Skill Analysis in Fetal Surgery: Motion analysis and Eye Gaze Tracking

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Abstract. We aim at building a platform for skill analysis in the context of fetal surgery, focused on procedures that involve needle insertion under ultrasound guidance. We introduce a system for measuring US and needle motion, as well as eye-gaze tracking of the practitioner during a simulated surgical procedure. This platform aims at studying useful metrics for evaluating hand-eye coordination and its correlation with surgical expertise.

Keywords: Skill Analysis, Fetal Surgery

1 Introduction

Surgical procedures in fetal medicine involving needle insertion under ultrasound (US) guidance carry a risk for the fetus and therefore must be performed by highly trained practitioners. In Chorionic Villus Sampling (CVS) the number of previous procedures performed by the practitioner highly correlates with lower miscarriage rates [2]. Despite the large amount of experience required to perform CVS there is little consensus on what constitutes an optimal performance [2].

The acquisition of data during intervention and simulated training sessions if of key importance to extract metrics that correlate with a good performance. Examples of such metrics include motion analysis [6], and eye gaze tracking [5, 7, 3]. This data provides useful cues that distinguish expert practitioners from trainees that can be used as feedback during training sessions, as well as performance metrics to assess learning curves of new technologies, such as recent developments in needle tracking systems [4].

We aim at capturing instrument motion and eye gaze patterns during ultrasound (US) guided procedures in the context of fetal medicine, including CVS, amniocentesis, and cordocentesis. These procedures involve the insertion of a needle to collect samples in utero, such as amniotic fluid, placental tissue, or umbilical cord blood (Fig. 1(a)). US scans are used to plan the procedure according to the fetus position and also to navigate the needle. Data can be obtained using simulation models [9] in a controlled environment where both experts and novices can perform safely. Instrument motion data can be obtained with an optic tracker and fiducial markers attached to both the US probe and the needle (Fig. 1(b)), while eye gaze can be obtained with eye tracking glasses.

Some challenges in US guided intervention for novice practitioners include hand-eye coordination while moving the US probe [1] and localisation of the needle tip in the US scan. While experienced users are able to move the US probe and/or surgical instruments to the desired position using just the feedback from US screen display, novice users might need to look directly at the US probe and the needle more often. A synchronized capture of eye gaze and instrument motion can provide useful patterns to differentiate between experts and novices.

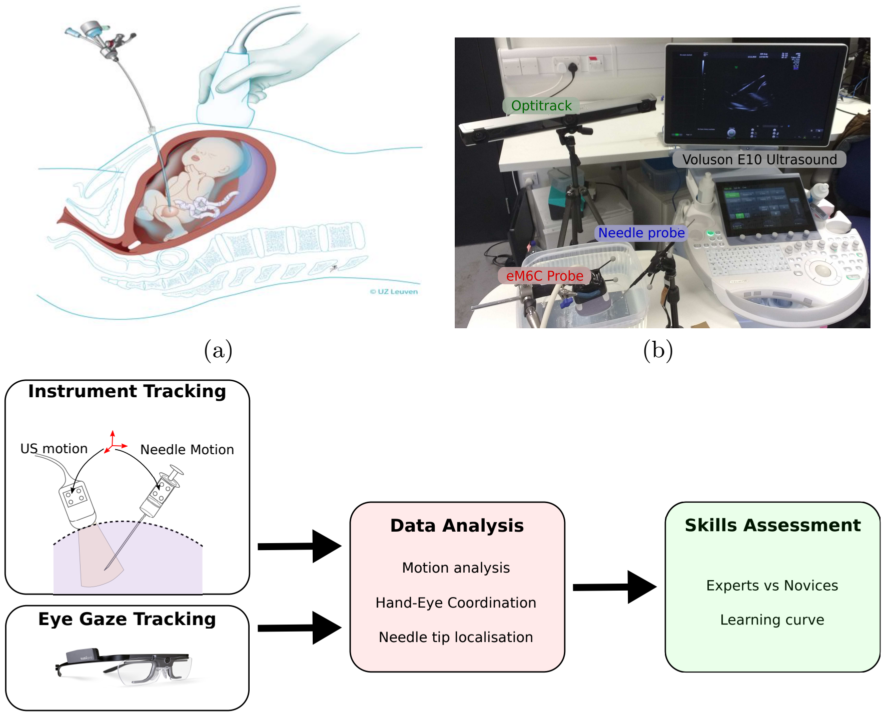
2 Methods

We propose a data capture platform that includes the Voluson E10 machine with a eM6C US 2D/3D US probe, an Optitrack V120 Trio system, a tracked needle, and the Tobii Pro Glasses 2 for eye-tracking. Both the US probe and the needle are attached to rigid bodies with optic markers. A calibration procedure must be performed to represent the instruments in the Optitrack reference frame. The needle is calibrated by determining two of its points with a stylus. In a second step, the US scan is calibrated using acquisitions of the tracked needle in different poses [8]. The Tobii Glasses produces a video representing the practitioner's field of view, as well as a 2D point corresponding to his gaze focus within each video frame. Image post-processing must be performed to annotate the frames in which the practitioner is looking at the US screen. The motion of the eye-tracking glasses is not tracked by optic markers and therefore its data only requires temporal synchronization with the Optitrack system either by hardware triggering or pre-defined events. In summary, we aim at capturing the following synchronized measurements: needle motion in the Optitrack reference frame; US scan motion in the Optitrack reference frame; Glasses video with embedded marker representing the eye gaze focus of the practitioner.

We validated the motion tracking system after spatial calibration. It is able to obtain measurements with 2mm accuracy in both 2D and 3D US scanning modes. Future work includes the validation of temporal synchronization using both the optic tracker and the Tobii Pro Glasses 2 for eye gaze measurement, as well as preliminary data capture using simulation models.

3 Conclusions and Future Work

We perform a preliminary validation of a data acquisition platform that is suitable for skill analysis in fetal surgery. Our long-term aim is to record synchronized motion and eye gaze data while a practitioner is inserting a needle through a simulated phantom. By collecting data from practitioners with different degrees of expertise, we expect to obtain metrics that correlate surgical experience with Hand-eye coordination. This evaluation can include generic motion metrics such as dimensionless jerk of the needle/probe, but also other dexterity metrics , such as the alignment between needle and ultrasound scan, and time/ratio spent looking at the US screen while moving the instruments.



(c)

Fig. 1. (a) Needle insertion procedure under ultrasound guidance. (b) Motion tracking system for both the needle and the US probe during its calibration procedure. (c) Our proposed system.

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