The generation of a comprehensive grasp taxonomy

Thomas Feix and Roland Pawlik
Otto Bock Healtcare Gmbh
1070 Vienna, Austria
Email: thomas.feix@ottobock.com
roland.pawlik@ottobock.com

Heinz-Bodo Schmiedmayer
Vienna University of Technology
Inst. for Mechanics and Mechatronics
1040 Vienna, Austria
Email: hschmied@mail.tuwien.ac.at

Javier Romero and Danica Kragić
Comp. Vision and Active Perception Lab
Centre for Autonomous Systems
School of Comp. Science and Communication
KTH, SE-100 44 Stockholm, Sweden
Email: jrgn,dani@kth.se

***Abstract*— The goal of this work is to summarize the grasping taxonomies reported in the literature. Our long term goal is to understand how to reduce mechanical complexity of anthropomorphic hands and still preserve much of the dexterity. On the basis of a literature survey, 33 different grasp types are taken into account. They were then arranged in a hierarchical manner, resulting in 17 grasp types.**

I. Introduction

The design of an anthropomorphic hand is always a compromise between hand complexity and the tasks it is supposed to accomplish. In general, sophisticated hands with many degrees of freedom are dexterous but pose significant requirements in terms of control. Many of the reported grasp type taxonomies have been made with the goal of understanding what types of grasps human commonly use in everyday tasks and use this as an inspiration for designing of robotic and prosthetic hands. The goal of our research is in the same direction: understanding how to minimize the complexity and maximize the dexterity of a mechanical hand. The first step was to review the literature on the grasp taxonomies, using is as the basis for our further research.

II. Method

A. Definition of a grasp

Since grasping in humans is a very broad area, it was necessary to find a definition of what is considered relevant for this work. We propose the following definition of a grasp relevant for our work:

> "A grasp is every static hand pose with which an object can be held securely with one hand."

The definition also implies that the grasp stability has to be guaranteed irrespective of the relative force direction between object and hand.

Therefore *intrinsic movements* are excluded because the object is not in a constant relationship to the hand. *Bimanual tasks* are not relevant because they use both hands. *Gravity dependent grasps* are ruled out, because the hand orientation is vital to the grasp stability. If one turns the hand, the object may fall down, which shows that it is not independent of the force direction. E.g. grasps being excluded are the *Hook Grasp* and the *Flat Hand Grasp*.

B. Comparison of Taxonomies

To develop the comprehensive taxonomy, several literature sources were compared. They range from the field of robotics [3],[10],[15], developmental medicine [5],[4],[6] to occupational therapy [9] and many more [11],[14],[18],[2],[17],[12],[13].

A small excerpt of the comparison table is shown in Fig. 1. Within one column equal grasps are located, whereas in the same row all grasps defined by an author are presented. Grasps which are defined by the author as power, precision or intermediate, are marked with a color code. Yellow is denoting a power grasp, green a precision grasp and yellow/green an intermediate grasp [16],[7],[8]. Red is marking a grip which is not further used, since it did not fit into the definition of a grasp.

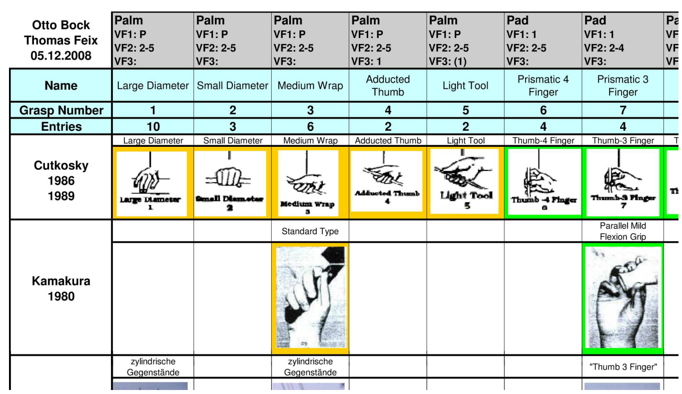

Fig. 1. The sheet used for comparison of different grasp taxonomies. This is just a small excerpt of the whole sheet, the complete table can be downloaded via the Human Grasping Database,[1].

III. Results

A. The comprehensive Taxonomy

In total, 147 grasps were listed and compared, with 45 different grasping patterns. Not all of them are relevant for our research since they did not fit into the definition of a grasp. Therefore the amount of grasps was reduced to a set of 33 grasps.

The grasps were then arranged in a taxonomy depicted in Fig. 2. The rough classification in the columns is done by the power/precision requirements. The next finer differentiation is

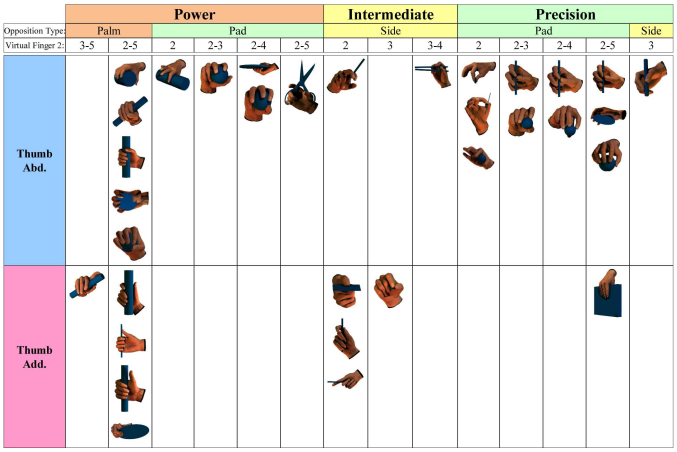

Fig. 2. Comprehensive Grasp Taxonomy which includes 33 different grasp types.

done, depending on whether the opposition type is Palm, Pad or Side Opposition. The opposition type is also defining the VF 1: In the case of Palm Opposition the Palm is mapped into VF 1, in Pad and Side Opposition the Thumb is VF 1. The only exception to this "rule" is the *Adduction Grasp*, where the thumb is not even in contact with the object. To differentiate between the two rows, the position of the thumb is used. The classification here depends on whether the CMC joint of the thumb is in an adducted or abducted position, which is a new feature introduced in our taxonomy, to further distinguish the grasps.

B. Merge of grasps within one cell

Since many grasps have the same properties (opposition type, thumb position etc.), some cells are populated with more than one grasp. The grasps within such a cell all resemble each other quite well, normally the sole difference is the shape of the object. This offers the possibility to reduce the set of all 33 grasps down to 17 grasps by a merge of the grasps within one cell to a corresponding "standard" grasp. Depending on the task, this offers the possibility to choose two different levels of accuracy of the grasp classification.

As comparison the classification of Cutkosky [3] has 15 different grasp types that fit into the grasp definition. This is very close to the amount of grasps the reduced taxonomy has. The comparison shows, that even though the number of grasps is nearly the same, the classification is very different. When one classifies the grasps according to our scheme, the grasps only populate 7 cells, which is a reduction by more than half. This is not so astonishing, since Cutkosky mainly differs his grasps by the object properties and this is done within one cell.

IV. Conclusion and Future Work

A comprehensive human grasp taxonomy, on the basis of a comparative literature research, was developed. A total of 33 different grasps was identified and arranged in a taxonomy which differs from that of other authors. The position of the thumb was introduced as additional attribute, which can be either abducted or adducted. Depending on the need for precision, the taxonomy offers a second level of classification which includes only 17 grasp types.

The taxonomy should cover the whole range of static grasping patterns, which will serve as a basis for further studies on human grasping. Therefore, the temporal sequences of hands performing the 33 grasp types will be recorded and analyzed on how this very complex model can be reduced in order to still allow a lot of dexterity.

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