Deep learning in medical image reconstruction

Part2: Conventional image reconstruction vs DL techniques.

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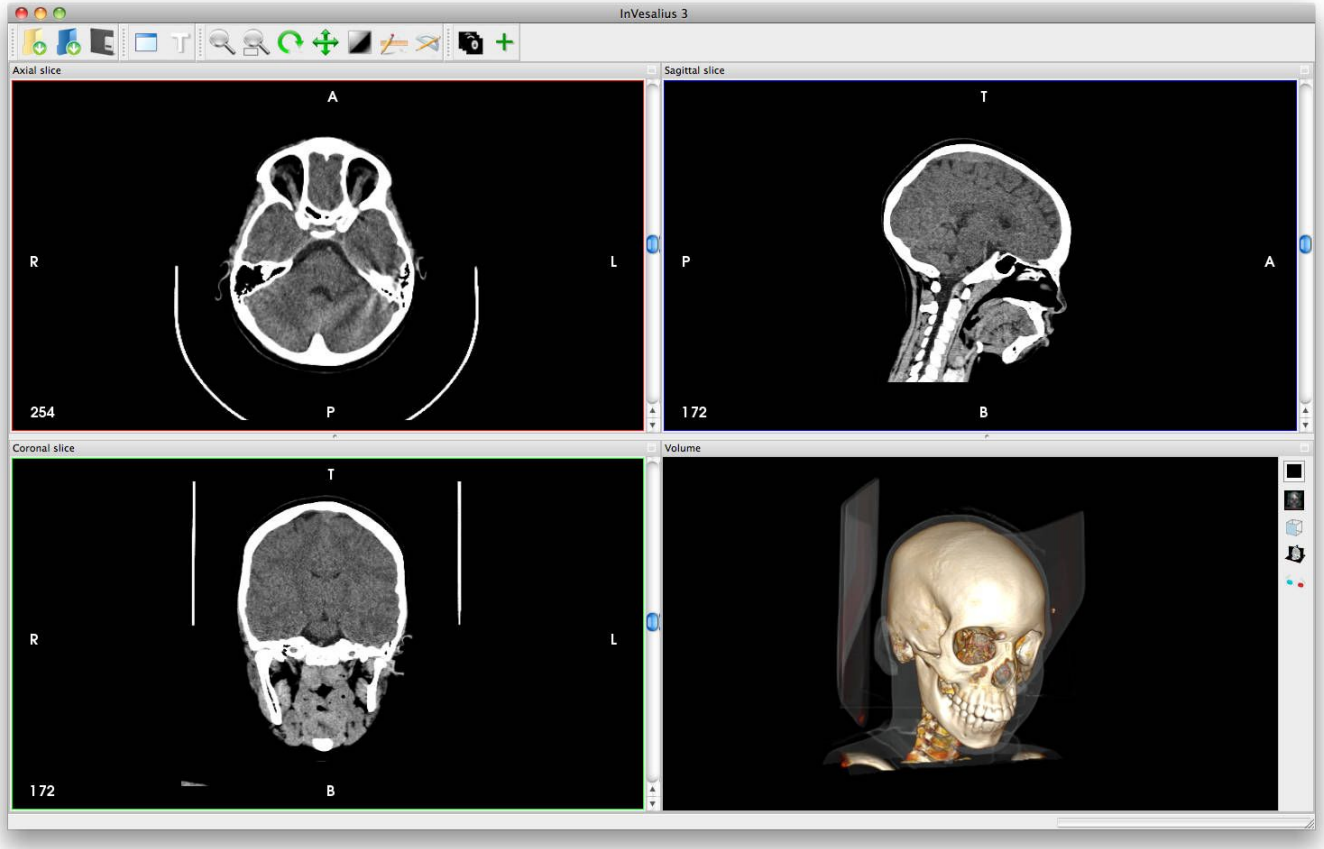
Medical image reconstruction

- Reconstruction algorithms require transforming signals collected by acquisition hardware into interpretable images.
- Reconstruction is a challenging task given the ill-posedness of the problem and the absence of exact analytic inverse transforms in practical cases.

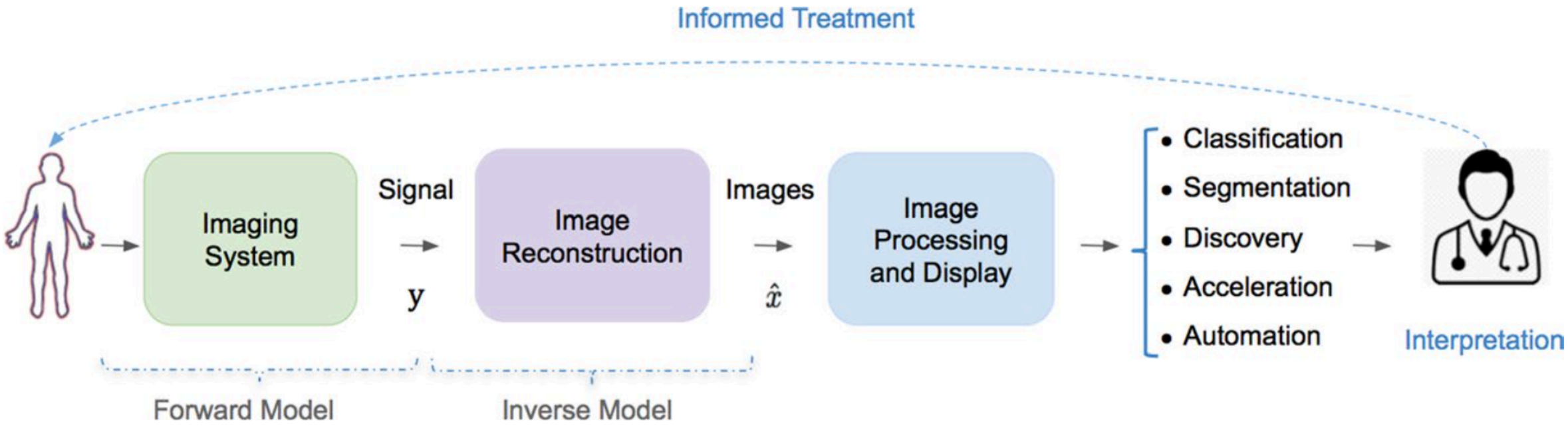


What are we going to discuss?

- **Conventional image reconstruction approaches**
- **Deep learning-based image reconstruction**

Data flow in a medical imaging and image interpretation system

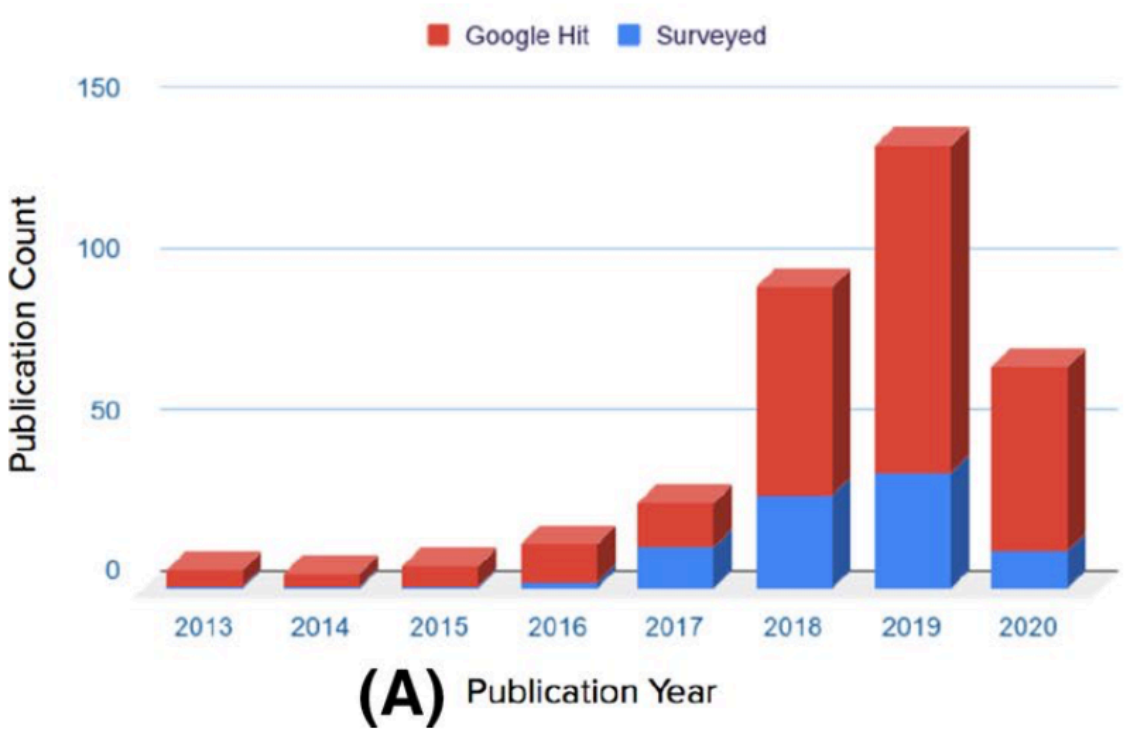
The success of diagnosis, evaluation, and treatment rely on accurate reconstruction, image visualization and processing algorithms

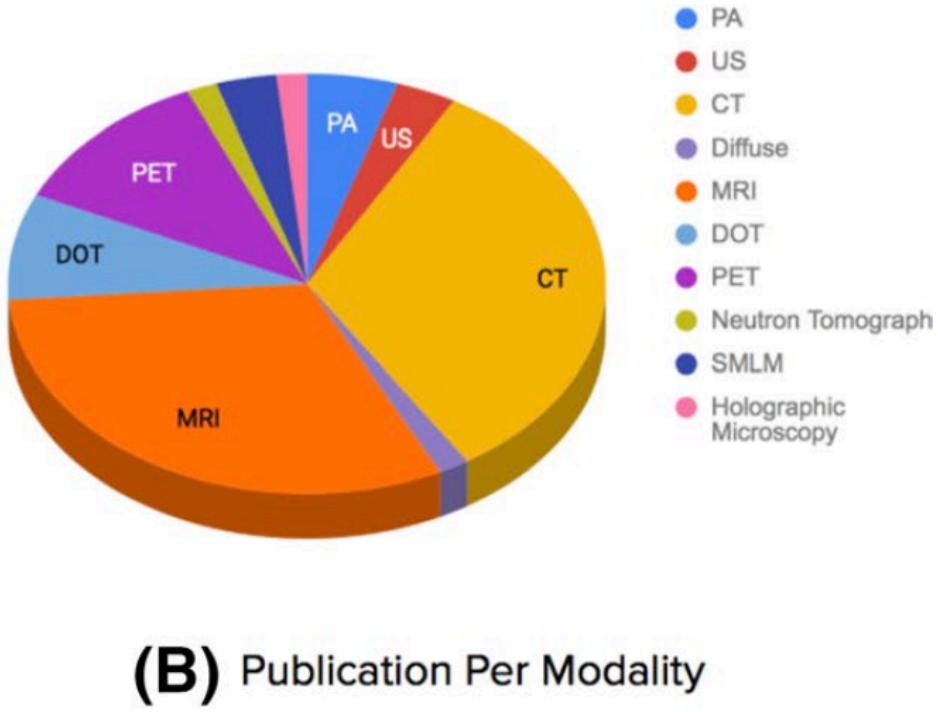


Biomedical image reconstruction

Classified into two categories:

1. Conventional methods (analytical and optimization-based methods)
2. Data-driven or learning-based methods.





Conventional image reconstruction approaches

- **Analytical methods**

Classical examples are

  - Inverse of the Radon transform such as filtered back-projection (FBP) for CT
  - Inverse Fourier transform (IFT) for MRI.

- **Iterative methods**

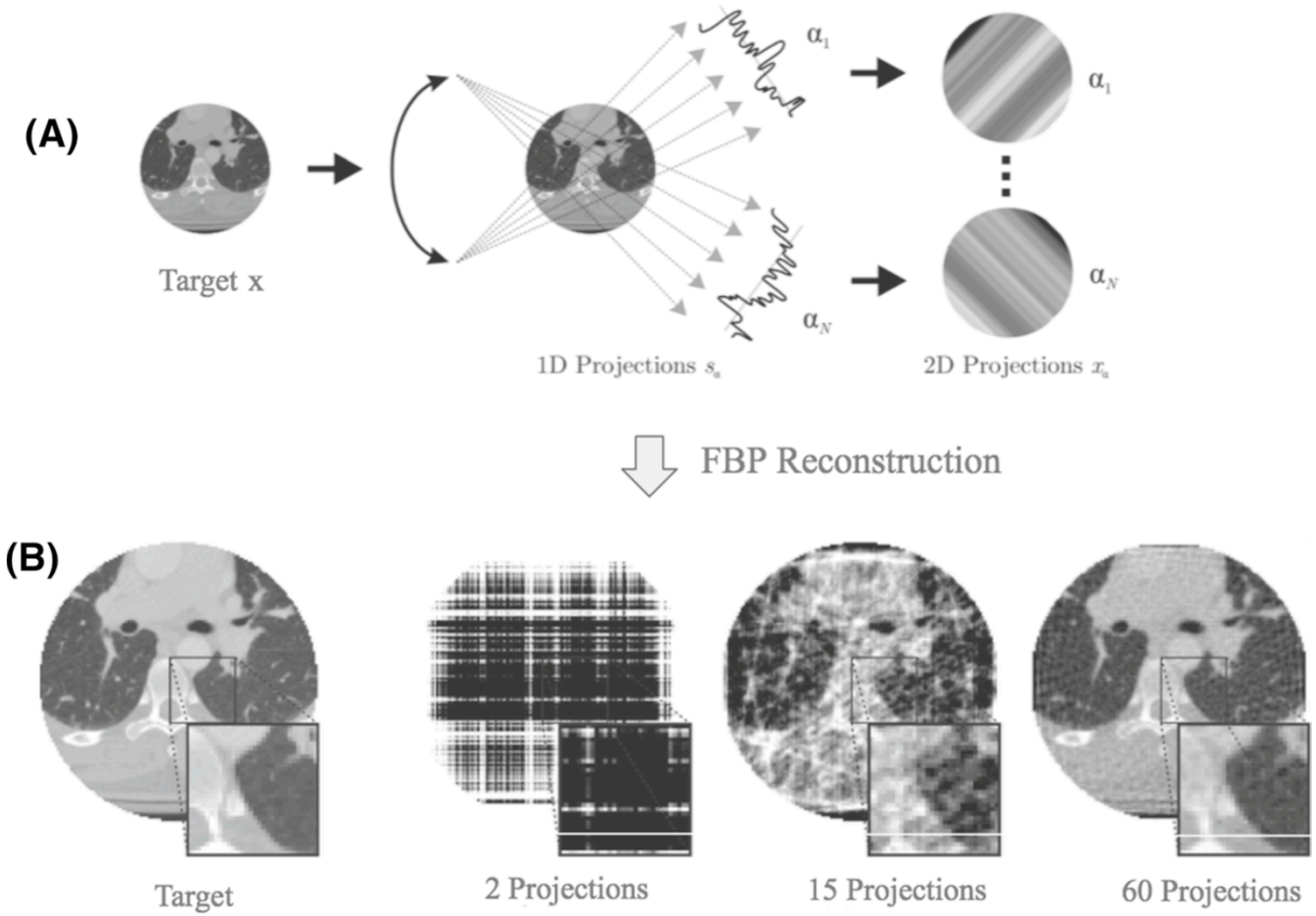
  They combine the statistical properties of data in the sensor domain (raw measurement data), prior information in the image domain, and sometimes parameters of the imaging system into their objective function

Analytical methods

CT Image reconstruction from sparse view measurements.

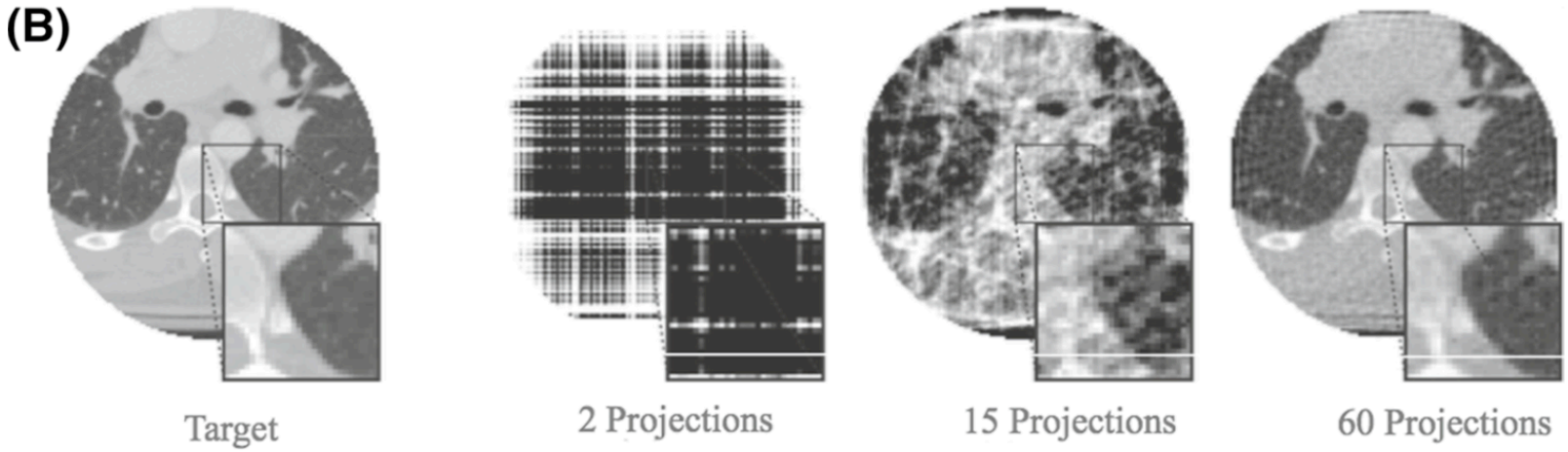
A. Generation of 2D projections from a target 2D CT slice image × for a number of N fixed angles αi.

B. Image reconstructed using conventional filtered back projection method for different number of a projection angles N.



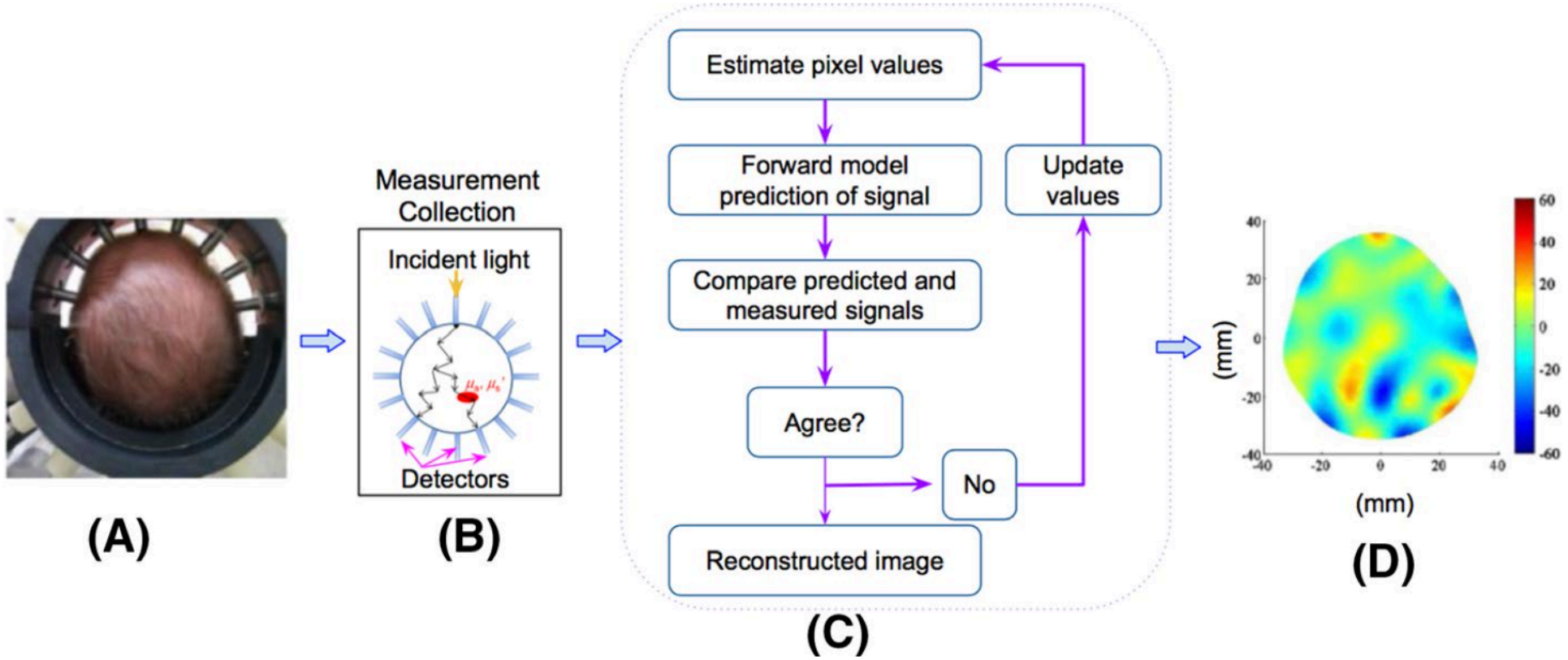
Analytical methods shortcoming

- These methods are usually computationally inexpensive and can generate good image quality in the absence of noise and under the assumption of full sampling/all angles projection.

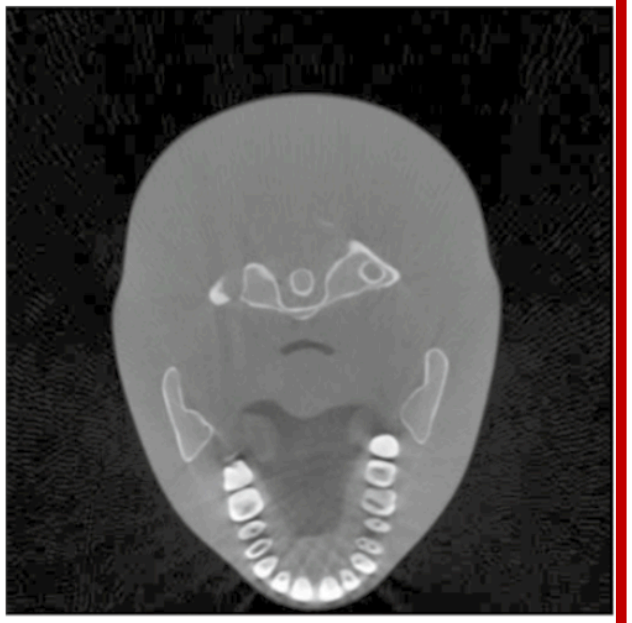


Iterative methods

An example of an iterative approach workflow for diffuse optical tomography (DOT) imaging.

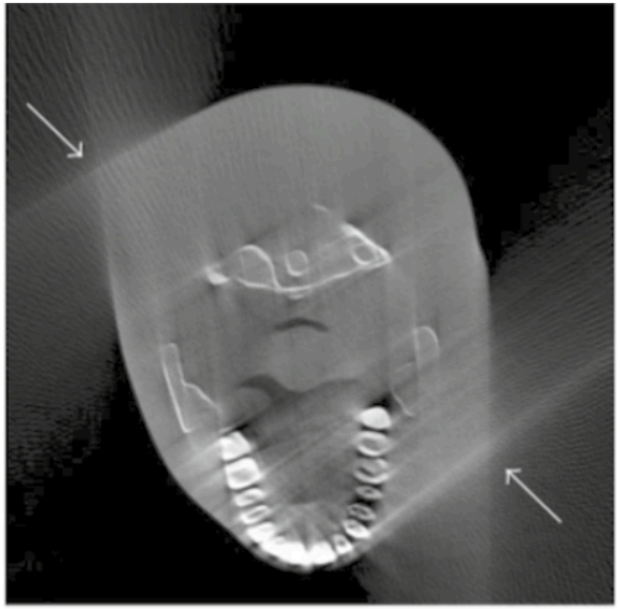


Iterative methods shortcomings



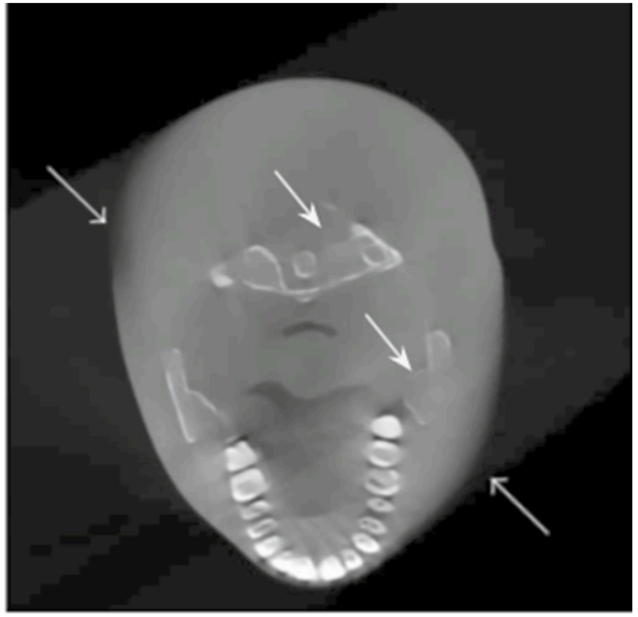
(A)

Reference image, reconstructed from 360 projections



(B)

Reconstruction using analytical FBP



(C)

Reconstructed by iterative method with initial zero image

Reconstruction results of a limited-angle CT real head phantom (120 projections). Arrows point out to artifacts present in the reconstructed images.

Iterative methods shortcomings

Overall, although iterative reconstruction methods showed substantial accuracy improvements and artifact reductions over the analytical ones, they still face three major weaknesses:

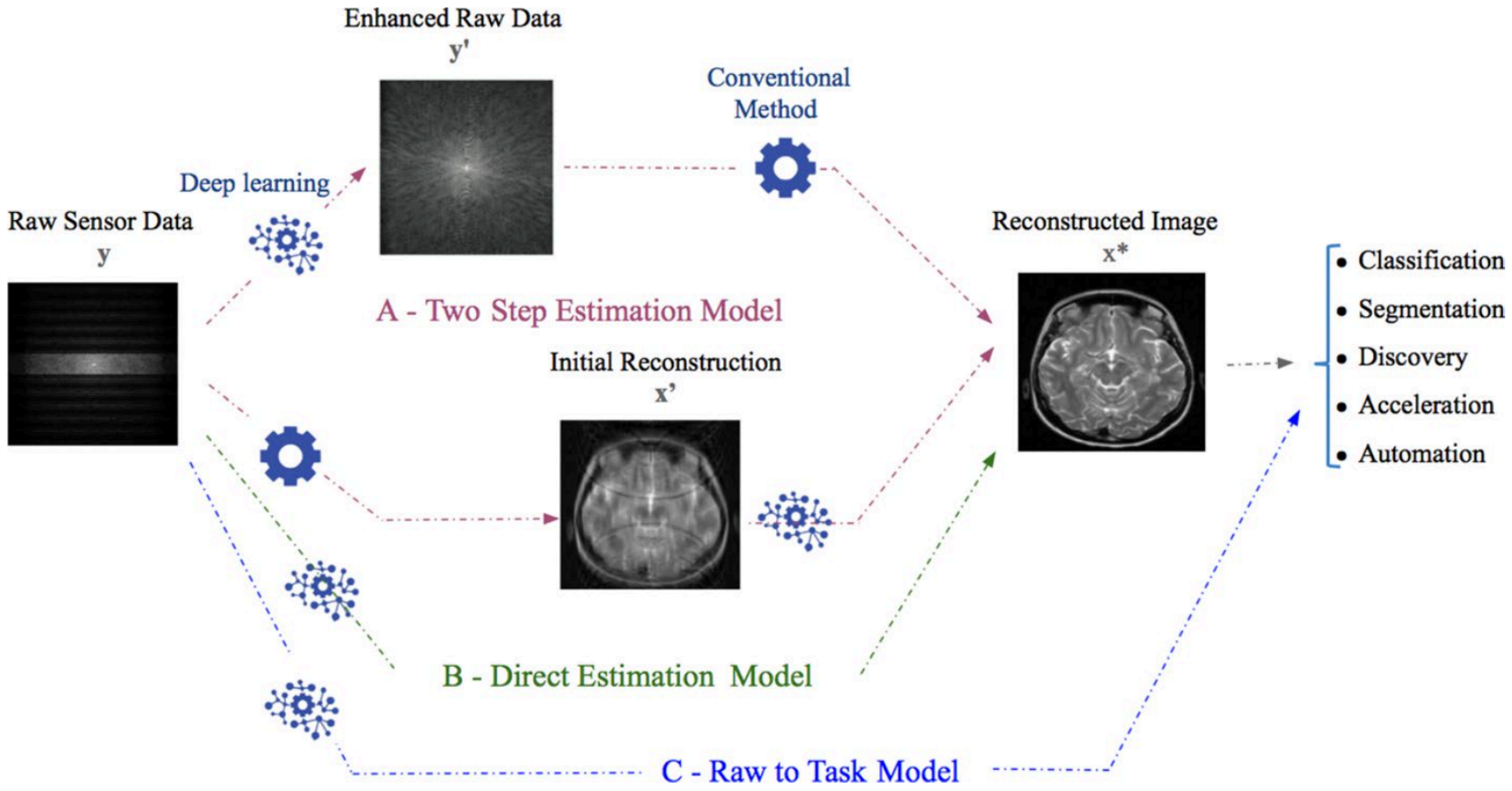
1. Iterative techniques tend to be vendor-specific
2. A trade-off between real-time performance and quality is made in favor of quality in iterative methods
3. Reconstruction quality is highly dependent on the regularization function form

Deep learning-based image reconstruction

A. **Deep learning as processing step: two step image reconstruction models**
   1. **A pre-processing step (sensor domain)**
   2. **A post-processing step (image domain)**

B. **End-to-end image reconstruction: direct estimation**

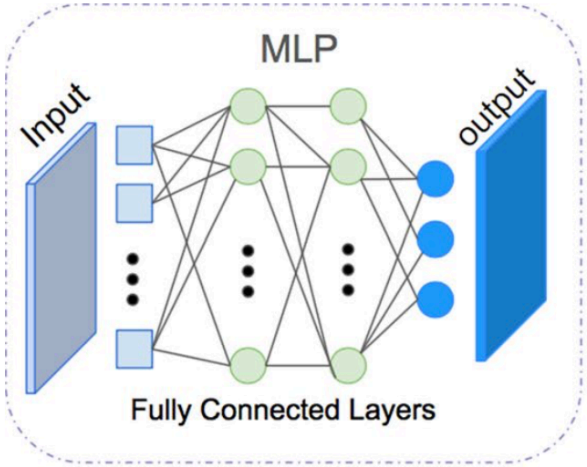
C. **Raw-to-task methods: task-specific learning**

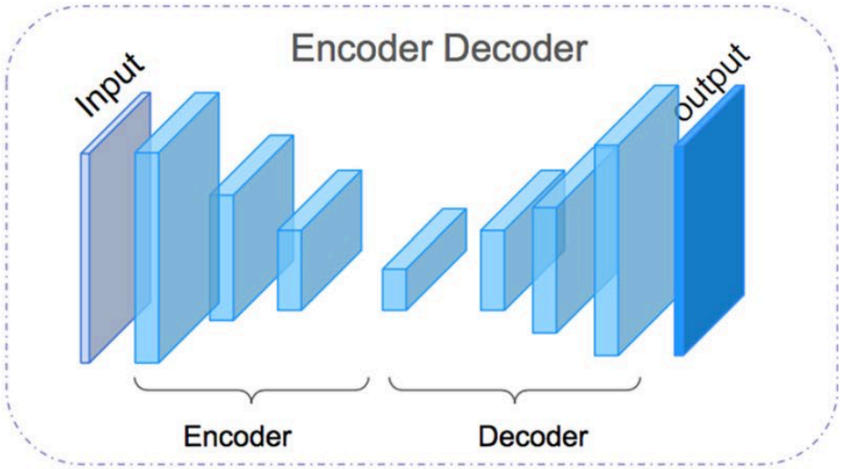


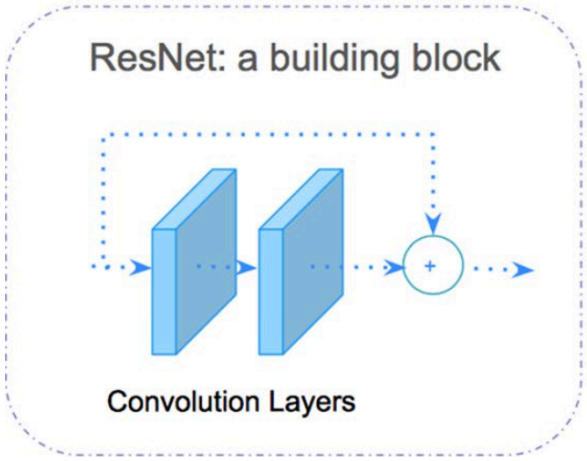
End-to-end image reconstruction: direct estimation

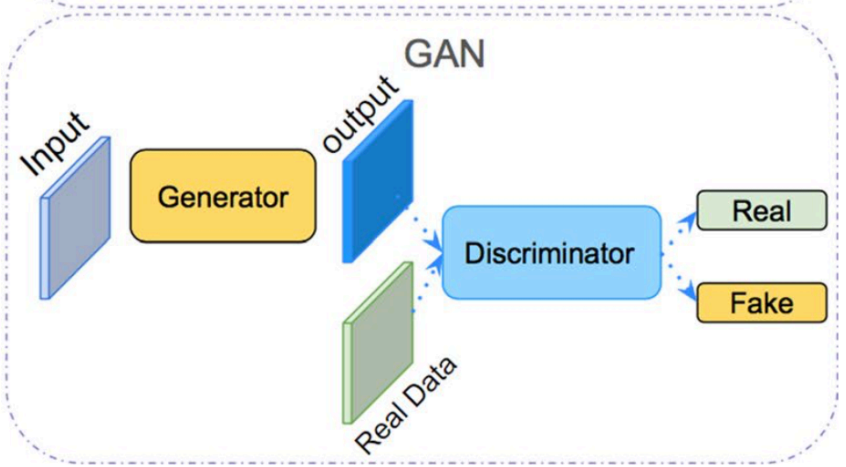
Common network architectures used for image reconstruction.

- A multilayer perceptron network based on fully connected layers
- An encoder-decoder architecture based convolutional layers
- A residual network
- A generative adversarial network (GAN).





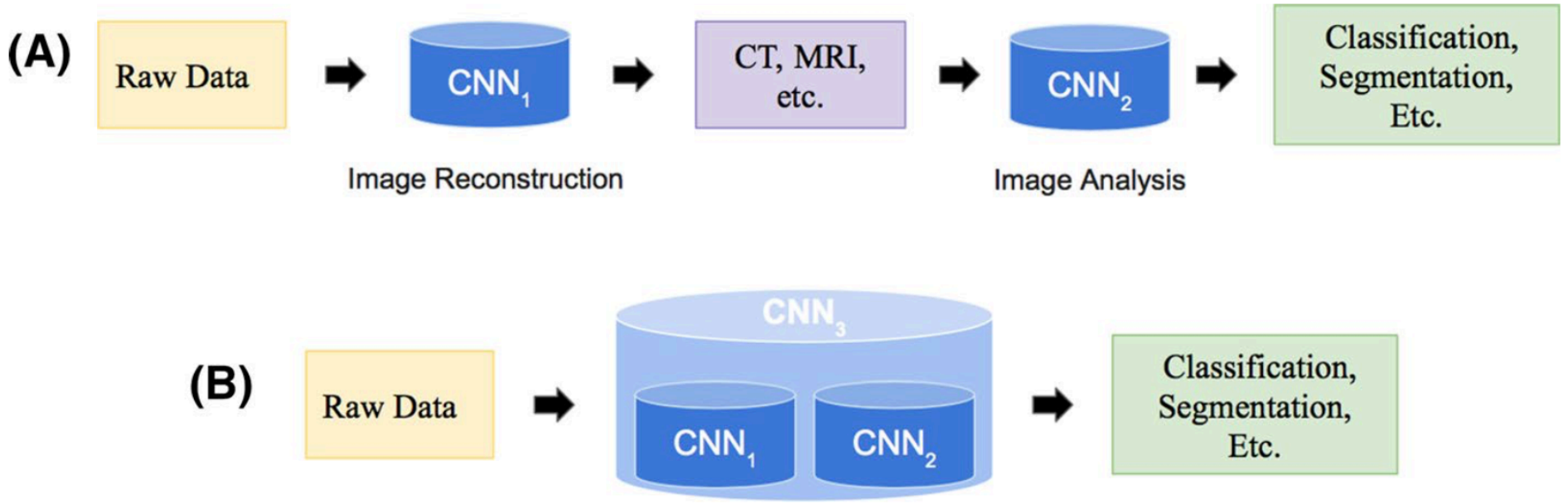




Raw-to-task methods: task-specific learning

Tasks:

1. Image reconstruction
2. Image processing (analysis)



Summary

- Classical image reconstruction algorithms approximate the inverse function relying on expert-tuned parameters to ensure reconstruction performance,
- Deep learning (DL) allows automatic feature extraction and real-time inference.

So, DL can present a promising approach to image reconstruction with artifact reduction and reconstruction speed-up.