Spatially tracked ultrasound   
for scoliosis quantification

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# Introduction

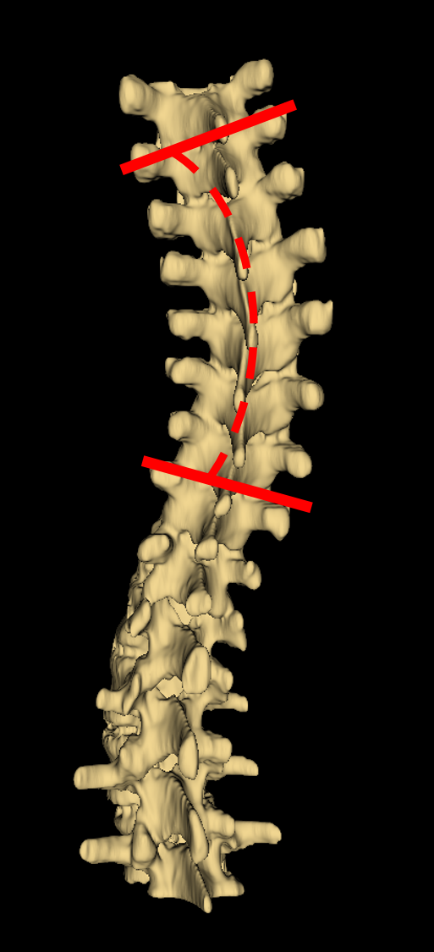


Figure 1: CT derived model with Cobb angle illustrated.

## Scoliosis

Scoliosis is a pathological curvature of the spine which typically manifests in adolescence and develops during growth. The disease can be quantified in terms of the Cobb angle, that is, the maximum angle between the end plates of any two vertebrae, as shown in Figure 1. The Cobb angle is of interest to clinicians because it provides an objective indication of how severe the scoliosis is. As such, it is used to decide which treatment plan to proceed with.

Cases with Cobb angles less than 20o are typically monitored so the deformation does not progress to the point of causing other health problems. Patients with Cobb angles between 20o and 40o often have braces prescribed to support the spine and slow further deformation. Cobb angles greater than 40o may require surgical vertebral fusing to halt deformation.

When possible, bracing is a preferable treatment to surgery. Surgical vertebral fusing results in permanent mobility loss and entails greater risks and financial costs than bracing. Therefore, with the curvature progressing during growth, regular assessment of the disease is important to ensure treatment risks and costs are minimized.

The current gold-standard method for assessment of scoliosis is to measure the Cobb angle directly from an X-ray of the patient’s back. Cumulative exposure to the ionizing radiation of X-ray imaging for scoliosis monitoring has been shown to increase cancer risks by [Doody2000]. This has motivated research into other methods for assessment of the disease, such as MRI [Diefenbach2013], surface topography [Frerich2012, Goldberg2001], and tracked ultrasound [**Cheung2015, Ungi2014, Zheng2015**].

Surface topography consists of projecting a particular shadow onto the patient’s back. When cast onto a flat surface, these shadows form some regular pattern, like many parallel lines. An image of the patient’s back with shadows is captured and analyzed with software. The geometry of the patient’s torso can be computed from the shadows contours. The asymmetry of the spine is used in the estimation of the Cobb angle. [Goldberg2001] reported moderate correlation (R2 = 0.66) between their surface topography method’s angle and the radiographic Cobb angle, and a false positive rate of 37.7%. [Frerich2012] reported intra and inter-observer variance of 5.14o and 6.54o in their topographic method. Their method underestimated curvature components by an average of 8.12o, except thoracic kyphosis, which was overestimated by an average of 7.26o.

MRI is an effective alternative to X-ray imaging as it produces a clear image of the spine, similar to X-ray, from which the Cobb angle can be measured directly. However, MRI is more expensive and less accessible than other methods like ultrasound and surface topographic methods. MRI is also incompatible with metal implants often used in scoliosis surgery [Diefenbach2013].

## Tracked ultrasound

Spatially tracked ultrasound presents an attractive imaging modality for scoliosis quantification. Unlike X-ray, it has no known health risks. This also means that fewer safety regulations are required for its use, translating into less financial cost and greater accessibility. [**Cheung2015, Ungi2014, Zheng2015**] investigated the applicability of their respective tracked ultrasound methods for scoliosis quantification. These papers are the focus of this survey. Their methods and results are described below, in their respective sections.

Using spatially tracked ultrasound for scoliosis assessment generally consists of locating landmarks in 3D space and projecting them onto the coronal plane. A proxy to the Cobb angle is then extracted from the landmark data. The proxy measurement is required because only certain anatomic structures can be located with ultrasound. Bone, having a higher acoustic impedance than other tissue, reflects most of the ultrasound. Therefore, bone surfaces approximately normal to the direction of propagation of the ultrasound appear as bright regions in the images with acoustic shadows under them. On the other hand, surfaces not normal to this direction reflect the ultrasound away from the transducer, resulting in a dark region in the image.

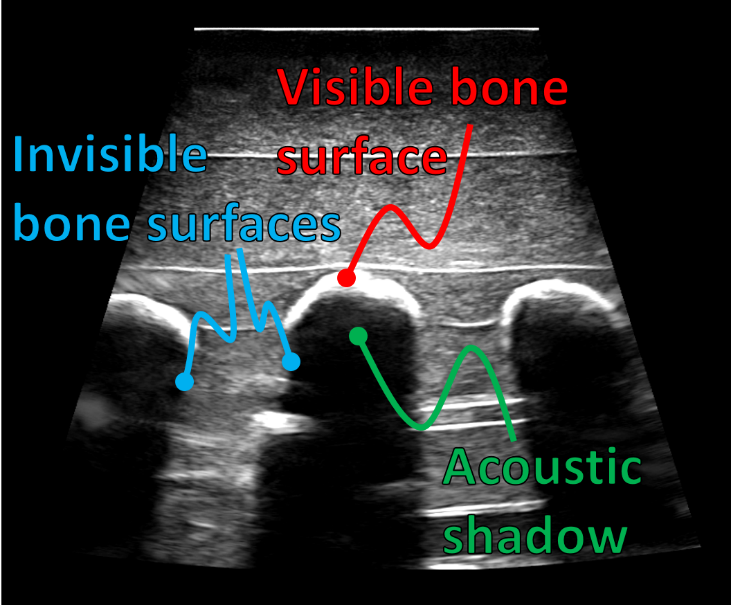


Figure 2: Parasagittal ultrasound image with bone surfaces, both visible and invisible, and acoustic shadows, illustrated.

# Methods

## [Ungi2014] – Sagittal Ultrasound Snapshots

## [Cheung2015] – Axial Ultrasound Snapshots

## [Zheng2015] – Axial Ultrasound Scan

# Results

## [Ungi2014] – Sagittal Ultrasound Snapshots

## [Cheung2015] – Axial Ultrasound Snapshots

## [Zheng2015] – Axial Ultrasound Scan

# Discussion

# References

**[Cheung2015] C.-W. J. Cheung, G.-Q. Zhou, S.-Y. Law, K.-L. Lai, W.-W. Jiang, and Y.-P. Zheng, “Freehand three-dimensional ultrasound system for assessment of scoliosis”, Journal of Orthopaedic Translation 2015; 3:123-133.**

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