Laser Depth Control

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Project MIRACLE
Planning and Navigation
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Motivation

Aim: We build a robotic endoscope to perform minimal invasive bone surgery with laser light on the tip of the endoscope. The laser light

- cuts through bones and muscle,
- while reducing trauma, and improving recovery time.

Our Task: We analyze acoustic waves during laser ablation [1] of the tissue to

- control the depth of the cut,
- reveal the structure of the bone,
- is real-time.

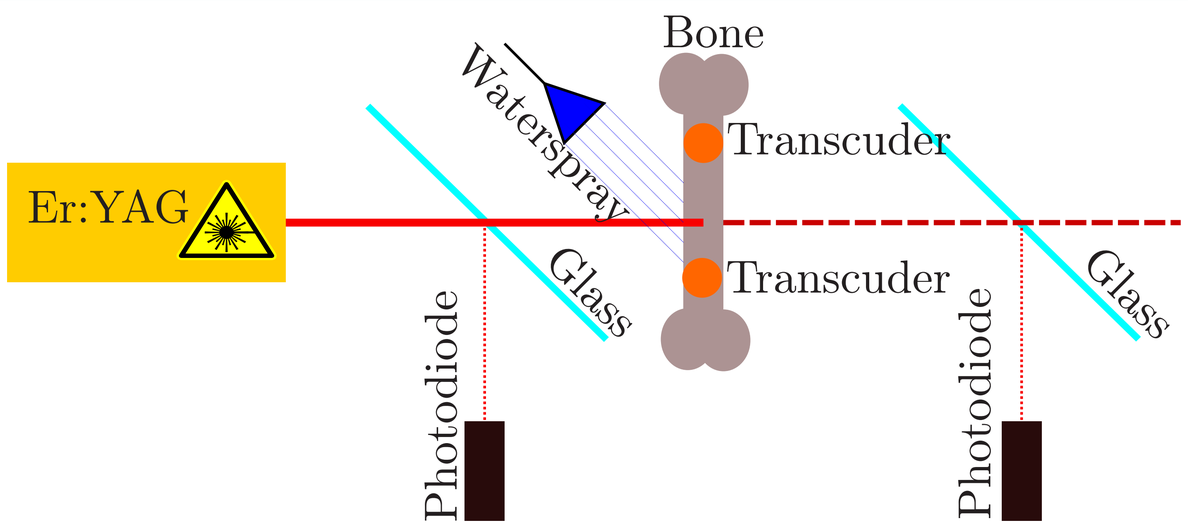
Challenge

Mathematical Simulations [2] vs Deep Learning

- slow computation (especially in 3D)
- unknown form of source (ablation)
- needs many transducers
- oversimplified

- fast computation
- requires a lot of training data
- small number of transducers required
- simpler to find reference measurement

Setup



Transducer (Pico-Sensor)

- ∅ 5 mm
- 200 kHz – 750 kHz

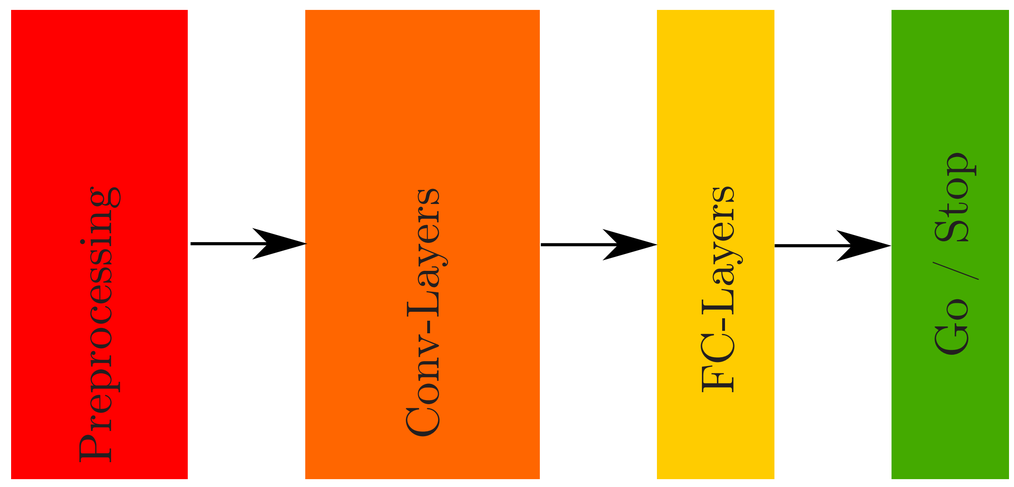
Er:YAG Laser

- wave length: 2940 nm
- repetition rate: 2 Hz
- duty cycle: 280 µs

Current Work

- Goal: detect a completed cut.
- Classifier: decide "Go" or "Stop" after each shot
- Tolerance: at least 10 shots before the end
- Input: acoustic wave of the last 5 laser shots

Network



- 4 Specimen: 2 training, 1 validation, and 1 testing.
- Preprocessing: nnAudio [3]
- Course grid search of hyperparameters [4]
- Training on the optimal found hyperparameters
- Accuracy: 77% = $\begin{cases} \text{Accuracy of } \textit{Go}: & 81\% \\ \text{Accuracy of } \textit{Stop}: & 73\% \end{cases}$

Open Questions

- Does the classifier actually detect the end or does it predict depth?
- How does the error depend on training data?
- How does the error depend on number of shots?
- How does the error depend on depth?

References

[1] H. K. Nguendon et al., "Comparison of acoustic shock waves generated by micro and nanosecond lasers for a smart laser surgery system", 2017.

[2] U. Nahum et al., "Bone reconstruction and depth control during laser ablation", 2017.

[3] K. W. Cheuk et al., "nnAudio: An on-the-fly GPU Audio to Spectrogram Conversion Toolbox Using 1D Convolution Neural Networks", 2019

[4] J. Bergstra et al., "Making a science of model search: Hyperparameter optimization in hundreds of dimensions for vision architectures", 2013.

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