Automated Liver segmentation in CT images using three dimensional to two dimensional fully convolutional network

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Introduction

- **Liver, largest abdominal organ**: Vital for human life but at the risk of trauma, physical injury and cancer.
- **CT scans:** Gold standard, but a tedious job to analyze slice by slice of a CT scan and prone to human errors.

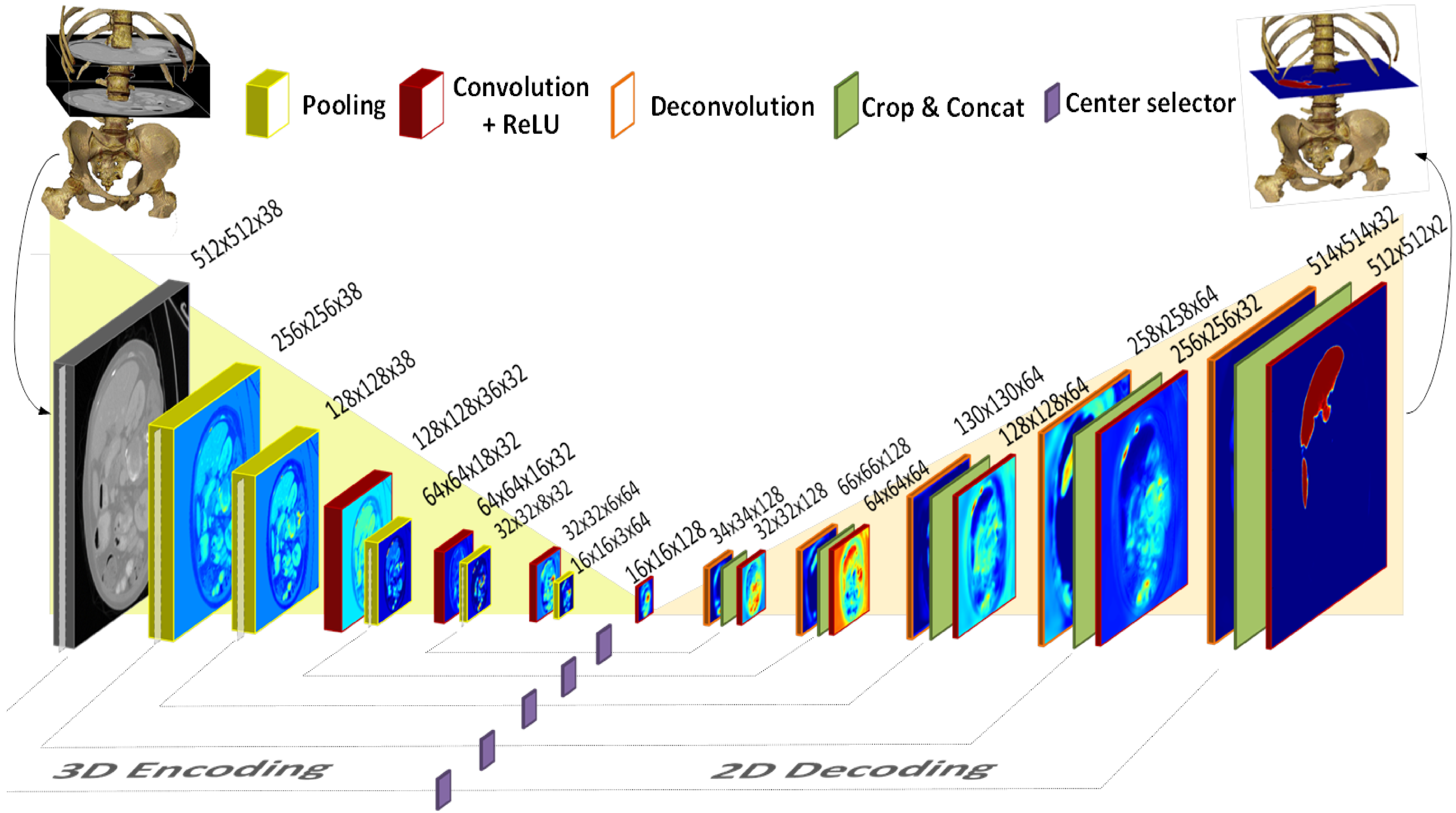
- **Automatic Liver Segmentation**: accelerating the process of trauma detection in emergency cases and pre-surgery calculations.
- **Previous Methods**: Time consuming with high memory usage, so not applicable in clinical settings.

Challenges

- **Low Quality** of CT images, due to artifacts.(e.g. motion artifacts)
- Inter-patient and intra-patient extremely **large** variety of **Liver location, size and appearance**
- Different **contrast phase** (e.g. portal venous) and **field of view**
- Similar intensity among **adjacent** organs with **vanishing borders**
- **Undetermined shapes** of liver at beginning and ending slices

Methods

3D CT scan → **Preprocessing** (Normalization) → **Liver segmentation** (3D-2D FCN) → **Postprocessing** (CRF) → Liver mask



3D-2D FCN Structure

- Cost function: Cross Entropy

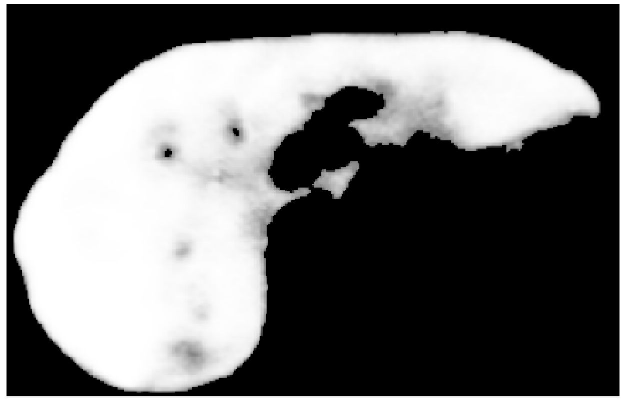
$$L(x,y) = -\sum_{(x,y)\epsilon\mathbb{Z}^2} log\,(p_c(x,y))$$

- Pixel weighting
  - The closer a pixel is to the boundary, the higher loss is imposed to the network

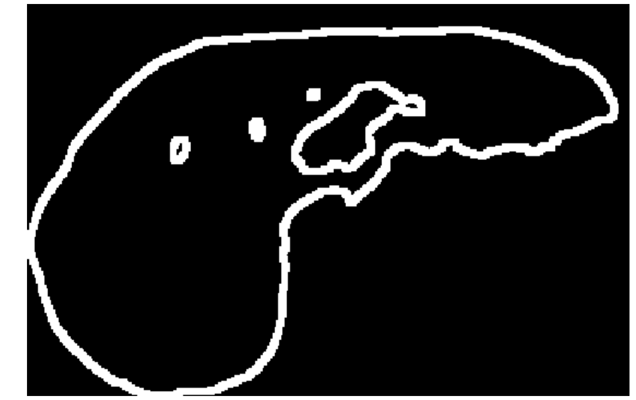
$$W(x,y) = 1 + w_0\, exp\,(-\frac{d(x,y)}{2\sigma^2}) \qquad E = -\sum_{x,y\epsilon\mathbb{Z}^2} w(x,y)\, L(x,y)$$

- Data augmentation
  - from -30 to 30 degrees in steps of 10
- Dropout layer (last layer of Encoder)
- Adam optimizer and Batch Normalization
- Early stopping (5-fold cross validation)

CRF PostProcessing



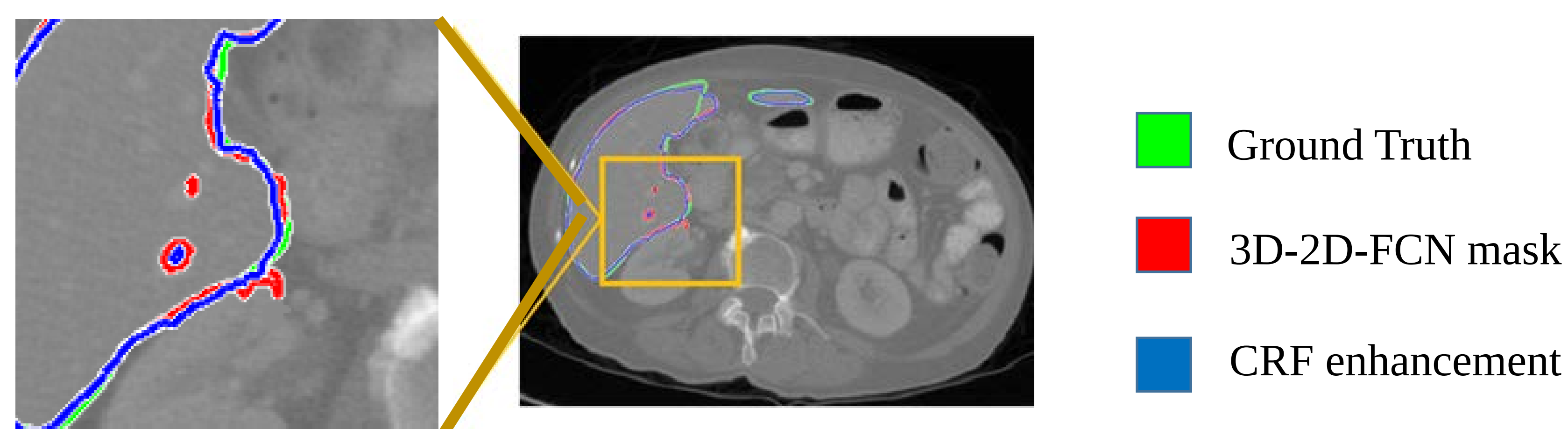
$$Border = (mask \oplus SE) - (mask \ominus SE)$$



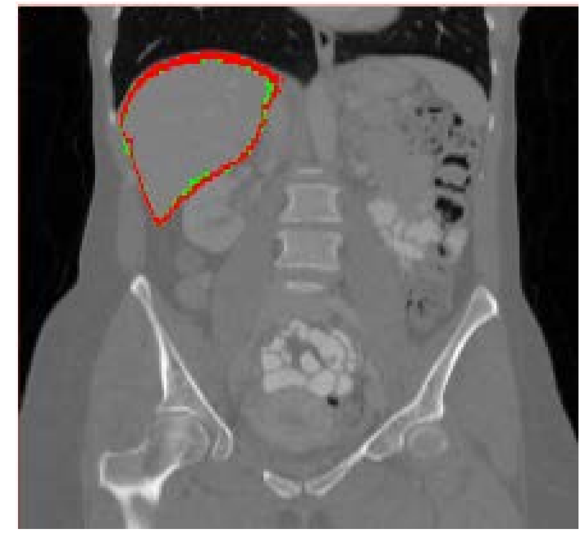
$$E(X) = \overbrace{\sum_i \psi_u(x_i)}^{\text{Unary = -log(pi)}} + \overbrace{\sum_{i,j\in N_i} \varphi_p(x_i, x_j)}^{\text{Pairwise}}$$

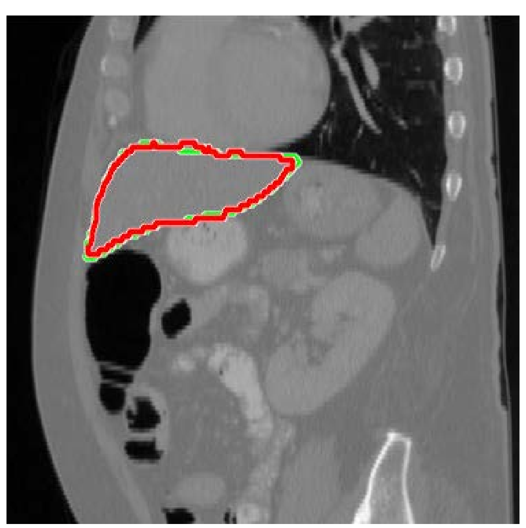
$$\varphi_p(x_i, x_j) = \mu(x_i, x_j)\left[\overbrace{w^{(1)} exp\left(-\frac{|p_i - p_j|^2}{2\theta_\alpha^2} - \frac{|I_i - I_j|^2}{2\theta_\beta^2}\right)}^{\text{bilateral}} + \overbrace{w^{(2)} exp\left(-\frac{|p_i - p_j|^2}{2\theta_\gamma^2}\right)}^{\text{unilateral}}\right]$$

$$\mu(x_i, x_j) = [x_i \neq x_j]$$







segmentation algorithms	Dice (%) $=\frac{2TP}{(2TP+FP+FN)}$	Time (second)
Heinrich[4]	92.95	1101
3D-2D-FCN	92.80	**42.72**
3D-2D-FCN + CRF	**93.52**	55.59

Table: Results on MICCAI dataset