Mobile 3D augmented-reality system for ultrasound applications

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Background:

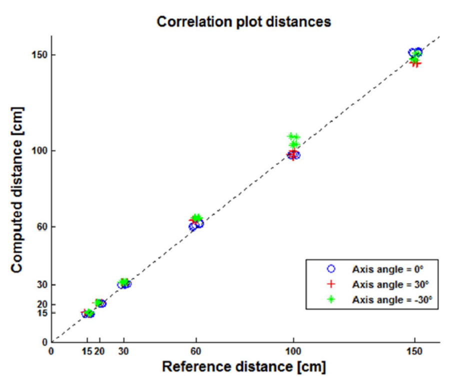
- ultrasound is a highly operator dependent modality and learning how to use it can take up to 12 months
- can we speed up the process of learning with augmented-reality based technologies?
- we need to provide a correspondence between the real-time ultrasound data and augmented 3D scene.

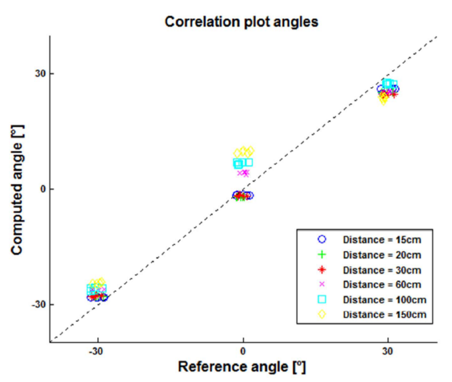
Goal:

- To establish a tablet-based system for visualizing the heart within a patients body using augmented-reality techniques in conjunction with the streaming data provided by a GE Vivid E9 ultrasound machine.
- To give the operator visual feedback as to the location of the heart within the body, the anatomical features the echo plane is intersecting and if the operator is currently

Experiments and Results:

- We measured the performance of the framemarker tracking in the 15 to 100 cm range, the typical range of our application, using ambient room lighting.
- Both the depth and rotational accuracy of the system were evaluated





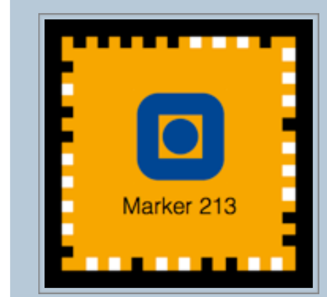
Conclusions:

Combining marker tracking with the RCTL LV volume tracking has allowed us to place the heart in the correct anatomical position within the patient's body as well as echo-plane relative position. This gives students ability to interpret diagnostic images even if they are not yet fully formed. The LV volume changes from red to blue when good lock on the LV volume lost or obtained to help the student quickly acquire the correct transducer position.

Augmented Reality

Visual guidance during data acquisition, which shows the relationship between the anatomy being imaged and the position of the scan plane, is one way of alleviating the image acquisition and interpretation difficulties. This technique is commonly referred to as augmented-reality and utilizes a variety of computer vision and display techniques to give the diagnostic data real-world points of reference.

Basic framemarker tracking



For positioning the heart model object on the tablet screen we are using specially encoded markers commonly referred to as **framemarkers**. When the app is running and a registered framemarker is visible we stream the pose matrix of the framemarker to the backend and route the matrix to the correct 3D object based upon a simple numeric identifier. This framemarker pose matrix is applied to the Model View of the object and causes the object to move into position relative to that marker in a convincingly realistic fashion.

Cardiac ultrasound

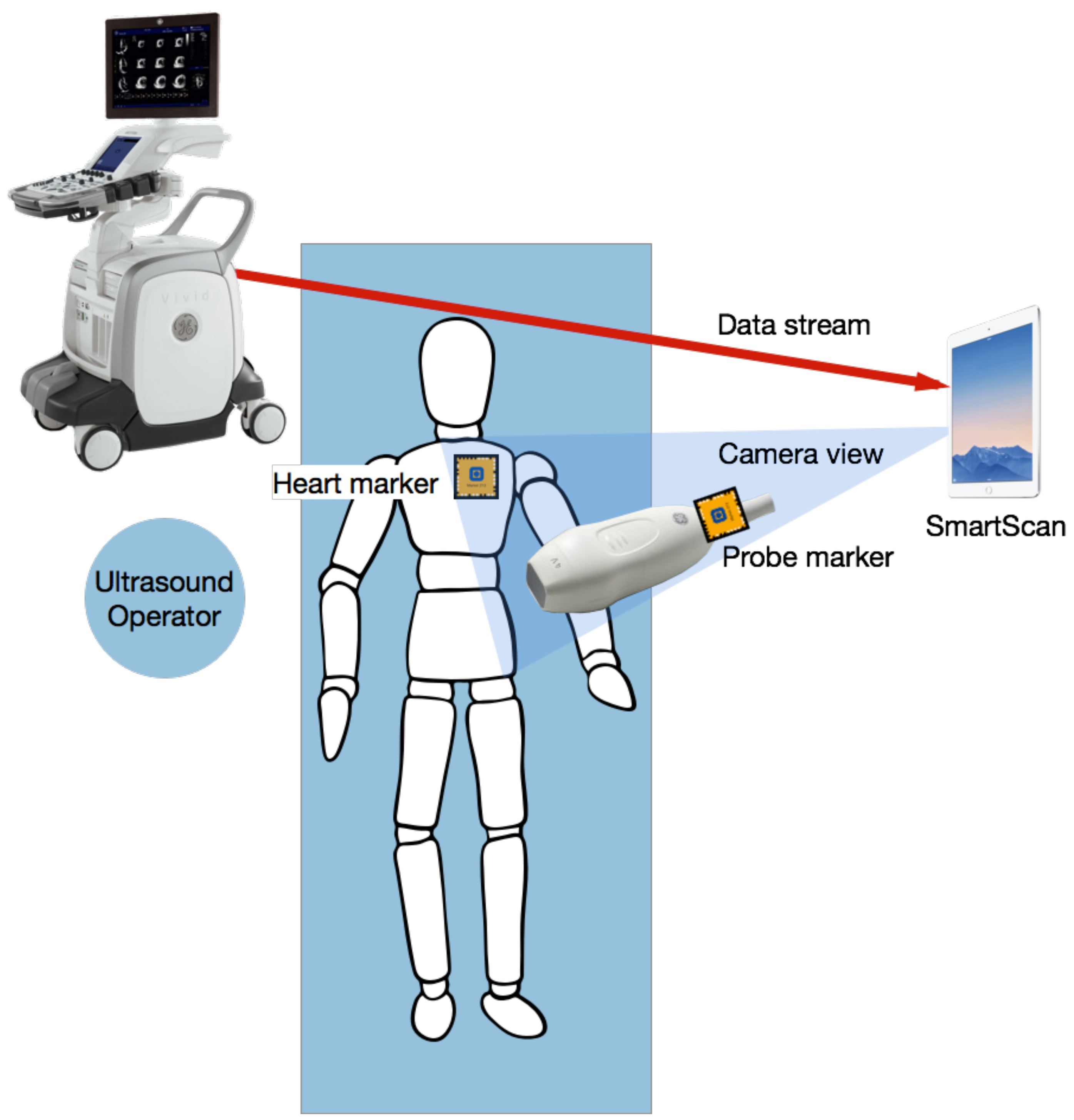
GE Vivid E9 scanner plugin: Leveraging our augmented-reality marker tracking and streaming ultrasound data we can visualize the 2D echo plane, render the measured left ventricle volume within the heart model, and deform the heart model in sync with the beating heart.
The 4V-D probe is currently required for RCTL (Real-time Contour Tracking Library) to capture the 3D volume.

For each 3D ultrasound volume acquired by the scanner the image plane corresponding to the 0° elevation is also extracted from the 3D data and resampled to a Cartesian grid. Finally, a structure containing the image plane together with the landmarks and the tracking score is sent to the tablet device, over WiFi.

Fetal ultrasound

A fetal version of SmartScan has been prototyped using the same basic principle, namely tracking a framemarker attached to a curvilinear probe and one on the patient.

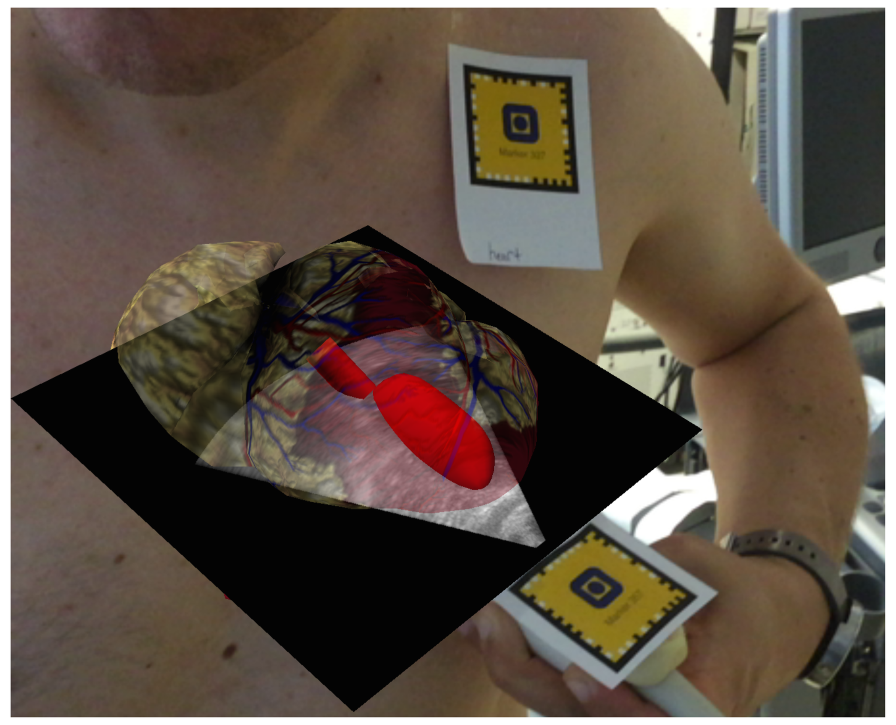
Introducing the SmartScan System

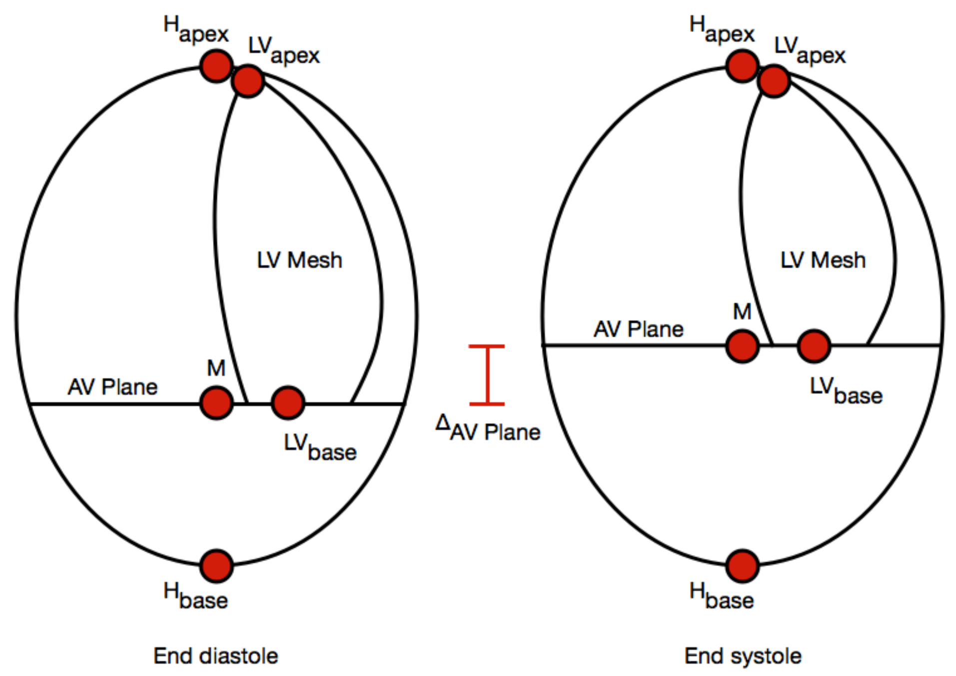


When using the system the patient lies on the examination table either flat on their back or on their side facing away from the examiner. The examiner sits to the patients right on a stool or edge of the table. The tablet and stand are on the patient's left-side angled so the front- facing camera can acquire the marker attached to the patient representing the heart and still capturing the area of interest while still affording the examiner with a view of the augmented scene.

The SmartScan Scene

In the typical SmartScan scene you can see the echo plane, LV volume and semi-transparent heart model.





Dynamically deforming the heart model

The final touch is to deform the 3D heart model in real-time, in sync with the beating heart. We established a kinematic heart model that simulates the movement of the AV plane. The movement is realized in the OpenGL vertex shader by holding the $\mathbf{H_{apex}}$ and $\mathbf{H_{base}}$ position constant and translating the vertices indicated by **M** and $\mathbf{LV_{base}}$.

Cross-sectional four chamber view, the simplified kinematic model for the whole heart and left ventricle. In the given view, $\mathbf{LV_{apex}}$ and $\mathbf{LV_{base}}$ are tracked automatically, while $\mathbf{H_{apex}}$, **M** and $\mathbf{H_{base}}$ were manually identified on the model.