Computer-Aided CT and MRI in Literature and the Clinic

Aidan Johnson | 01 June 2018 | Bioengineering 420

Introduction

- CT and MRI: a modality pair
  - Both tomographic
  - Scans map to image Fourier space
  - CT good for anatomical structures
  - MRI has better soft tissue contrast: neuroimaging
- State-of-the-art:
  - Goal: improve quality of care in the clinic
  - Limited supply of radiologists with rising costs of imaging
  - Advances in software and hardware techniques

Background

- CAD: computer-aided diagnosis
  - More complete patient information
  - Augments clinicians in the diagnosis process
  - Challenges: computer vision, quality
- Canonical steps of CAD:
  1. Preprocessing
  2. Segmentation
  3. Candidate/feature detection/extraction
  4. Classification

Image Reconstruction | Analytical

- Central Slice Theorem
  - Slice of the 2D FT of object = 1D FT of object projection
  - Not feasible to use in CT; method can be in MRI
- Filtered Backprojection (FBP): CT
  - Assumptions: approximation/estimation
  - Ignores 3D geometry of beam-cone
  - Subjectively sharper (clinically accepted) images

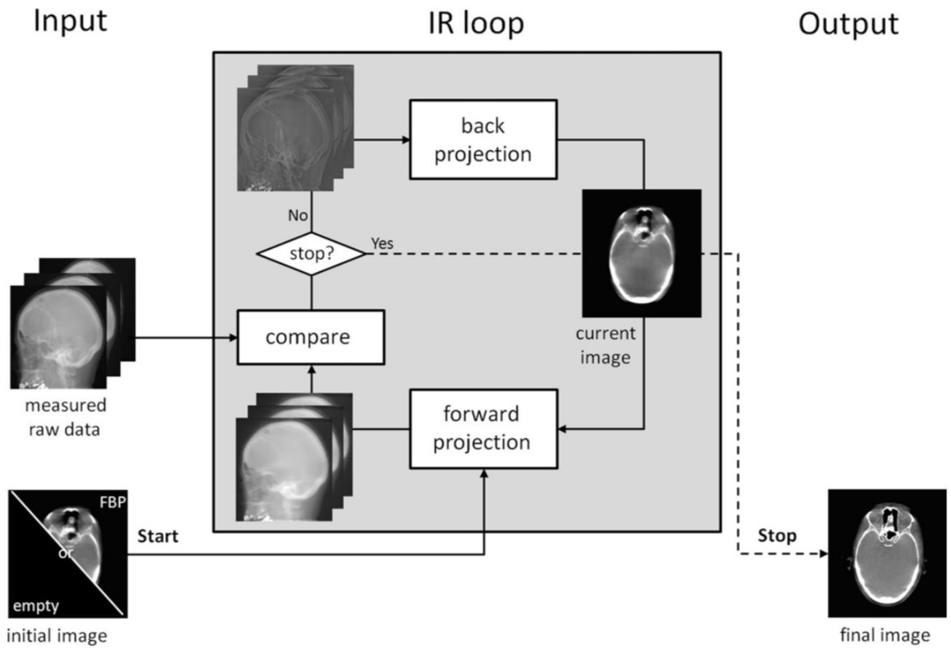
Image Reconstruction | Iterative

- IR first proposed in 1970s with introduction of CT
  - Parallel forward- and back-projections
  - Bases:
    - Statistical (random error of photons): ASIR
    - Model (geometry): MBIR
  - Initial estimate: a priori model
    - Model iteratively modified with measured raw data
    - Minimize cost/objective function

Image Reconstruction | GPUs

- IR: parallel modeling of:
  - X-rays pass through voxel instead of point
  - Pixel area of detector (process thread for each)
- Graphics processing unit:
  - Designed for parallel graphics computations
  - CPUs serial: separate instruction set per core (total: 4-12)
  - GPUs parallel: kilo thread processors per core (total: 20-40)
  - Trend of increasing clock speed, threads, memory

Iterative Reconstruction

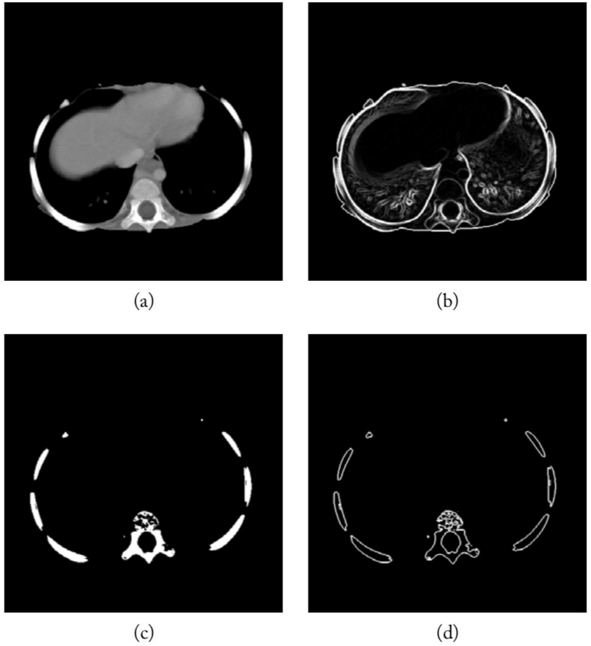


Schematic view of the iterative reconstruction process. The volume estimate is initiated either with an empty image or, if available, with a prior volume from e.g. an FBP reconstruction. First, a forward projection of the current volumetric image is necessary to create artificial raw data. Then artificial and measured raw data are compared and an updated image is computed which subsequently is backprojected to the current volumetric image. These three steps form the IR loop. If a stop criterion is matched, the loop is terminated and the current volumetric image becomes the final volumetric image.

Beister, Kolditz, Kalendar, 2012

Segmentation | Edges & Regions

- Segmentation: break image into partitions
- Detecting the segments by:
  - Edges
    - Thresholding (of histogram)
    - Gradient operators
    - Canny edge detector
  - Regions (similar pixels):
    - Merging
    - Splitting



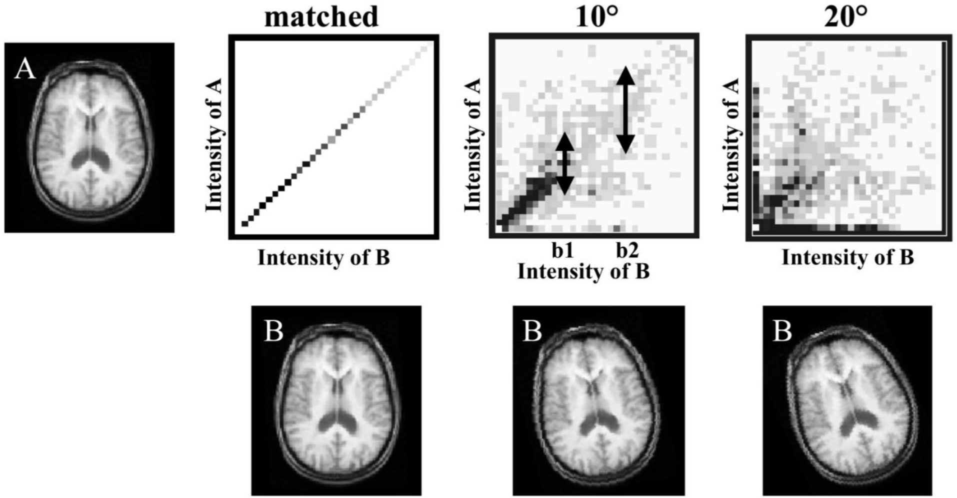
(a) A 512 × 512-pixel CT image showing a section through the chest with the display range HU=[-200, 400] out of [-3024, 1071]. (b) 2D gradient magnitude of the image in (a). Display range is adjusted to [5, 150] HU out of [0, 2371] HU. (c) The image in (a) thresholded within the range [200, 1008] HU. (d) 2D gradient magnitude of the binary image in (c). Banik, 2009

Segmentation | Deformable Models

- Detecting the segments by: deformable models
    - Active contours (snakes)
    - Snake, a curve evolves to minimize a cost function
    - Traverses image surface to find boundary of a region
    - Solving:
        - Lagrangian, dynamic programming, greedy algorithms
        - Parallel computations: GPUs!

Segmentation | Knowledge

- Make an atlas: database of expert knowledge, landmarks, anatomical images
- Align/map sensed image to reference image
    - Affine transforms
    - SIFT
    - Maximize mutual information



Joint intensity histogram. For two images, a joint intensity histogram is constructed by plotting the relative frequency of each pair of intensities. For voxels with a given intensity in B, the proportion of corresponding voxels in A with a particular intensity is plotted. The histogram approximates the joint probability density function and, therefore, the value in each cell estimates the probability of occurrence of a particular pair of intensities in the two images. For the special case of identical images (illustrated), the joint histogram forms a single line when the images are aligned, but disperses from this line as image B is reoriented. One approach to estimating dispersion is by measuring or standard deviation of voxel intensities in A for specific intensities in B (as illustrated for intensities b1 and b2).

Hutton & Braun 2003

Conclusions

- Primary motivation of CAD: accurate lesion detection
  - Mammography: breast cancer
  - Colonography: polyps
  - Pulmonography: malignant lung nodule
- Applications: Therapy, surgery, treatments:
  - Planning
  - Guiding
  - Monitoring
- Next steps: (1) improve algorithms; (2) computer vision specific hardware

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