The Vitruvian Baby: Interactive Reformation of Fetal Ultrasound Data to a T-Position

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Abstract

Three dimensional (3D) ultrasound is commonly used in prenatal screening, because it provides insight into the shape as well as the organs of the fetus. Currently, gynecologists take standardized measurements of the fetus and check for abnormalities by analyzing the data in a 2D slice view. The fetal pose may complicate taking precise measurements in such a view. Analyzing the data in a 3D view would enable the viewer to better distinguish between artefacts and representative information. Standardization in medical imaging techniques aims to make the data comparable between different investigations and patients. It is already used in different medical applications for example in magnetic resonance imaging (MRI). With this work, we introduce a novel approach to provide a standardization method for 3D ultrasound screenings of fetuses. The approach consists of six steps and is called "The Vitruvian Baby". The input is the data of the 3D ultrasound screening of a fetus and the output shows the fetus in a standardized T-pose in which measurements can be made. The precision of standardized measurements compared to the gold standard is for the finger to finger span 91,08% and for the head to toe measurement 94,05%.

CCS Concepts

• ***Applied computing*** → ***Health informatics;*** • ***Human-centered computing*** → *Visualization design and evaluation methods;*

1. Introduction

Ultrasound imaging and visualization is commonly used in prenatal screening, not only because it does not involve harmful radiation, but also because the costs are comparably low [VBS*13, HZ17]. This imaging technique is based on short ultrasonic bursts sent into the specimen and the resulting image is the analysis of the echo of the signal [KvdMF*17]. Due to the fact that the technique is based on acoustics there are some artifacts and problems involved [NPH*03]. Prenatal screening and analysis is highly affected by imaging data which is ambiguous. Changing from the more common two-dimensional (2D) analysis to a three-dimensional (3D) analysis method would cancel out the effect of some ultrasound imaging problems; namely the effect of objects obstructing the view or the effect of speckles [NPH*03].

Prenatal screening diagnostics does not only include having a brief look at the data to inspect the fetus for abnormalities, also standardized measurements are taken [LCEC09]. The head circumference, the crown-rump length, the abdominal circumference and also the femur length are a selection of possible measurements. Those measurements are taken using a 2D slice view of the ultrasound data, by simply applying a ruler in a standard medical imaging viewer [LCEC09]. This method may result in inaccurate measuring results due to slicing of the 3D data to a 2D representation, in case of an inaccurate slice plane selection. The measurements are used to compare the development of the fetus to tables representing standard growth [LCEC09]. Making data comparable is a common topic in medical imaging [NUX02, KQ03, MMNG17]. Standardization is applied in magnet resonance imaging (MRI) [NUX02], because the value range differs from patient to patient. Comparability between patients and also between different recording time points of the same patient is very important in medical imaging.

Considering these facts, our hypothesis is that a standardized visualization and analysis of the data of a 3D ultrasound screening of fetuses is important. One way to achieve this is to transform the fetus into a standardized pose like the T-pose of the famous drawing called "Vitruvian Man" of Leonardo da Vinci [Vin90] would be helpful. Considering that the fetus can have various poses during the pregnancy, the method should be flexible and adaptive. We introduce The Vitruvian Baby, a workflow consisting of different parts which are used to transform the data of a 3D ultrasound investigation of a fetus to the standardized T-pose. Preprocessing is performed in MeVisLab [AG], the rigging and the weighting in Bender [FOA*14], and the transformation in The Vitruvian Baby,

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which is a 3D Slicer [PHK04] extension. Our contribution specifically is the development of the workflow and the completely automatic transformation of the fetal data.

2. The Vitruvian Baby

The Vitruvian Baby workflow consists of six steps, namely loading of the data, preprocessing the data, rigging of the model, weighting of the data, transformation of the model, and the analysis. The *data* can be provided in numerous medical imaging file formats, e.g. DICOM [MIT]. The *preprocessing* step is dependent on the data provided and may consist of a thresholding step and a largest connected component analysis. The aim of this step is to get rid of artefacts and data not belonging to the fetus. *Rigging* of the model describes the step of incorporating a so called armature in the data, describing the skeleton of the fetus. The armature is an abstract representation of the hierarchical structure of the data. This armature can then be used to control the transformation of the data on a voxel base. This step is performed by using Bender [FOA*14], which is software based on 3D Slicer [PHK04]. The *weighting* of the data is the step where the voxels are linked to the corresponding armature segments. This step is also performed using Bender [FOA*14]. The weighting can be performed in multiple ways. Our approach uses a heat map between the different segments of the armature to obtain the border of voxel affiliation between the segments. The actual *transformation* of the data is carried out using The Vitruvian Baby 3D Slicer [PHK04] extension. The extension expects the armature and the weighted data as input and delivers the data in the T-pose as output. Each segment of the armature is rotated in the direction of the parent segment and the center of rotation is the connection point between those two segments. This method leads to a perfect T-pose of the data independent of the input pose. The input, intermediate step and output situation is visualized in Figure 1. The data used for this example is provided by Cortes et al. [CKM*16].

We've *analyzed* our method in terms of performance and measurement quality using a model with a known correct T-pose, which we have obtained from an online source [Squ10]. Since our aim is to improve measurement accuracy, the most important quality measurement for the approach is the precision of standardized measurements. We focused on the head to toe distance and the finger to finger span. In order to compare the result to a gold standard we used a model which is already given in the T-pose, in our case an adult model. Both similarities for each of the seven tested poses are visualized in Figure 2. The blue bars represent the head to toe measurement and the orange ones the finger to finger span. The used poses are based on standard fetus poses introduced by Haultain and Ferguson in their book about breech and face positions of the fetus before birth [FH89]. The finger to finger span measurement has a precision of 91,08 in average and the head to toe measurement of 94,05% on average.

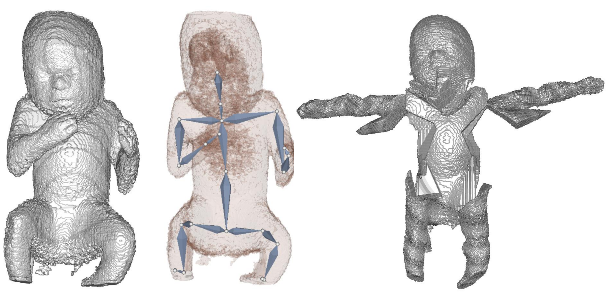

Figure 1: *Phantom of a 3D ultrasound investigation provided by Cortes et al. [CKM*16]. The left side of the image shows the fetus data, the middle part represents the armature embedded in the model and the image on the right shows the result after applying The Vitruvian Baby method.*

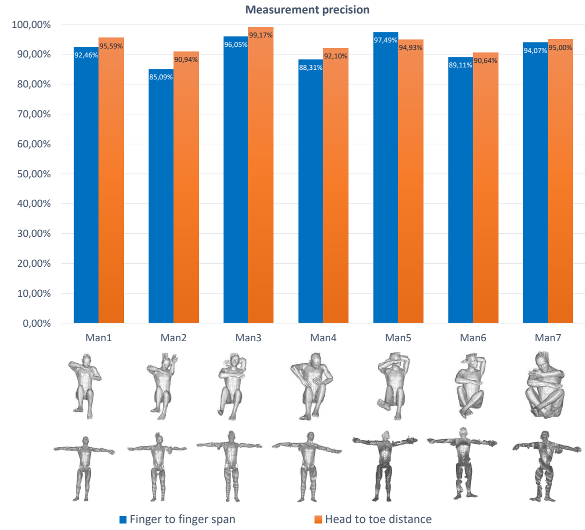

Figure 2: *The chart represents the measurement similarity between the goal T-pose and the result of The Vitruvian Baby method. The X-Axis shows the input data and the output data of the seven phantom models and the Y-Axis represents the percentage of similarity of the measurements.*

3. Conclusion and Further work

Standardization is a common technique in medical imaging data and enables the comparison of data between different investigation time points and also between patients. We introduce The Vitruvian Baby workflow to standardize fetus poses to enable accurate measurements. We hypothesize that a semi-automatic transformation of the data of a 3D ultrasound screening of a fetus to a standardized pose would lead to a much higher comparability of the data. Standardized measurements can be taken very precisely and also new measurement types, e.g., based on the volume of the body-parts of the fetus could be deployed. New measurements of the fetus could also lead to more insight about developmental disorders which would normally only be revealed after an amniotic fluid probe.

The method presented in this poster is a prototype workflow and offers a standardized approach for performing measurements on the fetus. Potential avenues of further research are automating the rigging, visualizing intermediate steps of the transformation, and constraining the weighting to prevent deformation artifacts.

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