ALZHEIMER'S ASSOCIATION®

AAIC 23

ALZHEIMER'S ASSOCIATION INTERNATIONAL CONFERENCE®

JULY 16-20 > AMSTERDAM, NETHERLANDS, AND ONLINE

ISTAART Neuroimaging PIA
THE BASICS OF NEUROIMAGING SEMINAR SERIES

ISTAART Neuroimaging PIA

The Basics of Neuroimaging Series

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BASICS OF NEUROIMAGING

DATA STRUCTURE AND FORMATS

DR LUDOVCA GRIFFANTI

UNIVERSITY OF OXFORD, UK

@ludogriffanti

GOALS

By the end of this session you should be able to:

- Describe the main **properties of medical images**
- Identify the main **steps of a neuroimaging study**
- Understand **how neuroimaging data are visualized** at different steps of the analysis pipeline

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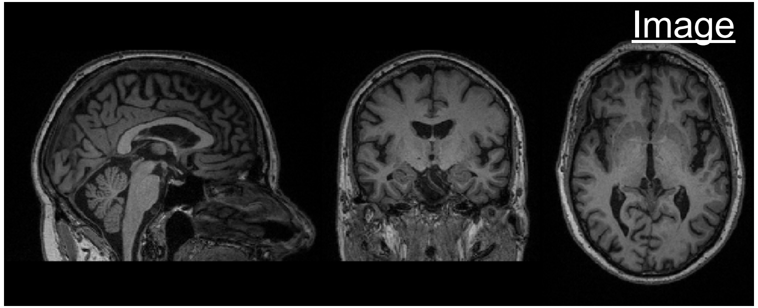
PROPERTIES OF MEDICAL IMAGING DATA



+

Header

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qto_xyz:2	-0.000059 0.999844 -0.017685 -88.219193
qto_xyz:3	0.032771 0.017677 0.999307 -94.454788
qto_xyz:4	0.000000 0.000000 0.000000 1.000000
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qform_yorient	Posterior-to-Anterior
qform_zorient	Inferior-to-Superior
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sto_xyz:4	0.000000 0.000000 0.000000 1.000000
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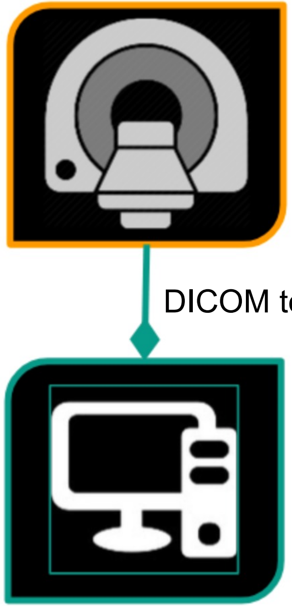
Image formats



"Raw" Scanner File Format
Example: DICOM

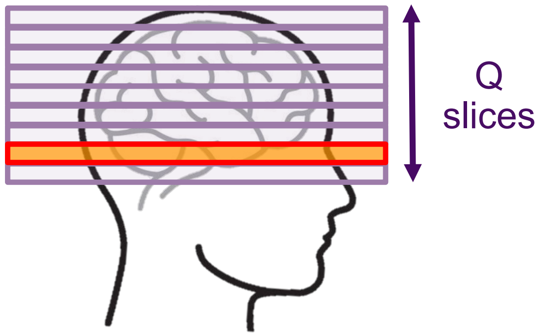
DICOM to NIFTI conversion (e.g. dcm2niix)

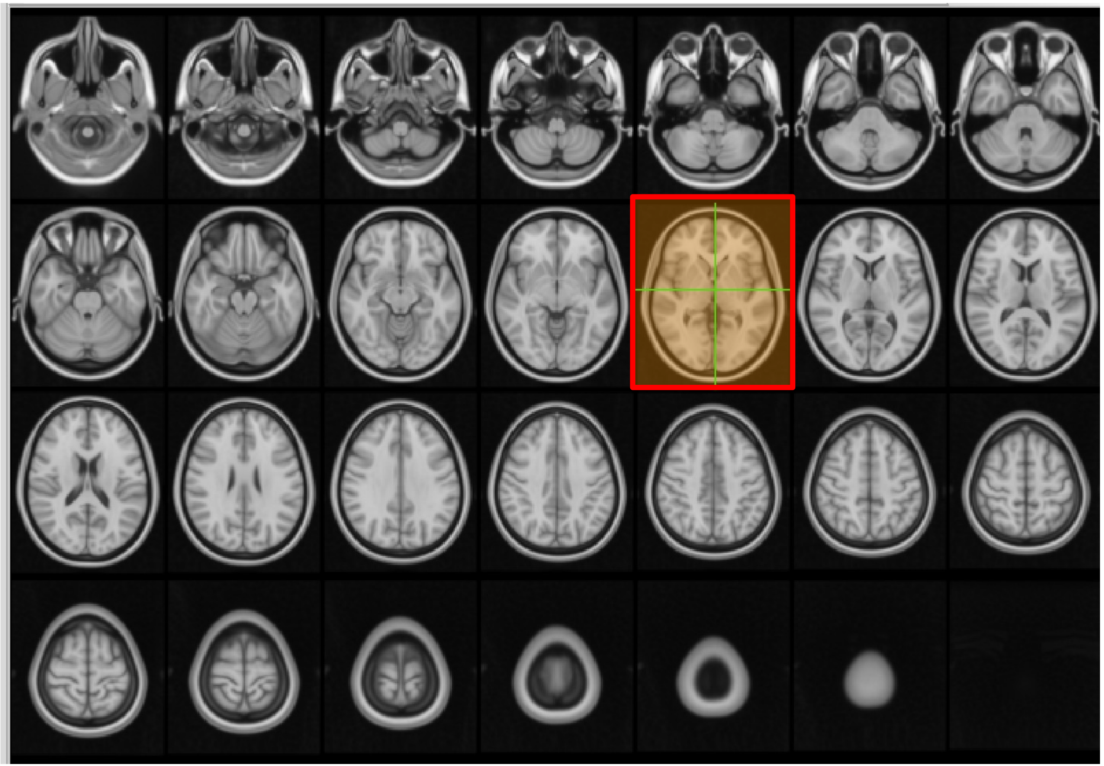
Analysis File Format
Example: **NIfTI** (**N**euroimaging **I**nformatics **T**echnology **I**nitiative)

https://carpentries-incubator.github.io/SDC-BIDS-IntroMRI/index.html

PROPERTIES OF MEDICAL IMAGING DATA

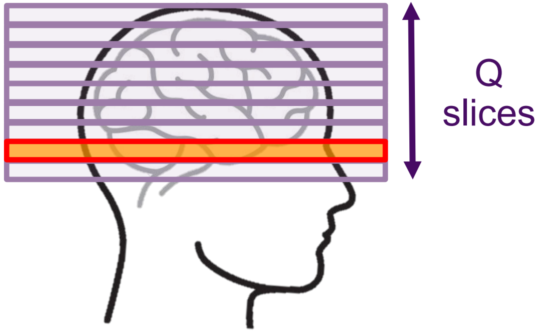
Image = cube of numbers

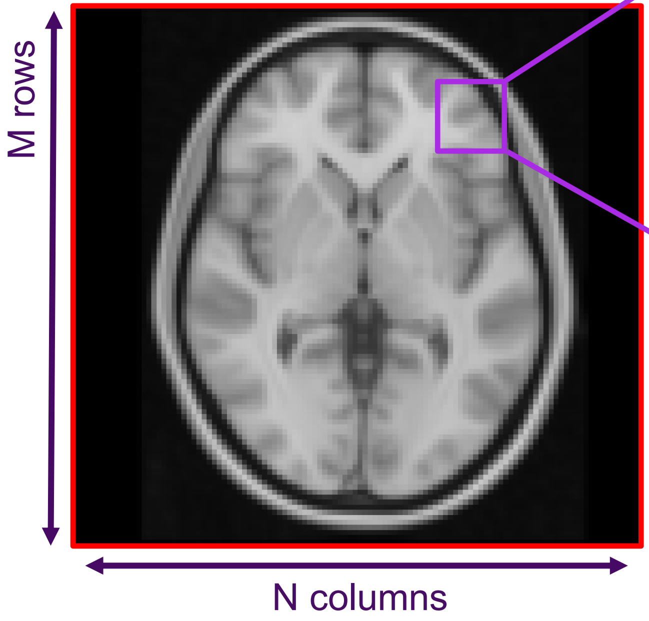


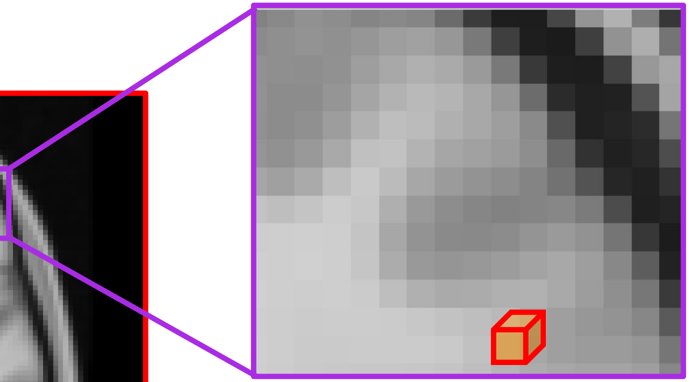


PROPERTIES OF MEDICAL IMAGING DATA

Image = cube of numbers





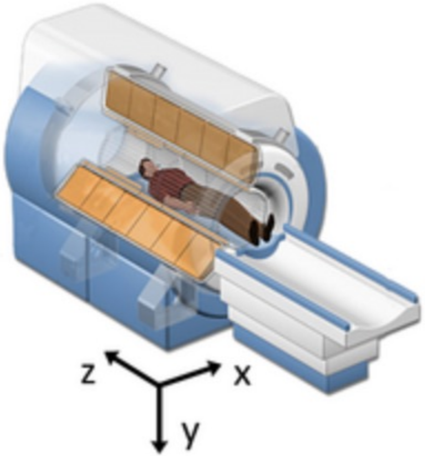


VOXEL (volumetric pixel)

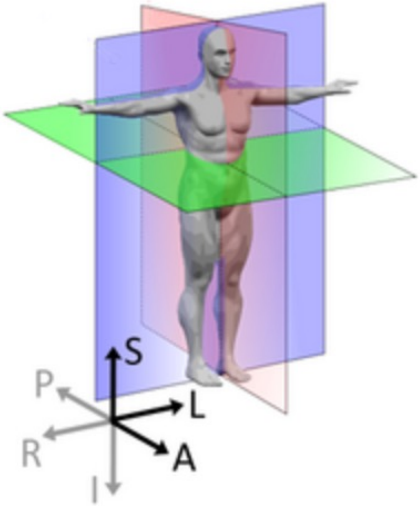
Image resolution =
voxel size in mm

PROPERTIES OF MEDICAL IMAGING DATA

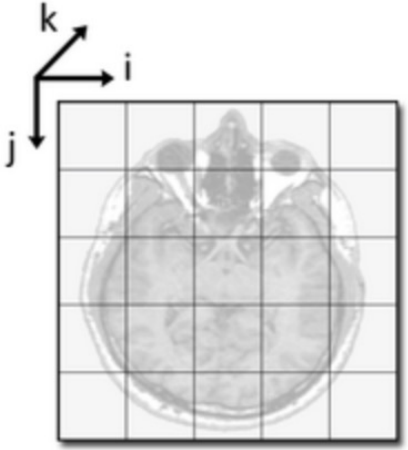
Coordinate systems



Scanner coordinates



Subject coordinates



Voxel coordinates

IMAGE COORDINATES & IMAGE REGISTRATION

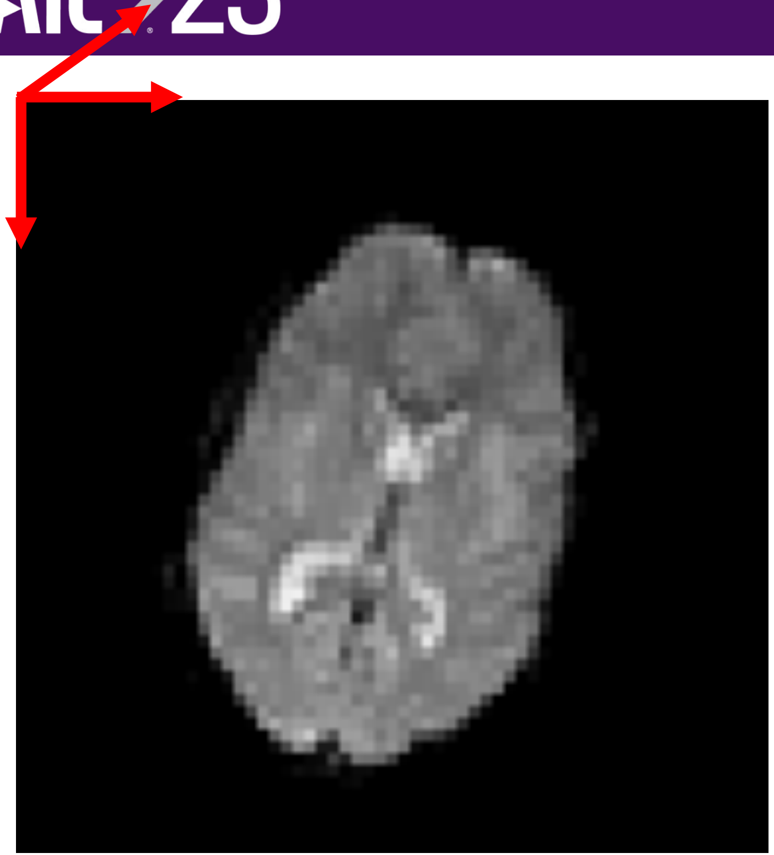


IMAGE COORDINATES & IMAGE REGISTRATION

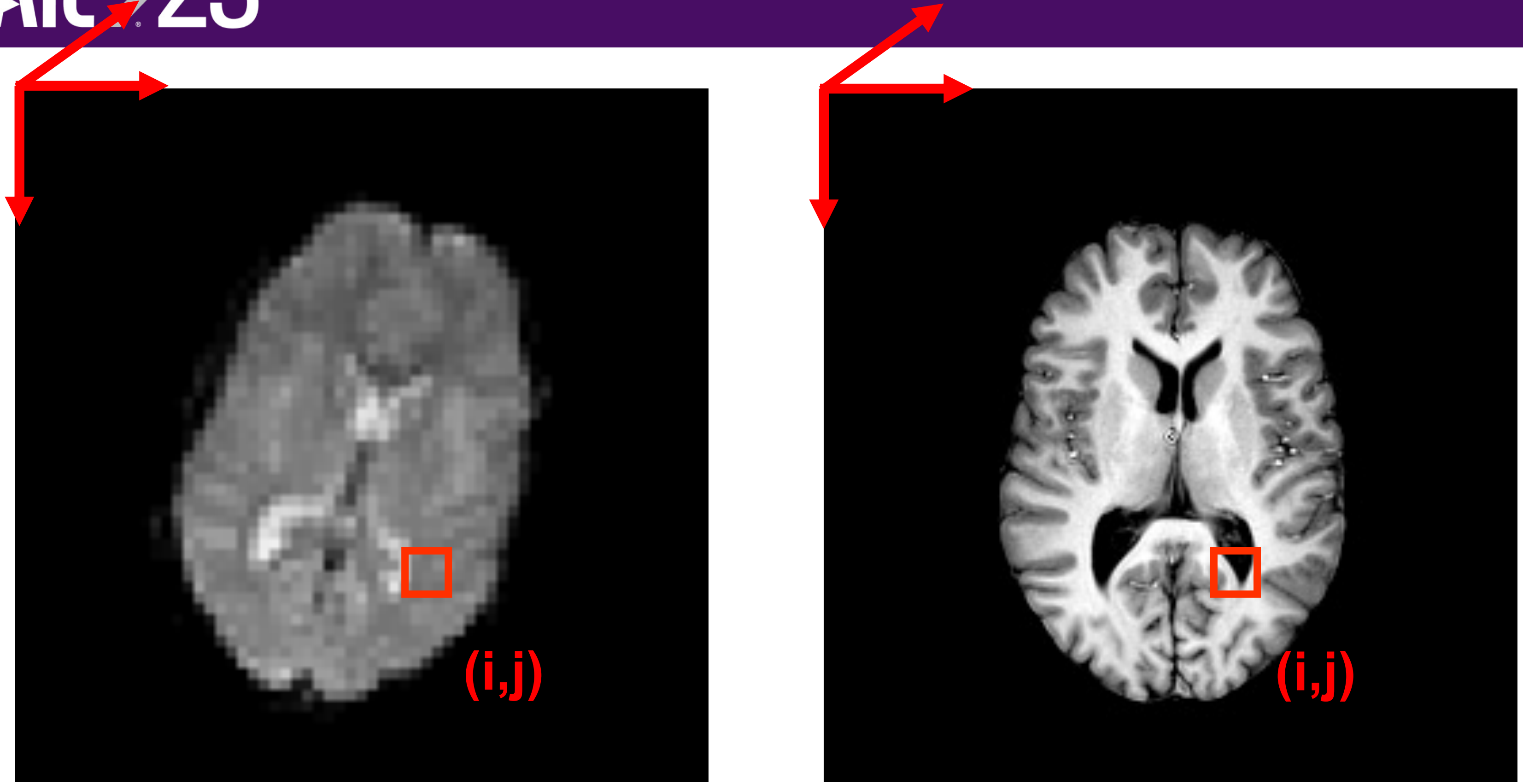
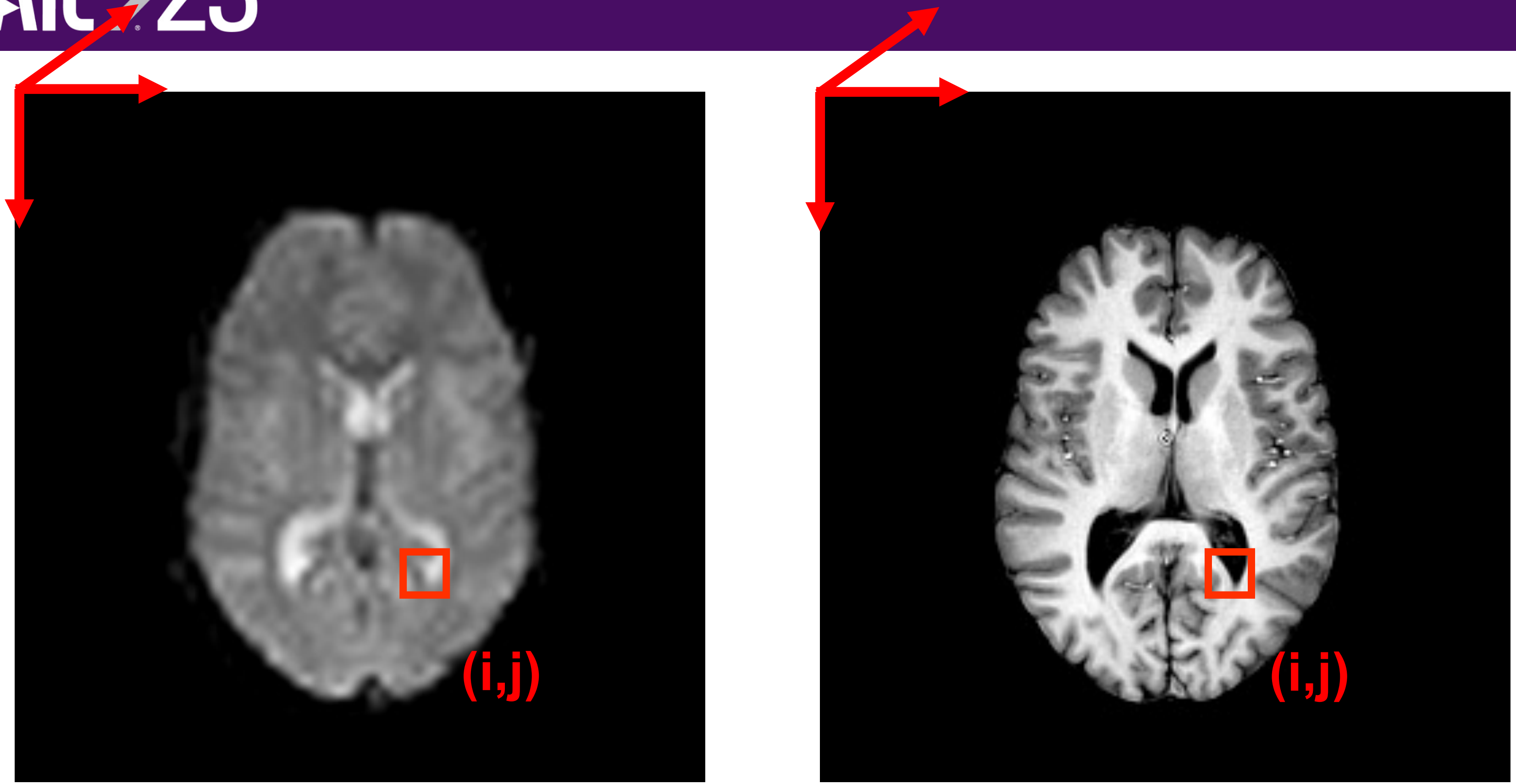


IMAGE COORDINATES & IMAGE REGISTRATION



INTRODUCTION TO IMAGE REGISTRATION

- Registration: the process of aligning images so that the same voxel in the image corresponds to the same anatomical location in the brain. (i.e. finding a one-to-one map between all points in one image and another)
- **Terminology** varies depending on software and type of transformation applied to the images (Synonyms: coregistration, alignment, normalization)

- Input Image
- Moving Image
- Source Image
- Deformed Image

- Reference image
- Stationary Image
- Target Image
- Fixed Image

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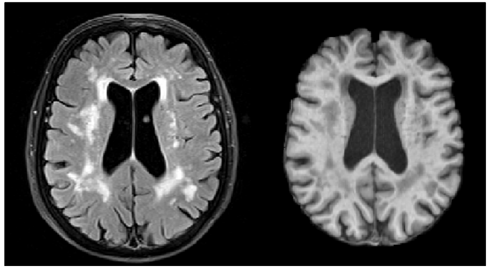
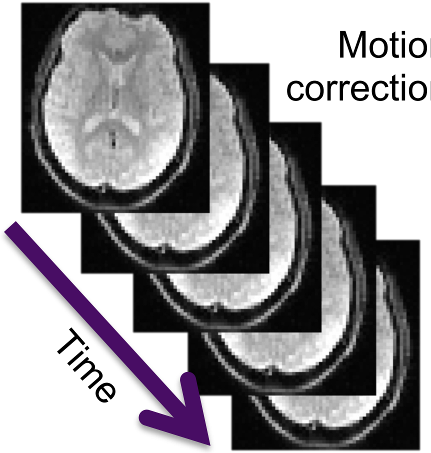
INTRODUCTION TO IMAGE REGISTRATION

Within-subject & session

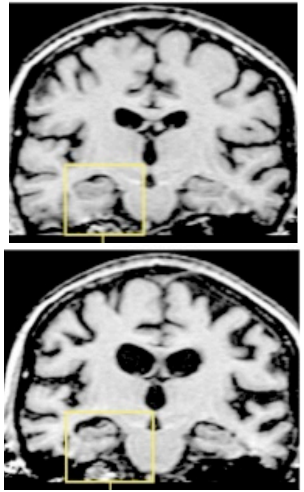


Between-modalities



Motion correction

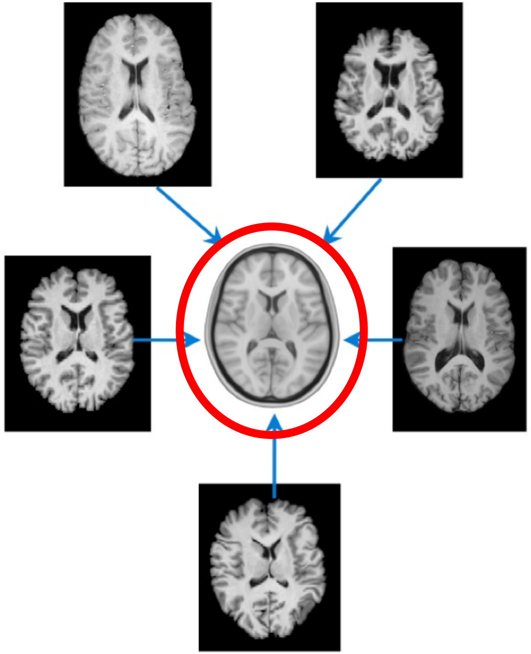
Within-subject, between sessions



Scheltens et al., 2002

Longitudinal data, change over time

Between-subjects



Template / Standard space = “average brain” used as reference

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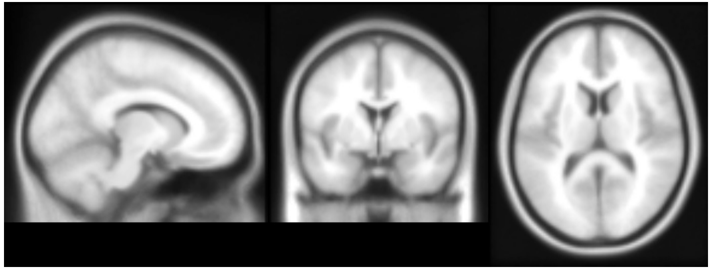
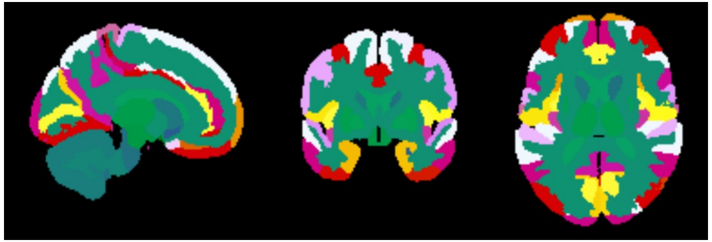
INTRODUCTION TO IMAGE REGISTRATION

MNI152 Template Space

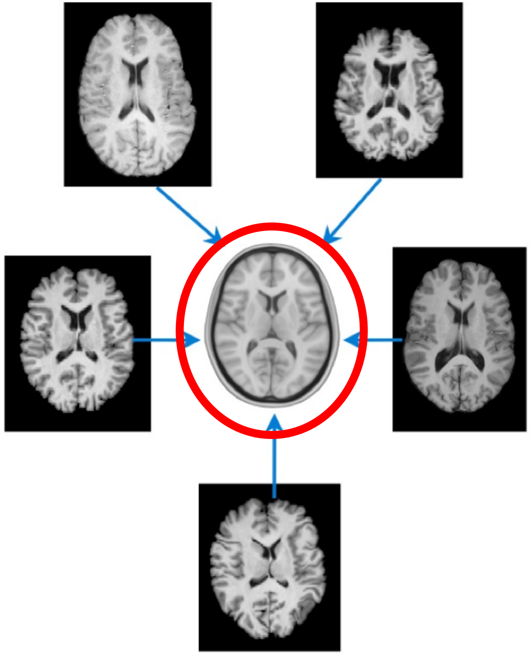
"Average brain"



Atlases



Between-subjects



Template / Standard space = "average brain" used as reference

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NEUROIMAGING DATA ANALYSIS: A GENERIC BLUEPRINT

1. Data acquisition	**Aim**: obtain good quality and consistent data	Trade-offs often necessary (e.g. time vs resolution). Optimize protocol for research aim.
2. Data preprocessing	**Aim**: Reduce noise and prepare data for further analyses	Some steps are common across modalities (e.g. brain extraction, registration), others are modality-specific (e.g. motion correction, distortion correction). Requires careful checking.
3. Single-subject analysis	**Aim**: Obtain measure of interest for each subject (often an image)	Modality-specific. (Examples: tissue-type segmentation, fractional anisotropy map)
4. Group-level analysis	**Aim**: Compare single-subject results across groups	Common step across modality (the difference is the input). Usually happens after all images have been aligned (*registered*) to a reference image (*template*)
5. Statistical inference	**Aim**: test reliability of results and generalizability to the general population	Common step across modalities

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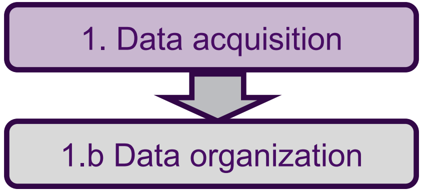
NEUROIMAGING DATA ANALYSIS: DATA STRUCTURE




```
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        anat/
            sub-01_T1w.nii.gz
        func/
            sub-01_task-rest_bold.nii.gz
            sub-01_task-rest_bold.json
        dwi/
            sub-01_dwi.nii.gz
            sub-01_dwi.json
            sub-01_dwi.bval
            sub-01_dwi.bvec
    sub-02/
    sub-03/
```

- Neuroimaging experiments usually generate multiple **images and non-imaging data**.
- So far there is **no consensus how to organize and share data** obtained in neuroimaging experiments
- **BIDS** is a framework for organizing data. Standardizes **file names** and **folders hierarchy** organization and dataset description.

BIDS
BRAIN IMAGING DATA STRUCTURE

https://bids.neuroimaging.io

NEUROIMAGING DATA VISUALIZATION: QUALITY CONTROL

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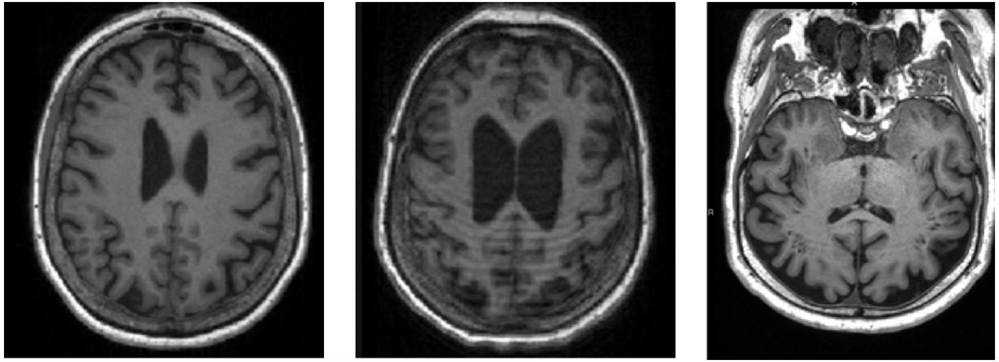
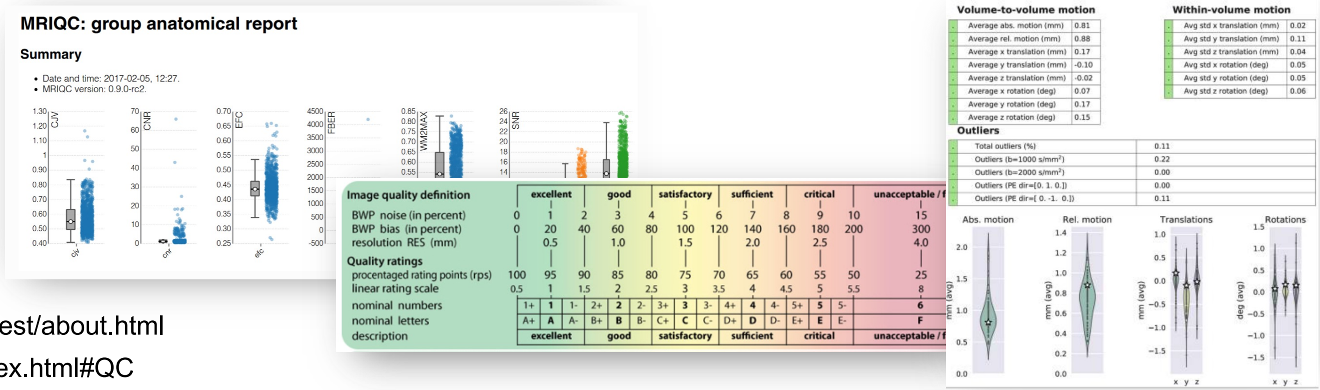
1. Data acquisition
2. Data preprocessing





MRIQC - https://mriqc.readthedocs.io/en/latest/about.html

CAT12 - https://neuro-jena.github.io/cat/index.html#QC

EDDY-QC (FSL) - https://fsl.fmrib.ox.ac.uk/fsl/fslwiki/eddyqc/UsersGuide

NEUROIMAGING DATA VISUALIZATION: QUALITY CONTROL

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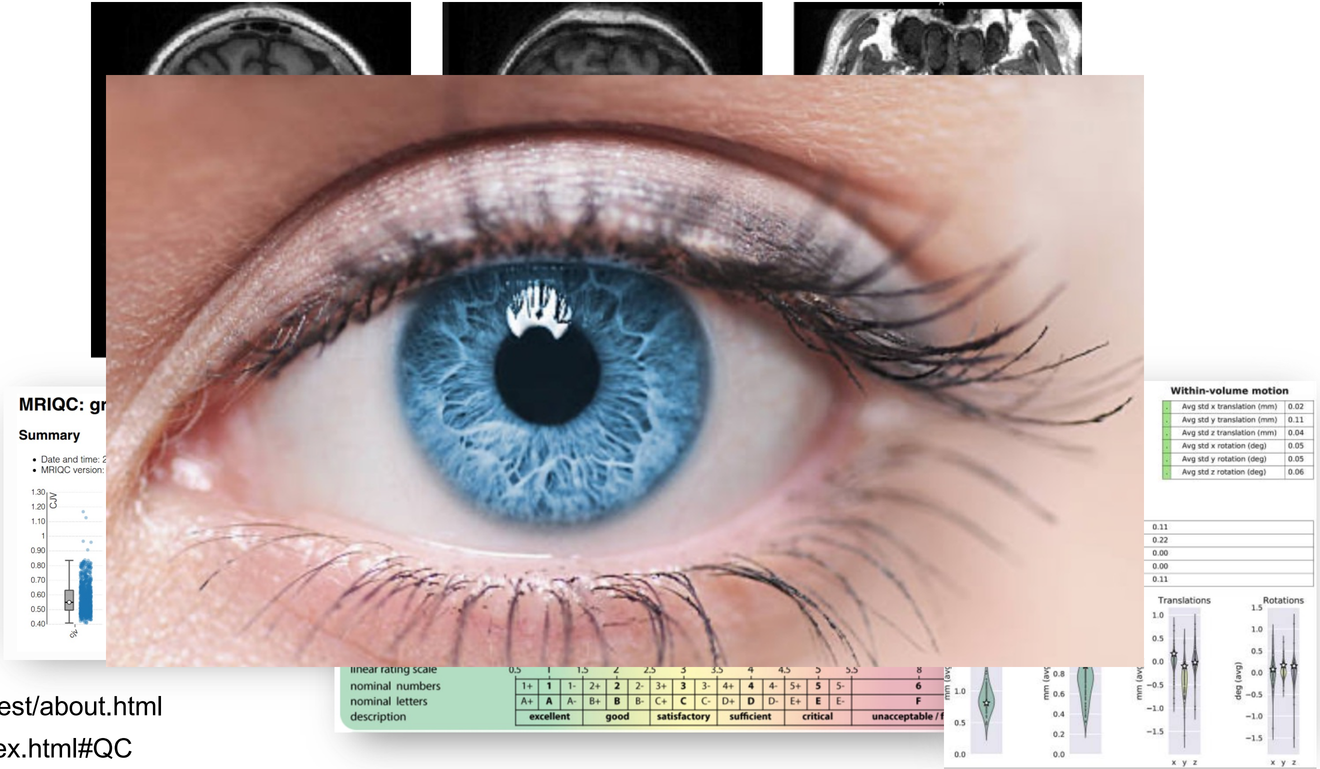
1. Data acquisition
2. Data preprocessing
3. Single-subject analysis
4. Group-level analysis
5. Statistical inference



MRIQC - https://mriqc.readthedocs.io/en/latest/about.html

CAT12 - https://neuro-jena.github.io/cat/index.html#QC

EDDY-QC (FSL) - https://fsl.fmrib.ox.ac.uk/fsl/fslwiki/eddyqc/UsersGuide

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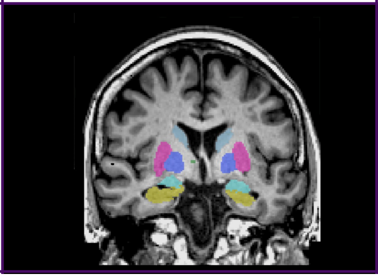
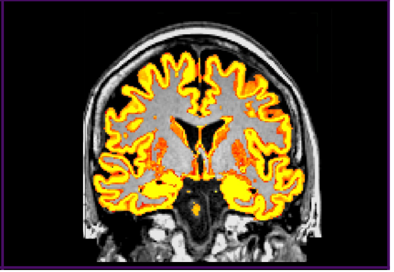
NEUROIMAGING DATA VISUALIZATION: SINGLE SUBJECT OUTPUT

1. Data acquisition
2. Data preprocessing
3. Single-subject analysis
4. Group-level analysis
5. Statistical inference

Images
or
Numbers

Images	Label/Region of interest (ROI)/ Parcel	Continuous measure
Volumetric		

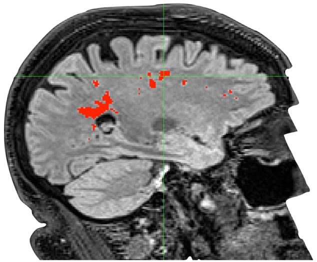
Images from: Miller et al., Nat Neurosci. 2016; FreeSurfer tutorial; Wang et al., PlosONE 2013

NEUROIMAGING DATA VISUALIZATION: SINGLE SUBJECT OUTPUT

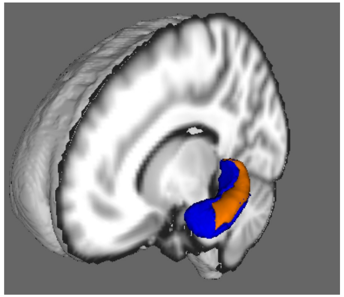
1. Data acquisition
2. Data preprocessing
3. Single-subject analysis
4. Group-level analysis
5. Statistical inference

Images
or
Numbers

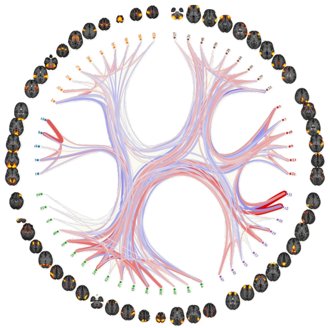
Numbers a.k.a. Imaging Derived Phenotypes (IDPs)



White matter lesion load



Brain structure volume



Connection strength

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NEUROIMAGING DATA VISUALIZATION: GROUP-LEVEL STATISTICAL OUTPUT

1. Data acquisition
2. Data preprocessing
3. Single-subject analysis
4. Group-level analysis
5. Statistical inference

- **Numbers** fed into 'classic' stats software (R, SPSS, STATA, python...)

- **Images** require specific stats (usually within imaging software tools)
- Input = single subject output, registered to a template
- Statistical maps in pseudocolours shows **significant voxels** (volumetric) or vertices (surface), overlaid on template.
- **Atlases** can help interpreting results

NEUROIMAGING DATA VISUALIZATION: GROUP-LEVEL STATISTICAL OUTPUT

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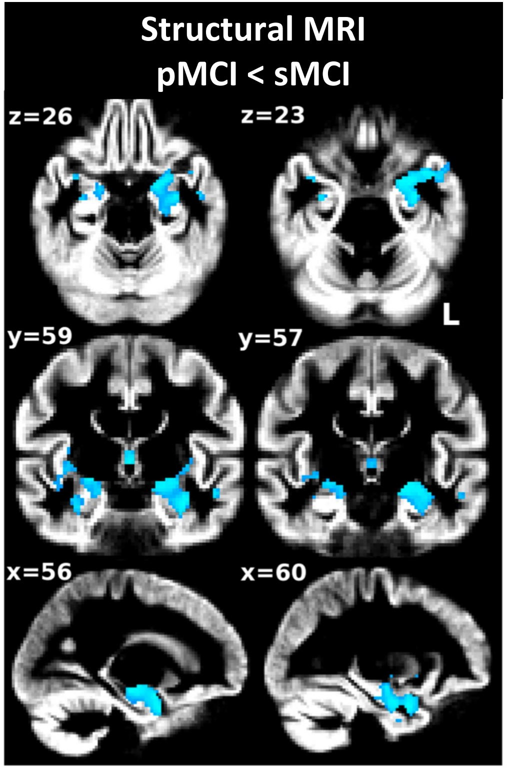
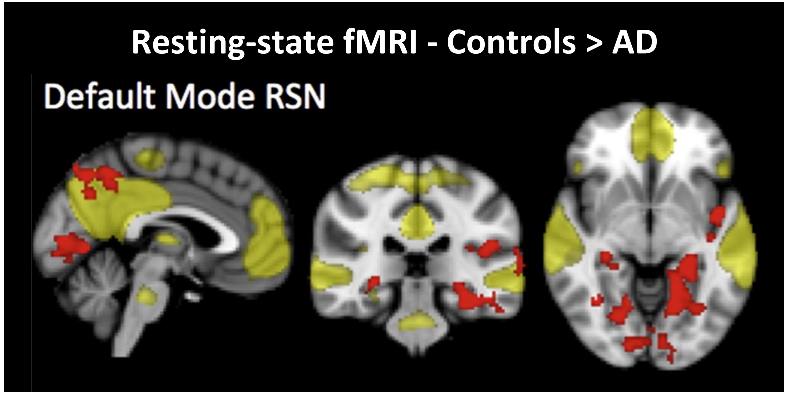
1. Data acquisition
2. Data preprocessing
3. Single-subject analysis
4. Group-level analysis
5. Statistical inference



Douaud et al., JNeurosci 2013



Zamboni et al., Biol Psych. 2013

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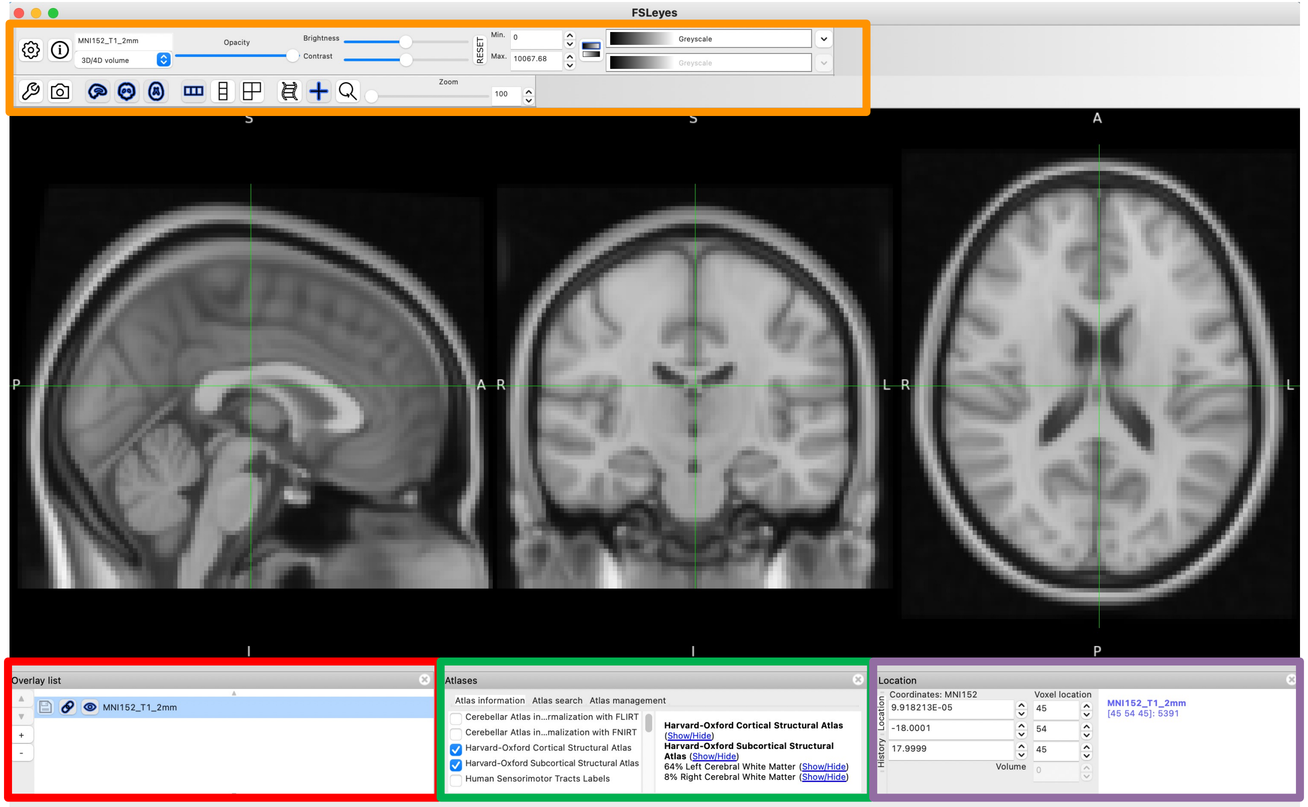
NEUROIMAGING DATA VISUALIZATION: FSLEYES

1. Getting started



4. Viewing Atlases

2. Viewing multiple images

3. Image information

THANK YOU!

@ludogriffanti
ludovica.griffanti@psych.ox.ac.uk

Next up:
Basics of Neuroimaging: Structural Magnetic Resonance Imaging (MRI) by David Cash
14 April, 2023; 9AM – 10AM CT
Basics of Neuroimaging: Positron emission tomography (PET) by Tobey Betthauser
19 April, 2023; 12PM - 1PM CT
Basics of Neuroimaging: Diffusion-Weighted Imaging (DWI) by Alexa Pichet Binette
21 April, 2023; 9AM – 10AM CT
Basics of Neuroimaging: Functional Magnetic Resonance Imaging (FMRI) by Luigi Lorenzini
26 April, 2023; 10AM – 11AM CT

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win