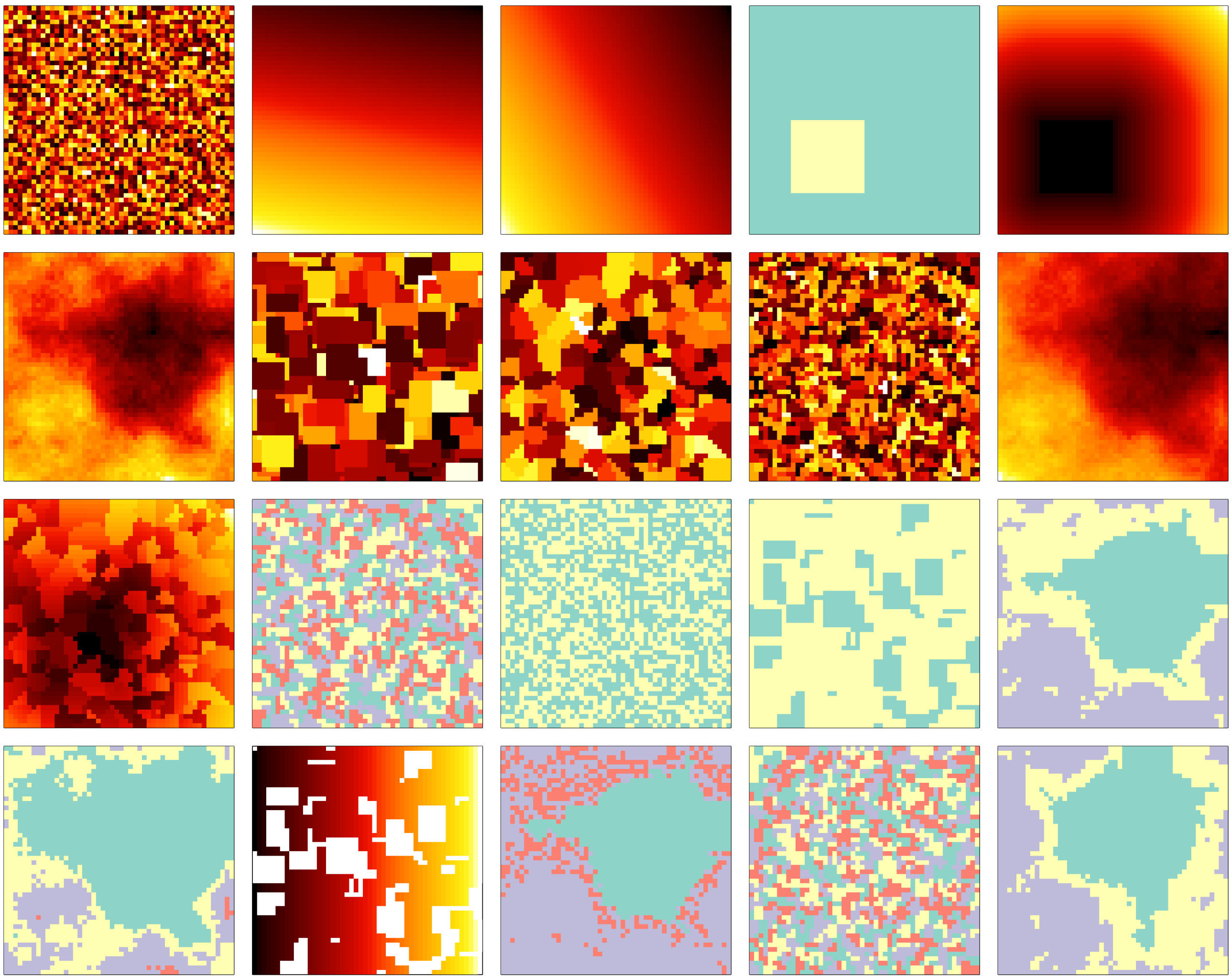

Figure 1: Recreation of the figure in `nlmpy` paper and the source, supplied in less than 40 lines of code.

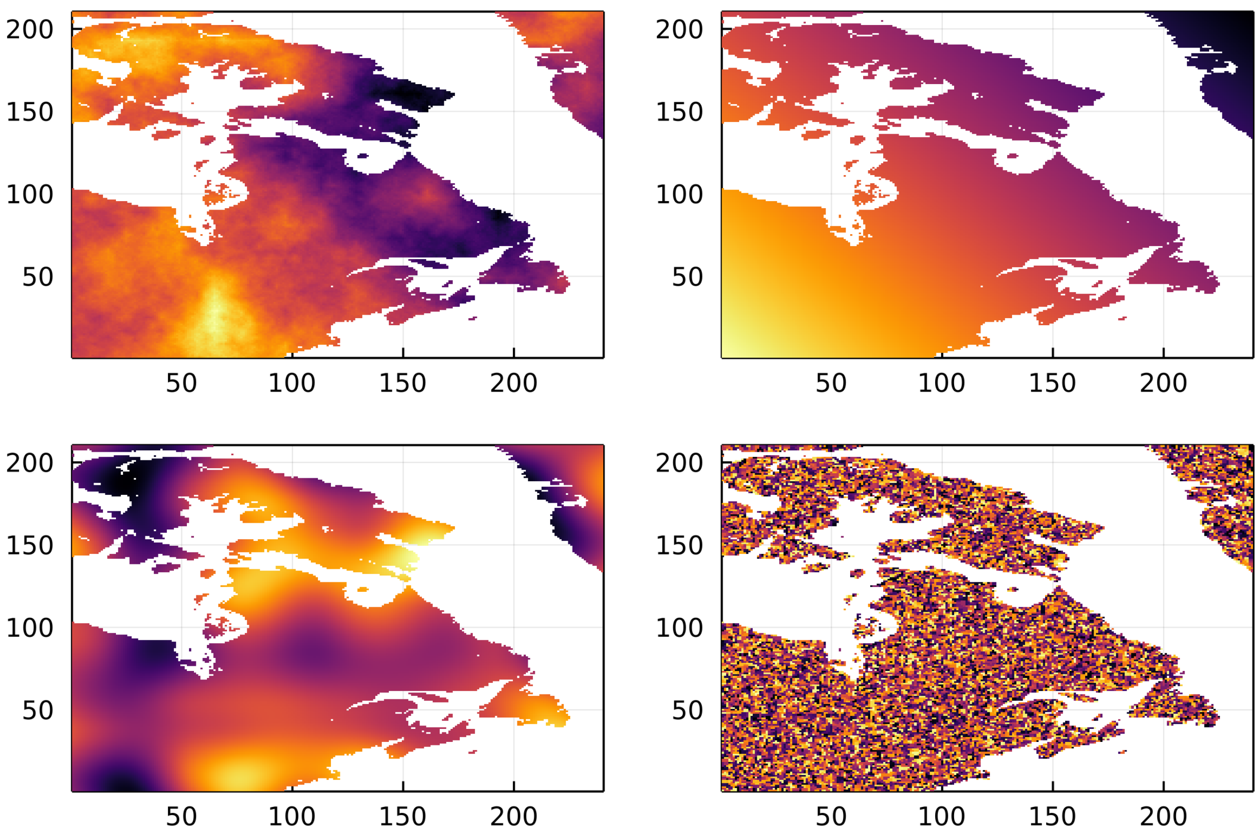

Figure 2: todo

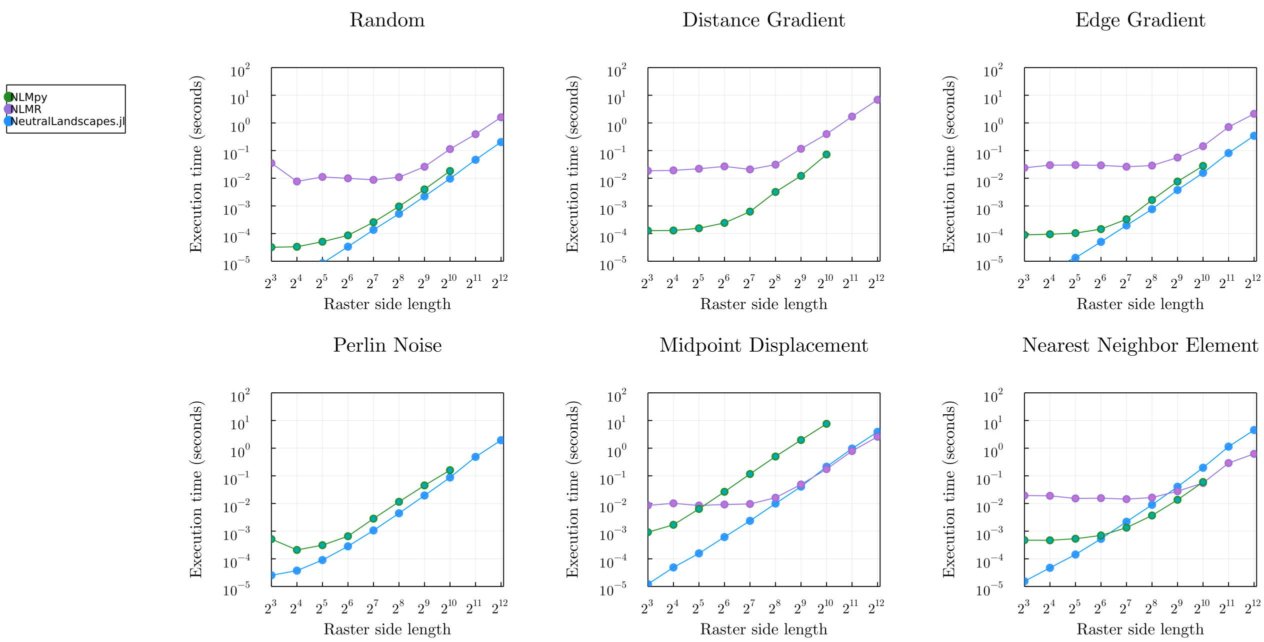

Figure 3: todo