Perceptually motivated analysis of numerically simulated head-related transfer functions generated by various 3D surface scanning systems

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Numerical simulations offer a feasible alternative to the direct acoustic measurement of individual head-related transfer functions (HRTFs). For the acquisition of high quality 3D surface scans, as required for these simulations, several approaches exist in the literature. We systematically analyze the variations between different approaches and evaluate the influence of the accuracy of 3D scans on the resulting simulated HRTFs. To assess this effect, HRTFs were numerically simulated based on 3D scans of the head and pinna of the Fabiani dummy head generated by 8 different methods. These HRTFs were analyzed in terms of interaural difference, interaural level difference, energetic error in auditory filters, and by their modeled localization performance. From the results, it is found that a geometric precision of about 1 mm is needed to maintain accurate localization cues, while a precision of about 4 mm is sufficient to maintain the overall spectral shape.

**Abstract**

In recent years, several approaches have been proposed with a focus on improving the accuracy of the simulated HRTFs by acquiring high quality 3D scans of head and pinna. Different techniques for the acquisition of 3D scans exist such as MRT scanners, structured light scanners, laser scanners, infrared scanners, stationary scanners, hand held scanners, or by using mobile camera pictures [1].

Each of them provides a different resolution and its accuracy directly affects the quality of the numerically simulated HRTFs which are subject to research. Here, we systematically analyze the accuracy of 3D surface scans obtained by different approaches and study their influence on the resulting HRTFs by means of interaural difference (ID), interaural level difference (ILD), energetic error in equivalent rectangular bandwidth (ERB) auditory filters, and their simulated localization performance.

To isolate the influence of the scanning method on the HRTF, the different scanning methods were evaluated against a high resolution structured light scan (ground truth) which showed a very good agreement to its acoustically measured counterpart in an anechoic study [2].

**Acquisition of Models using different scanning systems**

We acquired 3D surface scans of the head and pinna of the Fabiani dummy head by using 8 different methods (cf. Fig. 1).

- **gOM ATOS I (GOM-Ref):** Stationary, structured light scanner (0.01 mm point resolution).
- **Artic Space Scanner (SPY):** Hand-held structured light scanner, scanning at a working distance of 0.2 m to 0.3 m (0.05 mm point resolution).
- **Canfield Vectra M3 (CAN):** Stationary, stereo photogrammetry technology scanner (scanning at a working distance of 1 m (1 mm point resolution)).
- **Micro Kinect (KIN):** Low cost IR scanner with a working distance of 0.50 m (0.005 mm) point resolution.
- **Autodesk 123D Catch (123D):** Mobile application which allows the user to scan a 3D model from at least 5 to 6 overlapping photos.
- **The Python Photogrammetry ToolBox (PPT):** An open source tool which has a pipeline to construct a 3D model from a set of photos.

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**Reference**


