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Modeling of Interpolation Methods for Robot Assisted and Freehand Ultrasound Imaging System

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Abstract

The 2D ultrasound is one of the popular imaging modality amongst all existing medical imaging methods such as X-Ray, MRI, CT, PET and SPECT. However, 3D ultrasound is also increasingly being used in clinical and image guidance applications such as echo cardiology and obstetrics by robot assisted probe and freehand probe, but 3D ultrasound imaging has some limitations such as lack of suitable interpolation methods that leads to wrong interpretation. To overcome this problem, this study presents a modelling approach for interpolation methods to get the better 3D results for enhanced diagnosis. For this modelling, this research mainly uses four (4) interpolation methods such as conventional Distance Weighted (DW), Improved Distance Weighted (IDW), Conventional Olympic (C-Oly) and Improved Olympic (I-Oly) interpolation methods. In order to evaluate the performance, this study used ten (10) test cases, which are testified by each interpolation method. Each method calculates a value, which would be used to fill-out the empty space during interpolation. Therefore, on the basis of obtained results, it is reported that the I-Oly method is producing more optimal results due to the lowest error rate (2.48%) and performance improvement of 26.23% as compared to other existing methods. The outcome of this research could be imparted to post-graduate level for students undertaking sensor and systems either in the robot assisted or freehand ultrasound imaging field.

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Keywords: Interpolation methods; hole filling; 3D ultrasound reconstruction; conventional distance weighted; improved distance weighted interpolation; conventional Olympic; improved Olympic hole filling method

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1. Introduction

The 2D ultrasound is a popular non-invasive imaging modality with real time capability. It is helpful in the diagnosis of obstetrics, neurosurgery and musculoskeletal (MSK) disorders for last two decades[1]. Generally, the 2D ultrasound systems are under use around the world, but it has some problems such as low contrast regions and homogeneous textures that lead to wrong interpretation and unsatisfied image quality. However, some researchers are tried to recover these problems through 3D reconstruction of ultrasound images[2]. The 3D reconstruction used a specific arrangement of 2D ultrasound images according to their spatial information. The spatial information of each image should be consistent for accurate 3D reconstruction. Inconsistently adjusted ultrasound images lead to inaccurate 3D reconstruction due to geometrical errors[3-5].

Generally, ultrasound system uses two approaches for data collection, 1) robot assisted probe and, 2) freehand probe. Robot assisted probe helps in the acquisition of approximate accurately oriented data, because it follows the predefined instructions like angle of rotation and speed of movement. However, freehand probe most of time provides the irregular images that are the more challenging rather than robot assisted probe data[6]. It should be noted that the acquired data from the both approaches are not perfectly accurate, which are main causes of inaccurate 3D reconstruction[2,4]. To overcome these problems, this research attempts to models the suitable interpolation methods for enhanced 3D reconstruction to improve the diagnosis. Although, various research studies reported about the numerous interpolation methods for 3D ultrasound reconstruction[5,7,8], however, they show limitations such as unconvinced image quality.

In order to overcome these problems, there is a need to use the suitable interpolation method for 3D reconstruction, which is modelled in this study. The rest of the paper is organized as follows. Section 2 provides the information about 3D ultrasound reconstruction process flow and used interpolation methods. Section 3 presents the results and corresponding discussion in detail. The section 4 concludes this paper.

2. Methods

The 3D ultrasound reconstruction is not a wide spread technology still, but now it is getting more attention due to its additional beneficial features such as enhanced geometrical information, better visualization and accurate volume measurement. In order to reconstruct a 3D image, a model for freehand 3D Reconstruction of ultrasound images is presented in Fig. 1.

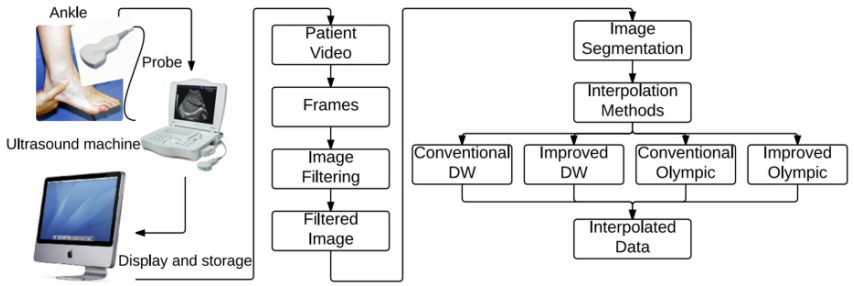

Fig. 1. Process flow for 3D ultrasound reconstruction.

According to Fig. 1, initially, data is acquired in video format (e.g., Avi format) and acquired video is converted into ultrasound images. For better visualization acquired images are filtered, which are used in segmentation to extract the desired region[4,9,10]. The segmented images are further used in 3D reconstruction. However, during 3D reconstruction, image interpolation is an unavoidable step, which used some methods to enhance the results such as DW, IDW, C-Oly and I-Oly methods[9-12]. However, the challenge of interpolation methods is to reduce the frame gap without loss of valuable information[8,13]. In current research, the four popular interpolation methods are DW, IDW, C-Oly and I-Oly are being used for interpolation that are illustrated in Fig. 2[14].