

Improving operational feeling in using virtual tools by reproducing virtual behavior from real one captured in advance

Kazuhiro ANNOURA, Norihiro ABE, Kazuaki TANAKA¹⁾, Hirokazu TAKI²⁾

- 1) Faculty of Computer Science and System Engineering
 Kyushu Institute of Technology
 noura@sein.mse.kyutech.ac.jp
 2) Faculty of System Engineering
 Wakayama University
 taki@sys.wakayama-u.ac.jp

Key Words: *virtual environment, virtual hand, operationarity of tool, sense of operation*

Abstract

As it is not easy for a user in virtual environment to use virtual tools, improving the feasibility of manipulating them is necessary to help him correctly achieve his intention. Tools are used to change the current state of an object into desirable one, so the several constraints are imposed on their movement, a grasping method and an object class to be manipulated. Consequently, it is possible for the system to predict user's intent by watching his behavior. We propose a method to measure the movement of real tools when they are exploited for a particular purpose and to store them so that they are retrieved according to their constraints. Inferring user's intention through the observation of his behavior, the system plays back one of the stored movements. This allows any users to exploit a virtual tool in virtual environment in the similar way to the real one.

1. INTRODUCTION

An artificial reality or a virtual reality have been attracted attention as techniques for having us intuitively understand problems which it is hard for us to experience in daily life. For making it easy for us to intuitively comprehend events occurring in virtual environments, a man machine interface plays an important role to secure fast and correct communication between us and a computer.

Displays, keyboards or mouses are well known as interface tool for bridging between a person and a computer, but a mouse does not allow a person with no experience in a virtual space to manipulate the 3 dimensional space at his own will. A number of purpose-built input/output devices have been developed in virtual reality studies to facilitate the 3 dimensional manipulation. Input devices such as a handle or an accelerator used in drive simulators are typical examples. These purpose-made devices generally make it difficult to generalize a system for controlling devices including problems of their sizes, costs and popularization into families. An approach of building a knowledge base of tools was proposed to

divide input devices from a core system by restricting them to 3 dimensional position sensors and data gloves (Funahashi et al., 1997). Using the tool knowledge base, interaction between operator's hands and various tools is defined in this system. We think that an action of a tool is decided by the gesture with an operator's hand and that the tool works as the result. In this case, if the system does not move a tool simply but move the tool exploiting captured data, the tool operation with a sense of reality can be visualized. As a tool is grasped by recognizing the gesture of operator's hands and operated referring to the tool knowledge base, it is difficult to realize any operation which an operator does not intend. As providing the semantic model for each tool and classifying operation of tools by grasping method and the movement, the proposed method is flexible and makes it possible to realize extension of new operation in addition to reproduction of operation.

Tools are used to manipulate an object for attaining a particular purposive operation, this allows a system to anticipate an operator's behavior. This means that it is possible to store in advance the behavior of hands observed at the time when he manipulated a real tool.

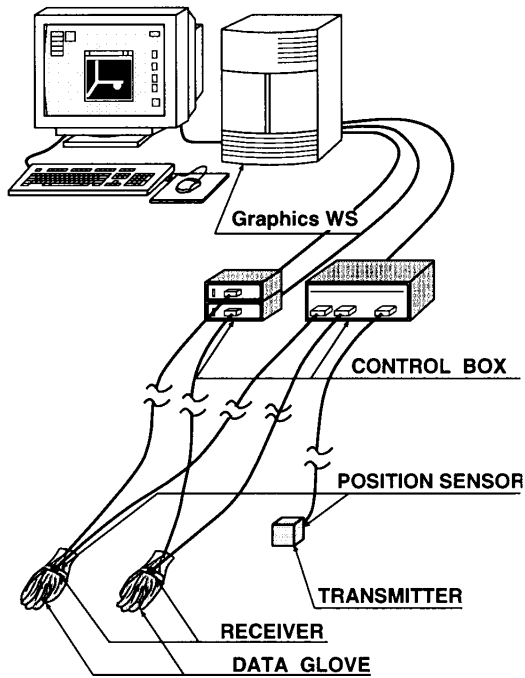


Figure 4.1: System configuration.

4. SYSTEM CONFIGURATION

System configuration is shown in Figure 4.1. By mounting data gloves and three dimensional position sensors on both hands, every joint angle of every finger and position information are always returned to the computer. Computer utilizes this information and allows any operator to make interaction with virtual environment. The system consists of a work station OCTANE/SSI of SGI company, three dimensional position sensor ISOTRAK II of POLHEMUS Company and Super glove of NISSYOU Electronics Company

5. MOTION CAPTURE OF HANDS DURING OPERATING A TOOL

5.1 Environment of Data Acquisition

The motion of a hand during operating a tool in a real environment is captured with the magnetic position sensors.

Magnetic sensors have a weak point that it is affected by environment, and what is worse the compensation of the influence is hard because it is non linear. Fortunately, as the measuring range is from 0 to 50cm, the distortion is very little and there is no need of data calibration. Figure 5.1 shows an amount of distortion occurring in position data measured with a magnetic sensor; dotted lines show measured values.

Because the head of a hammer is made of metal, it

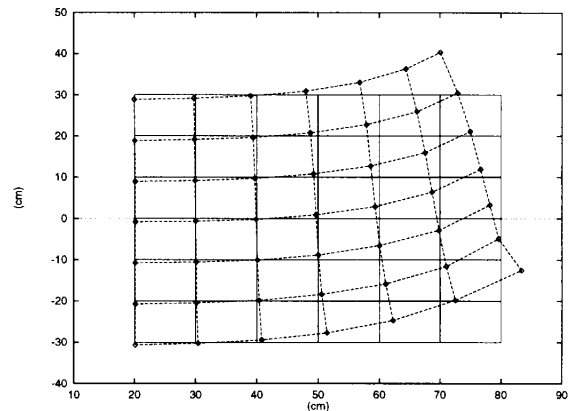


Figure 5.1: Distortion of magnetic field.

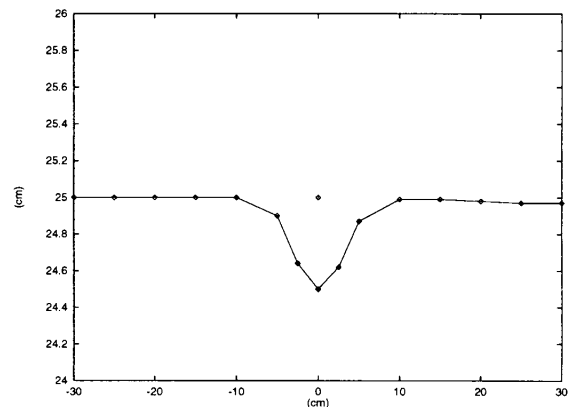


Figure 5.2: Effect caused with a hammer head.

certainly affects to the value measured with a magnetic sensor. Figure 5.2 shows the deviation in values of the magnetic sensor located at (0,25), with a transmitter located at (0,0) and a hammer moving along the horizontal line passing the point (0,20). From the result, it can be concluded that the influence of a hammer head to the magnetic field takes a maximum value when it is on the line passing both the transmitter and receiver, and is negligible when it is 10cm distant from the receiver. The motion measurement of a hammer is conducted without grasping a hammer head in a hand, no calibration is not specially taken into consideration.

5.2 Motion Capture of a Hand

The system proposed in this paper allows a person to manipulate a virtual tool according to his intention, and the operability of the tool to be promoted by giving both his virtual hand and the virtual tool the movement reproduced using the data obtained from the operation of the real tool with his own hand in

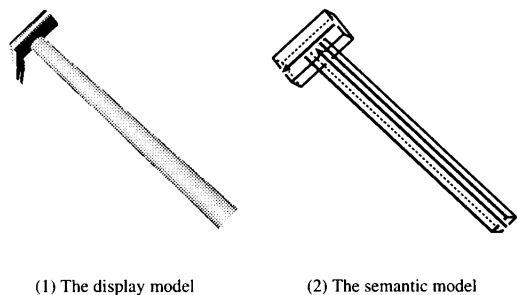


Figure 6.1: Two models prepared for a hammer.

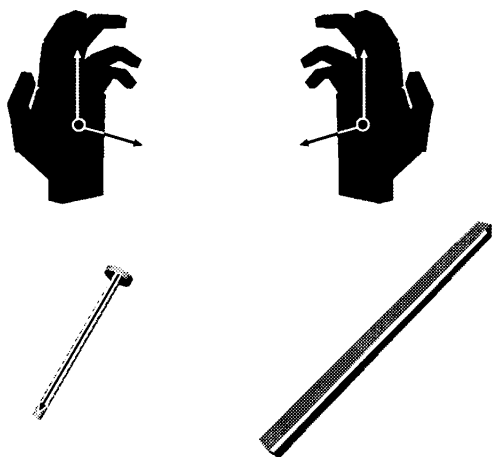


Figure 6.2: The semantic model for hands, a nail and a board.

6.2 Grasping an object with virtual hand

In the experimental system, a virtual hand is connected to a data glove and three dimensional position sensor, and operated by an operator in the real world. A tool or an object can be moved when it is grasped with either a right or left virtual hand. Condition under which a virtual hand can grasp an object is that the virtual hand is near the object and that it is going to accomplish grasping operation. In order to confirm the condition, when information acquired from a data glove shows bending of fingers, the interference check is done between the specific point a little apart from the center of a virtual manual palm and a model for interference check defined for the object. That is, relation between the apex of the virtual hand and the bounding box of the object model is examined as shown in Figure 6.3.

On the other hand, it is considered the object to have been got off when information acquired from the

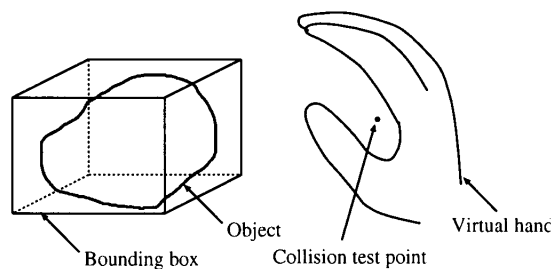


Figure 6.3: Collision detection method.

data glove didn't show bending of fingers.

6.3 Condition for data reconstruction

6.3.1 Static condition

The semantics model shown in Figure 6.1 is defined for a hammer, and those shown in Figure 6.2 are defined for the virtual hand, nail and board. In the experimental system, it is judged to be going to strike a nail with a hammer when the following conditions hold. When a left hand grasps a nail and a right hand grasps a hammer, relation between the directed line segment of the left virtual hand and that of the nail becomes as shown in Figure 6.4 (1). And when the relational between the directed line segment of the right virtual hand and that of the hammer become the state shown in Figure 6.4 (2). When the head A of the hammer (Figure 6.4 (2)) with keeping the current status approaches the nail head A' (Figure 6.4 (1)). When the head of the hammer (A in Figure 6.4 (2)) approaches the nail head (A' in Figure 6.4 (1)) with keeping the status mentioned above, and the point of the nail (B in Figure 6.4 (1)) comes right above the directed line segment of the board (B' in Figure 6.4 (1)) the following dynamic condition in the next section is verified.

When the right virtual hand grasps a hammer, if the relation between the directed line segment of the virtual hand and that of the hammer has become the state shown in Figure 6.5 (2), it is judged to be going to extract the nail with the hammer. When the head of the hammer (A in Figure 6.5 (2)) approaches the nail head (A' in Figure 6.5 (1)) with keeping the status mentioned above, and the point of the nail (B in Figure 6.5 (1)) comes right below the directed line segment of the board (B' in Figure 6.5), the following dynamic condition in the next section is verified.

When it is used as nail puller, there is no constraint on the position, and action of the left virtual hand.

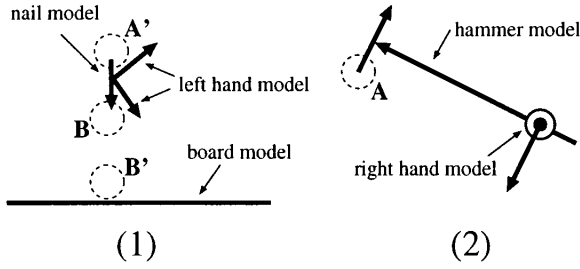


Figure 6.4: Relation among hammer used as hitter, hands, a nail and a board.

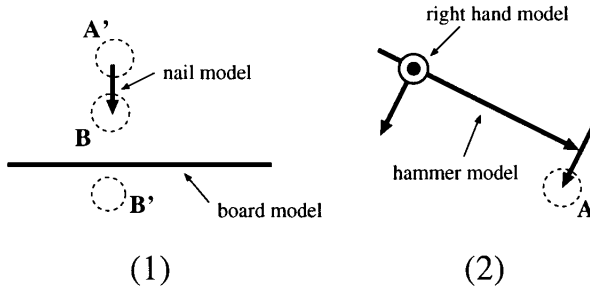


Figure 6.5: Relation among hammer used as extractor, a hand, a nail and a board.

6.3.2 Dynamic condition

In case to reproduce data only with the static condition, it is impossible to examine what kind of path a hammer has passed to approach a nail.

On this account, the experimental system keeps values of three dimensional position sensor to watch the action of the virtual hand when it grasped an object.

Striking a nail case

When a hammer was swung down for a nail, that is, if the directed line segment set on the extended line of the nail and the vector calculated from each position information provided from three dimensional position sensor have the same direction, the virtual hand motion measured beforehand is reconstructed.(Figure 6.6).

Nail puller case

When a hammer came close to a nail head so as to catch on it, that is, if each position information of the hammer provided from three dimensional position sensor moves on the tangent plane of the nail head, the virtual hand motion measured beforehand is reconstructed(Figure 6.7).

6.4 Reconstruction of action

In the experimental system, an object can be moved with right or left virtual hand. Data recorded are,

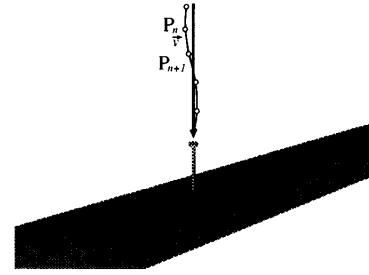


Figure 6.6: Dynamic condition for hitting a nail.

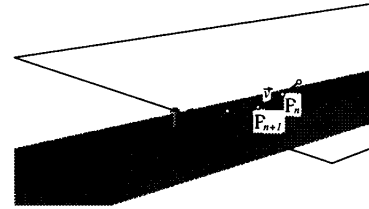


Figure 6.7: Dynamic condition for extracting a nail.

however, ones acquired from the sensor at a particular position where a nail is struck or extracted. Reconstruction of action at an arbitrary position in virtual environment is not attained by reproducing simply the stored data. On this account, a coordinate transformation of data recorded is necessary in reconstruction. Let the coordinate of the data and the homogeneous transformation matrix when they are collected be \vec{x} , and T_{origin} respectively. And let the homogeneous transformation matrix of the hammer and a coordinate to be calculated be T_{hammer} and \vec{x}' respectively. Then, the following equation holds:

$$\vec{x}' = \vec{x} \times T_{origin}^{-1} \times T_{hammer} \quad (6.1)$$

Coordinate transformation of measurement data is done using this expression (6.1).

7. CONCLUSION

For action such as striking or extracting a nail using a hammer in virtual environment, good eyesight effect has been attained and operational feeling has been improved. In the experimental system, both position and angle error rates occurring when a virtual hand grasps a tool are set within $\pm 10\%$.

Validation on whether this value gives sense of incongruity to the action reproduced or not is necessary. For tools with the similar facility but with a little dis-

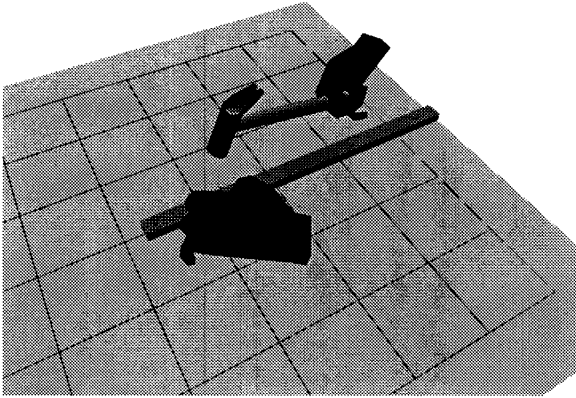


Figure 6.8: A situation a hammer is used as hammer.

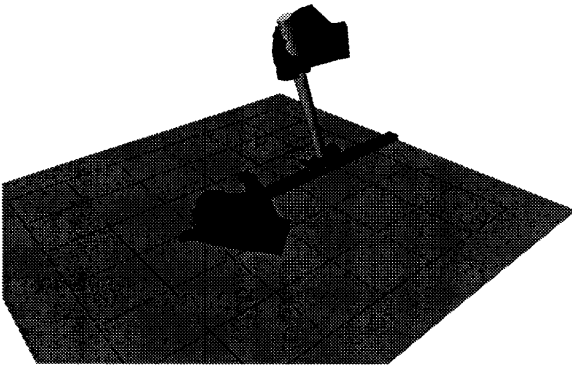


Figure 6.9: A situation a hammer is used as extractor.

function in dimension / shape, scale transformation will accomplish the saving in data preparation and sharing of data.

It is impossible to manipulate a hammer which must be supported with both arms in real environment by one arm in virtual environment. Consequently, extracting special features of objects and tools becomes very important. The special features of objects is equal to two kinds of model defined according to the purpose in the experimental system and the position relation to drive measurement data. At present, extracting these special features is performed by hand. As a number of objects is just three including a hammer, nail and board, the quantity of this work doesn't become problem in particular. There is the need that feature extraction process must be automated in order to adapt a lot of objects to this system. To offer this experimental system for practical use in future, various tools like drivers, cutting pliers, wrenches ex-

cept for hammers will be introduced into the system and they need to function effectively.

It is considered that the directed line segment model is effective in case of a hammer and nail. But in case of the hammer with no nail puller, either side of the head can beat a nail. In this case, a simple segment model is more advantageous than a directed line segment one.

REFERENCES

1. Duric. Z., Fayman. J. A., Rivlin. E.: "Function from motion", PAMI, Vol.18, No.6, pp.579-591(1996).
2. Funahashi et al: "Knowledge base for supporting usage of tools by hand in a virtual sapace.", Proc. VRSJ. Vol.2, pp.250-253(1997) (in japanese).
3. Ghazisaedy. M. et al: "Ultrasonic calibration of a magnetic tracker in a virtual reality sapace.", Proc. VARIS, pp.179-188(1995).
4. Hirai M. et al: "Human-demonstration based approach to the object motion detection and the recognition of process state transition in insertion of deformable tubes.", Journal of RSJ, Vol.15.No.8, pp.1172-1179(1997) (in japanese).
5. Ikeuchi K. et al: "Teaching roboto hand using vision.", Journal of RSJ, Vol.13, No.6, pp.599-602(1995) (in japanese).
6. Kuniyoshi, K. et al: "Learning by showing.", IEEE Trans. R & A. Vol.10, No.6,pp.799-822(1995).
7. Kuroda et al: "Inferring behavior of human's bust using 3 magnetic sencors.", Proc. VRSJ. Vol.2, pp.228-229(1997) (in japanese).
8. Sharma. R., Molineros.J: "Computer vison-based augmented reality for guiding manual assembly.", IEEE Presence. Vol.6, No.3, PP.292-317(1997).
9. Kazuhiro A., Kazuaki T., Jaing Y. Z., Norihiro A.: "One of method for improved using tools on virtual environment.", TECHNICAL REPORT OF IEICE, IN98-3, pp.17-22(1998) (in japanese).
10. Kazuhiro A., Kazuaki T., Jaing Y. Z., Norihiro A.: "Function of Object from Observing Human Action -Toward improving the operationality of virtual tools-", ISPRS Commission V Symposium, Vol. XXXII, Part 5, pp.860-865(1998).
11. Kazuhiro A., Kazuaki T., Jaing Y. Z., Norihiro A., Houjie HE, Hirokazu T.: "Reproducing operations virtual tools by using captured real operations.", Proc. VRSJ. Vql. 3, pp.83-86(1998) (in japanese).