Scoliosis is the most common deformity in school-aged children (Mirtz. 2005). Scoliosis is normally monitored using x-ray imaging, which is expensive and exposes patients to unnecessary amounts of radiation. Overexposure to x-ray radiation increases the likelihood of cancer later in life and can harm reproductive cells, which can be passed down to future children and grandchildren. With only 10% of minors actually requiring imaging for their scoliosis - 90% are exposed to radiation unnecessarily - it is our belief that a safer, low-cost, accurate imaging modality is needed to diagnose and track scoliosis in minors. Currently, other methods of diagnosis involve Magnetic Resonance Imaging (MRI), Computed Tomography (CT) scans, and Ultrasound. MRI is a viable option but it is expensive and is less available than other imaging modalities (Diefenbach. 2013). CT scans are also expensive and can expose patients to more radiation than x-ray imaging (Frerich 2012). Ultrasound (US) offers a cheap, portable, and safe option for detection but has lower spatial resolution. When examining US images, it can be difficult to discern bone surfaces from soft tissue if the user has not had much exposure to reading scans. Our design aims to be used as a teaching tool to aid in the analysis of US images. Using a MATLAB Graphical User Interface (GUI), an US image is inputted and segmented before being overlaid on top of the original input image. This allows the user to look at the original image and the bone surface segmentation at the same time. With enough practice and repetition, users may become more familiar with recognizing bone surface features in US images.

We began by developing a MATLAB script that utilized Gaussian filtering on the images that would be loaded in. This was done because we wanted to enhance the visibility of the bone surface as much as possible. In US scans, bone surfaces are lighter in shade in comparison to soft tissue which comes out black. This allowed us to effectively use Gaussian filters to exaggerate the lighter tones and distinguish them from the darker ones. Once this was done, we developed another MATLAB script that would find phase shifts in the image and automatically trace out a single path along the bone surface of the Ultrasound scan and output a binary image that corresponds to that segmentation. By running this step after the Gaussian filters, we produce results with more reliability because the phase shifts are more dramatic. By overlaying this segmented image with the original ultrasound image, users at all skills levels will be able to learn and better understand how to confidently identify bone surfaces from US scans. In order for users to easily utilize these techniques, we created a Graphical User Interface (GUI) that allows the user to load an US scan image, select a region of interest, segment the image, and overlay it with the original image just by the click of a few buttons.

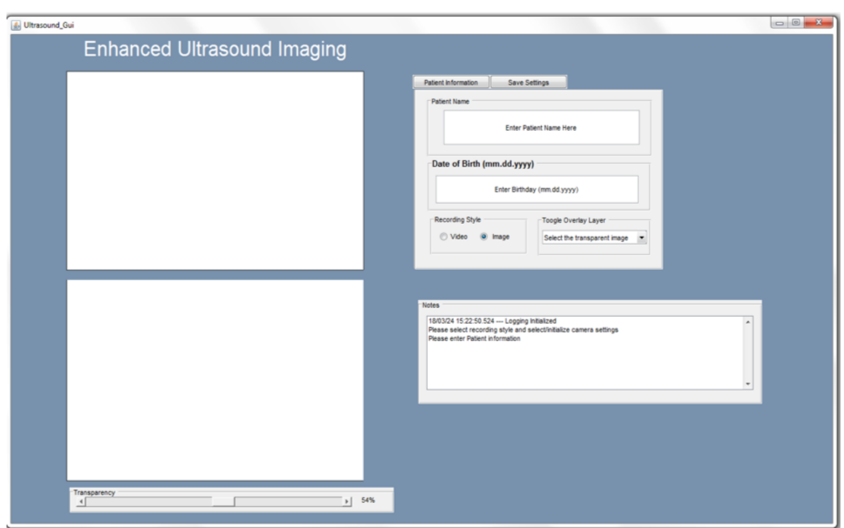

Figure 1: MATLAB GUI

Utilizing a wireless US probe, data is collected from volunteers. These US scans are passed through a MATLAB GUI of our design (Figure 1). The interface includes two boxes with the first box showing the selected b-mode ultrasound image and the segment box displaying the results of the automation segmentation script to detect bone surfaces. The GUI then overlays the automated vertebral bone segmentation on top of the initial US scans for easy comparison and visualization of bone surfaces. There are intuitive tabs for patient information and saving information. The patient information tab allows the user to add the patient's name, date of birth, and load specific ultrasound images for the patient. The results are saved according to the patient's folder.

The key results of our experiments quantitatively revealed that the segmented ultrasound images accurately outline the spinal bone surfaces. By processing ultrasound scans through Gaussian filters and segmentation processes, our code outputs bone surface path images. These images were compared to manually segmented images of the corresponding scans and the error values of each were recorded in mm. The error values are calculated by taking the sum difference between each point on the manually segmented line and the automatically segmented line (via the automated segmentation script). These differences are added together, and the final error is displayed. Our data is displayed in the box and whisker plot (Figure 2). Generally, an error less than 0.55mm shows that the automated segmentation was accurate. As shown by the plot, a majority of our results fall into this category, with a mean value of 0.39mm error.

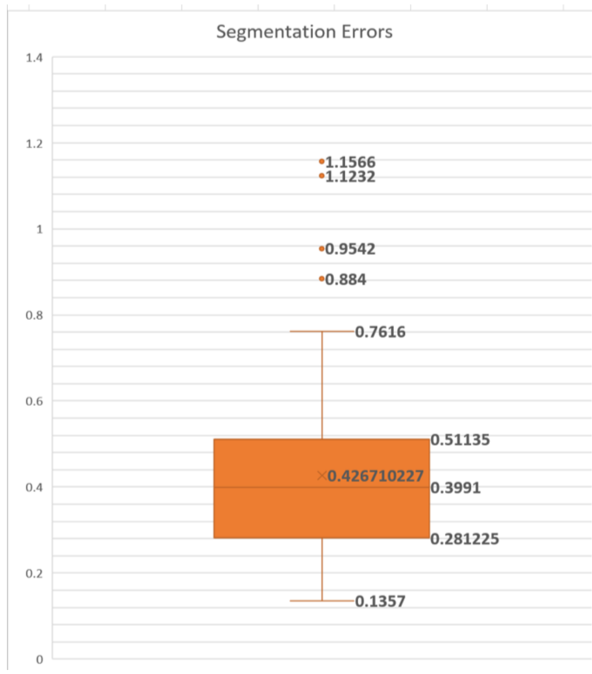

Figure 2: Automated vs Manual Segmentation Error.

Table 1: Cost associated with design in US Dollars

Item	Cost
Clarius Ultrasound Probe	$10,000
Parker Aquasonic Clear Ultrasound Transmission Gel[1]	$17.95
MATLAB Software	$0 (Academic License)
Ultrasound GUI	$0 (Downloadable Software)

[1] 5 Liter Sonicpac with Dispenser

A significant portion of our cost comes from the acquiring of a Wireless Ultrasound probe. Our current software design is compatible with all US probes both wireless and wired. This can impact the cost as there are various probes currently available in the market and depending on the probe a clinician plans to utilize cost may be substantially lower or higher. We currently are using an Academic License of the MATLAB Software provided by our school, we anticipate exporting our GUI as an executable file which will make it easy for users without a MATLAB license to use the program without having to pay for the program itself. Finally, the use of a transmission gel is required for US, this cost again varies as different companies create the transmission gel and the price point and quantity can differ.

As mentioned earlier, scoliosis is the most common deformity in school-aged children (Mirtz. 2005). Furthermore, 90% of children undergo unnecessary radiation when monitoring scoliosis and overexposure to radiation increases the likelihood of cancer. As of now, our design can be used as an effective learning tool for individuals at all skill levels to improve their abilities in confidently identifying bone surfaces through the use of ultrasound scanning. With this, doctors and technicians may have the ability to identify and monitor not just scoliosis, but bone fractures and breaks of any bone as well. The advantage of this is that users will not be restricted to the use of x-ray imaging which is both much more expensive and potentially harmful. Furthermore, the applications of our design can be revolutionary in the field of medical technology. With further developments in the code, processing power, and accuracy of our design, real-time imaging of segmented bone surfaces that also detect scoliosis severity based on the angle of each spinal column is possible. We believe this design will help people today and may help many more in the future.

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