Development of Soft Skin of Digital Hand in Real Time Operation

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***Abstract*—This paper presents a development of soft skin of a digital hand which mimics human hand and is able to show dexterous operation of an object in real time. In the operation, soft skin as shown in human skin plays an important role in the contact with objects. To develop it, design methods of the soft skin as a model of human skin and of enabling real time operation are described.**

Keywords-digital hand; soft skin; real time operation.

I. INTRODUCTION

This paper presents a development of soft skin of a digital hand which mimics human hand and is able to show dexterous operation of an object in real time.

Human hand performs various difficult tasks in daily life and shows dexterous operation to use tools or equipment as object, because it has numerous degree of freedom (DoFs) of finger joints more than 22 DoFs [1][2]. There are many types of grasp such as power grasps, precision grasps and miscellaneous grasps, and each types is also divided into many various hand postures [3]. These hand postures can be made by the hand's DoFs; basically the posture of holding and arch ensure the various hand posture. However, a study on dynamical operation of hand grasping objects has not been made in the field of anatomy, but only on grasping which shows static situation to fix objects.

In the related studies on Computer Graphics (CG), considering muscular, freedom of joints or tendons, a precise digital hand to mimic human hand has been tried to be made [4]-[7]. The purpose of these studies are merely to simulate hand motion or evaluate product designs when it grasps an object. They conduct only static grasping, do not show dynamic operation.

The dynamic operation of the digital hand has been slightly considered in [8][9]. In the researches, the body of the digital hand was made of rigid body. On the other hand, human hand is covered with soft skin which is deformable. While hand operates an object, the contact region between soft skin and the object is area but not point as seen in rigid skin, so the dynamic relationship on the contact region becomes complex. This means the real time operation of the digital hand requires numerous computational load and is hardly realized. Furthermore, manipulating the digital hand dynamically has numerous patterns of the digital hand posture for each operation cases. This leads to that the programming to realize all the patterns of hand motion by using a certain computer language is very troublesome.

This paper proposes a novel design method of making soft skin to be suitable for real time operation of the digital hand, and this is an unprecedented study.

The platform of the system is on Panda3D [10], and the software to make soft skin is Blender [11] which fits for both Panda3D and Python language. To realize the real time operation of the digital hand, Bullet Physics which is a physics engine in Panda3D and has a function of collision detection is used. The collision detection can enable the digital hand to grasp and operate an object. The Leap Motion Controller (LMC) [12] is introduced as a hand-posture sensor. A number of applications using another type of digital hand is presented in the Web site of LMC, but all of them does not have soft skin and the collision detection in real time.

The paper is organized as follows; the skeleton model of digital hands is described in Section II. In Section III, the design of soft skin is discussed. In Section IV, our idea to realize the real time operation is explained. And the demonstrations of real time operation of the digital hand are presented. In the last, the paper is concluded.

II. SKELETON MODEL OF DIGITAL HAND

The hand skeleton model is shown in Fig.1 based on anatomical and medical hand investigation [2].

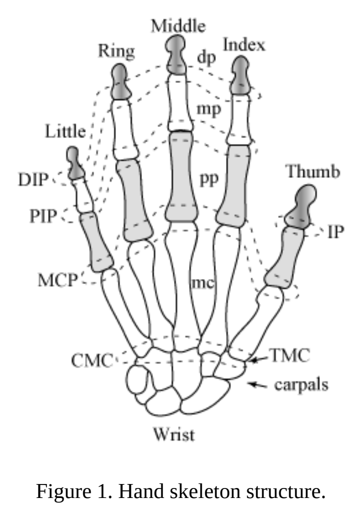


Figure 1. Hand skeleton structure.

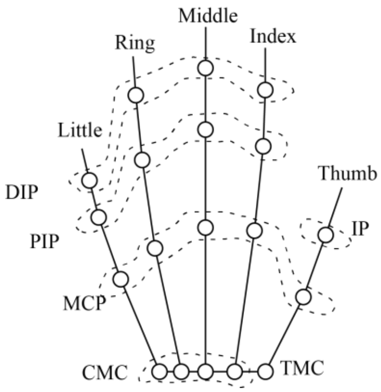


Figure 2. Skeleton model with bones and joints.

In Fig.1, abbreviated label for joints have following meanings (arranged in order from proximal to distal extremity). CMC stands for the carpometacarpal joint, MCP for the metacarpo-phlangeal joint, PIP for the proximal interphalangeal joint, and DIP for the distal interphalangeal joint. Other joint labels of thumb are: TMC for the trapeziometacarpal joint, MCP for the meta-carpophlangeal joint, and IP for the interphalangeal joint.

Each finger (not including the thumb) is composed of three bone links, called phalangeal bones. Each neighbouring pair of bone links are connected with a joint, i.e., a constraint that restricts relative translational motion of bone links in dynamics simulation. The DIP, PIP and IP has one DoF, the MCP has two DoFs, the CMC has two DoFs and the TMC has three DoFs. So, the total DoFs of human hand is 30.

It is very difficult to realize to operate a digital hand with such tremendous DoFs. Here, the joint of hand model of the LMC does not depend on DoFs, just on positions in three-dimensional Cartesian coordinate. From this, we designed that the joint of the digital hand are just connected each other. The rigid parts of the digital hand consists of the bones as rigid body and the joints, its structure is shown in Fig.2.

III. DESIGN OF SOFT SKIN

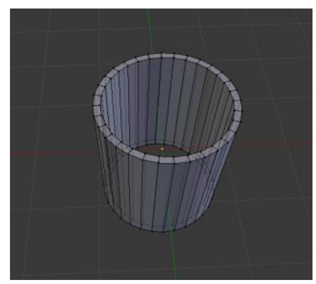
A. Design Method

There are two types of the soft skin for thimbles and fingertips, because a soft skin covering the entire digital hand makes the design and calculation load very complex. To overcome it, we designed that the soft skin covers the digital hand partially, and its design should be made to ensure the sufficient contact area between soft skin and object.

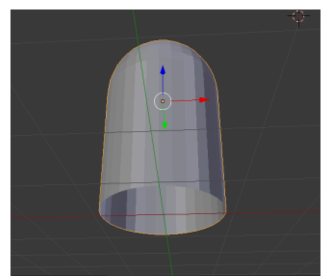
The configuration of soft skin is made by Blender, cylinder for thimbles and hemisphere with cylinder for fingertips. To give elasticity property to soft skin and convertibility to format used in Panda3D, the double structure for both is introduced. Fig.3 (a) shows a thimble which consists of two cylinders as double structure with different radius and both connected along with both edge,

TABLE I. PARAMETERS OF SOFT SKIN IN BULLET PHYSICS.

kDP	Damping coefficient; damps forces acting on soft body nodes to reduce their oscillation over time. Imagine a mass hanging on a spring. Range [0,1]
kDG and kLF	Drag and Lift coefficient; relating to aerodynamics (Wikipedia_Lift,2015, NASA,2015), Range $[0,+\infty]$
kDF	Dynamic friction coefficient; just friction of nodes against surfaces, as with rigid bodies. Range [0,1]
kMT	Pose matching coefficient; be used with setPose(bool, bool). Range [0,1]
kCHR, kKHR and kSHR	Rigid, kinectic and Soft contacts hardness; controling how strict any overlap between the soft body and other types is treated. Range[0,1]



(a) Double structure of thimble



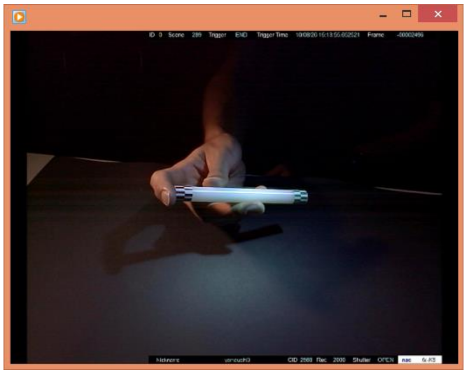
(b) Double structure of fingertip

Figure 3. Soft skin for thimbles and fingertips.

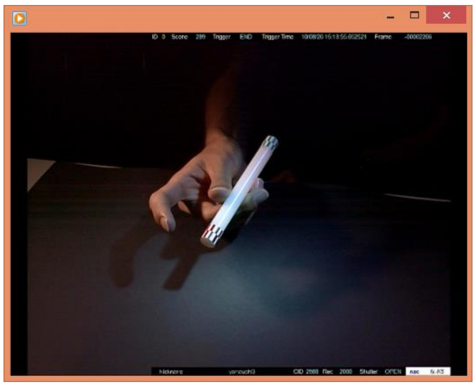
Fig.3 (b) shows a fingertip which consists of two couples of a hemisphere and a cylinder as double structure.

The number of mesh that makes up part of the thimbles and the fingertip will become too large, then the calculation time required for collision detection will be enormous, so it is difficult to achieve real time operation. Based on the trade-off of computational load and feasibility of the real time operation, the selection of the number is determined by trial and error.

The figure of the soft skin is introduced into soft body of Bullet Physics, and some parameters shown in TABLE I of soft body should be defined to set up it. However, the effective way to identify them have not shown yet, so we investigated that human hand played a dexterous



(a) t = 0.0 sec



(b) t = 0.1 sec

Figure 4. Scene of dexterous operation (1000 fps)

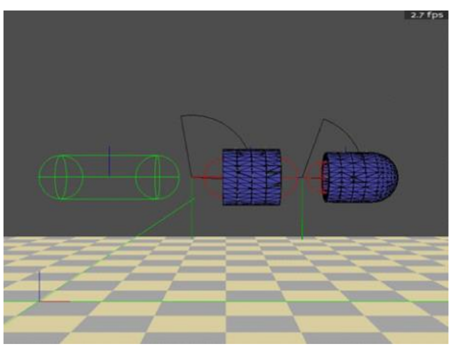
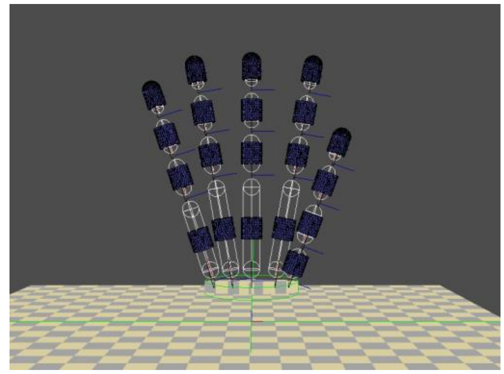


Figure 5. Digital finger with partial soft skin and rigid bone.

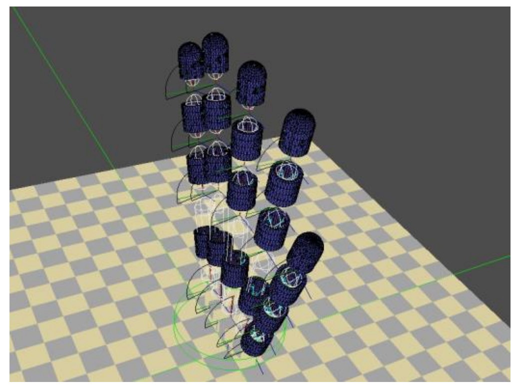
manipulation by using the high-speed camera (1000 fps) as shown in Fig. 4. Observing the situation of the deformable skin by investigating the movie, the parameters are adjusted to show the similar situation of the deformable soft skin.

B. *Connection between Softskin and Rigid Body*

A finger consists of three cylinder rigid body and the joint described in the previous section. Fig.5 shows one finger conducted by the design described above by using Panda3D. In Fig.5, the rigid bone and the partial soft skin are connected with anchors. Fig.6 shows the extending this configuration to the five fingers.



(a) Front view



(b) Overhead view

Figure 6. Digital hand, five fingers with rigid bones and partial soft skin.

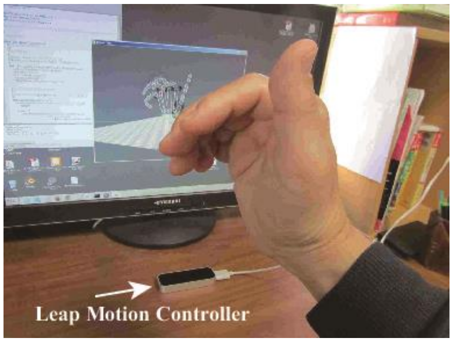
IV. REAL TIME OPERATION SYSTEM

A. *Hand Posture Sensing*

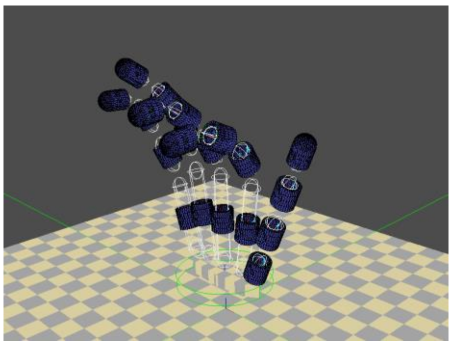
To realize the digital hand to mimic human hand operation in real time, a sensor which is able to sense the hand posture and also the position of hand is required, then the LMC is suitable for the requirement. The LMC observes a roughly hemispherical area, to a distance of about 1 meter, and can get 3D position data of all joints of fingers and palm within sampling rate 150-295 fps (USB 3.0 connection), this is made possible by the skeleton model of hand of the LMC. Then, the position data is sent through a USB cable to the host computer.

B. *Implementation*

A demonstrative application has been developed to evaluate the digital hand in operation by the postures. The goal is to set up the digital hand in real time operation. The software application is executable on the CPU (Core i7-4900MQ, 2.8GHz) and the GPU (Nvidia Quadro K4100M, 1152 Cuda processors). In the system, the roles of CPU and GPU are assigned separately as following



(a) Scene to get the humand hand posture using Leap Motion Controller



(b) Digital hand chage its own posture synchronously with human hand motion.

Figure 7. Digital hand system with LMC to obtain hand posture in real time operation.

Finger Callback : CPU
Graphics Thread : GPU
Physics Simulation : GPU

These processing assigned to CPU and GPU is enable to use PyCUDA [13], because Panda3D is built in Python and the assigned has been developing in the present circumstances.

C. Experiment

The user operated the digital hand to mimic the human hand in real time processing, using the LMC as the input device of the human hand posture is shown in Fig.7. Fig.7(a) shows the scene to get the human hand posture using the LMC. Fig.7(b) shows the scene that the digital hand change its own posture synchronously with human hand motion.

We have succeeded in the real time operation. According to the movement of human figures and palm of the hand, the digital hand change its posture to mimic the hand. And when the digital hand grasp an object in the virtual physic space in which the collision detection between the digital hand is automatically calculation then the digital hand can grasp it according to the varying hand posture in real time. However, this computational load becomes tremendous, so the real time operation is not able to attain smooth execution.

V. Conclusion

This paper proposed a novel design procedure of the partial soft skin of the digital hand, and shows the connection approach with rigid bone and real time operation system. The design of soft skin and rigid body is regular way in CG creation, but the connection approach is devised because the collision detection of each body shows different phases. This approach relates on the shape of the soft skin. The reason why the partial soft skin is conducted is to reduce the computational load, but the real time operation has not shown the sufficient operation.

The real time operation is considered about the digital hand by using the LMC. The applicable demonstration in real time operation is able to be realized by tuning PyCUDA, and it will be shown in the conference stage. In the future work, the authors will strive to improve the design procedure of the soft skin and the processing time in real time operation of the digital hand.

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