Tactile-Driven Gentle Grasping for Human-Robot Collaborative Tasks

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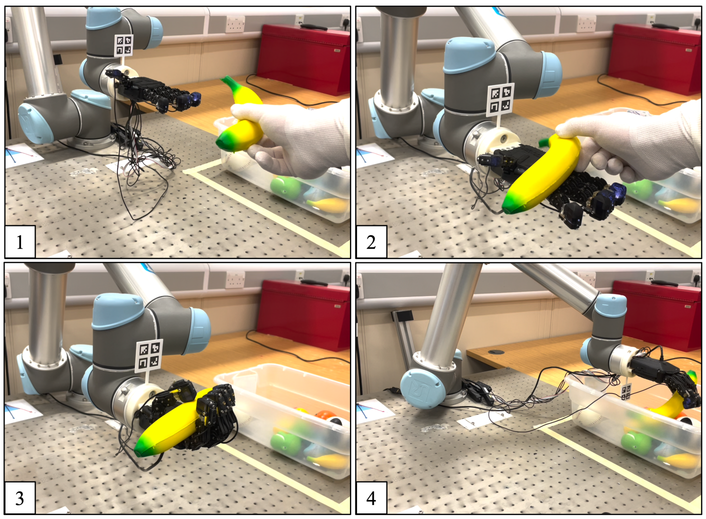

Fig. 1. *A human-robot handover with an anthropomorphic hand, made safe by the use of tactile-driven force sensitive grasping*

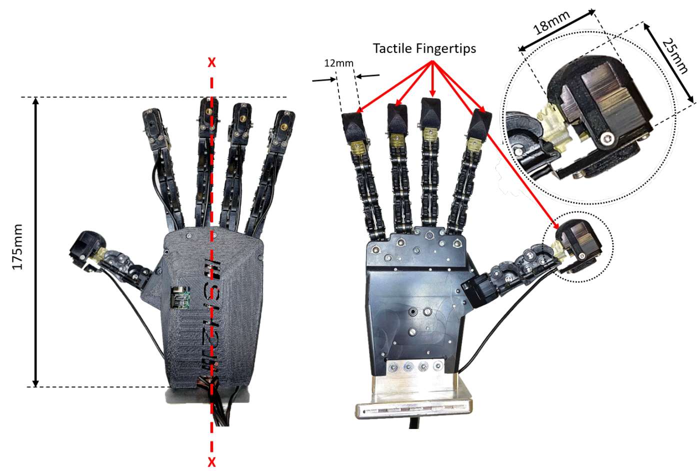

Fig. 2. *The tactile SoftHand*

This paper presents a control scheme for force sensitive, gentle grasping with a Pisa/IIT anthropomorphic SoftHand [1] equipped with a miniaturised version of the Bristol Robotics Laboratory TacTip [2], [3] optical tactile sensor on all five fingertips. In modern robotics, robust and reliable grasping and manipulation remain unsolved research problems [4] [5]. A central problem is the ability to apply force-sensitive, gentle grasping to handle fragile objects and apply such grasps to objects of various shapes, sizes and stiffnesses. Force sensitive grasping is also key in tasks which require humans to work directly with robots [6]. This fact is addressed in this work by demonstrating a human-robot handover task made safe by implementing a force-sensitive grasp. These gentle grasping requirements are met by using an adaptive soft robotic hand combined with high-resolution optical tactile sensors to provide state information from the contact interface. The soft properties of the SoftHand make it ideal for gentle grasping as opposed to other more highly actuated hands with rigid links, whilst the tactile sensors provide information about a grasp and how the fingers interact with held objects.

Whilst a highly actuated hand is in principle capable of greater dexterity, in practise an underactuated hand is much simpler to control. In this paper, we propose that the more limited dexterity of an underactuated hand is compensated by the use of soft synergies that interact with basic control of the hand using fingertip tactile sensing, allowing reliable force-sensitive grasping on a variety of objects. Moreover, human fingertips contain 1000s of tactile mechanoroceptors per square centimetre [7], so likewise artificial fingertip tactile sensors carrying similar information should also have a high spatial resolution, as offered by optical tactile sensors such as the TacTip-based design proposed here. Even though there are examples of simple robotic grippers using high-resolution touch for control [8] [9], we know of no examples of anthropomorphic hands with multiple high-resolution tactile sensors applied to force-sensitive grasping or the application to human-robot human-robot collaborative tasks.

We first describe a series of hardware developments in designing a miniature TacTip which can be integrated into all fingertips of the SoftHand as well as methods for acquiring and processing data from the tactile sensors asynchronously. This is a particular challenge, as reading image streams from multiple high-resolution cameras simultaneously is very computationally demanding and difficult to scale. Consequently, we present a distributed computing architecture which allows for the tactile image capture and processing to be handled by a cluster of external devices which feedback to the controller over a high speed network connection. This results in a fast control loop sufficient for real-time grasp control whilst preserving CPU resources on the main control PC.

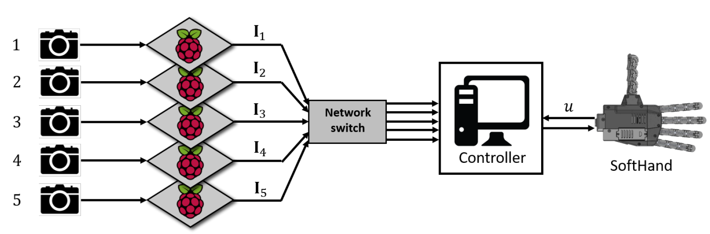

Fig. 3. *Asynchronous tactile data acquisition*

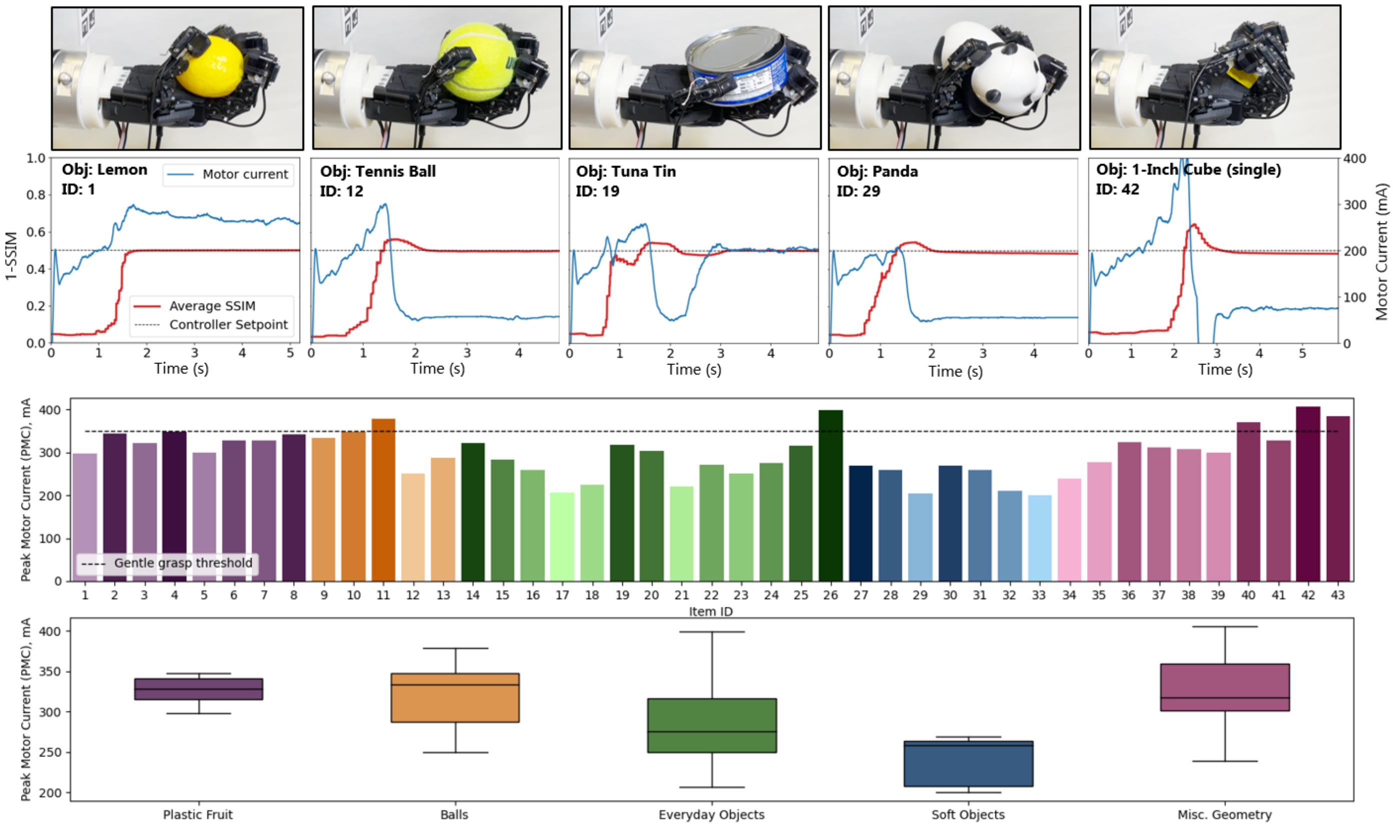

Fig. 4. *Force-sensitive grasping experiment results*

We then develop a novel grasp controller that uses tactile information extracted from the sensors in all five fingertip sensors simultaneously as feedback. Whilst the raw tactile data is high dimensional, it is processed in such a way that it can be used as feedback in a simple linear controller, removing the requirement for a complicated control scheme whilst preserving high-resolution and high-sensitivity sensing. The controller is then verified by testing its ability to gently and stably grasp 43 objects of varying geometry and stiffness, quantified by a SoftHand motor current below an established threshold. Next, the controller is contextualised through application to a human-to-robot handover task, whereby the tactile SoftHand is fitted to a UR5 industrial robot arm a vision system implemented to monitor the workspace. Then, a human operator presents objects into the workspace, the location of which is determined by the vision system, allowing the hand to move to the operator and accept the item. Once the handover is complete, the robot deposits the item into a bin.

Ultimately, this study aims to impart an anthropomorphic robotic hand with reflexive, force-sensitive control to apply a gentle grasp using tactile data from high-resolution sensors. The Pisa/IIT SoftHand used here is under-actuated, yet has soft adaptive synergies in its mechanical structure that simplifies the controller implementation whilst retaining a degree of dexterity by being able to conform around grasped objects. The tactile sensors add an extra capability to this platform by providing information on the nature of the grasp and how the fingers are interacting with an object whilst being small and low-cost compared to other works investigating tactile SoftHands. These developments open the door to more advanced manipulation with underactuated hands via fast reflexive control using high-resolution tactile sensing.

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