Sonometric Triangulation for Seated Pelvis Orientation

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Study Objectives: To determine accurate and noninvasive pelvic angle and surface tissue depth using ultrasound micrometry suitable for use in vehicles and vehicle seats with optically occulted skin surface.

Problem: Pelvis orientation, including anthropometry, orientation of the bony structure, details of tissue overlaying the pelvis, and resulting pelvis/torso interactions are crucial for effective restraint operation. Principal effects are derived from of sex and body mass distribution characteristics on anthropometric variation including obesity and age distribution of the belted occupant. Further, these effects may be different in different areas of the US owing to regional differences in anthropometric distributions and age distributions.

In contrast to the importance of pelvis position and orientation on occupant restraint performance across the body, measurement techniques using surface anthropometry alone do not adequately characterize essential and important details. *This is particularly true for the interaction between the surface and underlying bony structures in obese occupants, owing to uncertainties in the relationship between surface that are not captured or are poorly captured by surface registration and regression models.* Indeed, regression models to estimate the effects of obesity, for instance, on anthropometry tend to produce models that are not both sensitive and specific Unfortunately, obese occupants, in general, often have difficulty with proper belt fit and may have undesirable restraint responses and injury outcomes in crashes. This study provides an novel technique to improve the accuracy of the assessment of pelvis orientation including the in-vehicle assessment of tissue depth to bony landmarks in automobile seating.

Methodology: A novel technology, multi-crystal surface/impedance sonomicrometry, is used to assess relative locations of a mesh of ~2 mm ultrasound transceivers (n=16) placed on the surface of a porcine surrogate. The possible number of unique distances measured, with full sensor net frame rates to over 10 kHz, is a function of the number of crystals used, N, and is calculated as

$$dists = N!/2(N-2)!$$

These redundant measurements are used to assess 3D position of the sensor on the skin surface using robust triangulation.

The test matrix includes tests of three porcine cadavers (mean mass 50 kg) at four pelvic angles (75^0, 90^0, 105^0, 120^0) and a manually forced continuous motion from 75^0 to 120^0. A Romer arm measurement device (Series 7 Absolute Arm, Hexagon, Company) and camera are used to verify 3D position and planar position of the transceivers.

Data: Data was robustly transmitted and received across the sensor net for the extended sensor array with 16 nodes. Sonometrics system accuracy from sensor to sensor was measured at better than 0.1 mm. Global 3D displacement results showed good correlation with static and dynamic global motions.

Summary of Results: Preliminary work using porcine cadaveric specimens shows the ultrasound sensor approach to have strong potential for noninvasive measurement of 3D human body surface positions, especially for portions of the body under load or occulted by seating, vehicle interiors or other obstacles. Future work will include the development of clothing with implanted ultrasound transceivers for general research use.