UNSUPERVISED LEARNING OF ULTRASOUND SIMULATORS

Ortal Senouf[1], Sanketh Vedula[1], Alex Bronstein[1], Oleg Michailovich[2], Michael Zibulevsky[1]

1. Computer Science Department, Technion - Israel Institute of Technology
2. Electrical and Computer Engineering, University of Waterloo, Canada

1. Motivation

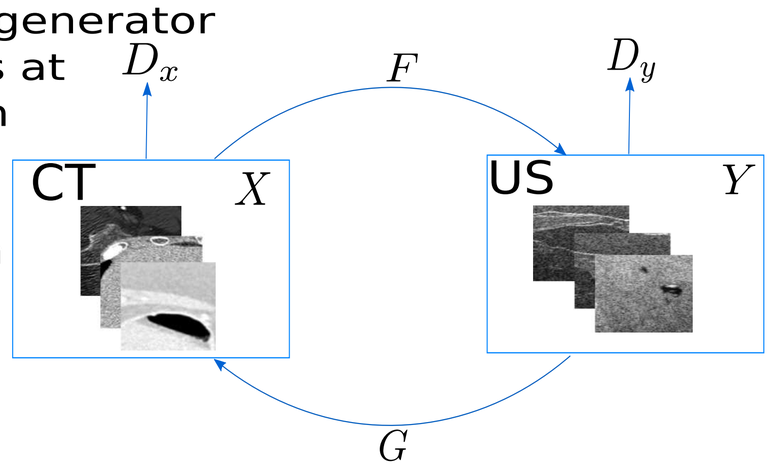
Simulators play an important role in medical ultrasound (US) imaging practice and research.

Common simulators for realistic imaging (e.g., Field-II and kWave) are not practical in conducting real-time simulations or for generating massive datasets.

Aiming at boosting simulation speed while maintaining realism, we propose an unsupervised learning method for simulating ultrasound images given corresponding X-ray CT image/scatterer map.

2. CycleGAN

CycleGAN [1] consists of two generator neural networks. The generator network F aims at synthesizing an ultrasound image (domain Y) from a given CT image (domain X), while G works in the opposite direction.



The generator networks are trained in an adversarial setting using two discriminator networks: D_X aims at discriminating between the real and synthesized CT images, and D_Y does the same for the ultrasound images.

$$\text{(1)}\quad \mathcal{L}_{GAN}(F, D_Y, X, Y) = E_{y\sim p(y)}[\log D_Y(y)] + E_{x\sim p(x)}[\log(1 - D_Y(F(x)))],$$

$$\text{(2)}\quad \mathcal{L}_{\text{cyc}}(G, F) = E_{x\sim p(x)}[||G(F(x)) - x||_1] + E_{y\sim p(y)}[||F(G(y)) - y||_1]$$

The generators and the discriminators are trained jointly to minimuze the loss as seen in (1).

Addtional regularization is applied to the optimaztion in the form of a cycle-consistency loss (2).

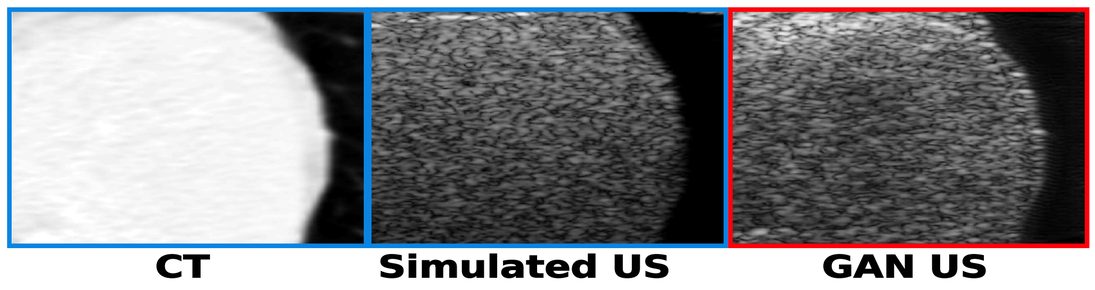
Acknowledgment

This research was funded by ERC StG RAPID

3. Experiments & Results

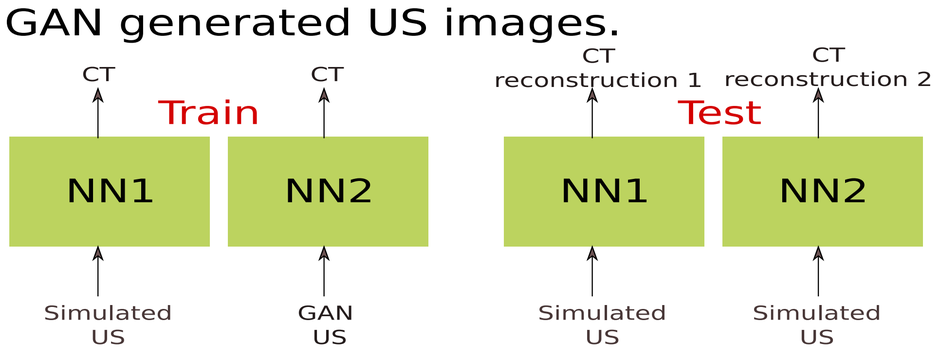
Visual insepction

In order to evaluate the performance of the generators, we provided the trained F with a CT image and the output was compared to the corresponding simulated US. A visual inspection of the results is presented below.

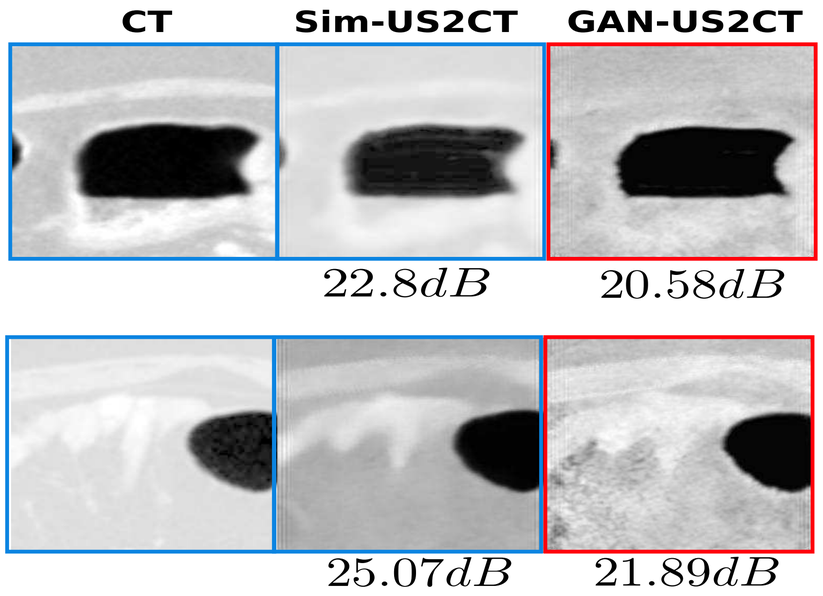


Inductive quantitative evaluation

CycleGAN generated US does not seem to preserve fidelity to the corresponding model-based simulated US images, possibly due to variability in the speckle noise realizations. We propose an inductive evaluation through the task of training an end-to-end network, as described in our previous work [2] on simulated and GAN generated US images.



The results show comparative performance of the network trained on simulated and GAN generated images, both visually and with respect to pSNR.



This provides an interesting avenue in bridging the gap between simulated and real ultrasound data in a learning based setting.

References

1. Zhu, Jun-Yan, et al. "Unpaired Image-To-Image Translation Using Cycle-Consistent Adversarial Networks." Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition. 2017.
2. Vedula, Sanketh, et al. "Towards CT-quality Ultrasound Imaging using Deep Learning." arXiv preprint arXiv:1710.06304 (2017).