Estimating Finger Postures by Attaching an Omnidirectional Camera to the Center of a User's Palm

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ABSTRACT

This research describes the development of a system that estimates the natural postures of a user's fingers from the images captured by an omnidirectional video camera attached to the center of the user's palm in real time. The finger postures can be estimated by detecting the fingertips on each image and referring to the following preset information: the positional relationship between the camera and the user's fingers/fingertips, the length between the finger joints, and the interdependencies between the finger joints.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction**;

KEYWORDS

Finger Detection, Finger Posture, Omnidirectional Camera

1 INTRODUCTION

This paper describes our method for estimating the natural posture of a user's fingers from the images captured by an omnidirectional camera attached to the center of the user's palm. Research on the three-dimensional reconstruction of a finger posture is actively being conducted for user interfaces such as AR and VR. For instance, Leap Motion [1] which estimates the position and orientation of a user's hand with an active infrared camera, and Myo [2] which estimates hand motion via wearable hardware equipped with both an acceleration sensor and an electromyogram sensor on a user's arm have been developed. Our system estimates natural finger postures from the fish-eye image captured by an omnidirectional camera by detecting the fingertips in an image and referring to the following preset information: the positional relationship between the camera and user's fingers/fingertips, the length between finger joints, and the interdependencies between the finger joints. In [3], the idea of estimating a user's hand pose by integrating multi-viewpoint silhouette images was proposed. The system requires plural cameras for capturing multi-viewpoint silhouette images. In [4], a system for detecting continuous hand openness using a Kinect-like device was proposed. However, this system cannot estimate the posture of each finger. Our system only requires that an omnidirectional video camera be attached to the center of the user's palm in order to estimate the natural posture of each finger in real time. The user attaches RICOH THETA S to the center of each palm as depicted in Figure 1 so as to not restrict the movement of the user's fingers as far as possible.

Figure 1. Attaching the omnidirectional camera

2 METHOD

Our idea for finger posture reconstruction is in the following:

1. Calculate the angle between the vector from the lens to each fingertip and the camera body, i.e., θ_{tip} in Figure 2, by detecting the fingertip from the captured fish-eye image,
2. Calculate the finger joint angles from the θ_{tip} by applying inverse kinematics.

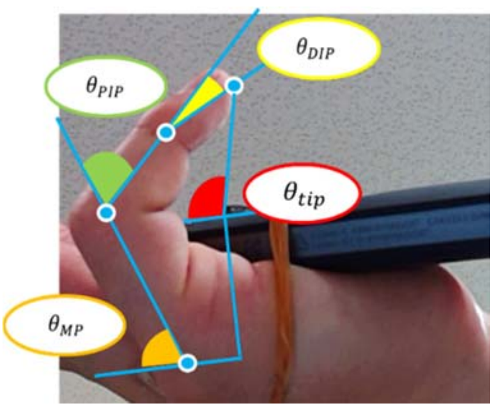
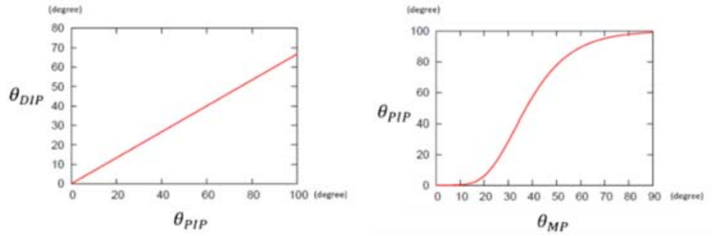


Figure 2. The finger posture considered in this research



(a) **Dependency between θ_{PIP} and θ_{DIP}** (b) **Dependency between θ_{MP} and θ_{PIP}**

Figure 3. The dependencies of each joint angle

The following section describes our method in detail. We apply the expression proposed by Sherrah et al. [5] to each pixel and extract the skin color region from the fish-eye image. We apply distance transformation to the binarized skin color regions to extract relatively large skin color regions and consider them as finger region candidates. We then apply a template-matching method to each finger region candidate with fingertip templates in order to detect a fingertip within the search area set by referring to the finger joint constraints proposed by Fujiki et al. [6]. Next, plausible candidates are selected as finger regions. The farthest pixel on the contour of a finger region from the base of the finger is acquired as its fingertip pixel. The θ_{tip} of each finger is calculated from the fingertip pixel with a fish-eye lens projection model and thus, the joint angles can be calculated based on inverse kinematics, as shown in Figure 3, by referring to the movable range and the interdependencies of the finger joints also proposed in [6]. We also estimate the natural finger postures from each calculated joint angle and the preset distance between the joints of the fingers.

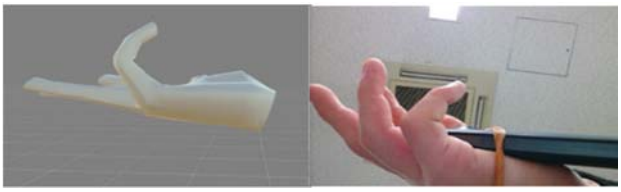
3 DISCUSSION

We conducted an experiment to evaluate the effectiveness of our method. We captured images of a subject's little finger to measure the θ_{tip} value with an additional video camera from the side of the hand and calculated each joint angle based on the value of θ_{tip}. We then compared the little finger joint angles detected by the proposed method with the measured angles. The results of the experiments in five postures of the subject's little finger are shown in Figure 4. Given that the error was within 5% of the angle range of each joint angle in the cases from posture 1 to posture 3, we consider that our method can estimate finger postures with an acceptable accuracy. Our method, however, could not detect the little finger because the brightness was insufficient in posture 4, where the finger touched the lens. In addition, the finger was not in view of the camera in posture 5. In fact, we believe that the proposed method could be improved by continuously tracking fingers.

4 CONCLUDING REMARKS

We have developed a system to estimate the natural finger postures from an image captured by an omnidirectional camera attached to the center of the user's palm in real time. We were able to estimate the finger postures with an acceptable accuracy if the fingers were successfully detected.

We are also currently working to detect the other hand and estimate the three-dimensional position and posture correspondences of both hands by attaching omnidirectional cameras to both palms. We plan to develop AR applications employing 3D hand postures and finger angles, e.g., pottery wheel-throwing.



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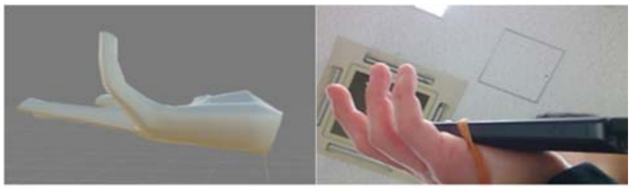

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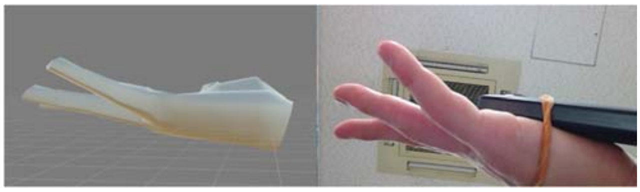

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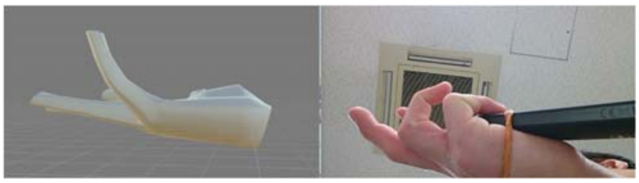

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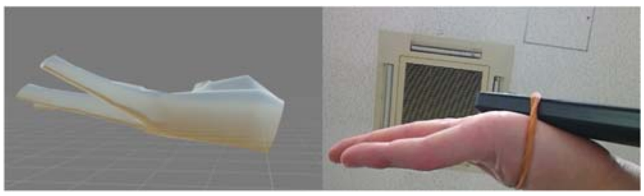

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Figure 4. Reconstruction and the finger pictures of Posture 1 to Posture 5

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