Deep learning in ultrasound image analysis

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https://qdata.github.io/deep2Read

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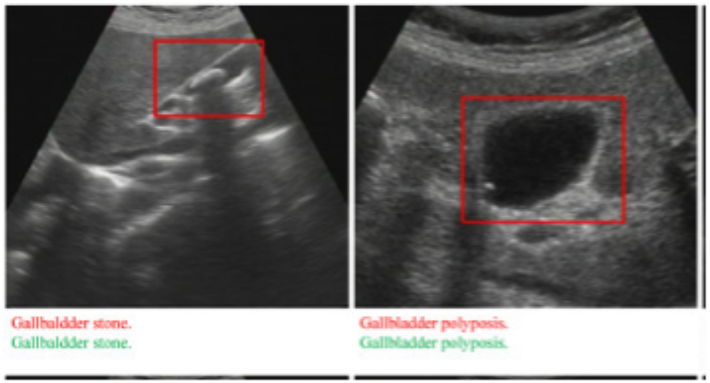
Medical imaging modalities: MRI, CT, X-ray, US

Properties of the US: safety, low cost, noninvasive nature, real-time display, operator comfort, and operator experience

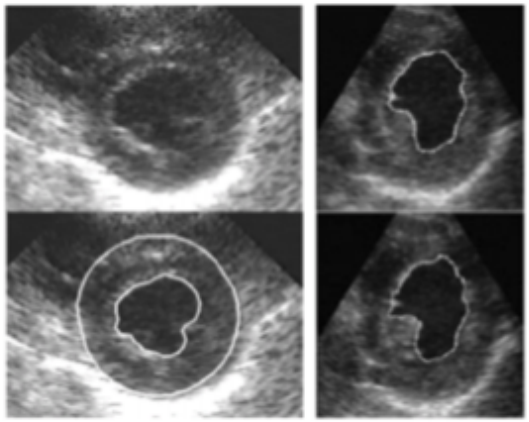
Challenges of the US: low imaging quality caused by noise and artifacts, high dependence on abundant operator or diagnostician experience, and high inter- and intra-observer variability across different institutes.

Applications of deep learning in US analysis:

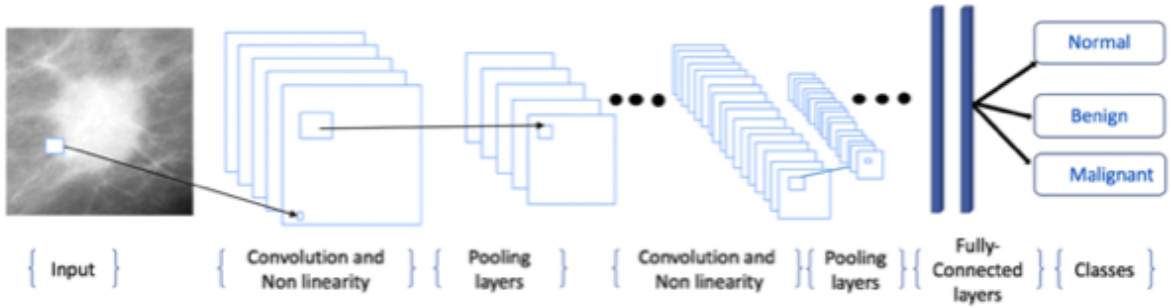
Classification, segmentation, detection, registration, biometric measurements, and quality assessment.



Detection



Segmentation



Classification

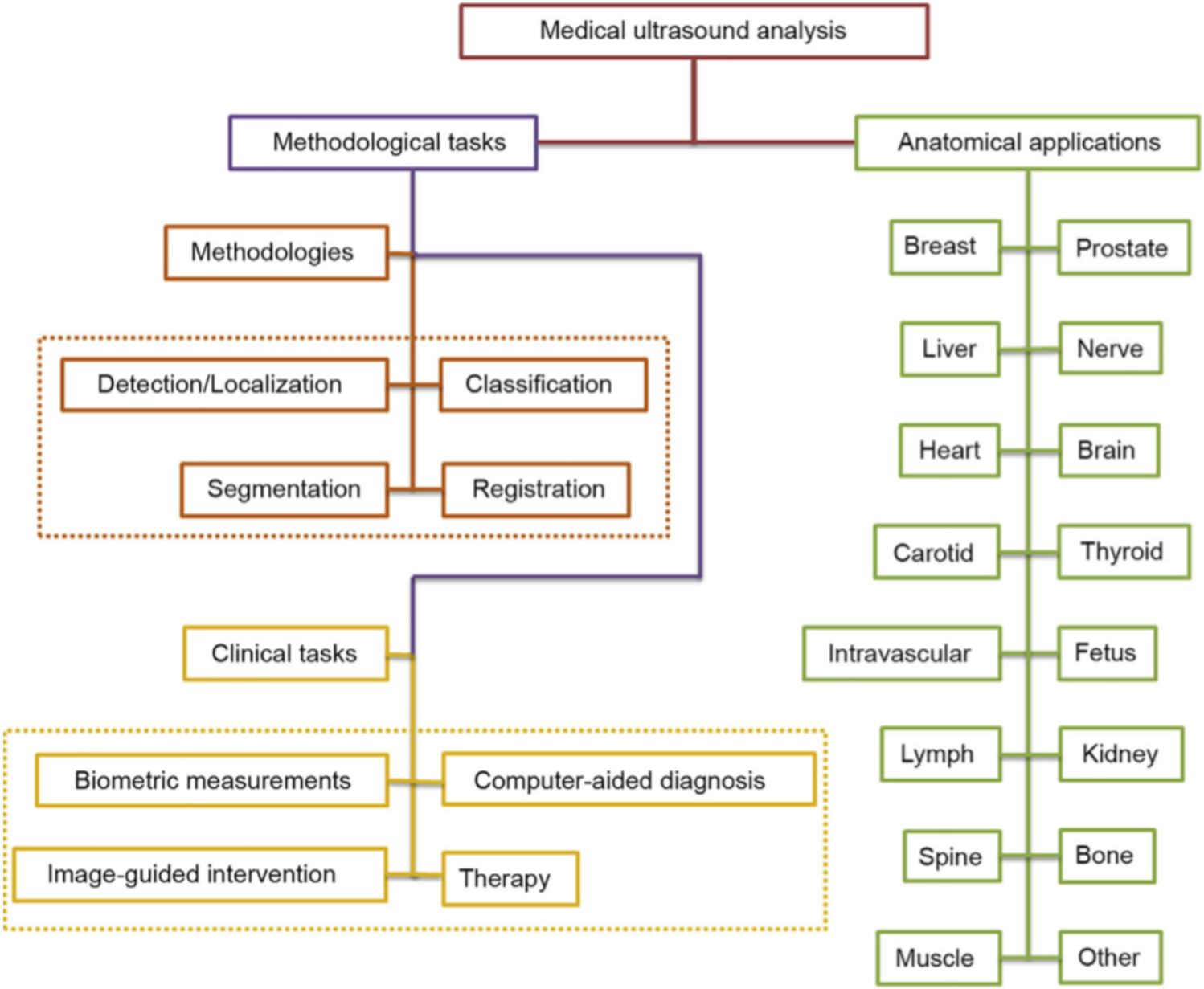
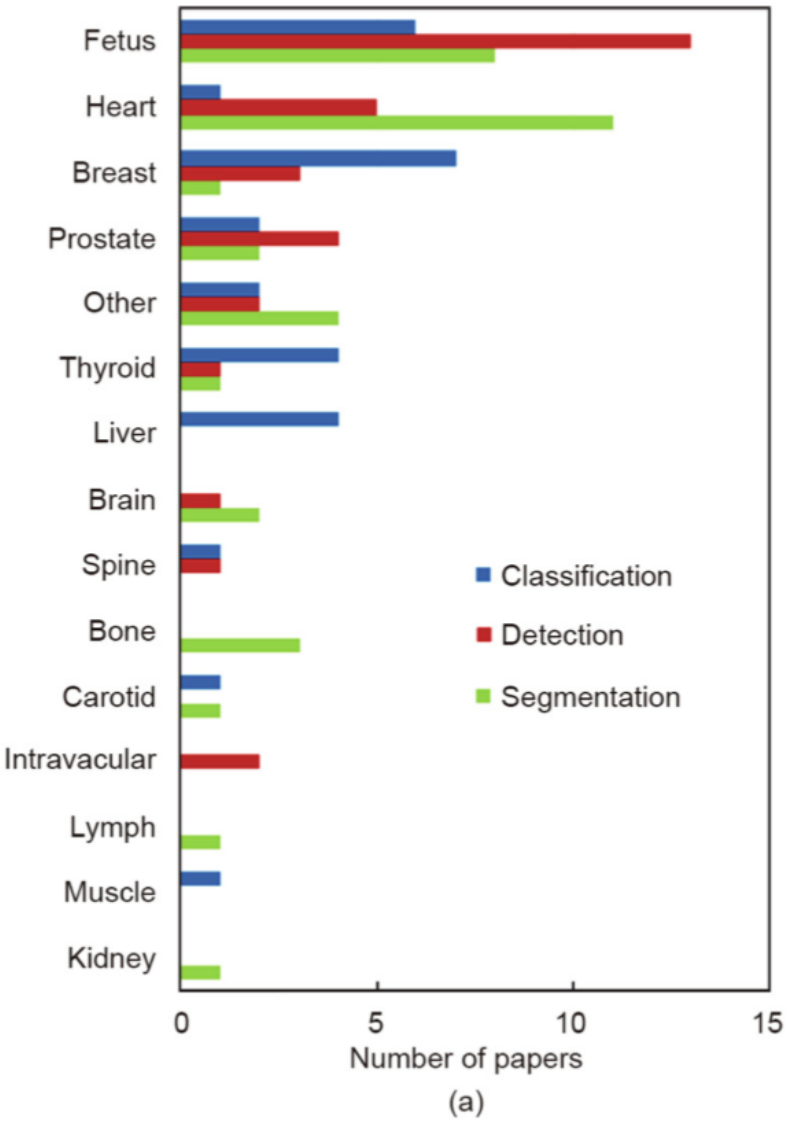
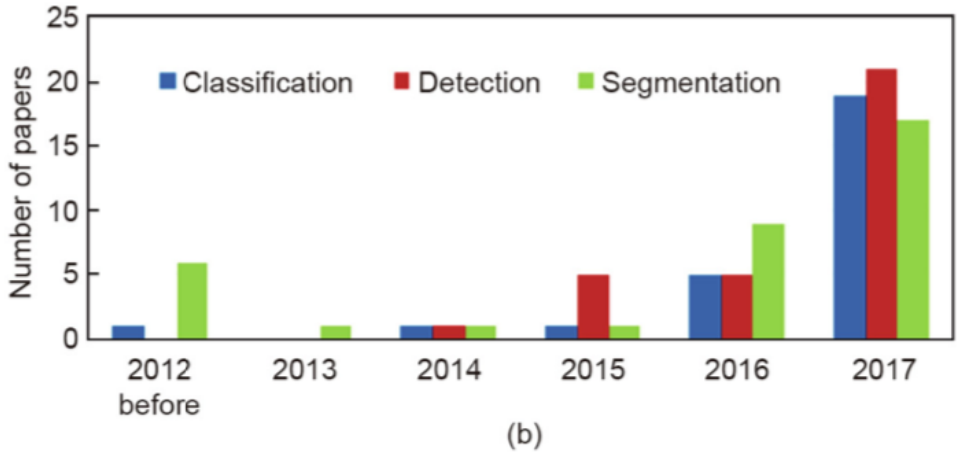
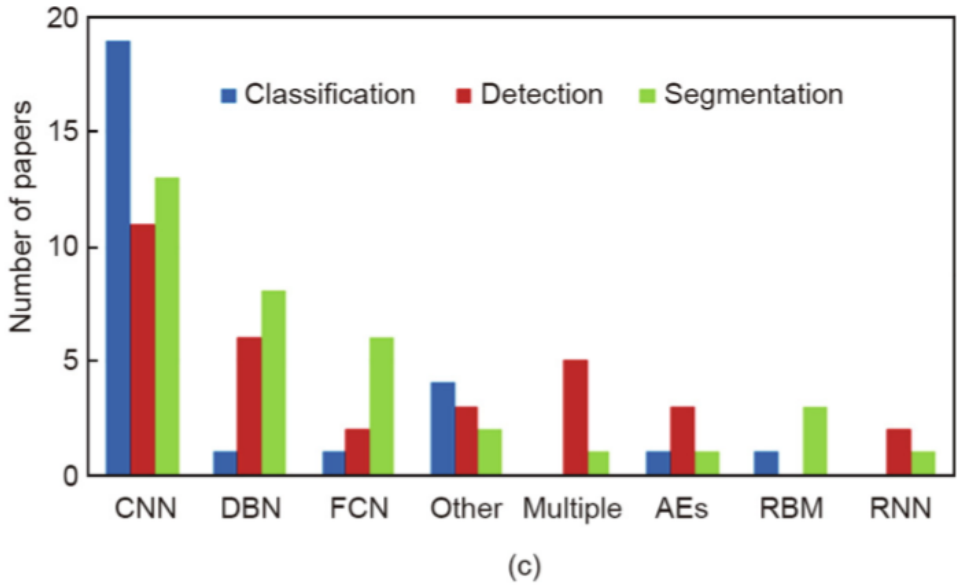


Fig. 1. Illustration of medical US analysis.


Fetus
Heart
Breast
Prostate
Other
Thyroid
Liver
Brain
Spine
Bone
Carotid
Intravacular
Lymph
Muscle
Kidney
Classification
Detection
Segmentation
0
5
10
15
Number of papers
(a)


Number of papers
25
20
15
10
5
0
Classification
Detection
Segmentation
2012
before
2013
2014
2015
2016
2017
(b)


Number of papers
20
15
10
5
0
Classification
Detection
Segmentation
CNN
DBN
FCN
Other
Multiple
AEs
RBM
RNN
(c)

Classification:

Tumors or lesions Several solutions:

- utilize various handcrafted features extracted from US images in combination with a multi-way linear classifier
  limitation: Susceptible to image distortion, such as deformation due to the internal or external environments, or to conditions in the imaging process.
- utilize unsupervised learning to learn image representation, and use the learned feature as input to supervised models.
- purely supervised model.

liver cancer

- Linear discriminant analysis (LDA), kNN, SVM, and back propagation net (BPN).
- Deep canonical correlation analysis (DCCA)—a variant of canonical correlation analysis (CCA)—combined with a multiple kernel learning (MKL) classifier

Nodules

two CNNs were trained on a large thyroid nodule US dataset separately, and then the two learned feature maps were fused as input into a softmax layer in order to diagnose thyroid nodules.

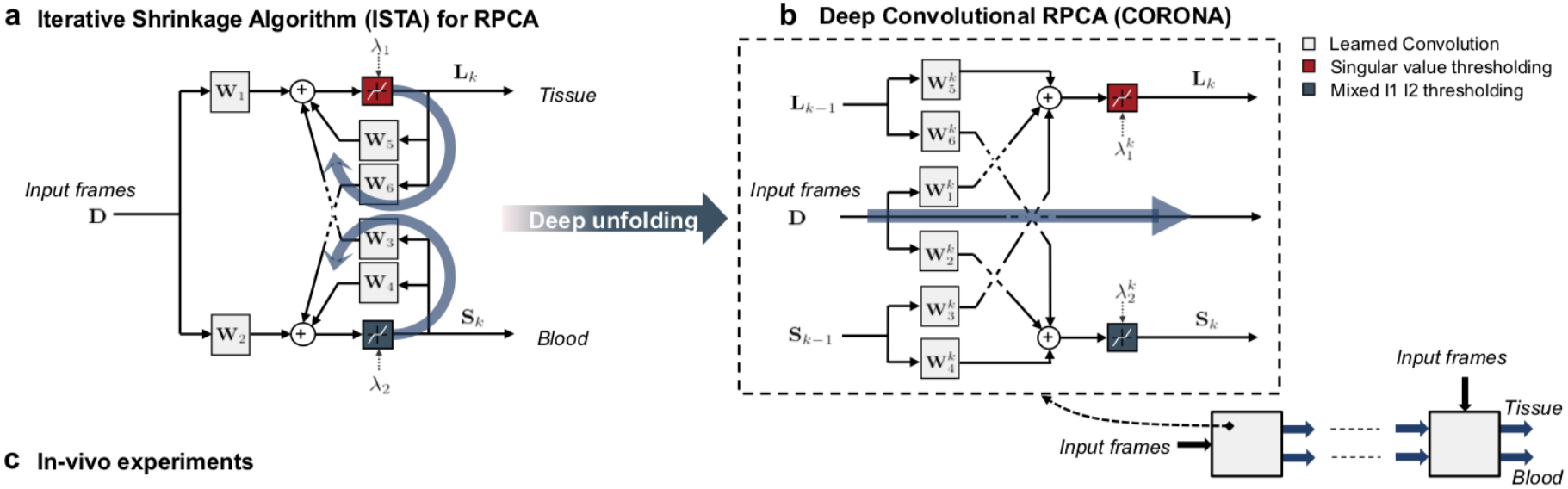
Segmentation

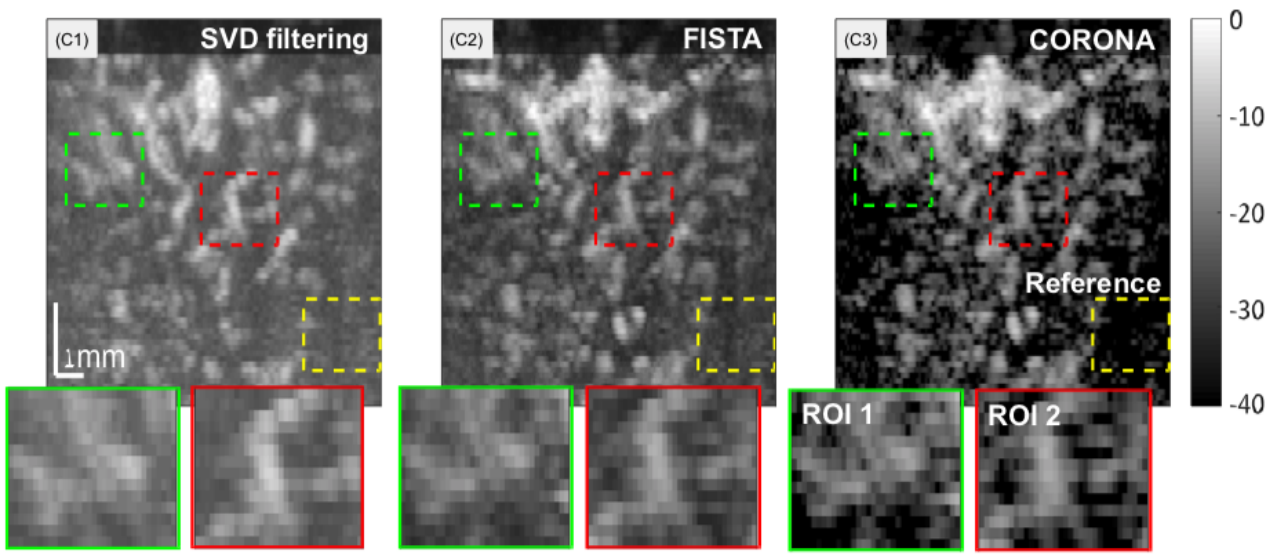
- Energy model: Partial differential equation based. Propose an energy function and optimize it based on Euler-Lagrange differential equation. Active contour, normalized cut
- Deep learning models: bottom-up and top-down models, FCN segmentation network.

US Image Denoising

Image denoising:
$D = L + S$, where L is low rank and S is sparse.
Solutions

- ISTA, FISTA
- LISTA, LFISTA, Cnvolutional robust PCA


a Iterative Shrinkage Algorithm (ISTA) for RPCA
Input frames
D
Tissue
Blood
Deep unfolding
b Deep Convolutional RPCA (CORONA)
Learned Convolution
Singular value thresholding
Mixed l1 l2 thresholding
Input frames
Tissue
Blood
c In-vivo experiments


c In-vivo experiments
(C1)
SVD filtering
(C2)
FISTA
(C3)
CORONA
Reference
1mm
ROI 1
ROI 2
0
-10
-20
-30
-40

Super-resolution Reconstruction $Y = AX + w$ where y is the vectorized image frame of the ultrasound sequence, A is the measurement matrix where each column of A is the point-spread-function shifted by a single pixel on the high-resolution grid, and w is a noise vector.