Optical Properties for Bioluminescence Tomography in Mice

Computer Integrated Surgery II
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Introduction

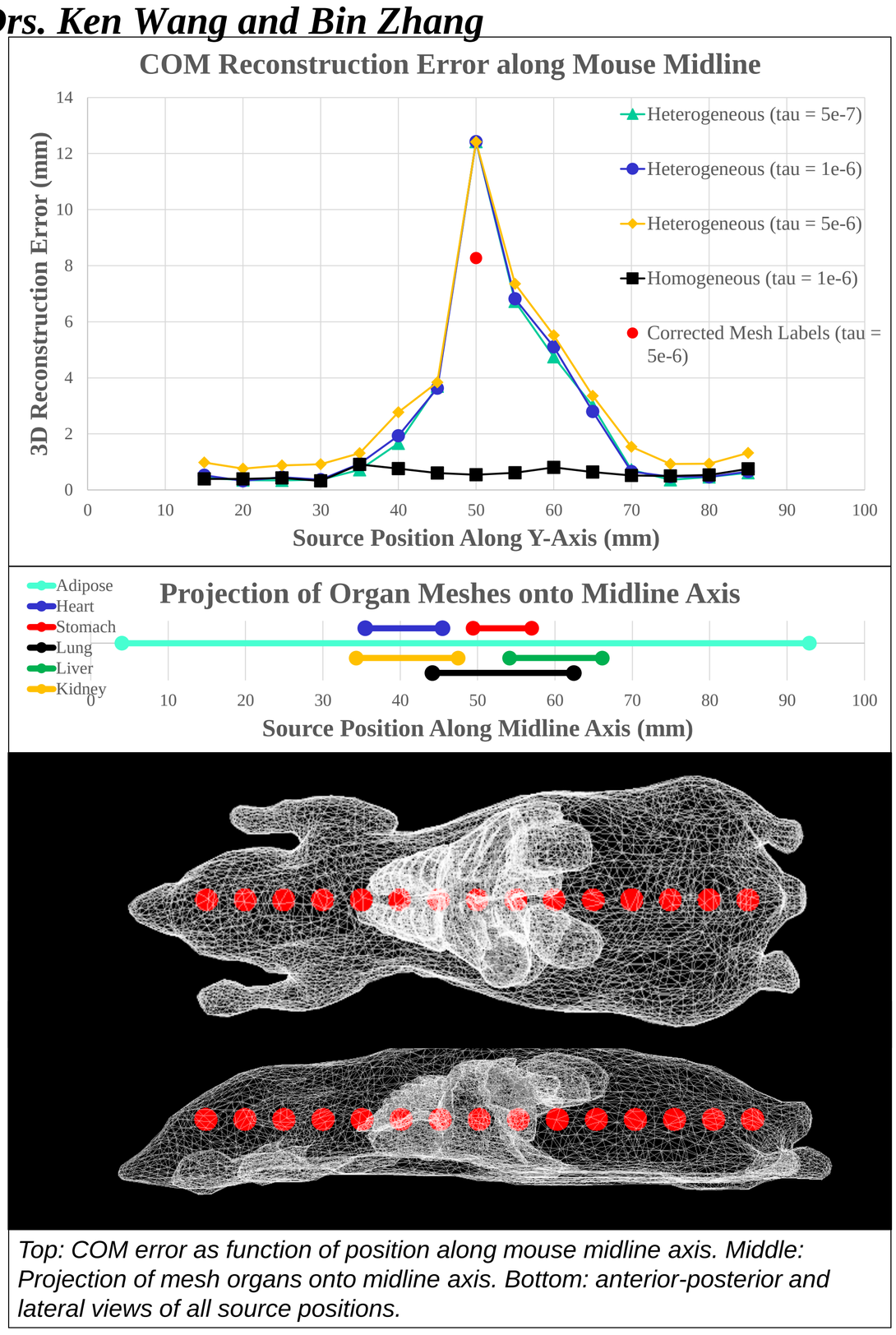
- Tabulated tissue-specific optical properties (absorption μ_a and reduced scattering μ_s') from literatures
  - Six organs (adipose, heart, kidney, liver, lung, stomach)
  - Four wavelengths 590, 610, 630 and 650 nm.
- Produced code to convert simulation results from open source Monte Carlo software, Molecular Optical Simulation Environment (MOSE), to Nirfast files for use in existing home-built bioluminescence tomography (BLT) implementation.
- Experimentally determined optimal number of photons to simulate in homogeneous medium for convergence of results.
- Performed BLT reconstruction experiments along midline in heterogeneous mouse mesh using forward-simulated surface transmittance

The Problem

- BLT has been implemented in the Small Animal Radiation Research Platform (SARRP) for purpose of localizing targets with low CT contrast in small animal models via 2D bioluminescence imaging.
- Previous experiments using the SARRP primarily explored localization of targets in regions of mouse that are relatively optically homogeneous (i.e. abdomen).
- Localization of targets in heterogeneous regions requires segmentation of organs as well as knowledge of optical properties to assign to those regions in reconstruction
  - Literature values for mouse organ optical properties are relatively sparse and have large variations, depending on:
    - Method of measurement.
    - Physiological conditions.
- It is useful to describe the target (e.g. tumor) localization uncertainty introduced of the SARRP BLT's reconstruction in an optical heterogeneous environment.

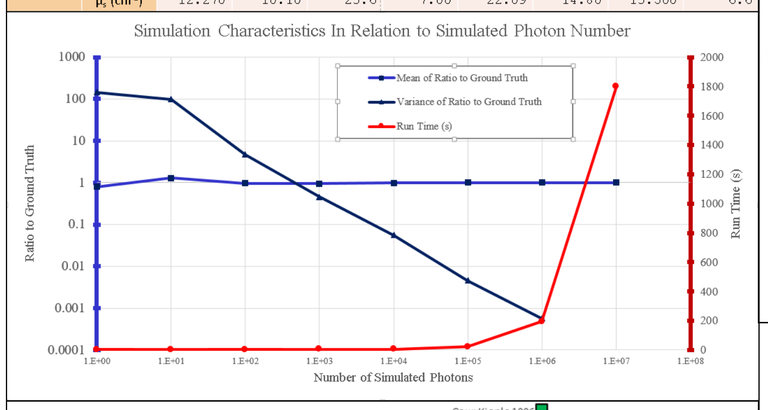
The Solution

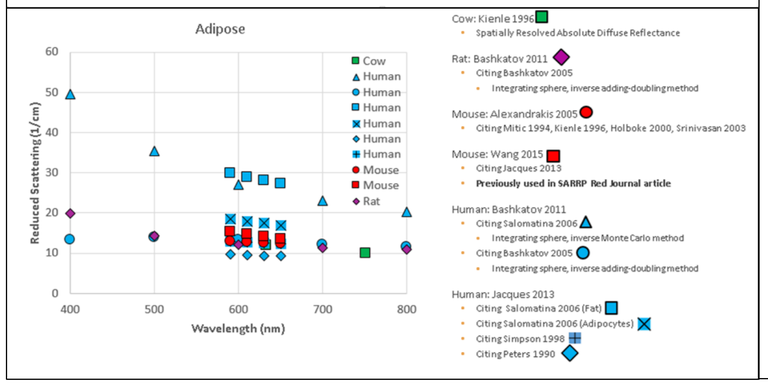
- Obtained optical properties for use in simulation and reconstruction by calculating using Alexandrakis' empirical model after evaluation in context of other sources (see 'top' and 'bottom left' figures below).
- Developed workflow to produce forward simulation data and reconstruct with BLT.
  - Assigned optical properties to segmented mouse mesh in MOSE
  - Experimented for optimal photon count for simulation (see 'middle' figure below). Used 1e6 due to runtime considerations. Results from 1e7 used as 'ground truth'.
  - Code to adapt MOSE simulation outputs for reconstruction in home-built BLT implementation
  - Recorded COM error along heterogeneous mouse midline



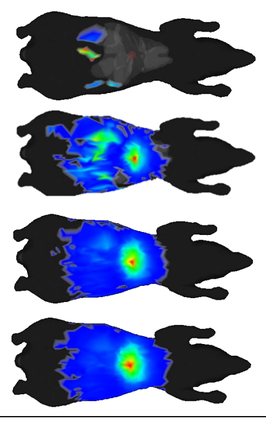
Top: COM error as function of position along mouse midline axis. Middle: Projection of mesh organs onto midline axis. Bottom: anterior-posterior and lateral views of all source positions.

λ (nm)		Alexandrakis						SARRP Red Journal	
		Adipose	Heart	Kidney	Liver	Lung	Stomach	Abdomen*	Tumor**
590	μ_a (cm^{-1})	0.431	6.65	7.45	39.90	21.08	1.29	0.431	3.8
	μ_s' (cm^{-1})	12.900	11.60	27.3	7.75	23.25	16.26	15.300	9.0
610	μ_a (cm^{-1})	0.127	2.00	2.24	11.99	6.63	0.38	0.127	2.3
	μ_s' (cm^{-1})	12.700	11.00	26	7.50	22.85	15.74	14.600	7.6
630	μ_a (cm^{-1})	0.069	1.08	1.21	6.45	3.59	0.21	0.069	1.9
	μ_s' (cm^{-1})	12.480	10.50	24.7	7.23	22.46	15.25	14.000	6.9
650	μ_a (cm^{-1})	0.050	0.78	0.87	4.67	2.61	0.15	0.050	1.6
	μ_s' (cm^{-1})	12.270	10.10	23.6	7.00	22.09	14.80	13.500	6.6





Top: optical properties used in simulation and reconstruction. Middle: surface transmittance convergence with respect to simulated photon count. Bottom left: example of gathered literature values. Bottom right: example transmittance map at wavelengths 590, 610, 630, and 650 nm.



Outcomes and Results

- Demonstrated inherent increase in localization uncertainty, even when provided complete knowledge of optical properties and organ segmentations in simulated condition (see above figures).
- COM error consistently <1 mm in homogeneous mesh regions, in agreement with prior expectations
- Peak COM error near position Y=50 mm deemed higher than prior expectations and warrants additional exploration.

Errata

- Forward simulation results were obtained using a labeled mesh, in which lung, liver, and kidney labels were swapped

Future Work

- Future work will address correction of the above errata by performing BLT reconstruction using same workflow and corrected mesh
- Note single point at position Y=50 mm plotted above, obtained with corrected mesh

Lessons Learned

- Clarity of presentation can be as important as the material presented
- Even code/calculations from credible sources should be verified
  - On several occasions, found likely errors in published optical property calculations and also in mesh labelling

Credits

- Alan Cham was the sole student partner in this project, under the guidance of Drs. Ken Wang and Bin Zhang.

Publications

- At this time, no submissions for publication are planned for the above-described work.

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