Microwave-Related Tissue Changes Using Ultrasound: Processing Images into Spectral Colors (08-ENBM-0034)

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Abstract

Microwaves in the medical field are used to denature proteins and deactivate abnormal cells. Ultrasound helps define organ structures and identify abnormalities. In my previous study, increased duration of exposure of tissue to microwaves was associated with statistically significant increase in intensity of brightness of the images. Ultrasound images are monochromatic which results in underappreciation of the subtle changes in the brightness of tissue by the naked eye. By processing the variations in spectral colors of the brightness of the reflected ultrasound waves, it may be possible to recognize the changes and help apply them in clinical practice. This engineering study seeks to advance the knowledge of reflected waves by processing ultrasound images to spectral colors for recognizing tissue changes with microwave exposure. Ultrasound images of lamb muscular, lamb liver, and chicken muscular tissue before and after exposure to microwaves were studied. A total of 30 organic tissue images were studied. Although this was a statistically significant increase in brightness of each of the studied tissues on exposure to microwaves energy (chicken muscle 41.18% vs 71.77%; Lamb liver 32.70% vs. 65.18%; Lamb muscle 54.04% vs 70.90%), the changes on monochromatic images were not well appreciated. Using an algorithm to represent the images in spectral colors (altering the intensity of brightness into RGB value of a color) resulted in better appreciation of the changes. The finding of the study could possibly helpful in real time appreciation of the changes in tissue exposed to microwave energy in clinical practice.

Introduction/Research

- Microwaves
  - electromagnetic radiation with wavelengths ranging from about one meter to one millimeter
  - frequencies between 300 MHz and 300 GHz.
- Microwave ovens
  - work by using microwave about 12 centimeters in length to force water and fat molecules in food to rotate quickly.
  - interaction of these molecules undergoing forced rotation creates heat, and the food is cooked.
  - heating organic tissue causes aggregation of protein structures identified in the form of increased opacification and shrinking of the tissue on gross examination.
- Medical applications of microwaves
  - rapidly developing field.
  - results in destruction of malignant/abnormal cells by rapidly increased temperature resulting in loss of self-protective mechanism of abnormal cells
  - extent of destruction of abnormal tissue is essential for
    - accomplishing successful therapy
    - reduce collateral damage
- Ultrasounds
  - sound waves with frequencies higher than the upper audible limit of human hearing (over 20KHz).
  - share physical properties of "normal" (audible) sound
    - reflected waves in the form of echoing of the sound.
    - The reflected waves have information of distance and also signal of the object it bounced against (brightness).
- Ultrasound in medical field
  - to identify organ structures in the body (McMahon).
  - In my previous study, I found that:
    - Increasing exposure to microwave => Increased intensity of reflected ultrasound waves
    - Although this was statistically significant, recognising the changes on visual examination was not distinct
- Humans can distinguish about 30 different monochromatic shades
  - Ultrasound scans are monochromatic
  - subtle changes might go unappreciated
- Computer programming may assist in these difference in brightness distinguishable

Goal, Criteria, and Constraints

- **My goal in this engineering project is to develop a process of modifying monochromatic ultrasound images to identify the changes in tissue exposed to microwave energy.**

The outcome pictures must:

- represent the monochromatic differences in a systematic pattern (similar to noted on the preprocessed images)
- Create an image with distinct patterns which can be easily appreciated
- Images should represent the specific reflection changes happening on exposure to microwaves.

The program must:

- Be able to convert digital images (.jpg, .jpeg, .bmp)
- Outcome images processing could be used in real time
- Programming language used should be available widely

Materials & Methods

Materials:

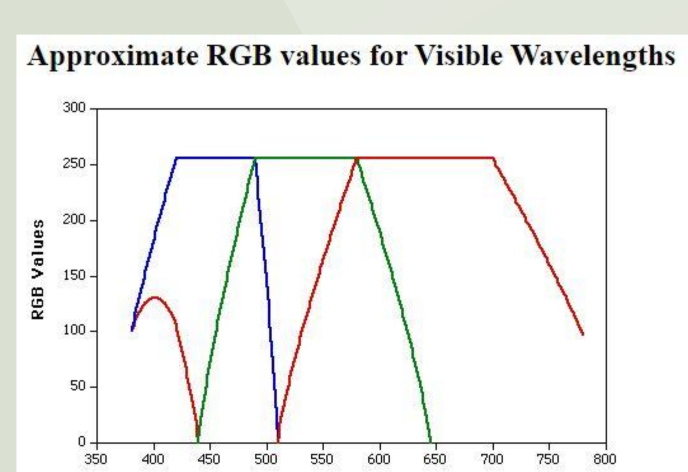
- 15 pieces of tissue (5 each of Chicken Muscle, 5 Lamb Liver, and Lamb Muscle) (obtained from the local store) over 2 cm in thickness (as measured in raw status).
- 3.5 MHz 2D M-Mode Ultrasound
- Sharp Knife
- Conventional Microwave
- Small container
- Water
- Paint App (Windows 10)
- Python IDLE version 3.11.2

Process to acquire images:

1. Tissue is cut to a 2 cm in thickness (as measured in raw status).
2. Ultrasound images of the raw state
3. Tissue is exposed to microwave energy for a duration of 1 min
4. Ultrasound images of the tissue after exposure to microwaves
5. Ultrasound reflection at a depth of 1mm is measured
6. 2-Tailed T-Test was used to define significance of the brightness change at 1mm depth. P<0.05 is considered significant

Post processing image modification:

1. Pre-Process image is inputted into the program
2. The program converts every pixel by:
   a. Recording the pixel RGB value
   b. Finds the mean of RGB values
   c. Calculate % of reflected ultrasound intensity and represent as visible wavelength
      i. x= RGB value
      ii. y=Output as wavelength
      iii. y= (-80/357)x+400
   d. Turns visible wavelength into an RGB tuple (R', G', B')
   e. Changes the pixel from (R, G, B) to (R', G', B')
3. Saves all the pixel and the final image



Results

- Total of 30 ultrasound images studied
- Highest intensity: 80.39%; Lamb Muscle After Exposure
- Lowest intensity: 27.84%; Lamb Liver Before Exposure
- Most difference in reflected ultrasound waves was lamb muscle tissue (54.04% vs 70.90%)
- Intensity of reflected ultrasound waves increased after exposure to microwaves
- T-Test confirmed the significant increase in the intensity of reflected ultrasound waves in each of the tissues studied (chicken muscle 0.010, lamb liver 0.006, lamb muscle 0.007).
- Algorithm helped represent monochromatic ultrasound scans into color images
- Intensity of ultrasound waves reflected in a pixel appropriately were replaced with a color on the electromagnetic spectrum
- Post processing images replicated the changes noted in monochromatic ultrasound scans
- Changes in intensity of reflected ultrasound waves were easily perceived by the naked eye
- Pre- and Post-exposure images were easily distinguishable and could be accurately identified (further randomized evaluation may be required)

Figure 1: Tissue before and after exposure

Figure 2: Process Diagram of Code and Algorithm Assisting in Processing a Monochromatic Ultrasound Image to Spectral Colors

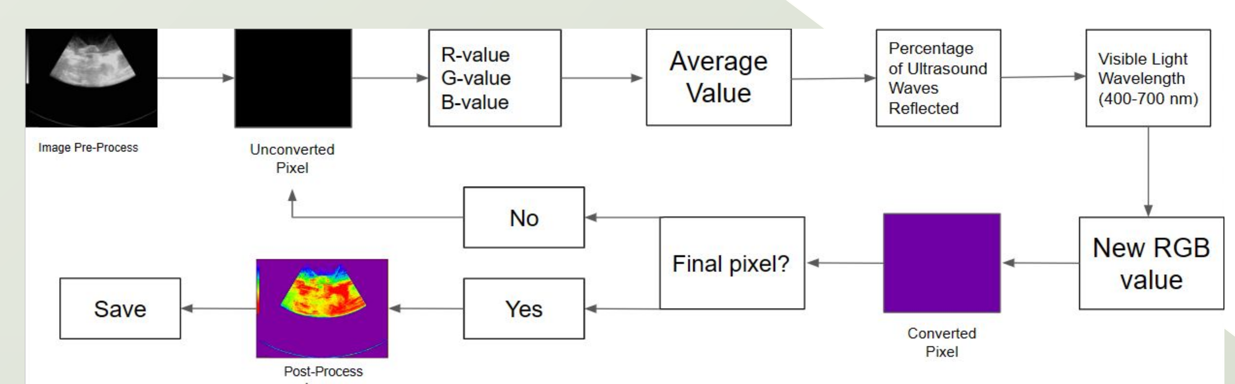


Figure 3: Table of Monochromatic Ultrasounds and Their Altered Counterparts

	Pre- Microwave Exposure		Post- Microwave Exposure	
	Monochromatic	Spectral Color	Monochromatic	Spectral Color
Chicken Muscle Tissue				
Lamb Liver Tissue				
Lamb Muscle Tissue				

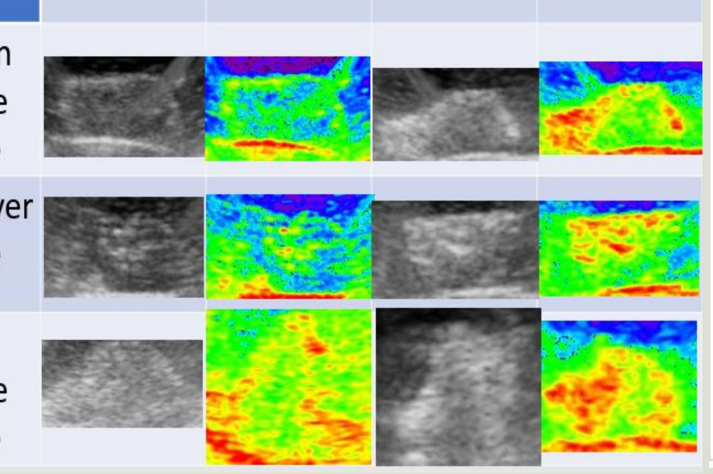
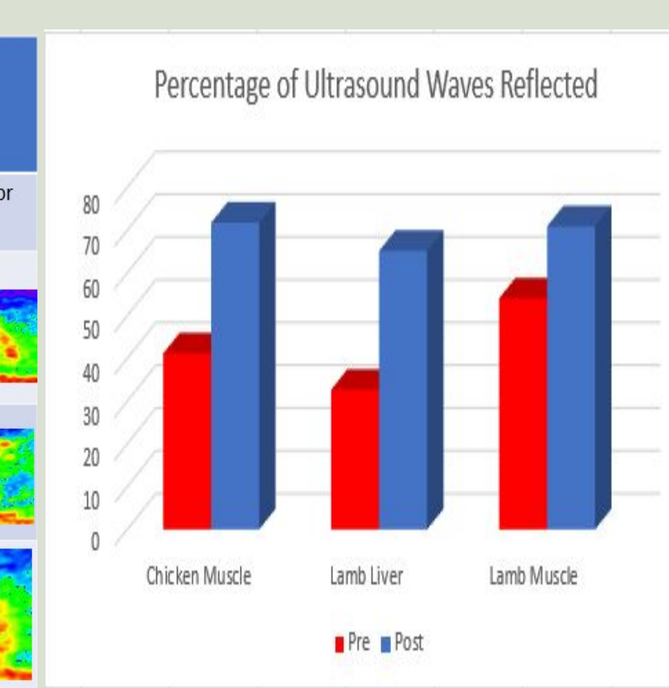


Figure 4: Percentage of Ultrasound Waves Reflected on Examination of Ultrasound Scans



Conclusion

- Intensity of brightness of tissue on ultrasound images increased with exposed to microwaves (similar to my previous study)
- Summary
  - Algorithm changed appropriately monochromatic ultrasound to color images
  - Intensity of ultrasound waves reflected in a pixel appropriately were replaced with a color on the electromagnetic spectrum
  - Post processing images replicated the changes noted in monochromatic ultrasound scans
  - Changes in intensity of reflected ultrasound waves were easily perceived by the naked eye
  - Each individual pixel's RGB value (of the ultrasound image) was converted it to the percentage of ultrasound waves brightness and represented in visible light wavelength, a new RGB value (R'G'B').
- Scope
  - This program can be utilized in microwave-related ablations for visualization of the lesions created in real-time.
- Additional Notes
  - Further studies are required to assess the program's use in real-time in-vivo procedures.

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