

Critical Analysis Report

Project Review:

Introduction

- US calibration necessary to compute transformation bridging tracker frame and US image frame
- Transformation matrix used to locate US image position and link US images together
- Calibration performed with 2 types of calibration phantoms - point based and structural
 - Point Based
 - Points in 3D space formed using stylus or cross wire
 - Superior accuracy - avoid intermediate registration process
 - Longer time
 - Difficult to automate midplane alignment process
 - Provides positional information of a point target
 - Main source of error: localization inaccuracy in elevation dimension due to US beam thickness
 - Structural
 - Pre determined structures
 - US images are segmented and registered to known structure
 - More flexible and easier to automate
 - Provides full pose (orientation and position) of phantom
- Goal of paper: present a calibration concept and algorithm to enable fast and accurate US calibration
- Proposed calibration concept
 - Multiple active-point (MAP) sources and active transmission of US signal from MAP sources
 - Minimizes times midplane detection must be performed

Theory

- Calibration is solving for rigid body transformation X via $BXp = XB$ or $AX = XB$ where $A, X, B \in SE(3)$, and $p \in R^3$
- BXp generally used for point-based
 - $AX=XB$ requires rotation information which point based does not have
 - Points imaged with US probe from varying poses
 - B is is sensor reading - homogenous transformation from tracking base to tracking sensor
 - p is location of point in US coords
 - Assumption: point perfectly aligned at center of US beam
 - Longer computation time
 - More accurate - lower elevational dimension error
- $AX = XB$
 - A = image pose
 - Closed form solution - faster computation

- Less accurate feature segmentation - US elevational beam thickness and insonification angle
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Ultrasound Calibration using MAP Phantom

- Active point target actively interacts with US receiver by transmitting acoustic waves
- Current phantoms are passive and rely on the US probe's acoustic wave
- Benefits of active point
 - Background free signals - acts as the lone acoustic source
 - Minimizes artifacts such as reverberation
- Extension in paper: distribute multiple active points in 3-D space
 - Multiple active points allows for definition of coordinate frame - rotation and translation are available -> $AX=XB$ possible

Critical Review:

Strength:

For the MAP phantom proposed in the paper, the strength of it is that it can improve calibration performance to achieve higher accuracy and precision than cross-wire phantom and AE phantom. Meanwhile, MAP phantom also can reduce the number of midplane detection processes necessary thus decreasing the data acquisition time during US calibration.

Critique:

The fabrication of a MAP phantom requires a special hardware setup including multiple active US elements. In specific, Multiple Active US elements with known geometric relationships are required. Or, one Active US element and an extra translational step for each pose to simulate the presence of extra points (this also adds error) are necessary to fabricate a MAP phantom.