LEAP HAND V2: Low-cost Anthropomorphic Hybrid Rigid Soft Hand for Robot Learning

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Abstract

The human hand is a marvel of biology, providing both great versatility and precision. They are strong and precise, allowing us to manipulate complex tools and do very fine-grained dexterous motions but they are also soft, safe, and compliant. The combination of incredible strength, a tight kinematic structure with many degrees of freedom, and soft compliance makes them the perfect manipulator. Emulating the capabilities of the human hand through a robot has been a long-standing challenge. Robot hands have fallen into one of two categories: soft or rigid. Soft hands, while compliant and safe lack the precision and strength of human hands. Conversely, while rigid robot hands can match the precision and power of human hands, they can easily break and are not safe to deploy. Our proposed solution is to build a robotic hand, that can bridge the gap between these two categories. It is soft when required and strong enough to apply power. We call this hand LEAP Hand v2, a dexterous, low-cost anthropomorphic soft hand. LEAP Hand v2 features three distinctive elements that allow it to be a hybrid between rigid and soft hands, all the while remaining simple to produce and under $3000. Firstly, it achieves a balance of human-hand-like softness and stiffness, via a 3d printed soft exterior combined with a 3d printed internal bone structure. Moreover, LEAP Hand v2 incorporates two powered articulations in the foldable palm: one spanning the four fingers and another near the thumb—mimicking the essential palm flexibility for human-like grasping. Lastly, LEAP Hand v2 boasts a dexterous Metacarpophalangeal (MCP) kinematic structure, making it highly human-like, easy to assemble, and versatile for various tasks. Through thorough real-world experiments, we show that LEAP Hand v2 exceeds the capabilities of many existing robot hands for grasping, teleoperated control, and imitation learning. We plan to release 3D printer files and assembly instructions by the end of the summer.

1. Introduction

Building a dexterous hand with all of the capabilities of a human has been a longstanding challenge for the community, which has led to the emergence of two primary approaches: rigid or soft hands. **Rigid hands** are designed in a very robust manner and can often match the strength and accuracy of human hands. They are ideal for high-precision tasks such as tool manipulation. However, much of this comes at the cost of safety, due to fragility and a lack of compliance. **Soft hands** are made from much more flexible and softer material, which endows them with great compliance. They are safe to deploy as they cannot break the objects they interact with. Soft hands are ideal for manipulating deformable materials (for example food). Unfortunately, due to their build, they struggle at high-precision tasks and cannot exert enough force for many tasks.

In this paper, we build a new **hybrid robotic hand design** that can leverage the advantages of both soft and rigid hands. Our Dexterous, Low-cost Anthropomorphic hand (LEAP Hand v2 Hand) has three new features that are critical to building a *hybrid soft and rigid* hand, taking qualities of both. First, we introduce 3D-printed multi-material fingers that are similar in stiffness, softness, and durability to human fingers. They have strong bones as well as soft skin that allows them to impart strong forces, yet be compliant when necessary. This compliance allows them to be resilient to bumps and bruises. Second, we introduce an **agile palm incorporating two integrated joints** meticulously designed to replicate the conforming characteristics of the human palm. This is a feature often lacking in numerous robot hands, but one we consider crucial. Our robot hand is adept at using its articulated soft palm to effectively grasp, stabilize, and support objects. Furthermore, the palm facilitates crucial opposition from the thumb to the rest of the hand. Third, we design LEAP Hand v2 with finger kinematics designed to maximize dexterity and similarity to a human hand. The MCP (Metacarpophalangeal) joint is designed to be strong yet provides even more flexibility than a human hand. The MCP side joint can move the finger

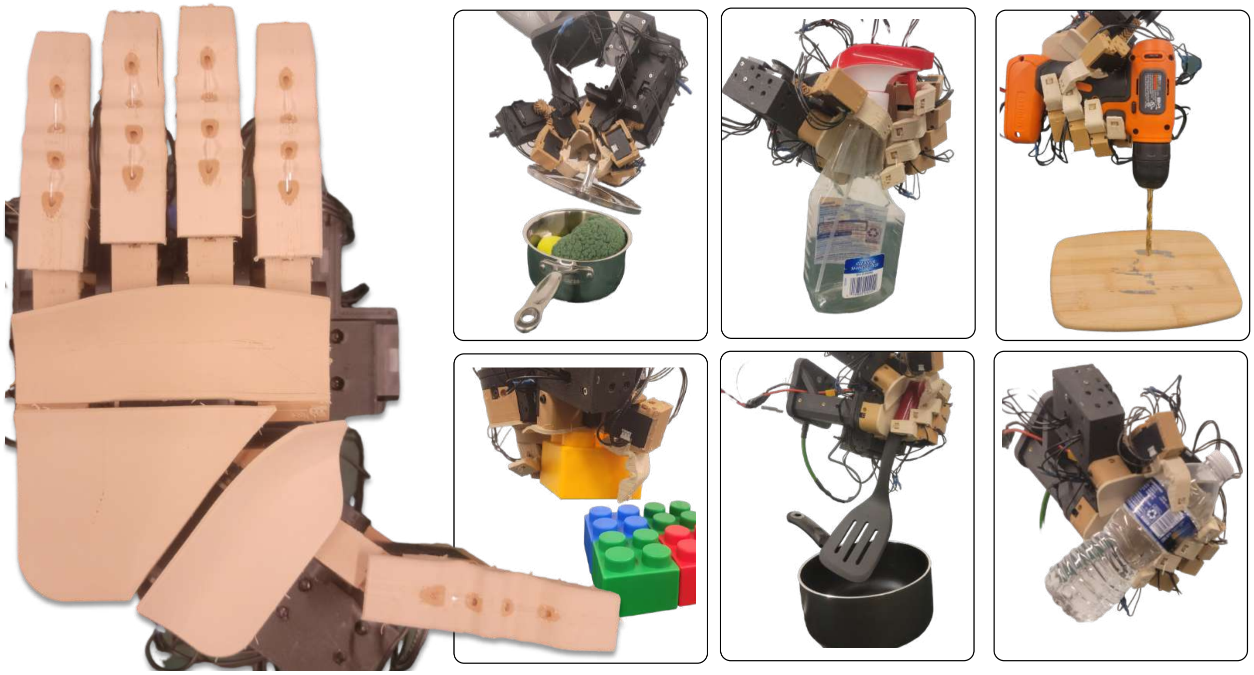

Figure 1. Presenting LEAP Hand v2, a robot hand designed to emulate the compliance of the human hand. It features a 3D-printed soft exterior skin complemented by a robust internal bone structure. The foldable palm incorporates two powered articulations—one spanning the four fingers and another across the thumb—facilitating human-like grasping. Additionally, a dexterous MCP joint enhances overall dexterity, resembling human hand movements. With its human-like size, straightforward assembly, cost-effectiveness, and open-source attributes, LEAP Hand v2 will be useful for dexterous hand research.

side-to-side in both the curled and open positions. The PIP (Proximal Interphalangeal)and DIP (Distal Interphalangeal) joints are articulated with one strong fishing line tendon, meant to emulate the articulations of the human hand.

Through our real-world experiments, we show that LEAP Hand v2 is very suitable for robot learning research and deployment of autonomous agents. It possesses robust strength while maintaining compliance and avoiding brittleness with its soft, yet strong fingers. The hand's palm enables it to execute a range of stable grasps, unlike any other robot hand. We illustrate its capacity to handle teleoperation for prolonged data collection, remaining resistant to fatigue, overheating, breakage, or loss of accuracy. This reliability allows for the seamless execution of autonomous, learned policies trained from the collected demonstrations.

Significantly, LEAP Hand v2 can be entirely 3D printed and assembled within a few hours by an inexperienced roboticist using less than $3000 worth of components. This efficiency is partly attributed to the smart utilization of a $1000 multi-material 3D printer, which handles a significant portion of the manufacturing process prior to assembly, streamlining the overall assembly process. All of the 3D print files and a detailed assembly guide will be released on our website upon acceptance of the paper. The community will be able to adopt LEAP Hand v2 easily and kickstart their robot hand research.

Task	Teleoperation	Behavior Cloning
Red Cup	0.92	0.8
Hammer Pickup	0.89	0.6

Table 1. We collect 75 demos of LEAP Hand v2 completing two different tasks. We then train policies, pre-trained on internet videos, and fine-tuned on our robot hand demos, and report our results as a percentage.

An important way to assess the capabilities is to assess our hand's performance directly at its end goal: How well can it complete tasks we expect robot hands to perform? First, LEAP Hand v2 is tested on grasping against a variety of other hands. Second, LEAP Hand v2 is teleoperated by an expert operator using a Manus Meta glove LEAP Hand v2 and a xArm. We choose a variety of different tasks that outline different grasps that humans can perform. We collected 75 demos through teleoperation on two different tasks. We train autonomous policies and see how LEAP Hand v2 performs during this whole learning process which requires resiliency and accuracy. Finally, we show results in sim2real.

References