Simulating fMRI Data with Realistic Noise using neuRosim

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Why an fMRI simulation package?

Simulation is often used as method to know the ground truth of the data and is a cheap and fast alternative for invasive procedures like iEEG.

Existing fMRI simulation studies use - almost exclusively - ad-hoc methods and in-house software routines, probably due to the non-existence of validated methods and the lack of widely-available simulators.

What can you do with neuRosim?

* specify your experimental design based on the stimulus onsets
* specify activated regions using an xyz-coordinate system

* simulate BOLD activation with the choice of different models
* simulate resting state activation (still under development)
* simulate fMRI noise accounting for different noise sources

* generate fMRI data from time series to 4D data

How is neuRosim organized?

Low-level functions are the building blocks of neuRosim and are intended for advanced users who want in-depth control over their simulated data.

Activation functions

```
stimfunction()
specifydesign()
specifyregion()

canonicalHRF()
gammaHRF()
```

Noise functions

```
systemnoise()
temporalnoise()
spatialnoise()
lowfreqdrift()
physnoise()
tasknoise()
```

High-level functions can simulate fMRI data directly.

Preparation functions

```
simprepTemporal()
simprepSpatial()
```

Simulation functions

```
simTSfmri()
simVOLfmri()
simRestingStatefmri()
```

Example: setting up the design

We consider the data from a repetition priming experiment performed using event-related fMRI (Henson et al. 2002).
* 2x2 factorial design
* famous vs non-famous faces
* effect of repetition

Setting up the temporal parameters (onsets and durations should be in list-format):

```
nscan <- 351
TR <- 2
total.time <- nscan*TR
onsets.N1 <- c(6.75, 15.75, 18, 27, 29.25, 31.5, 36, 42.75, 65.25, 74.25,
    92.25, 112.5, 119.25, 123.75, 126, 137.25, 141.75, 144, 146.25,
    155.25, 159.75, 162, 164.25, 204.75, 238.5)*TR
onsets.N2 <- c(13.5, 40.5, 47.5, 56.25, 90, 94.5, 96.75, 135, 148.5, 184.5,
    191.25, 202.5, 216, 234, 236.25, 256.5, 261, 281.25, 290.25, 303.75,
    310.5, 319.5, 339.75, 342)*TR
onsets.F1 <- c(0, 2.25, 9, 11.25, 22.5, 45, 51.75, 60.75, 63, 76.5, 78.75,
    85.5, 99, 101.25, 103.5, 117, 130.5, 150.75, 171, 189, 227.25,
    265.5, 283.5, 285.75, 288, 344.25)*TR
onsets.F2 <- c(33.75, 49.5, 105.75, 153, 157.5, 168.75, 177.75, 180,
182.25,
    198, 222.75, 240.75, 254.25, 267.75, 270, 274.4, 294.75, 299.25,
301.5,
    315, 317.25, 326.25, 333, 335.25, 337.5, 346.5)
```

Setting up the spatial parameters to define 5 activated regions:

```
region.1A.center <- c(13, 13, 11)
region.1A.radius <- 4
region.1B.center <- c(40, 18, 9)
region.1B.radius <- 6
region.1C.center <- c(10, 45, 24)
region.1C.radius <- 3
region.2.center <- c(15, 16, 31)
region.2.radius <- 5
region.3.center <- c(12, 16, 13)
region.3.radius <- 5
onsets.regions <- list(onsets, onsets, onsets, onsets, onsets)
dur.regions <- list(dur, dur, dur, dur, dur)
```

Defining the effect size per condition for each region:

```
region.1a.d <- list(160.46, 140.19, 200.16, 160.69)
region.1b.d <- list(140.51, 120.71, 160.55, 120.44)
region.1c.d <- list(120.53, 120.74, 104.02, 100.48)
region.2.d <- list(-0.24, 10.29, 80.18, 160.24)
region.3.d <- list(200.81, 50.04, 240.6, 50.83)
effect <- list(region.1a.d, region.1b.d, region.1c.d, region.2.d,
```

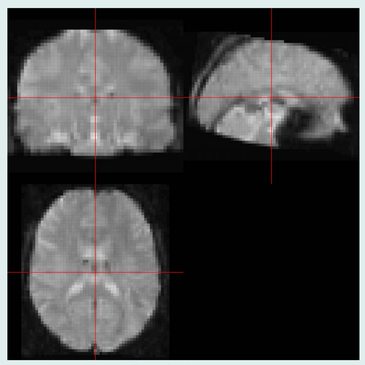
Example: simulating the data

First, we prepare the temporal and spatial structure of our simulated 4D fMRI data using the preparation functions of neuRosim.

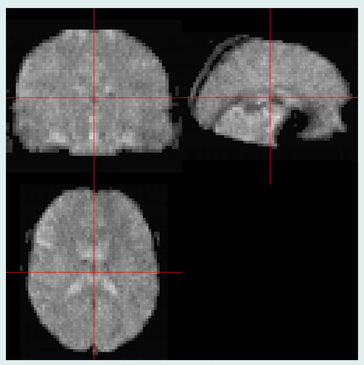
```
design <- simprepTemporal(regions = 5,
  onsets = onsets.regions, durations = dur.regions,
  hrf="double-gamma", TR = TR, totaltime = total.time,
  effectsize = effect)

spatial <- simprepSpatial(regions = 5,
  coord = list(region.1A.center, region.1B.center,
  region.1C.center, region.2.center, region.3.center),
  radius = c(region.1A.radius, region.1B.radius,
  region.1C.radius, region.2.radius, region.3.radius),
  form = "sphere", fading = 0.01)
```

Finally, we can generate the dataset. Note that the values for the SNR and temporal autocorrelation coefficients were estimated based on the real data.

```
sim.data <- simVOLfmri(design = design, image = spatial,
  base = baseline, SNR = 3.87, noise = "mixture",
  type = "rician", rho.temp = c(0.142, 0.108, 0.084),
  rho.spat = 0.4, w = c(0.05, 0.1, 0.01, 0.09, 0.05, 0.7),
  dim = c(53, 43, 46), nscan = 351, vee= 0,
  spat = "gaussRF", template = baseline.bin)
```



Real data



Simulated data

Technicalities

* neuRosim is available for all platforms (Linux, Mac, Windows)
* The Beta version can be downloaded from CRAN (http://cran.r-project.org)
* Including documentation in the form of help pages

References

Henson et al. (2002). Face Repetition Effects in Implicit and Explicit Memory Tests as measured by fMRI. Cerebral Cortex, 12, 178-186

Welvaert et al. (accepted). neuRosim: An R Package for Generating fMRI Data. Journal of Statistical Software.

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