Grasp sensing for daily-life observation
- concept proposal and prototype implementation for cylindrical object -

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Abstract

To collect natural hand behavior data in a daily life, we need an observation system that is applicable for bare hand and is robust for occlusion. Given models of the hand and an object and a grasping style such as power grasp, an outline of the hand to grasp the object can be estimated. Attachment of an appropriate sensor unit on an object to grasp is expected to help decrease occlusion problem. A purpose of this study is, therefore, to build a system to observe bare hand posture by partially capturing the hand with sensor equipment attached on an object and by utilizing 3D models of the object and the hand.

We fabricated a prototype sensing equipment with infrared distance sensors installed in a line and put it around a target object so that all the sensors directed downward. Each sensor provided a distance between the sensor and a detected edge on the hand. Using a 3D model of the target object with locations of the sensors on it, each distance was converted into a position of the detected point. The subject's hand model was generated by deforming a reference model to satisfy given dimensions. The whole hand posture was calculated through optimization to fit the hand model to the detected points and to avoid the interference between the hand model and the object model. A preliminary experiment showed the sensor equipment attached on the upper end of a water serving bottle successfully detected several points on the ulnar side of the thumb and on the radial side of the index finger and posture of the whole hand was reconstructed according to the different grasping location.

Keywords: Digital Hand Model, Casual sensing, Grasp.

1. Introduction

Human-centered product design has been of great concerns that is based on observation of how a product is actually used in a daily life. To enable this with quantitative data for handheld products, we need a natural behavior observation system.

As well known, slightly different behavior is observed if some markers are attached on the body surface as in an optical MoCap system. A glove-like equipment also changes the behavior. Therefore, the measurement system should be applicable for bare hand, which is also preferable in terms of enabling product assessment based on direct touch.

Regarding a device to capture human postures without attaching any markers on the hand, a commercial product "Leap Motion" is available. It effectively works for free unloaded motion if the whole hand is fully captured. However, it does not work when self-occlusion occurs or when any obstacle lies between the device and the hand. The former is mechanically inevitable for the hand. The latter corresponds to a failure when the hand touches an object. A wrist-worn device "Digits" proposed by Kim is an interesting approach to enable bare hand touching and feeling (Kim, et al., 2012), however, it also does not work for the hand grasping an object.

Many works on grasp taxonomy (ex., Feix, et al., 2009) suggests that profile of the grasping hand shape is almost determined if an object to grasp and a style of grasp is given. Then partial detection of the hand is expected to work to reconstruct posture of the whole hand as solved using inverse kinematics for detected thumb tip and fingertips position (Achibet, et al., 2015). Now let us consider the hand that grasps an object whose shape can be approximated as a cylinder in a power grasp style. The hand would contact the object with almost all the area on the palmar side and would be relatively located with its radial and ulnar side edges slightly inclined or perpendicular to the axial direction of the

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object. Ideally no occlusion would occur to detect either of these edges if any sensing system is attached on the surface of the object.
A purpose of this study is, therefore, to build a system to observe the bare hand grasping posture by detecting a side edge of the hand with a sensor equipment attached on an object. 3D models of the object and the hand would be utilized to reconstruct posture of the whole hand. After showing profile of our observation system in section 2, we show preliminary experimental results in section 3.

2. Measurement system

Figure 1 shows overview of our observation system which consists of a sensor system (hardware) that captures an edge of the hand and a software that converts sensor data to detect edge position and estimates posture of the hand.

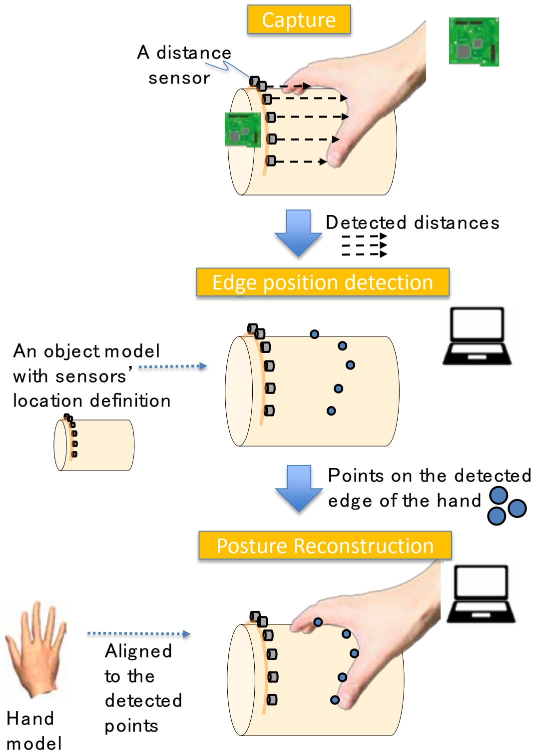


Figure 1 Overview of our system

2.1. Sensing system and an object model preparation for hand edge detection

To keep areas to be directly touched by the hand as wide as possible, we selected to attach distance sensors in line around an object at one of its longest axial ends. Each sensor was directed to the oposite end in parallel with other sensors along the surface of the object so that the sensor detects the hand in contact.
As a first prototype of a sensing system, we fabricated an equipment with 11 infrared distance measuring sensor units (SHARP CORPORATION, GP2Y0A21YK) connected with a microcomputer USB board (ARDUINO SRL, Arduino Mega 2560), which was for analog signal conversion into digital one and communication to a software running on the computer. Digital signals were then collected at different distances as shown in Figure 2 to be used for conversion into distances.
Location and orientation of each sensor should be defined on a 3D object model to convert each detected distance into a relative position to the object as shown in Figure 3.

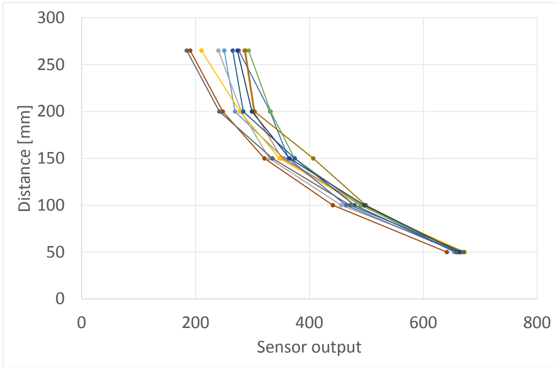


Figure 2 Calibration results to calculate distance from digital signal (ranged from 0 to 1023)

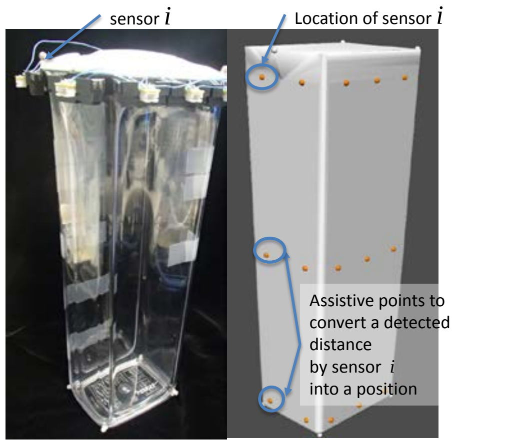


Figure 3 An example of an object and its 3D model with feature points to define sensor location and with assistive feature points to convert distance information into position.

2.2. Hand model preparation and posture reconstruction from partial edge detection

An individual hand model of the subject can be created by deforming a generic hand model to satisfy given hand dimensions (Miyata, et al., 2013). Here we estimated full set of hand dimensions using 22 manually measured dimensions utilizing the result of principal component analysis (Endo et al., 2015) of our hand dimension database of more than 500 Japanese adults (Kouchi, et al. 2015).
Several feature points were defined on the edge to be detected by the sensor system, on the fingertips, and on the palm as shown on the left in Figure 4. Goal position of the points defined on the side edge (yellow circles in Figure 4) were determined using

the detected points' position (light green circles in Figure 4). The nearest detected point from the sensor equipment was regarded as a goal position of the point on the side of the distal phalange of the index finger. The most distant point around this nearest point was regarded as the goal of the point on the crotch between the thumb and the index finger. The goal of the thumb tip was similarly determined. Goal of the rest of the points (red circles in Figure 4) were roughly estimated considering relative location with each other. Posture of the hand model was then adjusted through optimization that minimizes difference in position between corresponding points. To reduce the convergence time of this process, we prepared a reference hand model of average female size grasping an object model, which was also referred to reflect its relative location in rough estimation of the goal positions for the feature points which were not directly detected by the sensors.

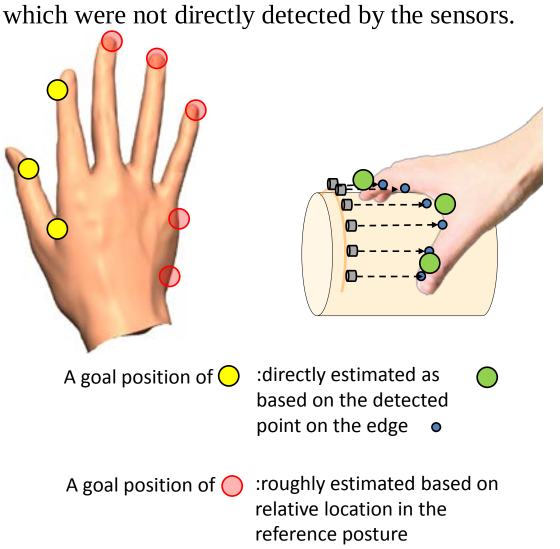


Figure 4 Hand model with feature points for posture reconstruction

3. Measurement experiment

To demonstrate feasibility of our system to observe human hand grasping posture by detecting an edge of the hand, we conducted two kinds of measurement experiments of the right hand to grasp bottles in a power grasp style.

In the first experiment, we captured grasping postures in various locations on the object by the proposed system for several participants. Figure 5 shows some snapshots of how our system worked in this experiment of one of the participants. The results showed that the system successively worked to reconstruct grasping postures interactively (every 30 msec.) according to the relative location not only for a water serving bottle (in upper two rows) but also for a different kind of object, a pet bottle (in the right of the lowest row). As we installed a 3 axes accelerometer with our sensor system, it could also detect posture change of the object (in the left of the lowest row).

In the second experiment, the grasping postures were captured simultaneously by the proposed system and the optical motion capture system (Vicon MX) as shown in Figure 6. The postures captured by the motion capture system was reconstructed by using DhaibaWorks. Comparison of the reconstructed postures are shown in Figure 7. The system could approximately reconstruct the grasping location but differences from MoCap results were found in detail especially in the fingers part. The difference was partly due to the low density and accuracy of the sensors, which could be approved by updating sensors to smaller and better ones. Improvement of reference grasping posture could also work.

One of the scenarios to utilize such grasp data is to analyze preferred location of grasp with respect to the products. Figure 8 shows an example of the analyzed result expressed as heat-map. Areas in red correspond to the location where the hand kept grasping for longer time and in blue the opposite. Such results with subjective evaluation can be used to find features to be approved in the tested product.

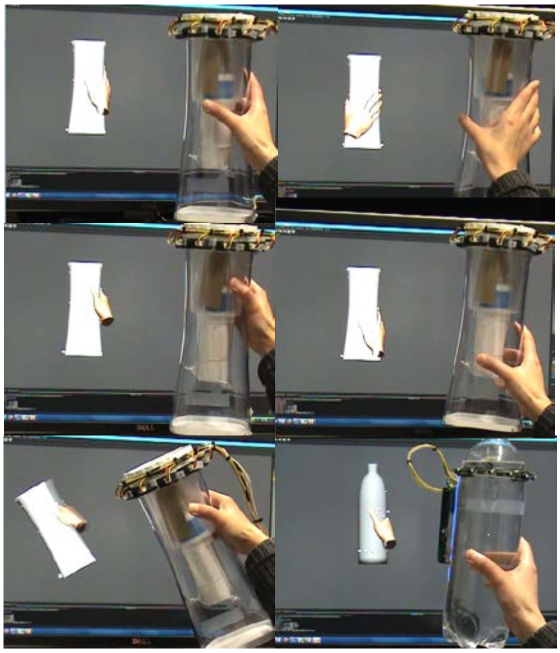
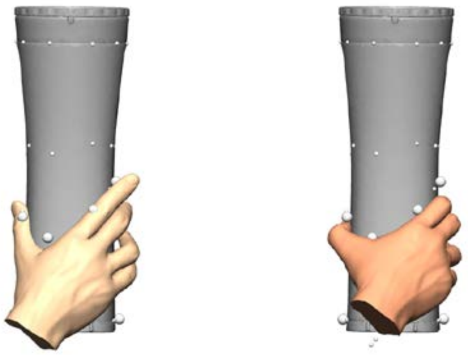
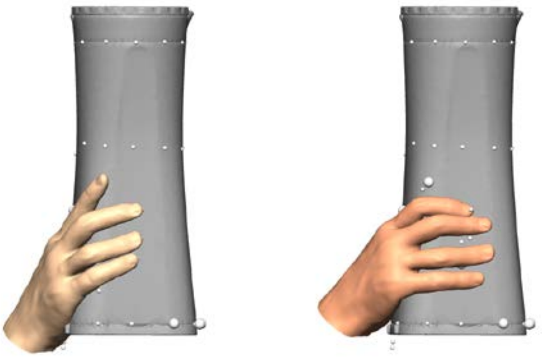


Figure 5 Some reconstructed grasps by the proposed system in various location

Figure 6 Simultaneous measurement experiment by the proposed system and an optical motion capture system

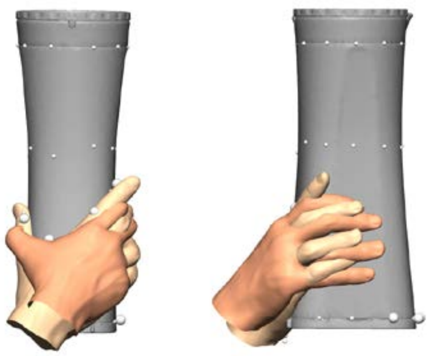


(view from back side)



(view from right side)

(a)by the proposed system (b)by the MoCap system



(view from back side) (view from right side)

(c)Superimposed results of (a) and (b)

Figure 7 Comparison of the postures by the proposed system and the motion capture system.

4. Conclusion

This paper proposed the grasp observation system for bare hand. Preliminary experimental results showed that the system worked to approximately reconstruct human hand grasping posture. One of the contributions of this work was to show a new way of digital human model usage.

Our future works include improvements in both hardware and software. To observe grasping data as naturally as possible, sensing system should be downsized. Wireless connection of the sensor band is now in progress. Faster and more accurate algorism of posture reconstruction is required especially for interactive use by measurement participants.

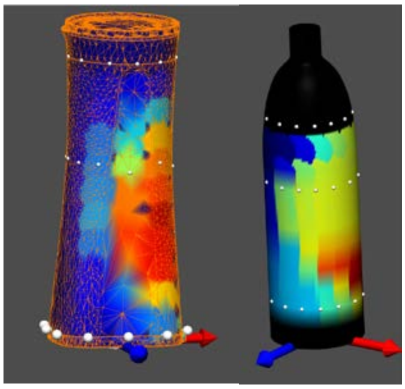


Figure 8 Examples of contact area analysis with grasp duration time drawn in heat-map.

References

Achibet M., Casiez G., Lécuyer A., Marchal M., 2015. THING: Introducing a Tablet-based Interaction Technique for Controlling 3D Hand Models. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI15), 317-326.

Endo Y., Tada M., Mochimaru M., 2015. Estimation of Arbitrary Human Models from Anthropometric Dimensions. Proceedings of the 17th International Conference on Human-Computer Interaction, 3-14.

Feix T., Pawlik R., Schmiiedmayer H.-B., Romeo J., Kragic D., 2009. A comprehensive grasp taxonomy, in Robotics, Science and Systems Conference, Workshop on Understand the Human Hand for advanced Robotic Manipulation.

Kim D., Hilliges O., Izadi S., Butler A., Chen J., Oikonomidis I., Olivier P., 2012. Digits: Freehand 3D Interactions Anywhere Using a WristWorn Gloveless Sensor. Proceedings of the 25th annual ACM symposium on User interface software and technology (UIST12), 167-176.

Kouchi M, et al, 2015, "Evaluation of estimated hand measurements for creating digital hands", In Proceedings of the 19th Triennial Congress of the International Ergonomics Association (IEA2015).