Functional Design Methodology for Customized Anthropomorphic Artificial Hands

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Abstract—**This short paper outlines a framework for an evaluation method that takes as an input a model of an anthropomorphic artificial hand and produces as output the set of tasks that it can perform. The framework is based on the anatomy and functionalities of the human hand and methods of implementing these functionalities in artificial systems and focuses on the evaluation of the intrinsic hardware of robot hands. The paper also presents a partial implementation of the framework: a method to evaluate anthropomorphic postures using Fuzzy logic and a method to evaluate anthropomorphic grasping abilities. The methods are applied on models of the human hand and the InMoov robot hand; results show the methods' ability to detect successful postures and grasps**.

Keywords— Haptic Feedback, Haptic Rein, Navigation

I. Introduction

The human hand is considered the most dexterous and sophisticated manipulator currently existing. Robotics developers naturally look towards the human hand for inspiration when designing robotic end-effectors. This inspiration varies from imitating its shape to attempting to replicate its functionality.

Hand *construction* (anatomy) gives rise to *capabilities.* Hand capabilities can be *motion* or *sensory*. Hand construction components can be categorised into *structure, [contact] surfaces, sensors,* and *actuation* components.

Consequently, functionalities can be categorized according to task aim into *information exchange (sensing), static grasping, within-hand manipulation, force exchange, or visual expression* [1].

We propose a framework for an evaluation method of functionalities of anthropomorphic artificial hands based on the anatomy and functionalities of a human hand.

II. Theoretic Consideration

Anthropomorphic artificial hands "should" approximate the human hand *physically* and *functionally;* therefore, understanding *anthropomorphism* requires understanding the construction and operation of both human and artificial hands.

By analysing the construction and tasks of human and artificial hands, a relation can be established between physical components of the hand and the tasks it can perform.

A simulation method must be used to evaluate the performance of the hand at each type of tasks (categorised according to the task aim).

The overall performance of the hand can be correlated to individual components by analysis or by repeating the evaluation while changing the component, therefore establishing a value representing the contribution of individual components to the overall performance allowing optimisation of hand construction.

The method should be able to describe generic tasks as well as specific ones (i.e. allow for arbitrary task modelling)

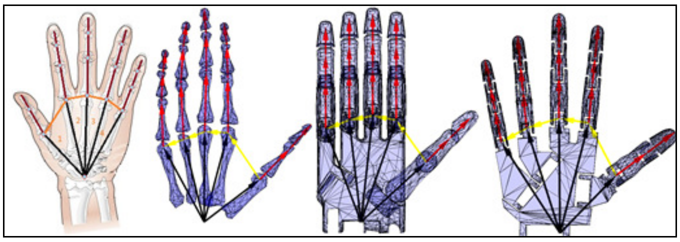

Fig. 1. Human and robotic hands “constructions”

III. Prototype Design

Task description syntax is developed that describes the task in terms of

1) *Anthropomorphic postures* used to perform the task
2) *Objects* involved in the task and the *Interaction* with the objects (pose, information or force exchange, contact locations, prehension)
3) *Motion* required to perform the task

Postures are described using a syntax based on descriptions of British Sign Language (BSL) signs. A posture description takes the form of “hand/hand part(s) is/are at [state]” (for example: “The hand is [tightly closed] and the thumb is [across the fingers]”) [2]

IV. Evaluation

Evaluation of a posture is performed using Fuzzy logic, evaluation of prehension is performed using grasp quality metrics.

The evaluation process scans the configuration space of the hand and compares the posture to the reference postures (from the task model) using a mapping based on the human hand skeleton.

The two methods are implemented in MATLAB and tested on models of the human hand, Shadow robot hand, and InMoov robot hand using the postures of the seventeen basic handshapes of BSL [2] and thirty-one of the grasps of Feix grasp taxonomy [3].

V. Results and discussion

The methods were tested by evaluating the performance of a human hand model. The results showed, as expected, that the model can perform all the reference tasks (which are known to be possible to perform using the human hand). Robot hands scored less, for example, the InMoov hand was only able to perform fourteen grasps, five of which had very poor anthropomorphism.
The hand configuration space is very large, scanning the entire space is time consuming, especially when it must be sampled at a fine resolution to allow valid contact on hands with rigid surfaces. This is even a bigger problem when the object itself has a large configuration space (range of possible poses w.r.t. the hand).

Using grasp quality metrics and not using a separate step to verify closure conditions leads to situations where the ability of the hand to grasp objects cannot be correctly determined.

VI. Future Work

Future research will focus on developing methods to evaluate the remaining functionalities (dexterous manipulation, active sensing, and non-prehensile manipulation). In order to achieve this we plan to perform the correlation analysis between hand components and hand functional performance to obtain values associated with the contribution of each component. Then we proceed with constructing a database containing hardware components, each pre-analysed and assigned *functional performance*, *compatibility*, and *cost (monetary, computational,* and *energy)* values for every defined hand function and other components. Based on the data in the database, new hands can be designed using a selection process that aims to maximise performance and compatibility sums while minimising cost sum.

References

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