Wrap & Sense: Grasp Capture by a Band Sensor

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ABSTRACT
This paper proposes a bare hand grasp observation system named Wrap & Sense. We built a band type sensing equipment composed of infrared distance sensors placed in an array. The sensor band is attached to a target object with all sensors directed along the object surface and detects the hand side edge with respect to the object. Assuming type of grasp as "power grasp", the whole hand posture can be determined according to the 3D shape of the object. Three types of application are shown as proof-of-concept.

Author Keywords
Digital hand model; grasping posture; a band type sensor

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
The measurement of human hand grasping posture is required in many fields such as human-computer interaction, biomechanics, and ergonomics. The measured motion of how the hand uses daily objects can be analyzed and utilized to refine the design of products and services.

In terms of precise measurement, an optical motion capture system that uses reflective markers attached to the hand is a precise tool. However, the unnatural sensations caused by the attached markers often lead to different behavior than usual. Although various devices including wrist-worn types have been developed to free the hand from such unnaturalness [4,5, 9,10], it is still challenging to capture bare hand in contact with objects because the hand is easily occluded by the objects. This occlusion problem can be combatted by directly attaching sensor devices to the target object, which limits direct touch of the object due to widely-spread sensors [2,3] or would limit capturable grasps to certain patterns due to complicated detection mechanism [7,8].

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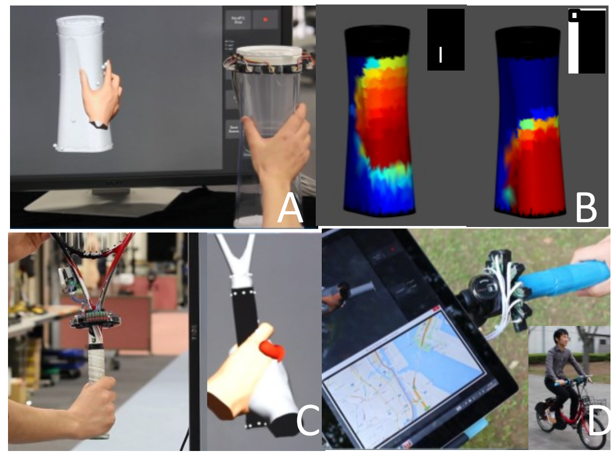

Figure 1. Wrap & Sense capturability and applications. A) grasp capture, B) grasp preference analysis, C) tennis grip instruction, D) navigation on riding

Instead of capturing the whole hand completely, some studies (e.g., [1]) have tried to detect the hand partially and reconstruct the whole hand posture by estimation from considering mechanical conditions. This approach looks natural because, as grasp taxonomy suggests, the profile of grasping hand posture can almost be determined if the object to grasp and the style of grasp are given.

In light of the above, we have developed a system Wrap & Sense (Fig. 1) to observe bare hand grasping posture by detecting a side edge of the hand by means of a band sensor attached to the end of an object. We discuss the principle and implementation of our system as well as showing applications for proof-of-concept.

WRAP & SENSE PRINCIPLE AND IMPLEMENTATION
Wrap & Sense aims to enable grasp capture of a target object by wrapping a band type sensing equipment around the object at the end of it. Assuming that we deal with a target object that can be roughly approximated as a cylinder, we propose to use a sensing equipment that is composed of distance sensors in which all the sensors are directed in the same direction along the surface of the object. If the object surface is not bumpy, each sensor can detect the distance between itself and the crossing point of the sensor direction with the contacting hand side edge, that is, the ulnar side of the thumb and radial side of the index finger.

An overview of our observation system is given in Figure 2. Once the sensing equipment is attached to the target object,

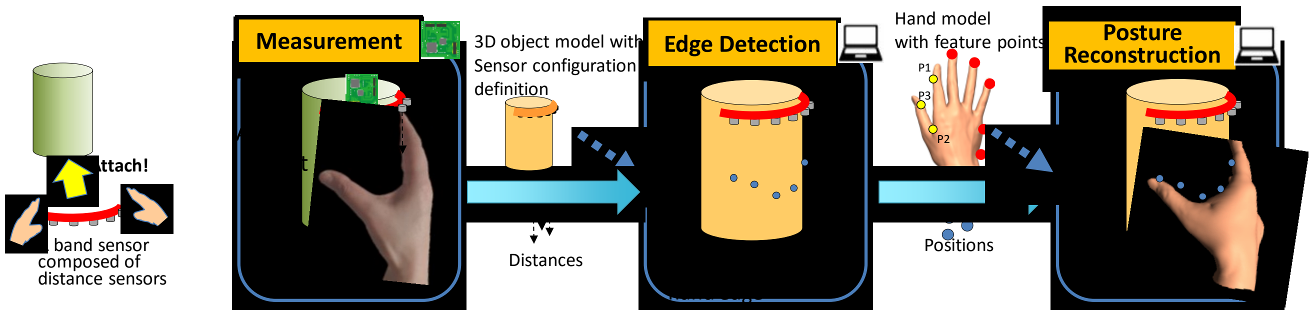

Figure 2. System overview of Wrap & Sense

measurement can be conducted. The equipment sends a set of distances to a computer and the computer converts each distance into relative coordinates on the object using a sensor configuration definition on a 3D object model. Considering the range of detected distance, we can find several adjacent points that are likely to correspond to the detected hand edge. A hand model is then aligned to these points so that the corresponding part overlaps. To define the whole hand posture with this alignment, we compensate for absent information about the part that was not directly detected by the sensor system on the basis of assumed grasp type. For example, when the hand is grasping an object in a power grasp style, the rest of the fingers (middle, ring, and little finger) are naturally aligned along the object surface and almost the entire area on the palmar side comes into contact with the object.

We fabricated a prototype of the Wrap & Sense sensing equipment (Fig. 3) using eight to eleven infrared distance measuring sensor units (Sharp Corporation, GP2Y0A21YK) connected with a micro controller (Arduino SRL, Arduino Mega 2560/Arduino ProMini), to convert an analog signal into a digital one and to communicate with the software running on the computer. A radio module (Digi International, XBee 802.15.4 module) was installed to enable wireless connection. Each digital signal was converted into distance on the basis of calibration data collected at different distances to deal with the nonlinear responsiveness of the system.

Hand model of an arbitrary user can be created by deforming a generic hand model derived from medical images to satisfy hand dimensions of the target user [6].

APPLICATIONS

The followings are applications that utilize capture of grasping postures by the proposed system as shown in Figure 1 A).

Preferred grasp location analysis for design assistance: The preferred grasping area on the object can be displayed in color map by analyzing the collected grasps. Figure 1 B) presents an example of different grasp preference for the same product at different locations.

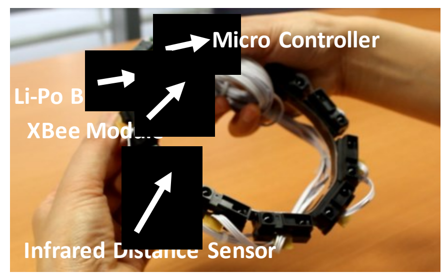

Figure 3. Prototype implementation

Grip instruction for tennis player: In addition to recording player's grip on a court, typical grasping hand image (a certain kind of grip in tennis) can be presented as well as the player's current hand posture (Fig. 1 C). This can help a self-schooling player to learn complicated grip techniques.

Navigation on a bicycle: Captured handle grasps are categorized into five groups according to the position of the metacarpophalangeal joint of the middle finger. The user can then control a map view without releasing the handle by using related navigation movements (eg., moving to east) of each group (Fig. 1 D).

CONCLUSION

In this paper, we proposed a grasp observation system, Wrap & Sense, for the bare hand. By means of attaching sensing equipment composed of infrared distance sensors formed as a band, the system detects the hand edge with respect to the grasped object and reconstruct the whole hand posture by aligning the hand model based on the detected edge location on the object model. The implementation of three applications demonstrates the potential of the proposed sensing and reconstructing system as a communication and interaction tool as well as measurement system.

Current system is limited to detecting "power grasp" of a cylinder(-like) object by a single hand. Our future work will include extension to seamless detection of both hands for more natural interaction detection as well as brushing up the current algorithm in terms of its speed and stability.

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