Constraints for Realistic Hand Manipulation

Salvador Cobos, Manuel Ferre, Miguel Angel Sánchez-Urán and Javier Ortego
Universidad Politécnica de Madrid
{cobosalvador, mferre, jortego@etsii.upm.es}, {miguelangel.sanchezuran@upm.es}

Abstract

This paper describes dynamic constraints of a human hand model. Inter-finger and intra-finger constraints have been develop in order to obtain quite realistic manipulation.

Keywords--- **human hand model, inter-finger, intra-finger, constraints.**

1. Introduction

The objective of this work consists of achieving realistic hand manipulation performed by their kinematic configuration and by inter-finger/intra-finger constrains that imitate the human motion in order to obtain a realistic hand manipulation and representation of the hand model. Cyberglove [1] was used for checking previous constraints and testing new constraints for more acceptable approximations so that more realism in grasp movement. Several tests with the Cyberglove have been performed to verify the human hand model. Kinematic model of the human hand is modeled in two representative models [2, 3]. The first model represents the kinematic model of the fingers: index, middle, ring and little with five degrees of freedom each one. The second model represents the kinematic model of the thumb with four degrees of freedom. All constraints are developing for these two models. The organization of this work is in two parts: the Section 2 relates constraints for two models and finally, conclusions are presented.

2. Constraints

Fingers carry out movements in specific range caused by static constraints, intra-finger constraints and inter-finger constraints. These two mentioned constraints are often called dynamic constraints, which are responsible of giving natural movements statically and dynamically. However, this range of movement is somewhat ambiguous because the range depends on various factors involving human hand biomechanics. The ranks of movement of each joint are represented by static constraints [4, 5, 6].
The hand has two types of movements: active and passive. Active movements are actuated by muscles and tendons that permit a range of free movement, and passive movements are range of movements not actuated. The hyperextension in Interphalangeal (IP), Distal interphalangeal (DIP) and Trapeziometacarpal (TMC) joints are considering such as passive movement.
In this paper, new constraints have been implemented in inter-finger and intra-finger so as to acquire realistic movement of the hand model. This realistic movement generates an adequate degree of presence when the user interacts with the application.
Intra-finger constraints have been developed to reproduce movements within of the rank of grip trajectories such as circular and prismatic grasps.
Inter-finger constraints have been verified in experiments carried out with a Cyberglove to obtain the dependency of tendons mainly among the middle, ring and little fingers. The functionality of this glove depends on calibration of the joints [7].

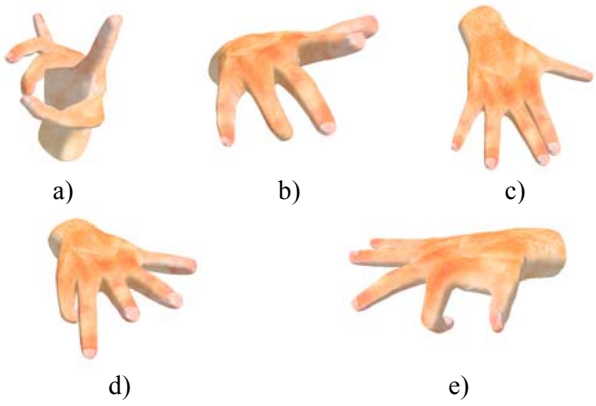

Figure 1 Represents intra finger constrains a) Middle and ring. b) Middle, ring and little. c) Abduction / adduction between ring and little. d) Little and ring e) Index and middle.

2.1 Intra-finger Constraints

Intra finger constraints refer to dependency of joints internals. In this section, intra-finger constraints are divided into two categories, the first is for index, middle, ring and little fingers, and the second for thumb model.

2.1.1 General finger model

Intra- finger constraint $\theta_{DIP} \approx 2/3\ \theta_{PIP}$ has been accepted by several researches as [8] and efficiently checked in our experiments. However, the constraint for $\theta_{PIP} \approx 2\theta_{MCP\ (f/e)}$ [9] in experiments carried out had been inappropriate. It is

because θ_{PIP} and θ_{DIP} depends on variation of $\theta_{MCP\ (f/e)}$. The trajectory of the finger with this constraint becomes very close. Consequently, is proposing a new constraint for θ_{PIP} and $\theta_{MCP\ (f/e)}$ as equation (1).

$$\theta_{pip} \approx \frac{3}{4}\theta_{MCP(f/e)} \quad (1)$$

2.1.2 Thumb model

The type of constraints being presented has been developed for θ_{IP}, $\theta_{MCP\ (f/e)}$ and $\theta_{TMC\ (f/e)}$. The following equations (2) and (3) show the intra constraints for thumb model.

$$\theta_{IP} \approx \frac{1}{2}\theta_{MCP(f/e)} \quad (2)$$

$$\theta_{MCP(f/e)} \approx \frac{5}{4}\theta_{TMC(f/e)} \quad (3)$$

2.2 Inter-finger Constraints

The inter-finger constraints were obtained by using the hand model and Ciberglove. These types of constraints are coupled movements among index, middle, ring and little finger. The relationship among angles with middle, ring and little finger has been measured to represent real movements of the hand model.

2.2.1. Cases of coupling movements. There exist coupling movement when there is flexion in $\theta_{MCP\ (f/e)}$ and the flexions of index and little finger are equal to zero. When this unique flexion is generated, the flexion of middle finger is equal to the flexion of ring finger as described in equation (4). Such as shown in figure 1.a

$$\theta_{MCP(f/e)M} \approx \theta_{MCP(f/e)R} \quad (4)$$

Another coupling movement is produced when there is flexion solely in the ring finger $\theta_{MCP\ (f/e)}$. This causes the flexion of middle finger to be equal to the flexion of little finger as described in equation (5). Such as shown in figure 1.b

$$\theta_{MCP(f/e)M} \approx \theta_{MCP(f/e)L} \quad (5)$$

Finally, coupling movement in abduction / adduction is generated among ring and little fingers. In most cases, the movement is similar to equation (6). Such as shown in figure 1.c

$$\theta_{MCP(abd/add)R} \approx \theta_{MCP(abd/add)L} \quad (6)$$

2.2.2 Relations of angles. This kind of relationship is summarized in two types; the most important relationship is when flexion in MCP of little finger exists as shown in figure 1.d. Equations (7), (8), (9) and (10) represent this type of relationship among these fingers.

$$\theta_{MCP(f/e)Ring} \approx \frac{7}{12}\theta_{MCP(f/e)Litle} \quad (7)$$

$$\theta_{MCP(f/e)Ring} \approx \frac{2}{3}\theta_{MCP(f/e)Middle} \quad (8)$$

$$\theta_{MCP(f/e)Ring} - \theta_{MCP(f/e)Middle} < 60^{o} \quad (9)$$

$$\theta_{MCP(f/e)Ring} - \theta_{MCP(f/e)Litle} < 50^{o} \quad (10)$$

The Second relationship is when MCP flexion exists in the index finger as shown in figure 1.e. Equation (11) represents this type of relationship between the index and the middle fingers.

$$\theta_{MCP(f/e)Middle} \approx \frac{1}{5}\theta_{MCP(f/e)Index} \quad (11)$$

Conclusions

New constraints for inter-finger and intra-finger were presented and it allows a reasonable representation of independence among joints and fingers. These constraints are very important because they are responsible for generating realistic movements of the hand model simulating a real human hand.

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