Hand Gesture Control for Interventional MRI

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Purpose

During MRI-guided interventions, e.g. percutaneous needle biopsies, interventionalists often need to change slice positions and sequence parameters to hit the planned target position accurately and safely. Various tracking approaches have been proposed to update slice positions by aligning them with the interventional device [1,2]. However, the interventionalist cannot change sequence parameters, e.g. image contrast or number of parallel slices, oneself without interrupting the actual procedure. In this work, we propose a novel MR-based hand gesture recognition (HGR) method to facilitate automated parameter changes by the interventionalist during real-time imaging.

Methods

All experiments were performed in a 1.5 T wide-bore MRI (Magnetom Espree, Siemens, Erlangen, Germany). The gesture recognition algorithm was implemented on the image reconstruction system to directly control sequence parameters.

***Hand Gesture Recognition Slice*:** A pulse sequence extension was developed that utilizes one additional thick HGR slice (bSSFP, TE = 2.3 ms, TR = 4.6 ms, α = 70°, matrix = 192 × 192 px, field of view = 300 × 300 mm, slice thickness = 50 mm) at a fixed position above the patient (cf. Fig. 1). This acquisition is interleaved with the actual real-time imaging. Before a full HGR slice is acquired, k-space center is measured to assess if there is signal in the HGR volume. If no signal is available, no full HGR slice will be acquired and normal real-time acquisition is continued immediately to maintain temporal resolution.

***Image Processing*:** Before applying the actual HGR the following image processing steps are performed to detect the outer edge of the hand robustly: (1) A binary image is created using a threshold of 4% of the maximum magnitude. (2) Holes in the binary image are filled automatically. (3) The largest connected object is selected and all other objects are discarded. (4) A morphological closing operator (kernel radius = 4 px) is applied to close small gaps. (5) New holes are closed again. (6) Finally, edge detection was performed.

***Hand Shape Classification*:** The hand shapes are classified based on their first 16 Fourier descriptors [3]. Therefore, positions of the sorted edge pixels were employed to create a centroid distance function of the shape:

$$r(i) = \sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2} \tag{1}$$

Where (x_i, y_i) is the pixel coordinates of pixel i, and $(\bar{x}, \bar{y})$ is the mean coordinates. r is then transformed to frequency domain using Discrete Fourier Transform: $a = DFT(r)$. a is normalized and the complex phase is discarded to make this representation of the shape invariant to shift, rotation, and scaling:

$$a'(n) = |a(n)/a(1)| \tag{2}$$

The shape is then classified by calculating the Euclidian distance to template shapes in Fourier descriptor domain using $a'(1)$ to $a'(16)$ only. Two gestures were used: straight hand with spread fingers (G1) and fist (G2). If a maximum distance is exceeded, no classification will be performed.

***Pulse Sequence Parameter Control*:** After classification, the information was sent from the image reconstruction system to the scanner to control slice orientation in real-time.

Results

Figures 3(a) and (b) show the HGR slice with gestures G1 and G2. The total processing time for image processing steps 1 – 5 (Fig. 3(c,e)), the edge detection (Fig. 3(d,f)), the calculation of the Fourier descriptors (Fig. 4), and classification was 0.17 ± 0.06 s. The classification of the hand gestures was successful in 43 of 52 HGR slice acquisitions. Due to motion artifacts, 9 HGR slice acquisitions were automatically rejected. False classification was prevented for all acquisitions.

Discussion

This novel approach for MR-based hand gesture recognition allows for convenient sequence parameter control during MR-guided interventions by the interventionalist oneself. The results show that the method allows for robust parameter modification in real-time. In the future, the number of distinguishable gestures will be increased. A full investigation of the adaptability to different interventional scenarios is warranted.

References

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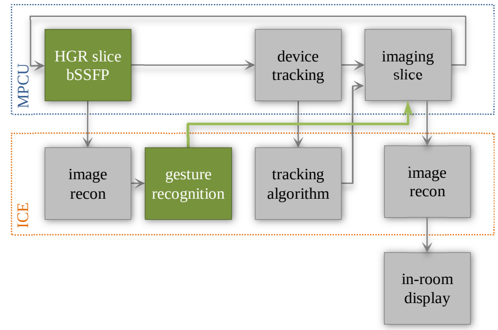

Fig. 1: Flow diagram of an interventional pulse sequence (gray) extended by a hand gesture recognition (HGR) slice acquisition on the scanner (MPCU) and the HGR algorithm (green) on the image reconstruction system (ICE).

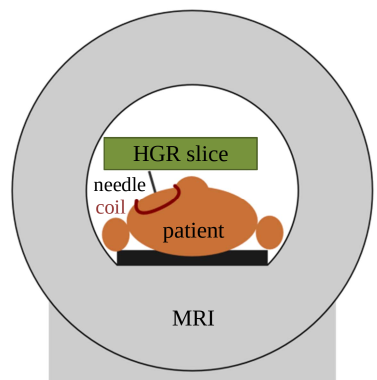

Fig. 2: HGR slice (green) is acquired at a fixed position above the patient (brown).

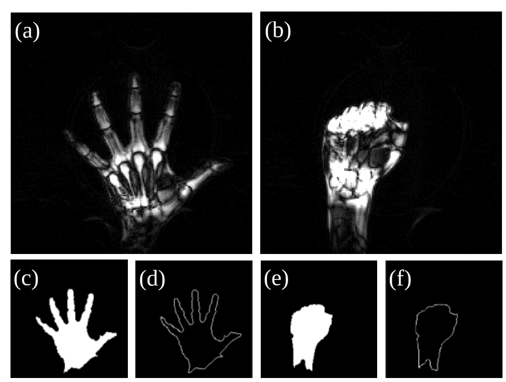

Fig. 3: Acquired hand gesture control slices (a,b), binary images after post-processing (c,d), and edge images used for shape classification (e,f).

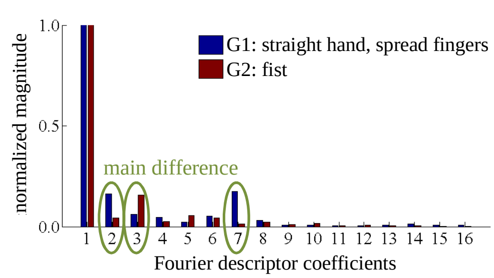

Fig. 4: First 16 Fourier descriptor coefficients of hand gestures shown in Fig. 3.