Plausible Digital Hand Grasp Synthesis considering the Grasping Constraints of Information Appliances

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Abstract: The purpose of this study is to propose a new data-driven grasp synthesis algorithm for a digital hand. The digital hand is a 3D model of a human hand used in the virtual ergonomic assessment of information appliances. The plausible grasp postures can be derived from the grasping constraints of these appliances, the constraints of the human hand's range of motion, and the display visibility. The effectiveness of the algorithm was evaluated using a case study on cell phone grasp synthesis.

Key words: virtual ergonomics, digital hand, information appliances, joint range of motion

1- Background

To reduce the cost of developing user-friendly handheld information appliances, a "digital hand" has been applied to the virtual assessment of ergonomics [Y1]. The digital hand is a deformable and precise 3D model of a human hand with dimensional variations. Assessment requires grasp synthesis which can generate plausible grasp postures for the appliances. So far, grasp synthesis wherein the user specifies corresponding contact points between a product model and a digital hand has been proposed [Y1]. However, inputting contact points which enabled plausible grasp postures was difficult for the users. Alternatively, data-driven grasp synthesis [Y2] has also been proposed. However, the generated postures included some where the user is unable to manipulate user interfaces of information appliances. The purpose of this study is to solve these problems by proposing a new data-driven grasp synthesis algorithm which generates only plausible grasp postures by considering the grasping constraints of information appliances.

2- Algorithm of Plausible Grasp Synthesis

2.1 – Digital Hand [Y1]

Figure 1 shows a flowchart of the proposed plausible grasp synthesis. Details of the steps are as follows.

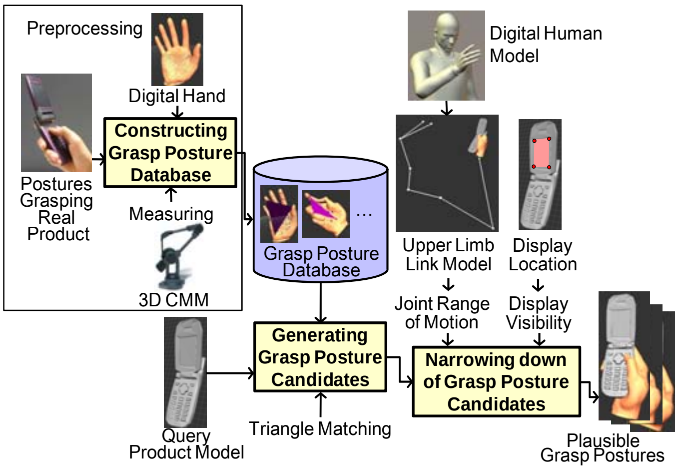

Figure 1: Grasp Synthesis Flowchart

A digital hand consists of a link model with 28 DOF and a mesh model of the skin's surface (Figure 2(a)). The link model simulates finger joint rotations. The joints on each link each have one, three or six DOF. The mesh model of the skin's surface is a 3D polygon mesh obtained from CT scanning. The mesh is able to deform when the finger joint rotates.

2.2 – Constructing Grasp Posture Database

To store grasp posture data for a real product in the database, the locations of 21 feature points (Figure 2(b)) on the surface of a real human hand grasping a product were measured in advance by 3D-CMM (MicroScribe). The grasp posture was then reproduced using the digital hand by fitting the feature points of the digital hand to the measured locations. Alternatively, representative points (Figure 2(c)) were selected on the surface of the digital hand. Then, a small set of contact points (Figure 2(d)) which may come in contact with the real product surface were manually selected from the representative points. Triangles were subsequently generated for all combinations of three contact points. The triangle with the largest area was selected as an *alignment triangle* (Figure 2(e)) for the digital hand grasp posture. This grasp posture and its alignment triangle were stored in the

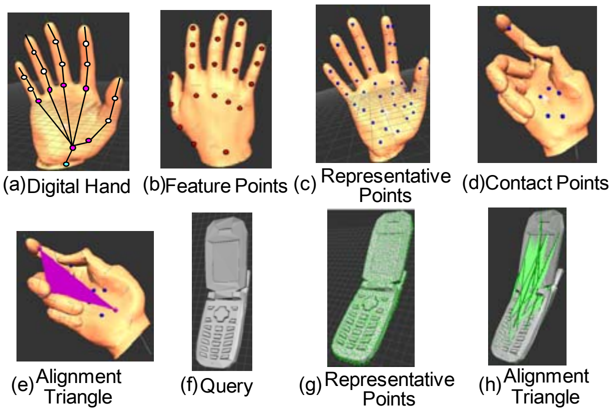

Figure 2: Digital Hand and Product Model

grasp posture database.

2.3 – Generating Grasp Posture Candidates

When a new query product model (Figure 2(f)) whose shape is different from the stored products is entered into the system, the system first generates grasp posture candidates for the query using the following process. First, a set of representative points (Figure 2(g)) is generated on the surface of the query product model. A set of alignment triangles for the model (Figure 2(h)) is then generated by randomly selecting 3 points from among the representative points. Finally, the system matches the alignment triangle of the grasp postures stored in the database to those of the query product model to minimize the distances between the corresponding vertices of the two alignment triangles by triangle matching.

2.4 –Constraints on the Joint Ranges of Motion

In the improper grasping postures, the user cannot view the display from the correct angle while holding the device. To eliminate such postures, constraints on the joint ranges of motion (J-ROM) are introduced in an upper body link model. This model (Figure 3) consists of an upper limb link model and a head link model derived from a commercial digital human model. The digital hand is connected with the upper limb link model through the wrist joint with 3DOF.

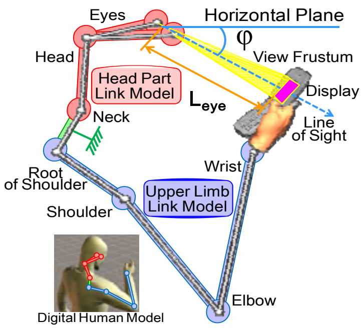

Figure 3: Upper Body Link Model

First, as shown in Figure 3, to situate the product model in the right position and orientation relative to the upper body link model, the user specifies the parameters φ and L_{eye}. The positions of 4 corners of the display in the model coordinate is also specified. φ denotes the angle between the line of sight and the horizontal plane, and L_{eye} the distance between the eyes and the display surface. The system then automatically rotates the head joint so that the angle between the line of sight and the horizontal plane is identical to φ, and so that the display is placed perpendicular to the line of sight with the length of L_{eye} and in the right direction.

After this placement, the grasp candidates are narrowed down by considering the constraints on the J-ROM. Twelve rotation angles for four upper limb joints are computed by solving the inverse kinematics based on CCD (Cyclic-Coordinate Descent) Method [C1] so that the position and orientation of the wrist of the upper body link model match those of the grasp posture candidate wrists. If those angles are beyond the J-ROM, the grasp posture candidate is eliminated by the system.

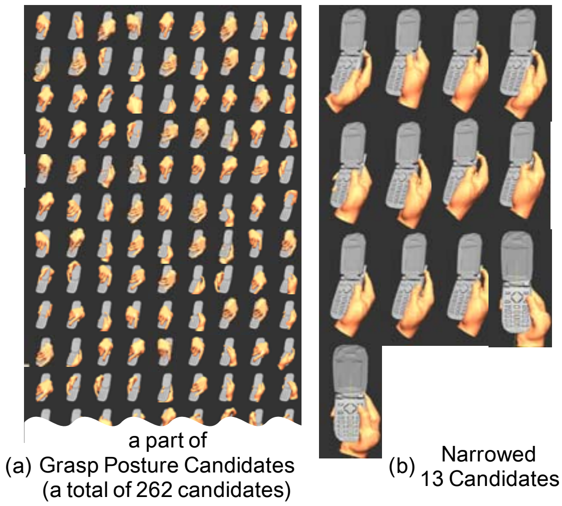

Figure 4: Results of Plausible Grasp Synthesis

2.5 –Constraints on the Display Visibility

Moreover, the grasp posture candidates are narrowed down by considering constraints on the display visibility. Two view frustums with bottom surfaces identical to the display's bottom surface are constructed. If a portion of the digital hand collides with these frustums, the grasp posture candidate is eliminated.

3- Results of Plausible Grasp Synthesis

Figure 4 shows results for a query conducted on a cell phone. The grasp postures for a different cell phone were stored in the database in advance. 262 grasp candidates (Figure 4(a)) were generated for the query using triangle matching. The candidates were then narrowed down to 23 postures using the constraints on the J-ROM. Finally, those candidates were further narrowed down to 13 candidates (Figure 4(b)) using the constraints on the display visibility. It was confirmed that only plausible grasp postures remained after the proposed information appliance grasping constraints were applied.

References

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