

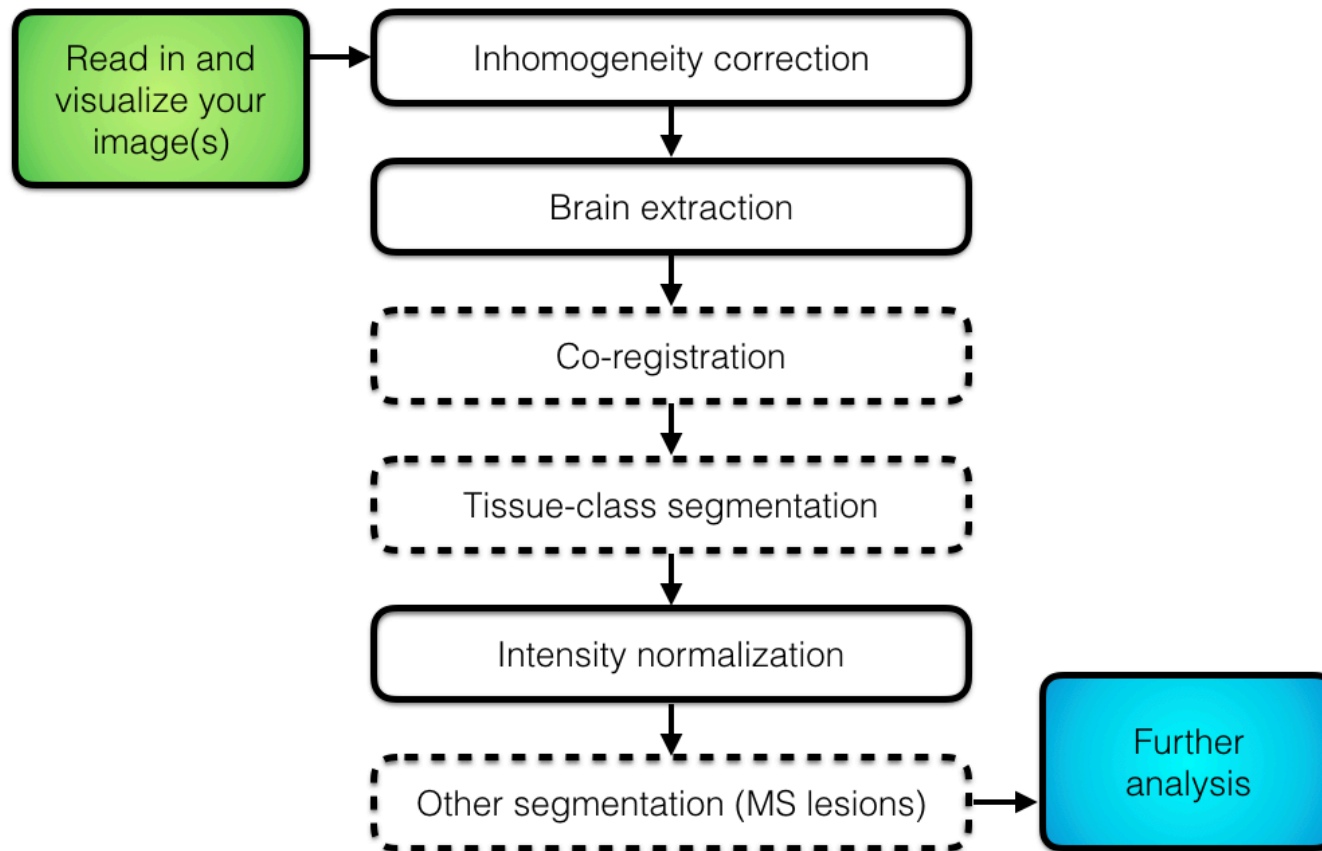
Inhomogeneity Correction

MS Lesion

Let's reset and read in the T1 image from a MS lesion data set:

```
t1 = neurobase::readnii("training01_01_mprage.nii.gz")
```

Overall Pipeline



Inhomogeneity correction

- Scans can have nonuniform intensities throughout the brain
- Usually low frequency - smooth over the brain (assumed)
- Referred to as bias, bias field, or inhomogeneity

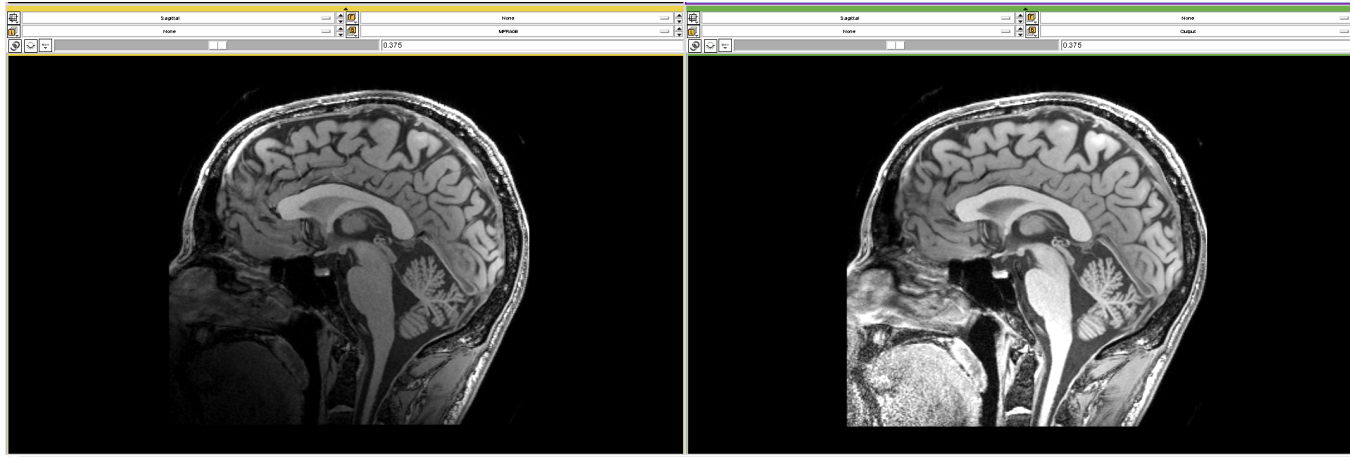


Image From

https://www.slicer.org/w/images/7/77/MRI_Bias_Field_Correction_Slicer3_close_up.png

Image Data

It's hard to see subtler bias fields, but sometimes they can be seen visually.

```
ortho2(robust_window(t1))
```

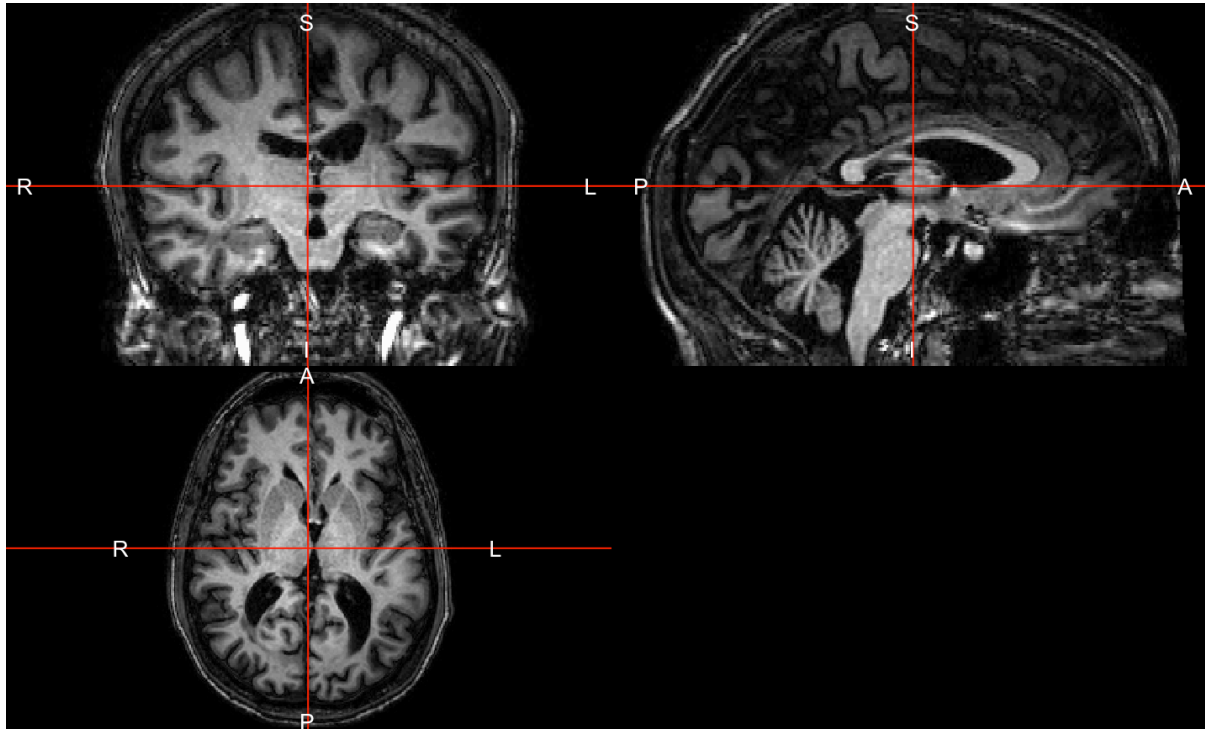
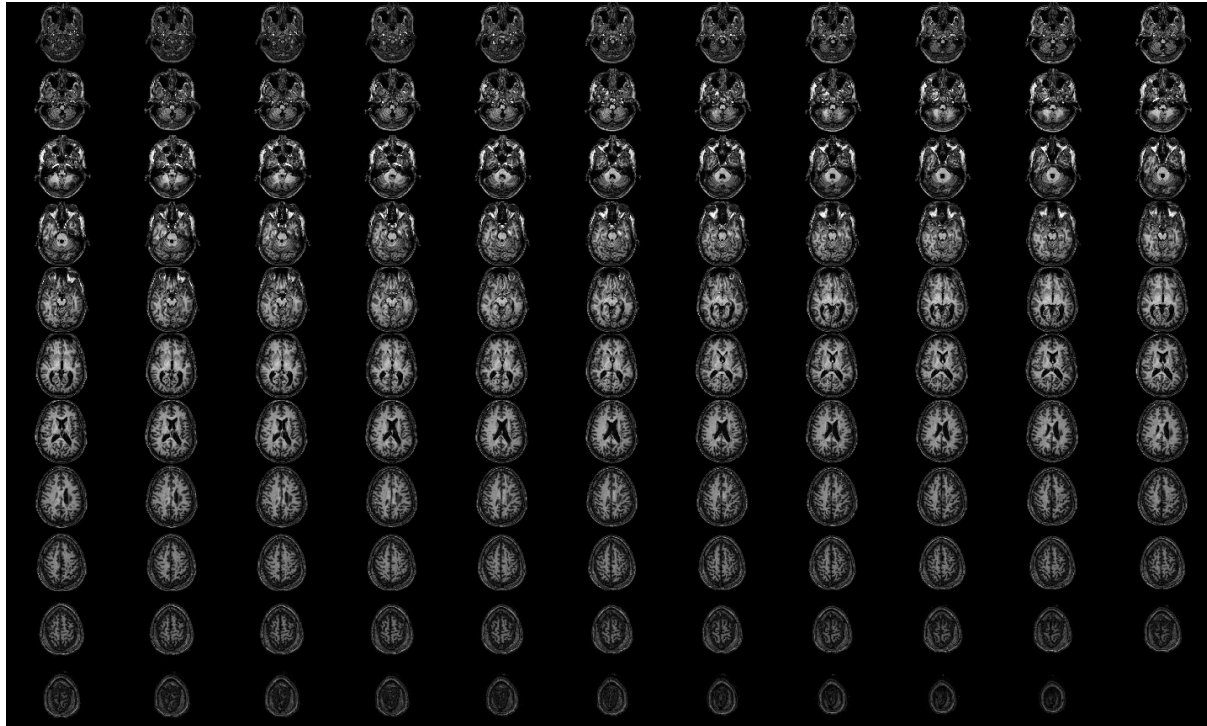


Image Data: Lightbox

```
image(robust_window(t1), useRaster = TRUE)
```



N4 Inhomogeneity Correction

We will use N4: Improved N3 Bias Correction (Tustison et al. 2010).

The model assumed in the N4 is:

$$v(x) = u(x)f(x) + n(x)$$

- v is the given image
- u is the uncorrupted image
- f is the bias field
- n is the noise (assumed to be independent and Gaussian)
- x is a location in the image

N4 Inhomogeneity Correction

The data is log-transformed and assuming a noise-free scenario, we have:

$$\log(v(x)) = \log(u(x)) + \log(f(x))$$

- N4 uses a B-spline approximation of the bias field
- It iterates until a convergence criteria is met
 - when the updated bias field is the same as the last iteration
- It outputs the data back in the original units (not log-transformed)

Bias Field Correction

Here we will use the `bias_correct` function in `extrantsr`, which calls `n4BiasFieldCorrection` from ANTsR.

You can pass in the image:

```
library(extrantsr)
bc_t1 = bias_correct(file = t1, correction = "N4")
```

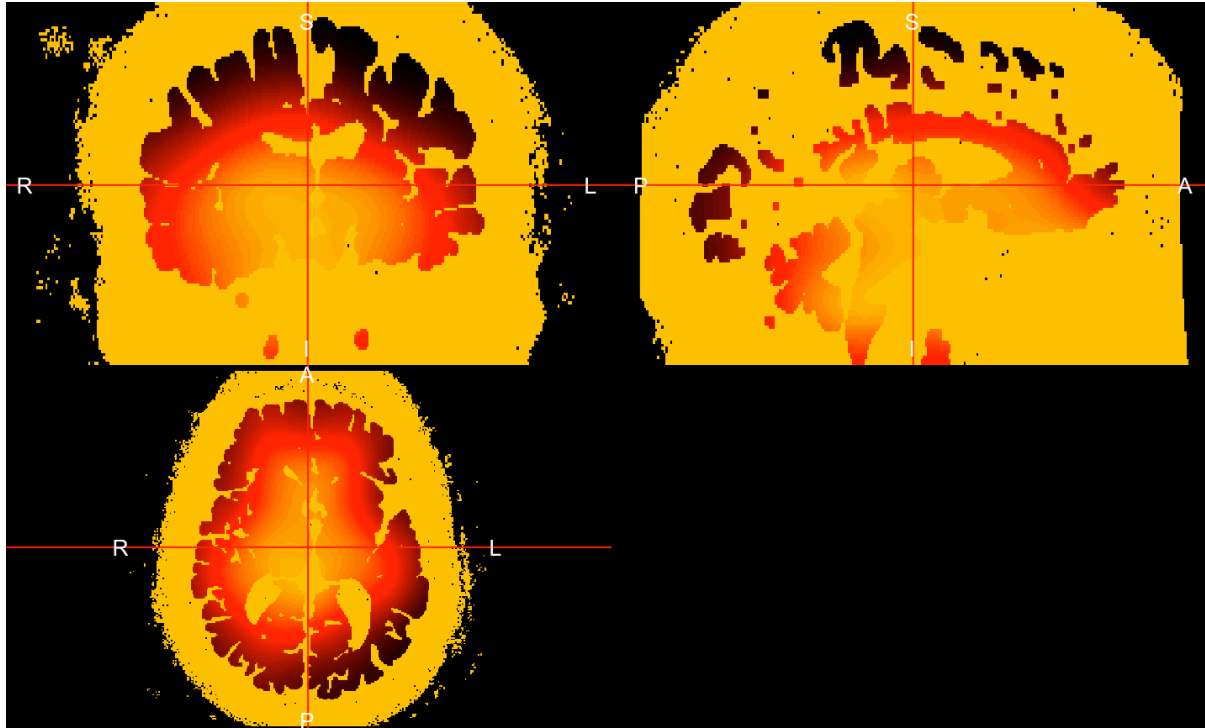
or the filename:

```
bc_t1 = bias_correct(file = "training01_01_mprage.nii.gz", correction = "N4")
```

Visualizing Bias Field Correction

Here we take the ratio of the images and overlay it on the original image:

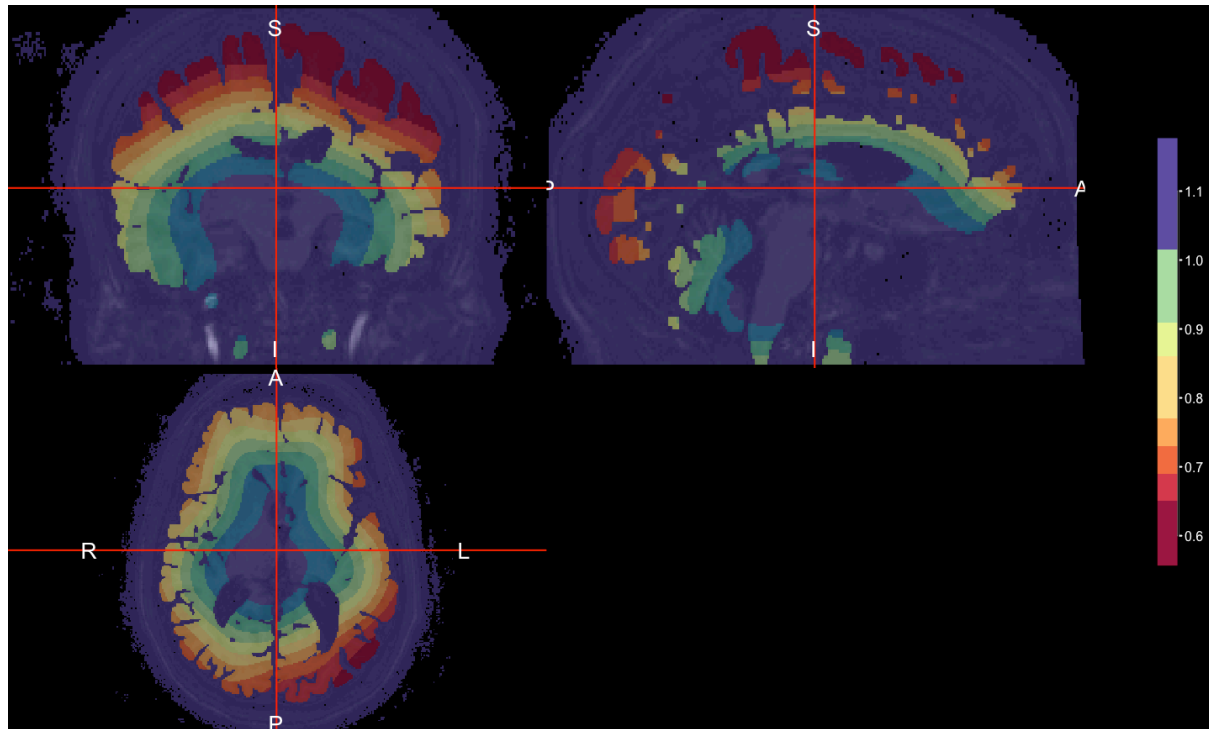
```
ratio = t1 / bc_t1; ortho2(t1, ratio)
```



Visualizing Bias Field Correction

We are breaking the ratio into quantiles:

```
ortho2(t1, ratio, col.y = colors, ybreaks = quants, ycolorbar = TRUE)
```



Conclusions

- Inhomogeneity correction is one of the first steps of most structural MRI pipelines
- Inhomogeneity can cause problems for other methods/segmentation
- Corrections try to make tissues of the same class to have similar intensities
- Use the `extrantsr bias_correct` function
 - There is also `fsl_biascorrect` from `fslr` (not as effective in our experience)
- You may also want to run corrections after skull stripping on the brain only
 - this is possible with the result after the brain extraction lecture
 - correction before skull-stripping may be necessary and can improve after correction

Website

http://johnmuschelli.com/imaging_in_r

References

Tustison, Nicholas J., Brian B. Avants, Philip A. Cook, Yuanjie Zheng, Alexander Egan, Paul A. Yushkevich, and James C. Gee. 2010. "N4ITK: Improved N3 Bias Correction." *IEEE Transactions on Medical Imaging* 29 (6): 1310–20. doi:[10.1109/TMI.2010.2046908](https://doi.org/10.1109/TMI.2010.2046908).