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# Deep Learning in Tractography

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# Outline

- **What is tractography**  
some introduction & background
- **Deep learning in medical image**  
Typical challenges and solutions
- **Deep learning in tractography**  
Current works and what I am doing
- **Future opportunities**

# Diffusion



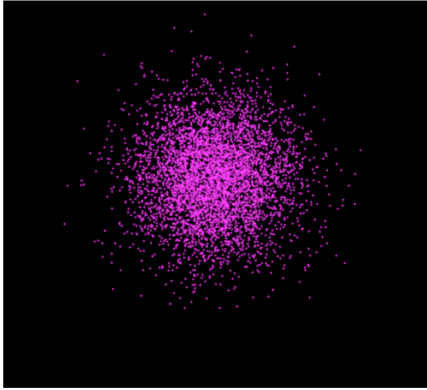
Robert Brown, 1773-1858

Brownian motion: molecules are randomly move if the temperature is greater than  $-273^{\circ}\text{C}$

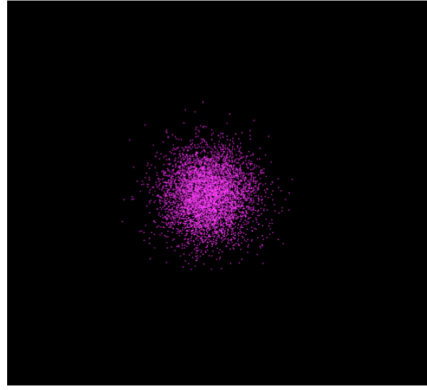
→ Diffusion: random motion is driven by thermal

Einstein's Equation: for a barrier-free medium, diffusion displacements follow a **Normal distribution**.

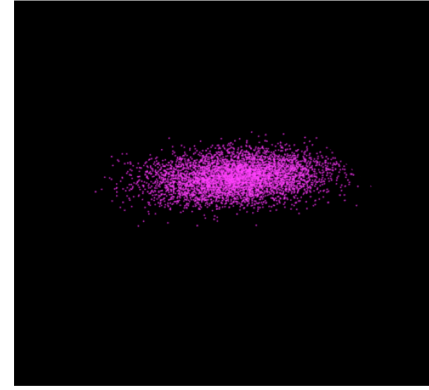
# Water diffusion in the brain



Isotropic, free diffusion in  
Cerebrospinal Fluid (CSF)



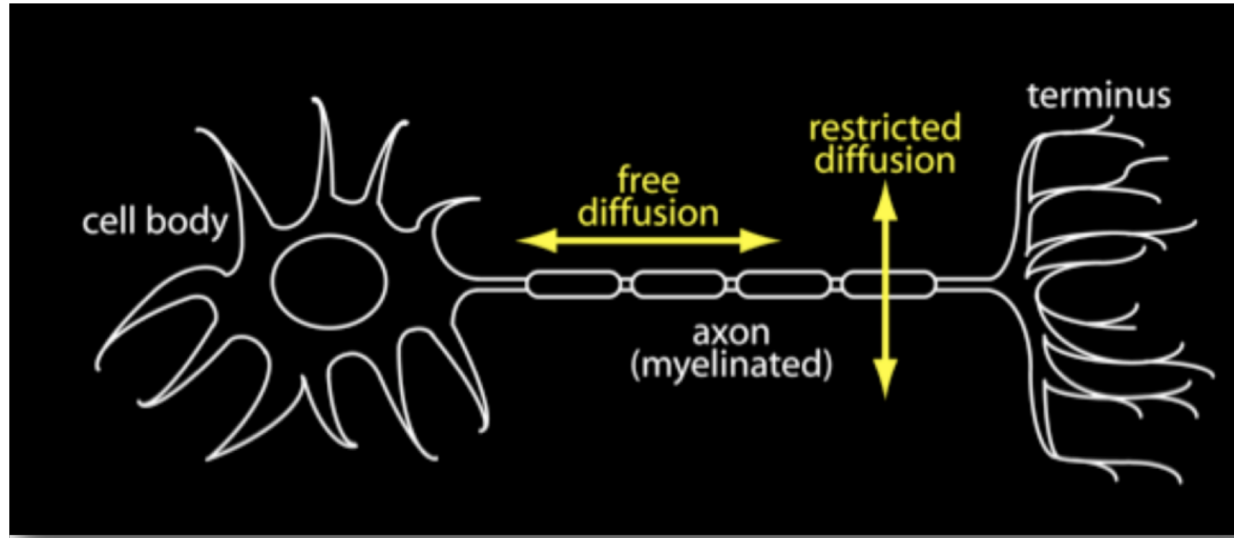
Isotropic, restricted  
diffusion in Gray Matter



Anisotropic, restricted  
diffusion in White Matter



# Anisotropic and isotropic



From: Beaulieu, NMR Biomed, 2002

# What is tractography

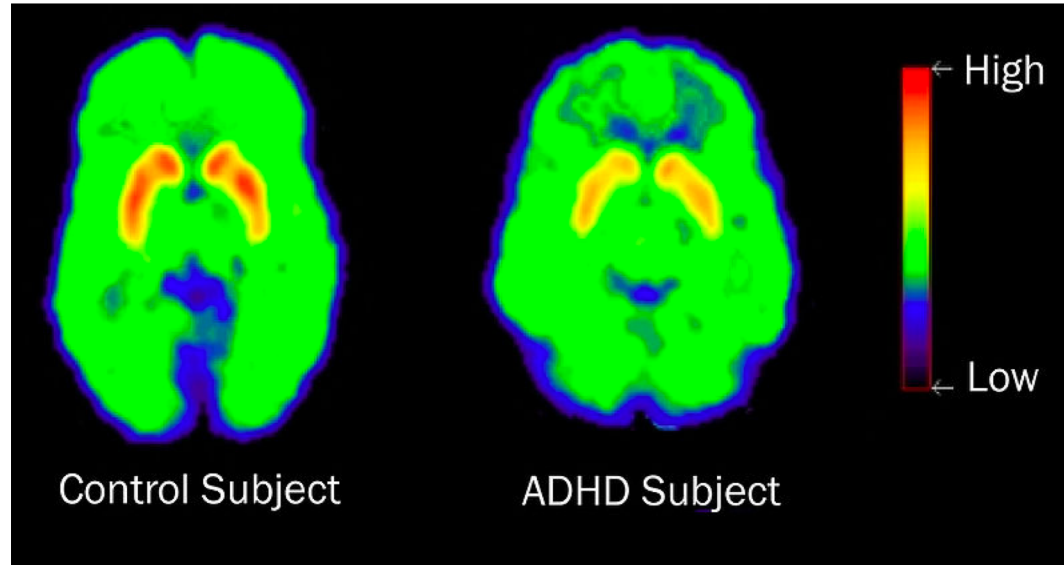
A 3D modeling technique to visualize nerve connections

Unique **non-invasively**

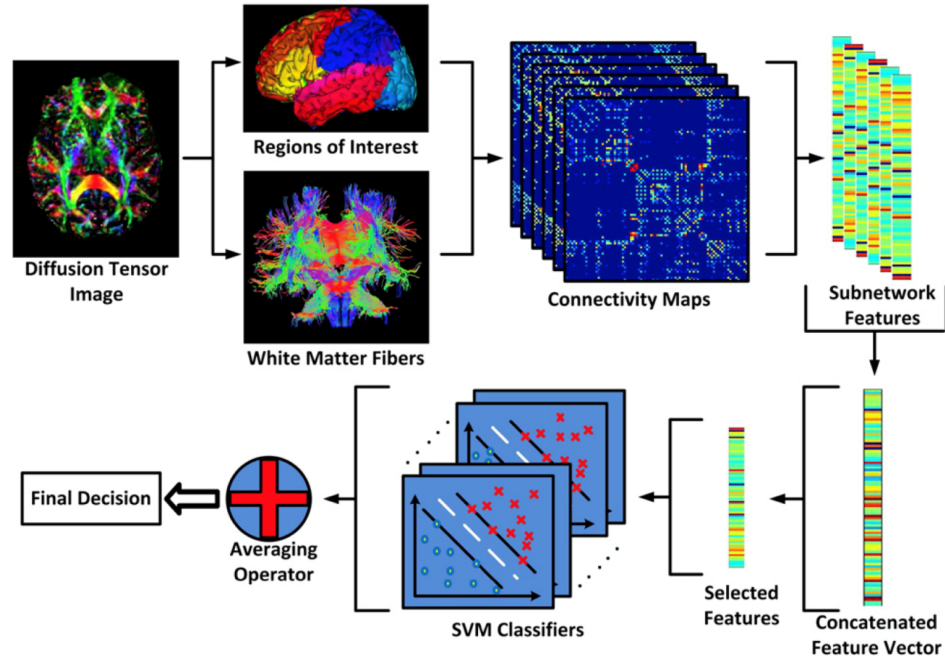
An ***in-vivo*** method



# Brain scan with and without ADHD



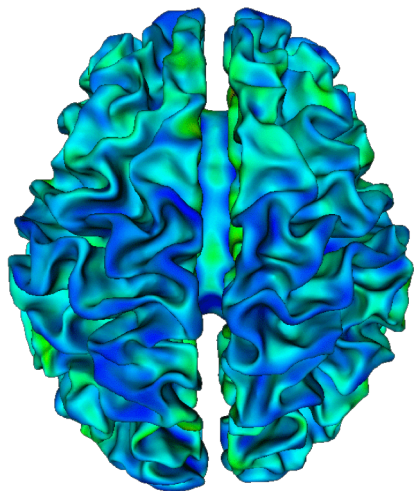
# Neuro-diagnosis for MCI



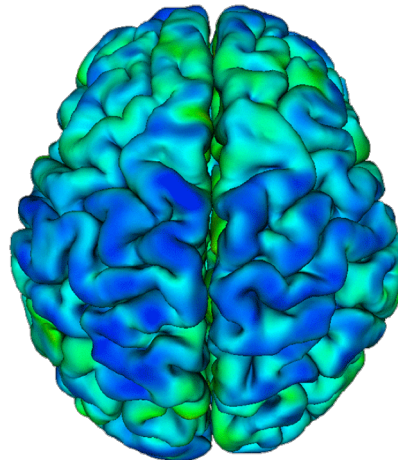
**MCI**: mild cognitive impairment, an increased risk of developing Alzheimer's Disease (AD).

# Evolution of Cortical Surfaces

2 weeks



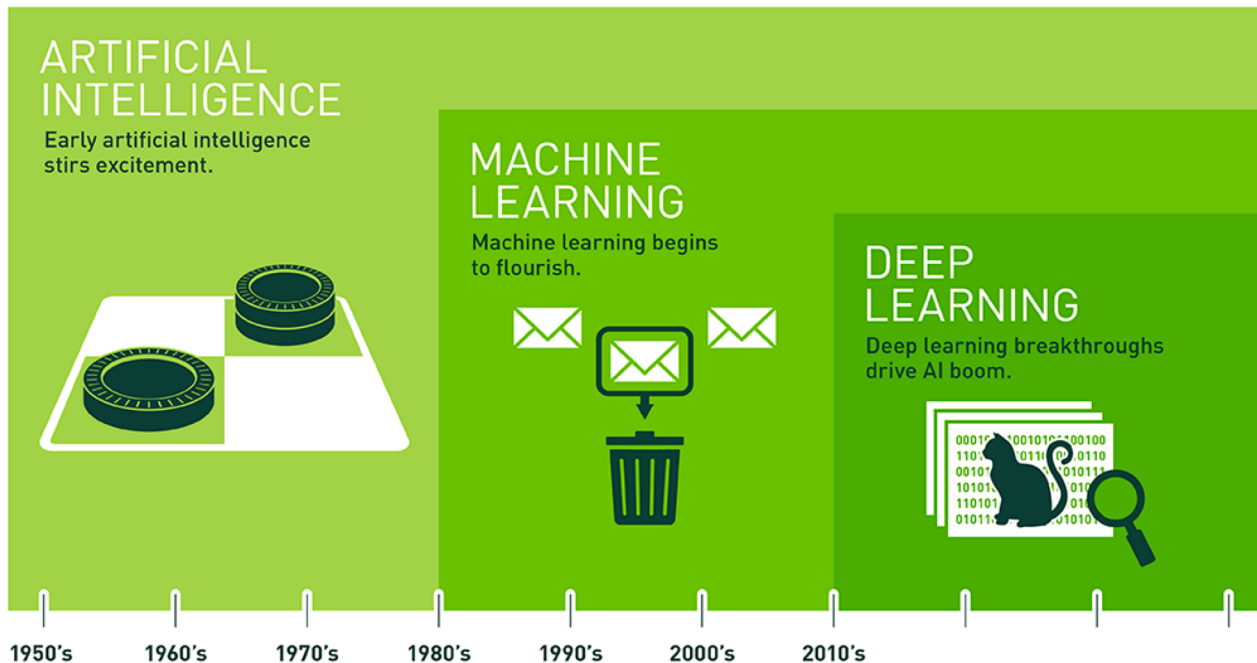
White matter - Gray matter



Gray matter - CSF

1mm 6mm  
Cortical Thickness

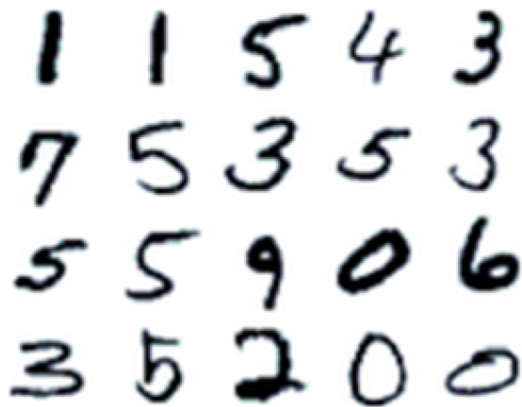
# Machine learning vs. deep learning



Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

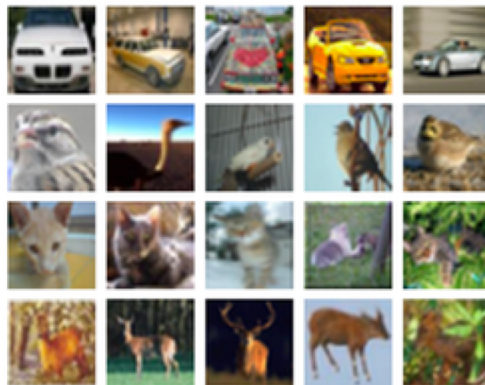
# Public datasets for deep learning in computer vision

# MNIST



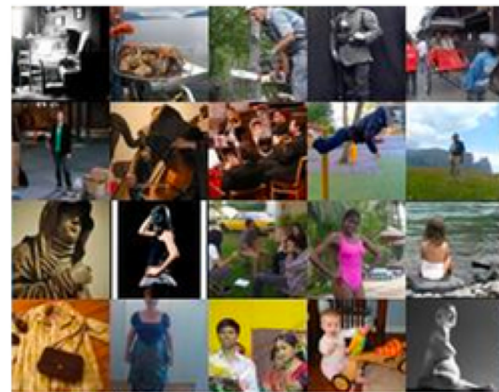
**60K + 10K**

## CIFAR-10



50K + 10K

## ImageNet



More than 14M

## Public datasets for neuroimage



2168 MRI



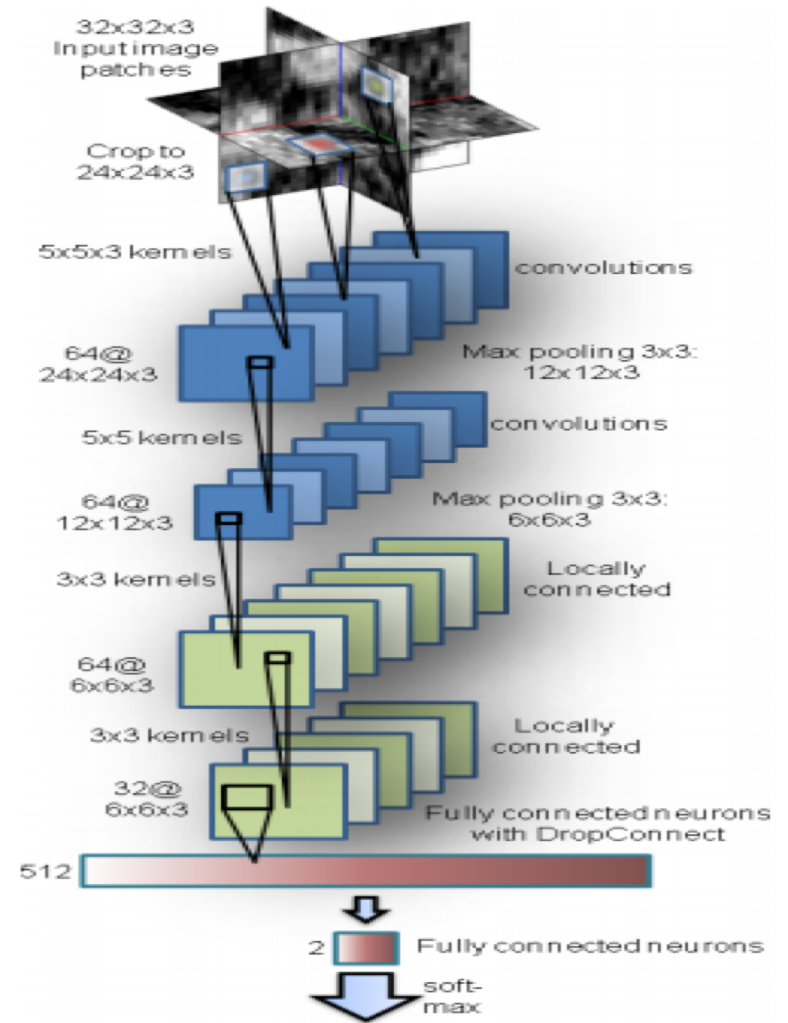
1833 participants till ANDI-3



# Strategies for solving overfitting

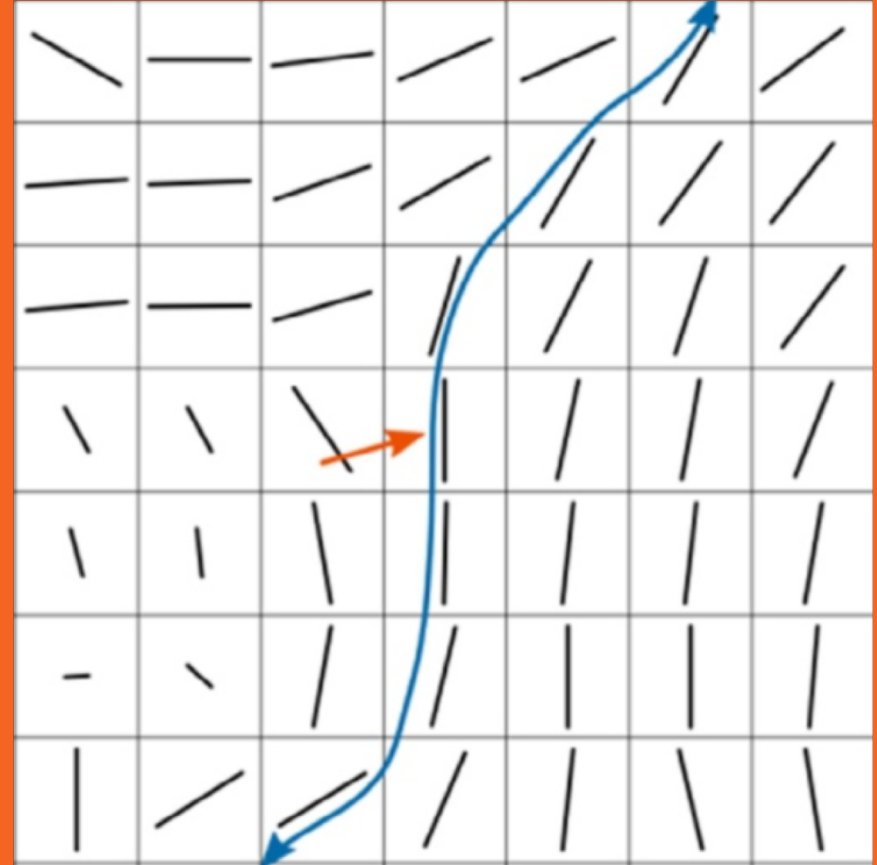
1. Using patches not the full-size image as input.
2. Using transfer learning.
3. Using CNN taking 2D and 3D values as input.

From Holger , TMI 2015

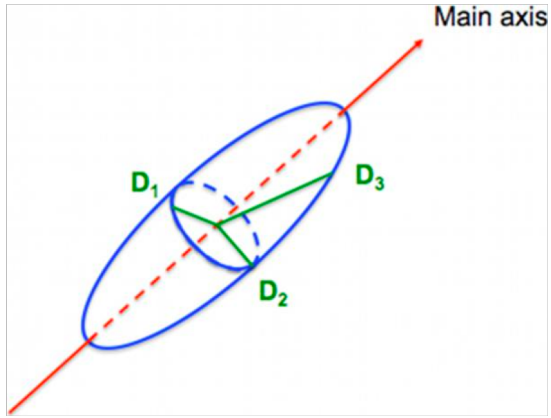


# Tractography=model fitting + connecting

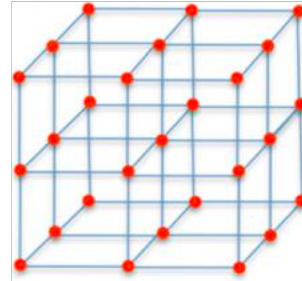
- Model fitting: determining fiber directions in each voxel.
- Connecting: How to gather these directions to pathways



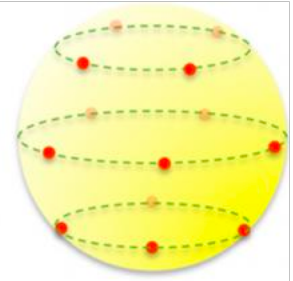
# Tractography-- model fitting



Tensor model

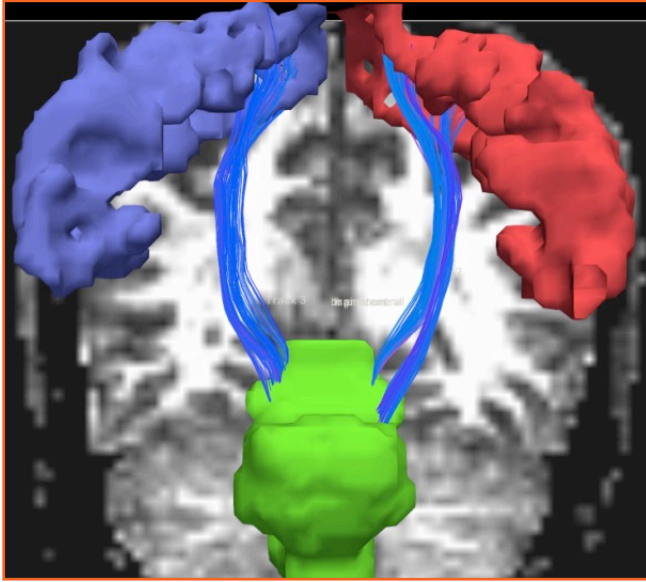


DSI sampling

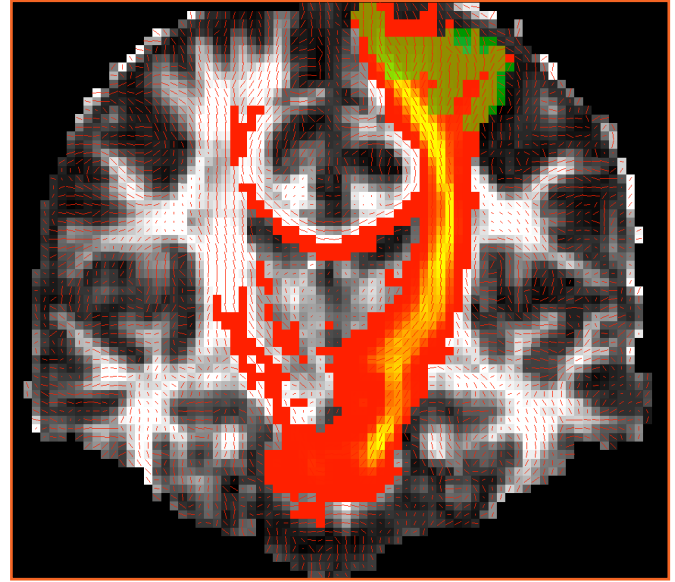


Q-ball sampling

# Tractography– deterministic vs probabilistic

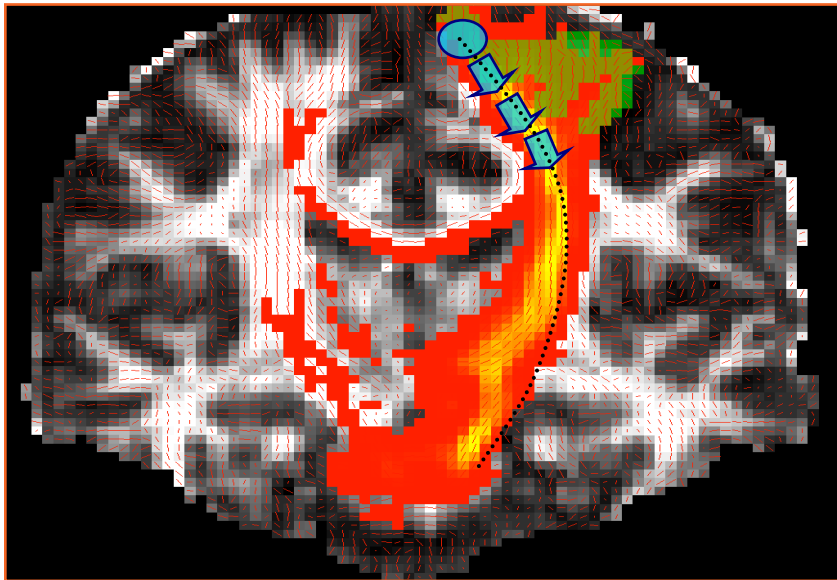


Deterministic tractography

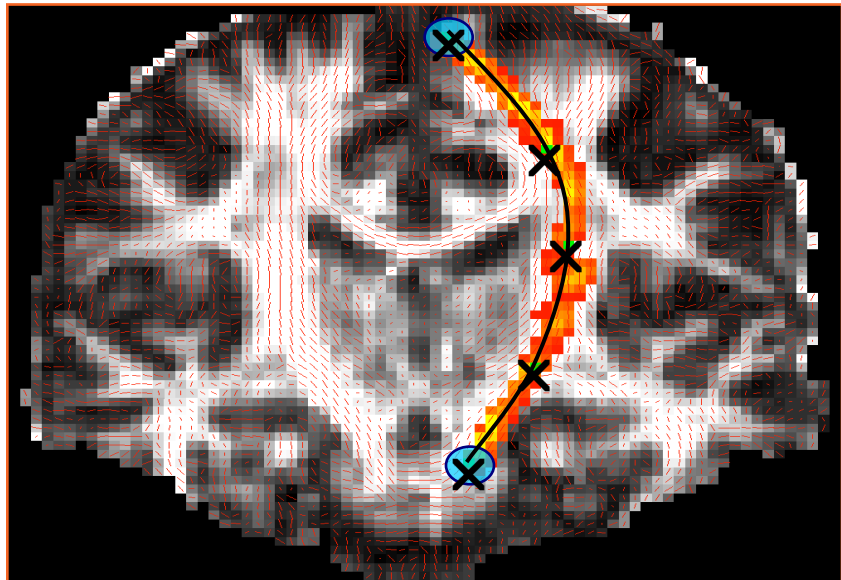


Probabilistic tractography

# Tractography– local vs global

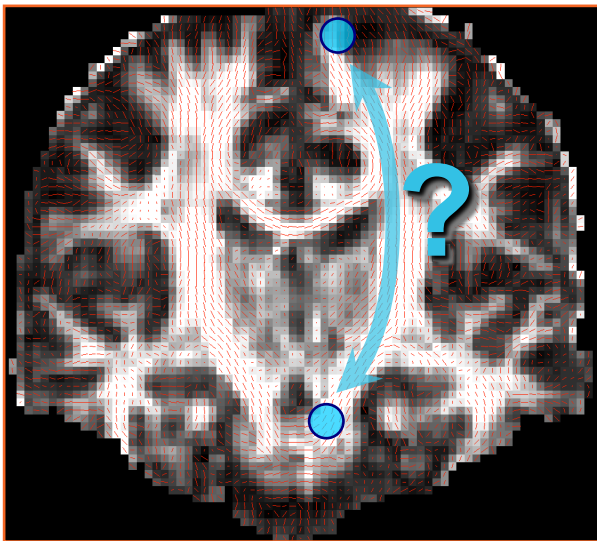


Local tractography



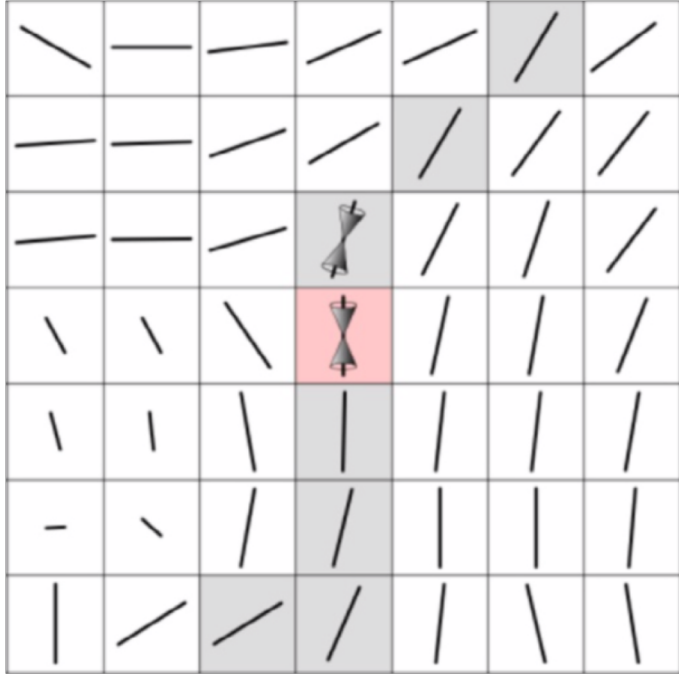
Global tractography

# Why tractography needs deep learning ?



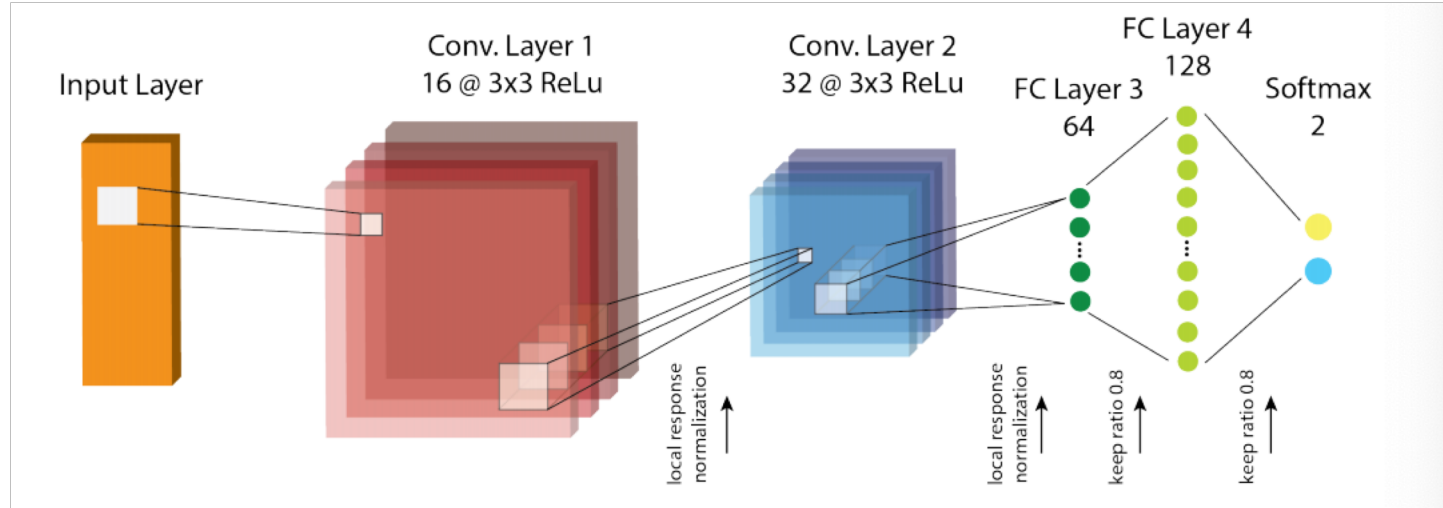
- Which model?
- Deterministic or probabilistic?
- Local or global?:
- Different data from different MRI device manufacture i.e. 'GPS'
- Too many expert knowledges/experiences

# What tractography benefits from deep learning ?



- Model → data-driven tractography
  - 1. Treat local voxel orientation as a regression problem
  - 2. Treat streamline as a sequence → use RNN, GRU

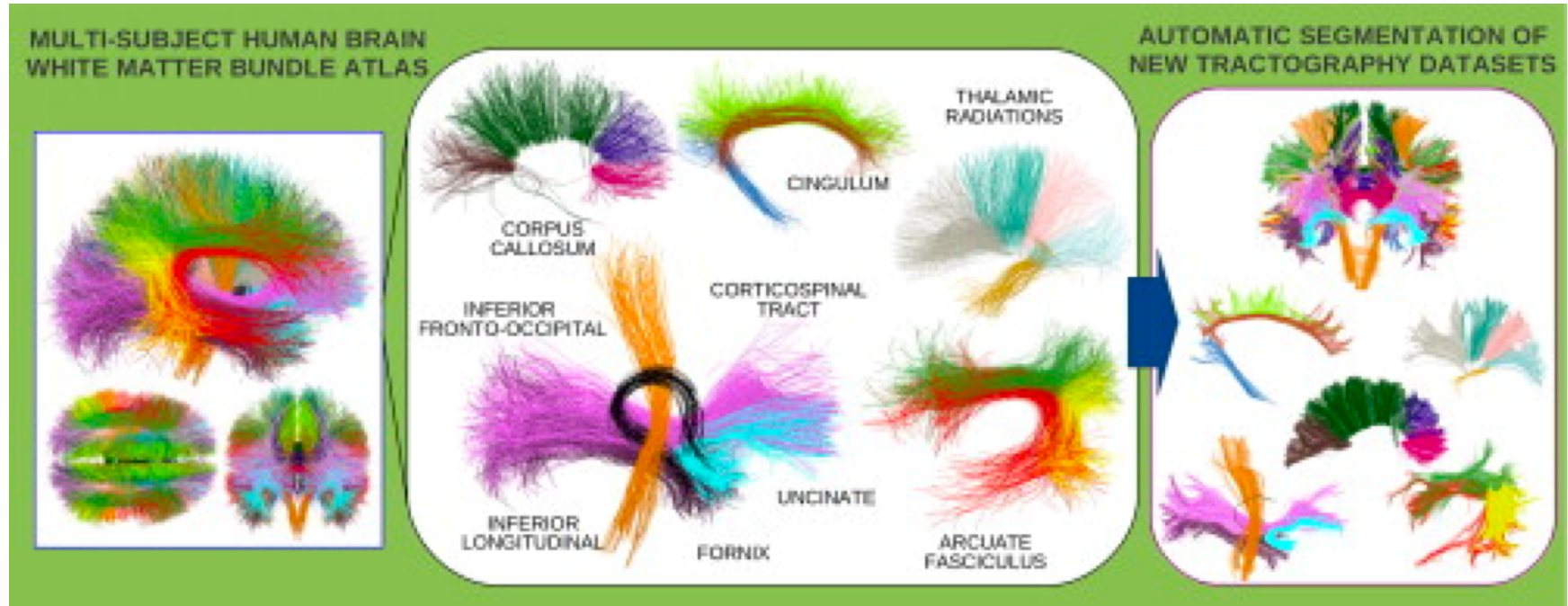
# Fiber clustering utilizing CNN



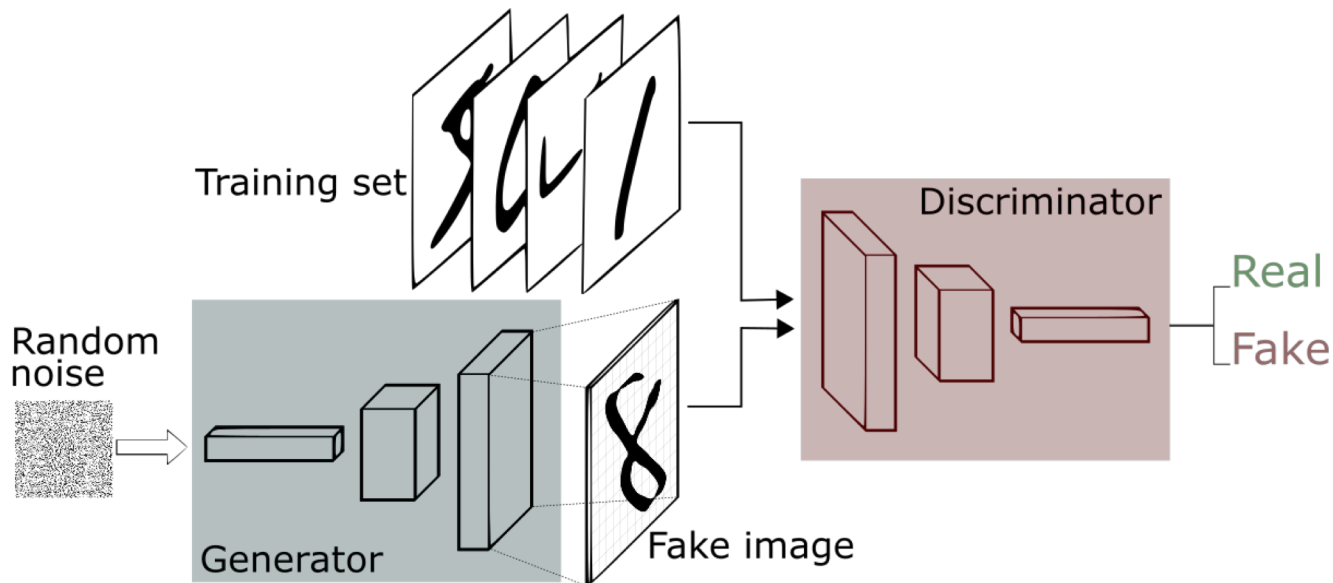
From: Vikash, ISBI 2018



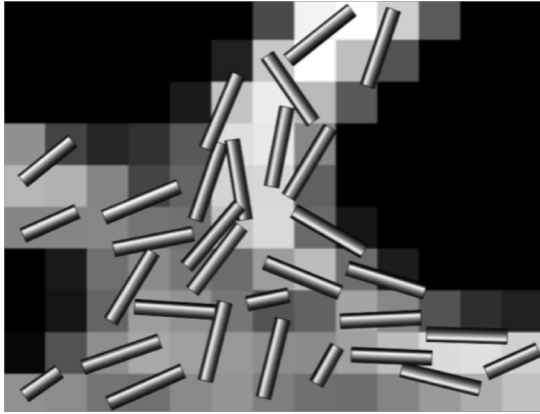
# *Future, fiber segmentation, registration, ...*



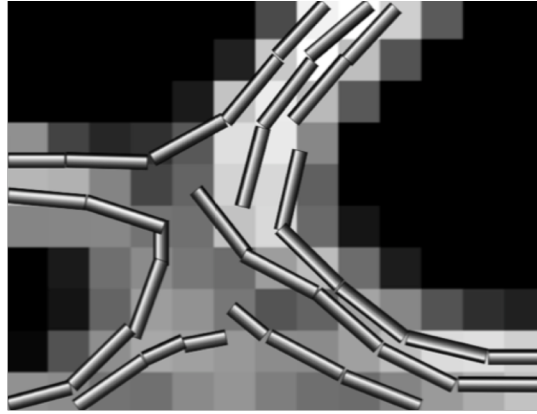
# Generative adversarial networks (GANs)



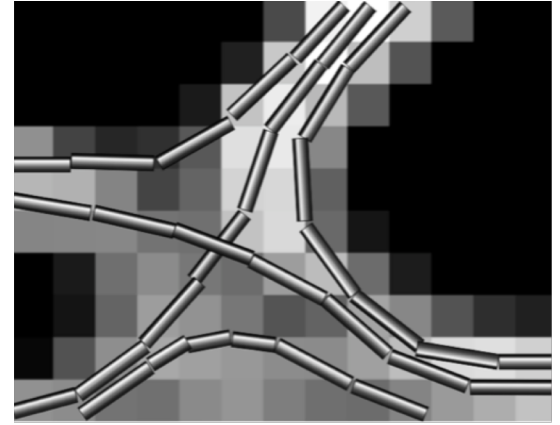
# *Procedure of global tractography*



Distributed randomly



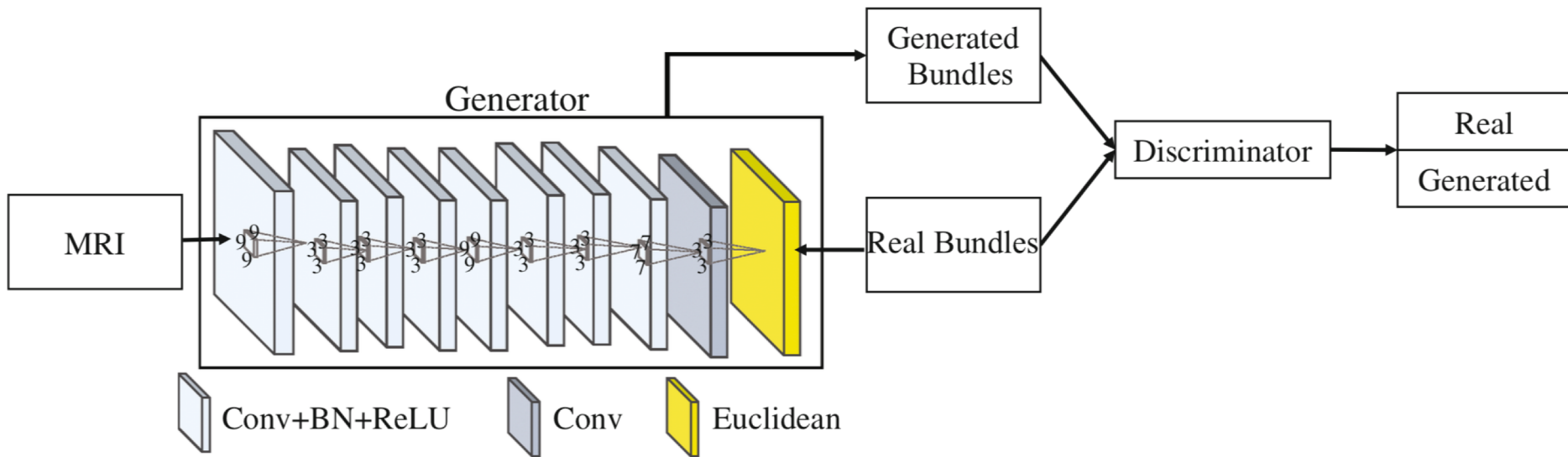
Partly arranged



Well arranged

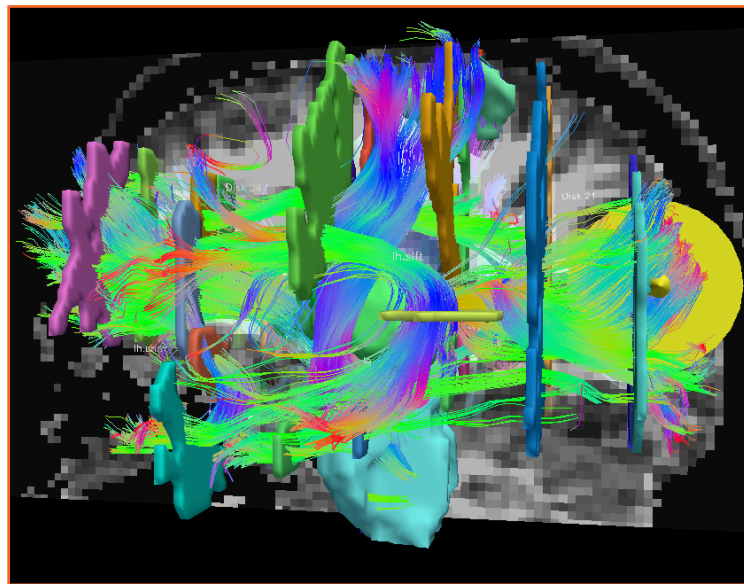
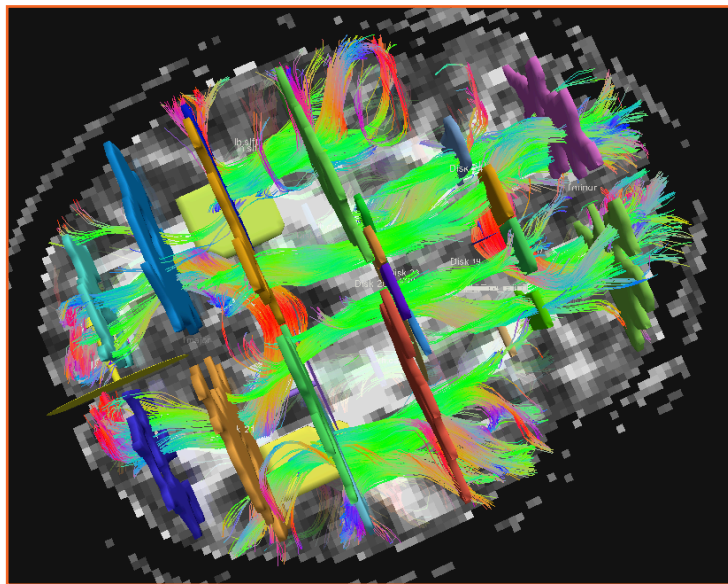
Like a solution of chemical monomer

# Tractography through Context-Aware GANs



Architecture of proposing GANs

*In the future: public labeled dataset*



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IEEE senior member

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# Thank you

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