An Augmented Reality based Simulation of Obstetric Forceps Delivery

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Abstract

During the process of human childbirth, obstetric forceps delivery is a justified alternative to Caesarean section when vaginal delivery proves difficult or impossible. Currently, training of forceps interventions is done on a real case due to the lack of realistic dummy models. This paper presents a basic augmented reality implementation of a forceps delivery which provides a platform for both training of forceps placement and manipulation for junior obstetricians as well as the assessment of any mechanical effects these actions may have on the fetus, and the fetal head and skull in particular.

1 Introduction

Currently, when the risk of continuing vaginal delivery during the human childbirth process is too high, an emergency Caesarean section (ECS) is often resorted to. Unfortunately, ECS quadruples the risk of severe obstetric morbidity as compared to vaginal delivery [5]. An alternative solution to ECS whilst maintaining vaginal delivery is the use of the obstetric forceps. When applied skillfully, the latter is an efficient tool which carries few risk of adverse outcomes. Unfortunately, training of obstetric forceps manipulation is currently done on real cases as dummy models do not provide a sufficiently realistic simulation as it is difficult to make affordable and realistic bio-materials. A virtual or augmented reality (AR) based simulation, in conjunction with haptic feedback would allow to model more realistic bio-tissue to bio-tissue and bio-tissue to forceps interaction without the need of expensive, yet still deficient, bio-material models. The work presented in this paper is a first implementation of such a novel simulation. It currently allows to place a real forceps, tracked using a NDI Polaris optical tracking device, around the head of a virtual fetus, which is then extracted from a currently real pelvic model. The latter reduces the polygon count though the use of a virtual pelvis model in the future is preferred as it allows better emulation of the soft tissues, i.e. the uterus and the pelvic floor muscles and ligaments, and is easier to register with the virtual fetus. After establishment of contact between forceps blades and fetus, twist moments and traction forces, manoeuvre the fetus out of the vaginal tract. The next section discusses current implementation issues.

2 Implementation and results

2.1 Model generation

The fetus model was created from MR (Magnetic Resonance) and CT (Computed Tomography) images - the former for the outer shape, the latter for the bony skull. A volume-rendering software called 3Dview, developed by the authors [2] allows to segment anatomical parts of interest using watershed segmentation. The segmented models are then tesselated using the Marching Cubes algorithm [3] followed by a mesh decimation algorithm. Figure 1 shows a segmented fetus and the 3Dview interface. The same procedure can be used to segment and model a virtual bony pelvis.

2.2 Forceps tracking

Both blades of the obstetric forceps need to be tracked as the left blade is first placed, after which the right blade is clipped upon the left. This latter placement is crucial and
is often done badly, resulting in local peak pressures on the fetal skull! Currently passive optical markers are placed on the handles of the forceps and an NDI hybrid Polaris tracking device tracks the six degrees of freedom.

2.3 Forceps to head contact

First the real forceps is registered with its virtual counterpart (currently obtained using digitisation with the Polaris). Virtual forceps to (virtual) head contact is then established using a hierarchical algorithm which first checks boundary box intersection after which local face to face collision detection is performed to establish full contact (see Figure 2). No real-time deformation of the fetal head under influence of the forceps is currently implemented though off-line calculations of deformation using implicit Finite Element Analysis have been performed and successfully validated with a study on pressure and traction force evaluation of obstetric forceps using strain gauges [4].

Figure 3 shows snapshots from the simulation.

3 Discussion and Future Work

A first implementation of an obstetric forceps delivery has been presented. The tool can currently already be used to assess (off-line), the effect of the forceps on the fetal head. For forceps training purposes, further developments will include the real-time deformation of the fetal head in contact with the forceps using explicit FEA. Note that this is a challenging problem as it is a dual mechanical contact problem: contact between the head and two forceps blades and contact between the blades and the soft tissue, i.e. connective tissue and underlying pelvic floor muscles and ligaments. Once the contact forces and resistive torque between head and forceps can be accurately evaluated, haptic feedback can be added. The latter is crucial to impose virtual forceps to virtual head collision on the real forceps - its absence currently being the reason why the real forceps occasionally detaches from the head! The authors have already implemented a skin-based surgical simulation on the Telluris device [1], designed by the ICA Lab at the University of Grenoble. Telluris is a multi-purpose haptic feedback system, which allows maximum forces of 200N and mount arbitrary tools such as an obstetric forceps.

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References