Imaging Packages in R

Some packages we will use

All packages we will discuss are loaded on the RStudio Server:

- `oro.nifti` - reading/writing NIfTI images
    - made the `nifti` object/data class: like an array - but with header information
        - the main data class we will use
- `neurobase` - extends `oro.nifti` and provides helpful imaging functions

Let’s load them:

```
library(oro.nifti)
library(neurobase)
```

Reading in NIfTI images: assignment

We will use the `readnii` function (from `neurobase`) to read in a `nifti` object (this is an `R` object).

Here we read in the “training01_01_t1.nii.gz” file, and assign it to an object called `t1`:

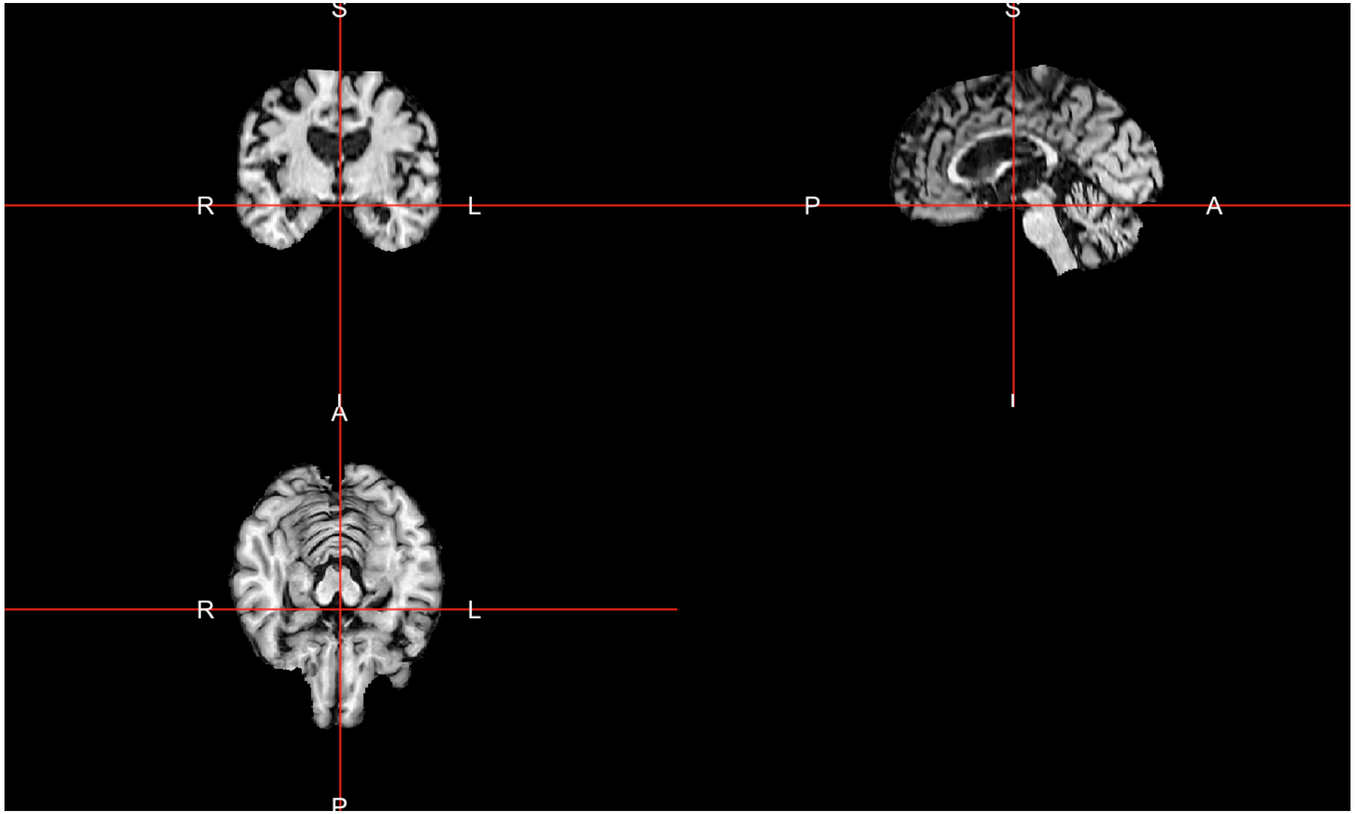
```
t1 = readnii("training01_01_t1.nii.gz")
```

Now, an object `t1` is in memory/the workspace.

```
class(t1)
```

```
[1] "nifti"
attr(,"package")
[1] "oro.nifti"
```

`nifti` images



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`nifti` images

By default, if you simply pass the object, it is printed, we can also do `print(t1)`:

```
t1
```

```
NIfTI-1 format
  Type            : nifti
  Data Type       : 16 (FLOAT32)
  Bits per Pixel  : 32
  Slice Code      : 0 (Unknown)
  Intent Code     : 0 (None)
  Qform Code      : 1 (Scanner_Anat)
  Sform Code      : 0 (Unknown)
  Dimension       : 192 x 512 x 512
  Pixel Dimension : 0.8 x 0.47 x 0.47
  Voxel Units     : mm
  Time Units      : Unknown
```

Operations with **`nifti`** objects

These work with an image and a number (`img + 2`) or two images of the same dimensions `img1 + img2`.

- Comparison: `>`, `>=`, `<`, `<=`, `==` (equals), `!=` (not equal)
- Logical: `!` - not, `&` - and, `|` - or (a “pipe”)
- Arithmetic: `+`, `-`, `*`, `/`, `^` - exponents
- Standard math functions: `log`, `abs`, `sqrt`

```
t1 + t1 + 2 # still a nifti
```

```
NIfTI-1 format
  Type            : nifti
  Data Type       : 16 (FLOAT32)
  Bits per Pixel  : 32
  Slice Code      : 0 (Unknown)
  Intent Code     : 0 (None)
  Qform Code      : 1 (Scanner_Anat)
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  Dimension       : 192 x 512 x 512
  Pixel Dimension : 0.8 x 0.47 x 0.47
  Voxel Units     : mm
  Time Units      : Unknown
```

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Working with `nifti` objects

Again, we can use a logical operation. Let's create an image indicating values over 400:

```
class(t1 > 400) # still a nifti
```

```
[1] "nifti"
attr(,"package")
[1] "oro.nifti"
```

```
head(t1 > 400) # values are now logical vs. numeric
```

```
[1] FALSE FALSE FALSE FALSE FALSE FALSE
```

We will refer to images such as `t1 > 400` as a "mask", simply binary images with logical values in them (or 0s and 1s)

Subsetting with `nifti` objects: like `arrays`

The subsetting here is similar to that of arrays. Since `t1` is 3-dimensional the subsetting goes to the 3rd dimension:

```
t1[5, 4, 3]
```

```
[1] 0
```

```
t1[5, 4, ] # returns a vector of numbers (1-d)
t1[, 4, ] # returns a 2-d matrix
t1[1, , ] # returns a 2-d matrix
```

- You can subset with a logical array of the same dimensions!
- We can view values of the `t1` greater than 400 (`head` only prints the first 6 values):

```
head(t1[ t1 > 400 ]) # produces a vector of numbers
```

```
[1] 409.0842 414.6199 416.8652 430.9107 413.1289 422.2794
```

`which` with `nifti` objects

The `which` function works to get indices, but you can pass the `arr.ind = TRUE` argument to get "array" indices:

```
head(which(t1 > 400, arr.ind = TRUE))
```

```
     dim1 dim2 dim3
[1,]  129  376  179
[2,]  128  377  179
[3,]  128  378  179
[4,]  134  251  194
[5,]  135  251  194
[6,]  135  252  194
```

But can get the "vector" indices as well:

```
head(which(t1 > 400, arr.ind = FALSE))
```

```
[1] 17570241 17570432 17570624 19020806 19020807 19020999
```

Working with `nifti` objects: reassignment

Subsetting can work on the left hand side of assignment too:

```
t1_copy = t1
t1_copy[ t1_copy > 400 ] = 400 # replaced these values!
max(t1_copy) # should be 400
```

```
[1] 400
```

```
max(t1)
```

```
[1] 829.8354
```

Note, although `t1_copy` was copied from `t1`, they are not linked - if you change values in `t1_copy`, values in `t1` are unchanged.

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Writing Images out

We now can write out this modified `t1_copy` image:

```
writenii(nim = t1_copy,
         filename = "training01_t1_under400.nii.gz")
file.exists("training01_t1_under400.nii.gz")
```

```
[1] TRUE
```

We have seen that `file.exists` returns `TRUE` if a file exists

- useful in conjunction with `all`: `all(file.exists(VECTOR_OF_FILES))`

Vectorizing a `nifti`

To convert a `nifti` to a `vector`, you can simply use the `c()` function:

```
vals = c(t1)
class(vals)
```

```
[1] "numeric"
```

Essentially “strings out” the array. If you do `array(c(t1), dim = dim(t1))`, this will put things back “in order” of the `t1`.

Vectorizing is useful for making `data.frames` (covered later) when you want to do modeling at a voxel level.

```
df = data.frame(t1 = c(t1), mask = c(t1 > 400)); head(df)
```

```
  t1  mask
1  0 FALSE
2  0 FALSE
3  0 FALSE
4  0 FALSE
5  0 FALSE
6  0 FALSE
```

File helpers - for constructing filenames

Use `paste` if you want to put strings together with spaces, `paste0` no spaces by default.

`file.path(directory, filename)` will paste `directory` and `filename` w/file separators (e.g. `/`)

```r
c(paste("img", ".nii.gz"), paste0("img", ".nii.gz"))
```

```
[1] "img .nii.gz" "img.nii.gz"
```

```r
x = file.path("output_directory", paste0("img", ".nii.gz")); print(x)
```

```
[1] "output_directory/img.nii.gz"
```

`nii.stub` will strip off the nifti extension. If `bn = TRUE`, it removes the directory as well:

```r
c(nii.stub(x), nii.stub(x, bn = TRUE))
```

```
[1] "output_directory/img" "img"
```

Main Packages we will use

- `oro.nifti` - reading/writing NIfTI images
- `neurobase` - extends `oro.nifti` and provides helpful imaging functions
- `fslr` - wraps FSL commands to use in R
    - registration, image manipulation, skull stripping
- `ANTsR` - wrapper for Advanced normalization tools (ANTs) code
    - registration, inhomogeneity correction, lots of tools
- `extrantsr` - allows `ANTsR` to work with objects from `oro.nifti`

Data Package we will use

- `ms.lesion` - contains training/testing data of patients with multiple sclerosis (MS)
    - from an open MS MRI data set (Lesjak et al. 2017)

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Conclusions

- We have (briefly) covered some R data classes and types to get you started
- We will be using `nifti` objects
    - They are special 3-dimensional arrays
    - Contain numbers or logicals
- `readnii` and `writenii` are used for reading/writing `nifti` objects to NIfTI files
- We have briefly covered subsetting and image manipulation
    - more on that later

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Website

http://johnmuschelli.com/imaging_in_r

Lesjak, Žiga, Alfiia Galimzianova, Aleš Koren, Matej Lukin, Franjo Pernuš, Boštjan Likar, and Žiga Špiclin. 2017. “A Novel Public MR Image Dataset of Multiple Sclerosis Patients with Lesion Segmentations Based on Multi-Rater Consensus.” . Springer, 1–13.