A comprehensive grasp taxonomy

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***Abstract*—The goal of this work is to overview and 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 their 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 taxonomies have been made with the goal of understanding what types of grasps humans commonly use in everyday tasks and use this as an inspiration for designing 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.

Since there is little consensus in the existing literature on the grasp types humans use, the first step was to review the existing literature. The goal was to find the maximal number of grasp types, which will act as basis for 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 a grasp relevant to our work. We thus propose the following:

> "A grasp is every static hand posture 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 hand and object.

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. Thus 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, developmental medicine, occupational therapy to biomechanics [1],[2],[3],[4],[5],[6],[7],[8],[9],[10],[11],[12],[13],[14].

An excerpt of the comparison table is shown in Fig. 1. Columns store equal grasps, whereas rows store all grasps defined by an author. Grasps that 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 as defined in [15],[16],[17]. Red is marking grasps that are not conforming to our definition of a grasp.

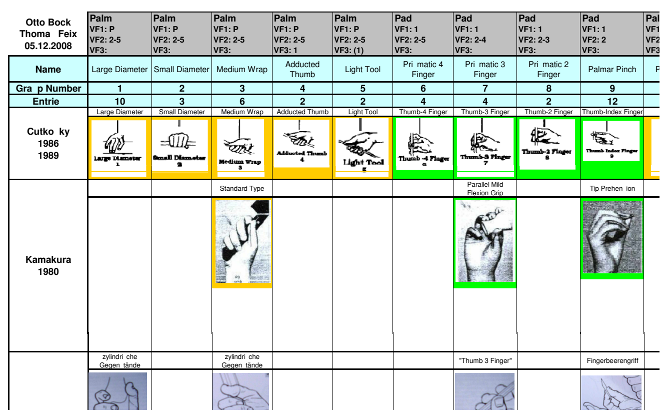

Fig. 1. The sheet used for comparison of different grasp taxonomies. This is just a small excerpt of the whole sheet, the complete table can be downloaded via the Human Grasping Database, [18].

III. Results

A. The Taxonomy

In total, we have found 147 grasp examples in the considered literature sources. Out of those 147 examples, we have detected only 45 different grasp types. A further classification based on our grasp definition has revealed only 33 valid grasp types.

The grasps were then arranged in a taxonomy depicted in Fig. 2. The classification in the columns is done by the power/precision requirements. The next finer differentiation is done, depending on whether the opposition type is *Palm*, *Pad* or *Side Opposition*. The opposition type is also defining the

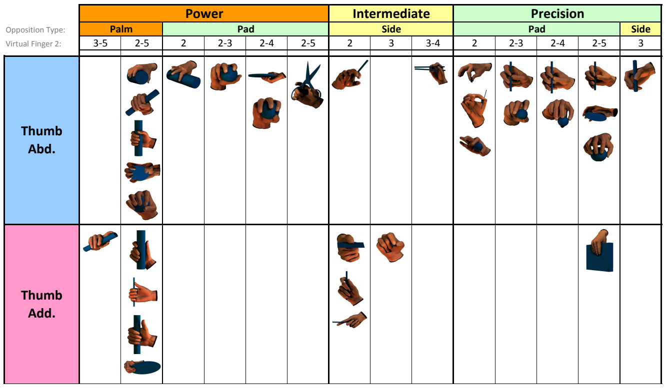

Fig. 2. Comprehensive Grasp Taxonomy which includes 33 grasp types.

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 in contact with the object.

To differentiate between the two rows, the position of the thumb is used: the thumb CMC joint can be in a either adducted or abducted position. This is a new feature introduced in our taxonomy.

B. Merging of grasps within one cell

Since many grasps have similar properties (opposition type, thumb position etc.), some cells are populated with more than one grasp. In the literature examples, the sole difference between such grasps is the shape of the object the hand is manipulating. 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 a comparison, the classification of Cutkosky [1] has 15 different grasp types that fit into our definition of a grasp. This is very close to the amount of grasps the reduced taxonomy has. However, our comparison shows that even though the number of grasps is nearly the same, the classification is very different. When one classifies the grasps from [1] according to our scheme, the grasps only populate 7 cells, which is a reduction by more than half. This is only natural, since [1] mainly differs grasps by the object properties which in our case 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 grasp types were identified and arranged in a taxonomy. 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 gross grasp types.

Compared to the existing taxonomies the present one is more sophisticated, since it incorporates a larger number of grasp types than the reviewed literature sources. This should allow a better description of the human grasping capabilities and therefore will be an excellent starting point for further research. As next step the grasp types will be modeled in a 20 DoF hand model and the corresponding joint angles will be determined. This will then act as a basis for an analysis on how the complex hand model can be simplified, but still preserve a lot of dexterity. This will be defined via the grasp types it can to accomplish. Finally this will lead to an anthropomorphic hand setup which is dexterous and simple in design.

Acknowledgment

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