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March 15, 2011

Critical Review of Paper

Paper: Nathanael Kuo, Hyun Jae Kang, Travis DeJournett, James Spicer and Emad Boctor, "Photoacoustic imaging of prostate brachytherapy seeds in ex vivo prostate", Proc. SPIE 7964, 796409 (2011); doi:10.1117/12.878041

Summary:

This paper focuses on the development of a novel method for prostate brachytherapy seed visualization using photoacoustic imaging. The paper begins by describing the significance of improving prostate brachytherapy, mainly attributing its importance to the fact that prostate cancer is one of the leading causes of death in America. It then describes the surgical procedure for low dose rate (LDR) prostate brachytherapy in which tiny radioactive seeds are implanted in a patient's prostate to eradicate cancerous tumors and growth.

The paper then explains what intraoperative treatment planning (ITP) is. The authors detail how deviations in seed placement from the pre-surgical plan (caused by patient edema or seed migration) can lead to a sub-optimal dose distribution of radiation. They then explain how ITP can compensate for deviations in seed placement, and argue that ITP will only be possible when proper and accurate seed visualization exists. At this point, the authors describe the current technologies used in LDR prostate brachytherapy, mainly transrectal ultrasound (TRUS) imaging, and argue that it can only be used for pre-surgical planning since its seed visualization capabilities are poor. The authors then explain that photoacoustic imaging for seed visualization is simpler in setup and cheaper than other seed visualization methods.

The paper then details the methods of the experiments that were conducted. The authors begin by listing and explaining all the hardware and software used: Surelite II Laser, SonixCEP Ultrasound System and Transducer, SonixDAQ Module, SonixRP Software, DAQControl Software, and Matlab Software. The authors briefly mention that the SonixDAQ is the most important piece of hardware as it allows them to record raw radio-frequency (RF) pre-beamformation data directly from the ultrasound machine. The authors then explain that the Matlab software allows the DAQ data to be read and converted to pre-beamformation images and post-beamformation B-mode images.

The actual protocol for each of the three experiments is then described. Mainly, for each experiment, the brachytherapy seeds are implanted on the surface of each phantom. The ultrasound transducer is then placed perpendicular to the plane of the firing laser. Finally, the laser is aimed and pulsed at the seeds and the data is recorded.

The authors then details the results of each experiment. They performed a signal to noise ratio calculation on only one of the experimental results. The authors then discuss how all of the photoacoustic images have some noise and artifacts, but argue that with future advancements in signal processing algorithms and improvements in hardware, the noise and artifacts will be diminished. Overall, the authors conclude that their results from the experiments indicate that photoacoustic imaging for the visualization of brachytherapy seeds looks very promising for the future.

Positives in this Paper:

The authors of this paper give very strong motivation for the advancement of prostate brachytherapy seed visualization and describe the significance of ITP in great detail. The experimental methods section of the paper was also very detailed as they explained exactly what each piece of equipment was responsible for and explained the process by which all the hardware was synchronized.

The setup of the experiments was also very well thought out. In particular having the ultrasound transducer perpendicular to the plane of laser firing to ensure that all the seeds could be imaged was very clever. The authors also thought of delay time (caused by hardware) between triggering the laser and the actual firing of the laser. They accounted for this type of delay in the software they wrote. This was another well implemented solution to a problem that most would forget about.

As a whole, the software was also implemented very well. Having the code process both a pre-beamformation image and a post-beamformation B-mode image allowed them to troubleshoot any imaging issues they may have had and isolate whether the problem was arising from the data acquisition or the actual processing (beamformation) of the data following acquisition.

Criticisms:

The major problem with this paper was that it was very qualitative. The only quantitative analysis performed on the data was a signal to noise ratio calculation on the one-seed phantom experiment. However this quantification was very vague. The authors did not describe their quantitative methods at all, and just included a signal amplitude plot as justification for their calculations. They should have performed this calculation for all of the experiments performed.

In addition, this paper did not adequately explain why photoacoustic imaging seed visualization is better than regular ultrasound imaging (not TRUS). For all of the experimental results the authors included an image of the seeds visualized under normal ultrasound. In two cases (the one and four seed phantom experiments), it looked like the ultrasound images of the seed were clearer than the photoacoustic images of the seeds as the seeds appeared with greater intensity in the ultrasound images. The ultrasound images appeared to have a bit more noise; however, without quantification, this could not be verified.

This leads into another problem with this paper. The signal to noise ratio calculation should have been performed on all the experiments (as previously stated) and should also have been completed on the ultrasound images for each experiment. This would truly show whether photoacoustic imaging of the seeds is better than the regular ultrasound imaging of the seeds. In general, not enough comparison between the two imaging modalities was given.

Another issue with this paper is that not enough background information was provided. Short explanations of ultrasound terminology such as beamformation and B-mode would make the paper less confusing to those without a medical imaging background.

Possible Future Work:

Improvements in the signal processing algorithm need to be made. There was still a noticeable amount of noise in each of the photoacoustic images. Improvements in the hardware will also need to be done. In all of the photoacoustic images, there was a consistent horizontal noise artifact near the top of the images. The authors attributed this artifact to an issue with the SonixDAQ. A method to further control the laser would be useful. Currently the laser needs to be aimed by hand onto the seeds. A method to focus the laser would also be an improvement. Currently the laser pulses are very wide, if they were focused more, the photoacoustic effect would be greater, and the images could be higher quality.

Motivation for Paper Choice:

This papers experimental setup is very similar to what our project will be using. We will be using the same ultrasound system, the same laser, and will be using the SonixDAQ to collect data as well. The description of the experimental setup is thus very helpful for our project's purpose. The main difference in setup is that we will not be using brachytherapy seeds, will be using a lower wavelength of light, and the transducer will be directly in line with the plane of the laser. In addition, Nathanael Kuo, a graduate student who we have been working with, and Dr. Emad Boctor, are two of the authors of this paper. They recommended this paper for background on our project.