

Transformation of Shadow Dextrous Hand and Shadow Finger Test Unit from Prototype to Product for Intelligent Manipulation and Grasping

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Abstract

The transformation of the Shadow Dextrous Hand from prototype to the first humanoid robot product available in Europe was completed in March 2004 by the Shadow Robot Company supported by Manu Systems. Most important within the transformation was the research, development and design of tactile sensing. This paper describes the transformation and illuminates the importance of the technology breakthrough in tactile sensing.

1. Introduction

The Intelligent Manipulation and Grasping capabilities of a human hand have been modelled in humanoid robot prototypes before. The problem of a prototype developed by a single research and development group is that it is only a single piece available for only a single major research activity at a time. Often a handmade prototype cannot be easily reproduced, and for a system of this complexity that was a definite issue.

The transformation of the Shadow Dextrous Hand from a prototype, which was shown at Robodex 2002 in Japan [1][2], to a product, solved the availability problem for professional research regarding Intelligent Manipulation and Grasping.

Redesign of all parts of the prototype enabling machine production directly sourced from the CAD files enables the Shadow Robot Company to reproduce the Shadow Dextrous Hand within a short time.

A second product, the Shadow Finger Test Unit, has been derived from the Shadow Dextrous Hand. Both products provide optional tactile sensing.

2. Comparison of different subtechnologies and importance of those chosen

a. Tactile Sensing

Most important within the transformation from prototype to product, was the research, development and design of a tactile sensor. The first customer for a Shadow Dextrous Hand required a

tactile sensor optimized for robot manipulation tasks.

As no commercial components were available to perform this vital function Shadow Robot Company explored possible methods to perform tactile sensing in the fingertip in close cooperation with the University of Bielefeld.

Mechanisms based on optical sensing were tried, and the literature searched. The only viable mechanism was one based on a proprietary new composite material using quantum tunneling effects.

This technology enabled Shadow Robot Company to construct fingertip tactile sensing with 34 tactile regions in the tip area, sensitive from 3 kN/m² (equivalent to a 3 g weight applied to a single sensing region of 10 mm²) up to 400 kN/m².

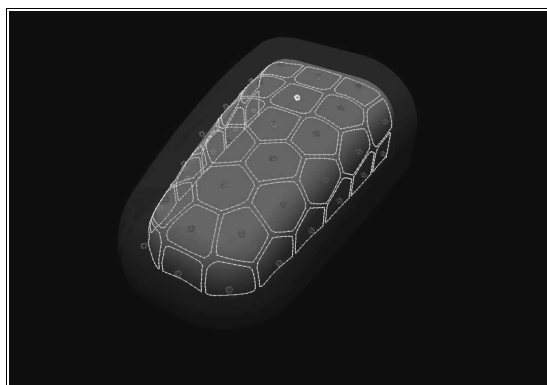


Figure 1. Tactile sensing regions on fingertip.

b. Actuation

The Shadow Dextrous Hand and the derived Shadow Finger Test Unit are driven by Shadow Air Muscles, a flexible pneumatic actuator, which is small, light, simple and "friendly" [3].

This technology was used both in the prototype and the final product. It was selected for its several advantages over conventional robotic actuators.

The main advantages for Intelligent Manipulation and Grasping are:

- The Shadow Dextrous Hand could be constructed in a considerably smaller envelope than is possible with electrical driven manipulators.

- The Shadow Dextrous Hand is extremely safe to use in direct contact with humans. The muscle is inherently compliant, and therefore it is acceptable to be in direct contact with humans. Other robot manipulators are oriented for differing applications and do not have the inherent compliance of the Shadow Dextrous Hand; these would need a separate safety case making.
- The variable compliance of the Shadow Air Muscles allowed the Shadow Dextrous Hand prototype for example to screw in a light bulb without using sensor data. The grasping operations of several fragile objects have been performed in open-loop timed control.

c. Mechanical Structure

The mechanical structure of the Shadow Dextrous Hand provides 25 degrees of freedom. This allows all the movements of the human hand to be shadowed, including the curling of the palm, all movements of the thumb and the finer dextrous finger movements.

This was necessary for real research into grasping and manipulation and a very important argument for the transformation from prototype to product.

d. Transformation Results

As of May 2004 two products for Intelligent Manipulations and Grasping have resulted from the transformation from prototype to product.

The Shadow Dextrous Hand is the first humanoid robot hand unit commercially available offering 25 degrees of freedom and optional tactile sensing embedded in all fingertips. It offers specific advantages in that it has been designed as a modular solution to robotic manipulation requirements.



Figure 2. Shadow Dextrous Hand.

The Shadow Finger Test Unit is derived from the Shadow Dextrous Hand and allows research into the operation of compliant manipulators. The Shadow Finger Test Unit is driven by Shadow Air Muscles and allows all sensing capabilities used in the Hand system to be experimented with on a smaller scale.



Figure 3. Shadow Finger Test Unit.

3. Conclusions

With the transformation of the Shadow Dextrous Hand from prototype to product the Shadow Robot Company supported by Manu Systems has made a important step forward in the development of tools and components for general purpose robotics.

The most significant single step in this advance was the research and development leading to the production of a viable tactile sensor unit for the fingertip.

The ability to provide a modular solution with 25 degrees of freedom has been the main argument for the transformation of the Shadow Dextrous Hand from prototype to product.

The Shadow Air Muscle Technology provides the compliance necessary for Intelligent Manipulation and Grasping in direct and safe contact with human beings or fragile objects.

High compliance has become state of the art for Intelligent Manipulation and Grasping.

The transformation from prototype to product is important to provide access to the best hardware for professional research groups active in Intelligent Manipulation and Grasping.

Many more products shall become available through transformation from prototype to product.

4. References

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