Towards Multi-Modal Sensing for Space Robotic Manipulation: Exploring the GelSight Vision-Based Tactile Sensor

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Introduction

Robot perception is a key element to enabling autonomous operations. It provides environmental awareness allowing robots to interact and adapt to the environment. Traditionally, vision is used in isolation. However, the use of multiple modalities allow learning and designing more robust environment representations (by complementing sensory information) that enable the design of complex robot behaviors for on-orbit and planetary use cases (dealing with on-board resource constraints and dynamic environment). Touch sensing is essential for contact-rich tasks, providing critical information of the shape, surface, texture, stiffness of the objects, among others. Tactile sensing technologies significantly shift from touch detection to sophisticated systems capable of recreating and improving the sense of natural human touch enabling more intelligent robot interactions. Integrated into the hands or fingertips of robots, this technology have proved useful in terrestrial applications, for object property estimations (shape, texture, and hardness classification), slip detection, deformable object manipulation, etc. The CONOPS is given in Fig. 1 below.

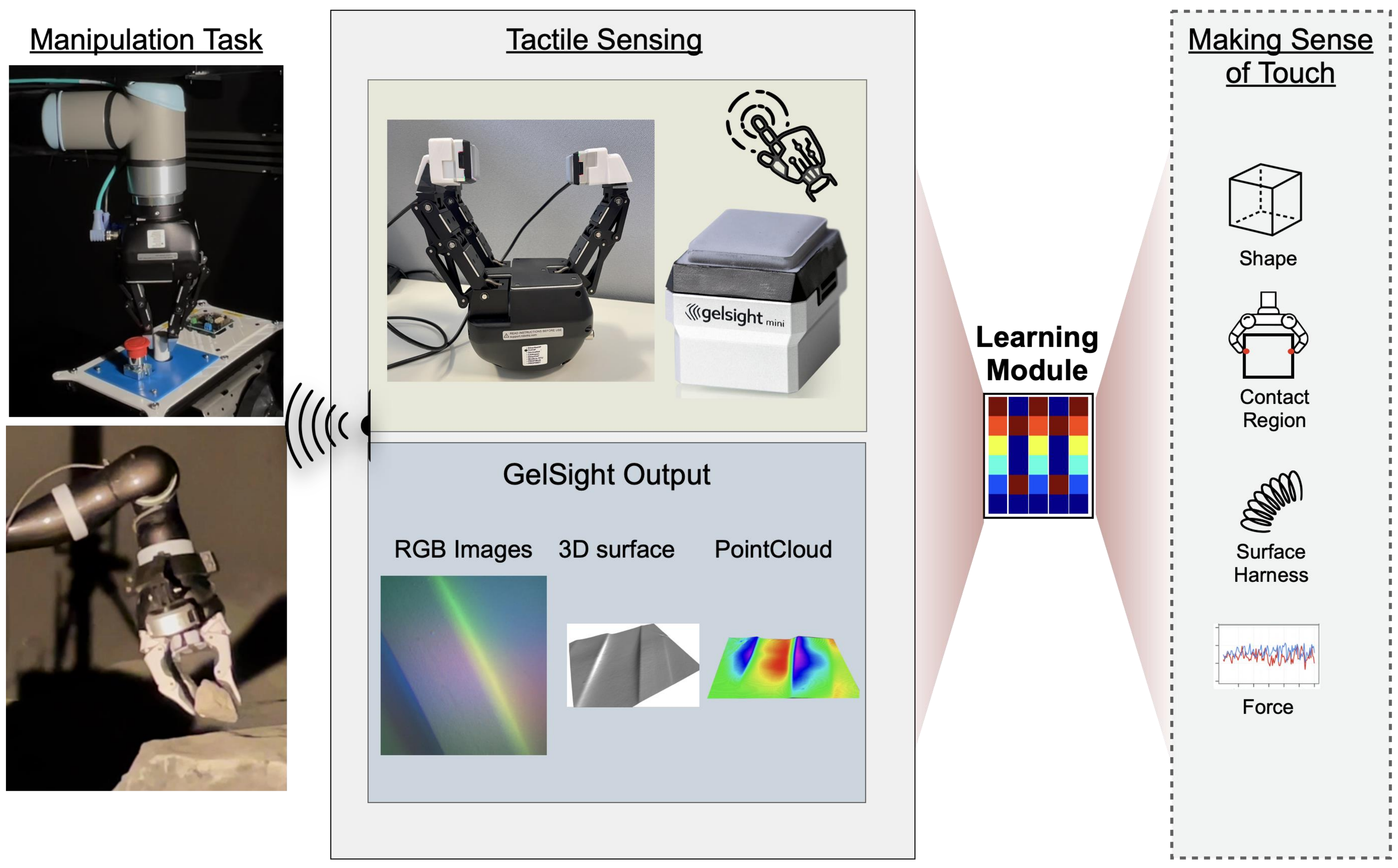

Fig. 1: Concept of operations

In space domain, tactile sensors need to function precisely for extended durations (often years) without the chance for recalibration. They must operate in a near vacuum, endure radiation, withstand direct sunlight (heat) and complete darkness (cold), and handle temperature fluctuations ranging from approximately +120 to -160 °C. Thus, the use of tactile sensing in space has been studied from various perspectives, including the investigation of the technical requirements needed for tactile sensors to withstand harsh and challenging space conditions, and developing an on-ground experimental setup allowing further studies into the application of tactile sensing in space.

Assembly Use Case

Two GelSight sensors have been integrated in the fingertips of a 3-Finger ROBOTIQ Gripper shown in Fig. 2. The sensors can then be utilized to enhance the information the gripper uses to perform its tasks. This tactile sensor offers by default an important range of data outputs, namely a raw RGB image for surface inspection, 3D reconstruction capabilities and a point cloud array representation is also available. These outputs become important to analyze the materials and surface.

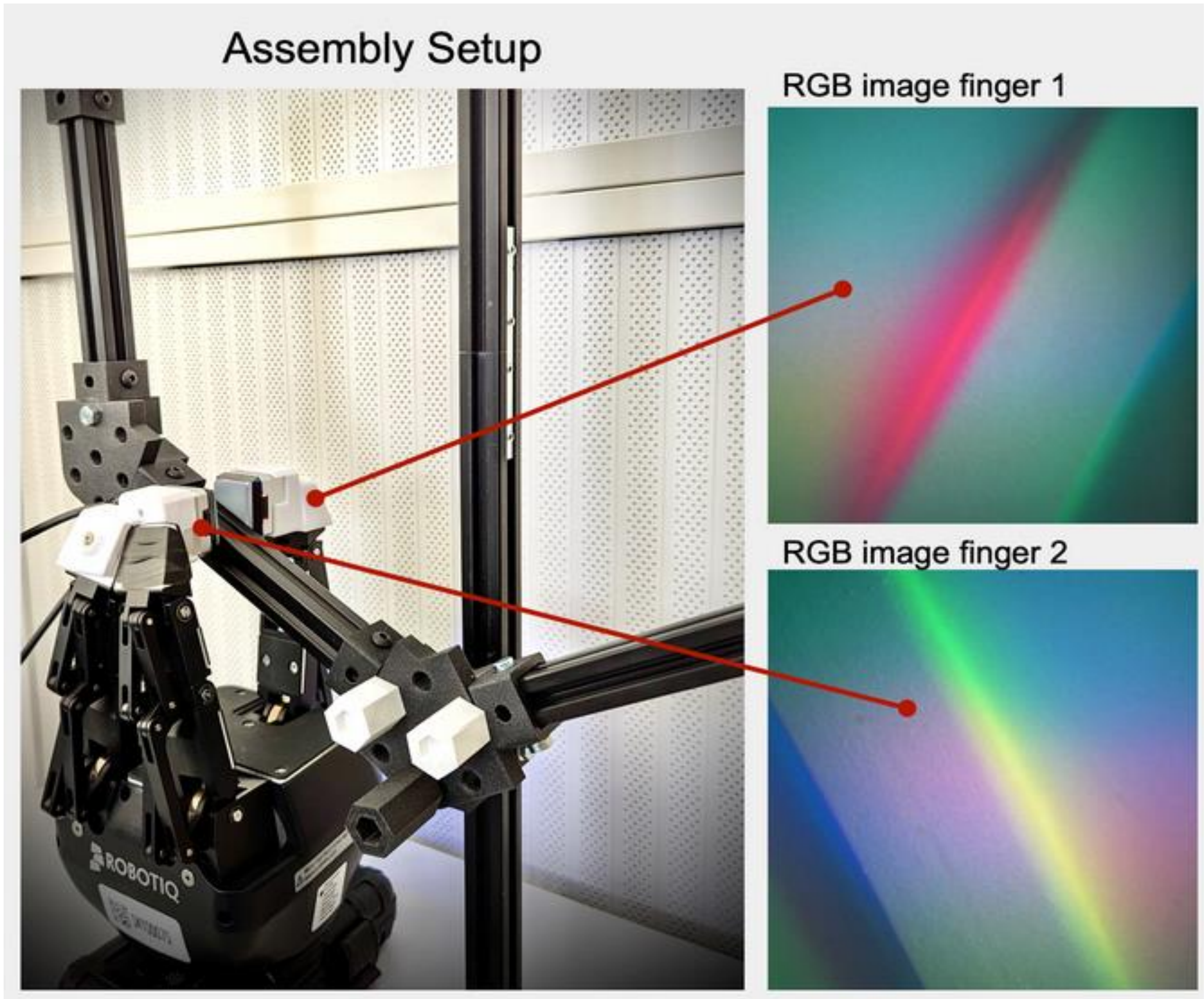

Fig. 2: Two GelSight Mini tactile sensors integrated on the ROBOTIQ Gripper, grasping a solar panel frame

Inspection Use Case

The crack on the Cube-Sat seen in the first row of Fig. 3 is almost unnoticeable to the naked eye, but cracks and other integrity concerns can be examined with precision, including determining their dimensions. In the second row, a bolt having a crack-free surface is being investigated.

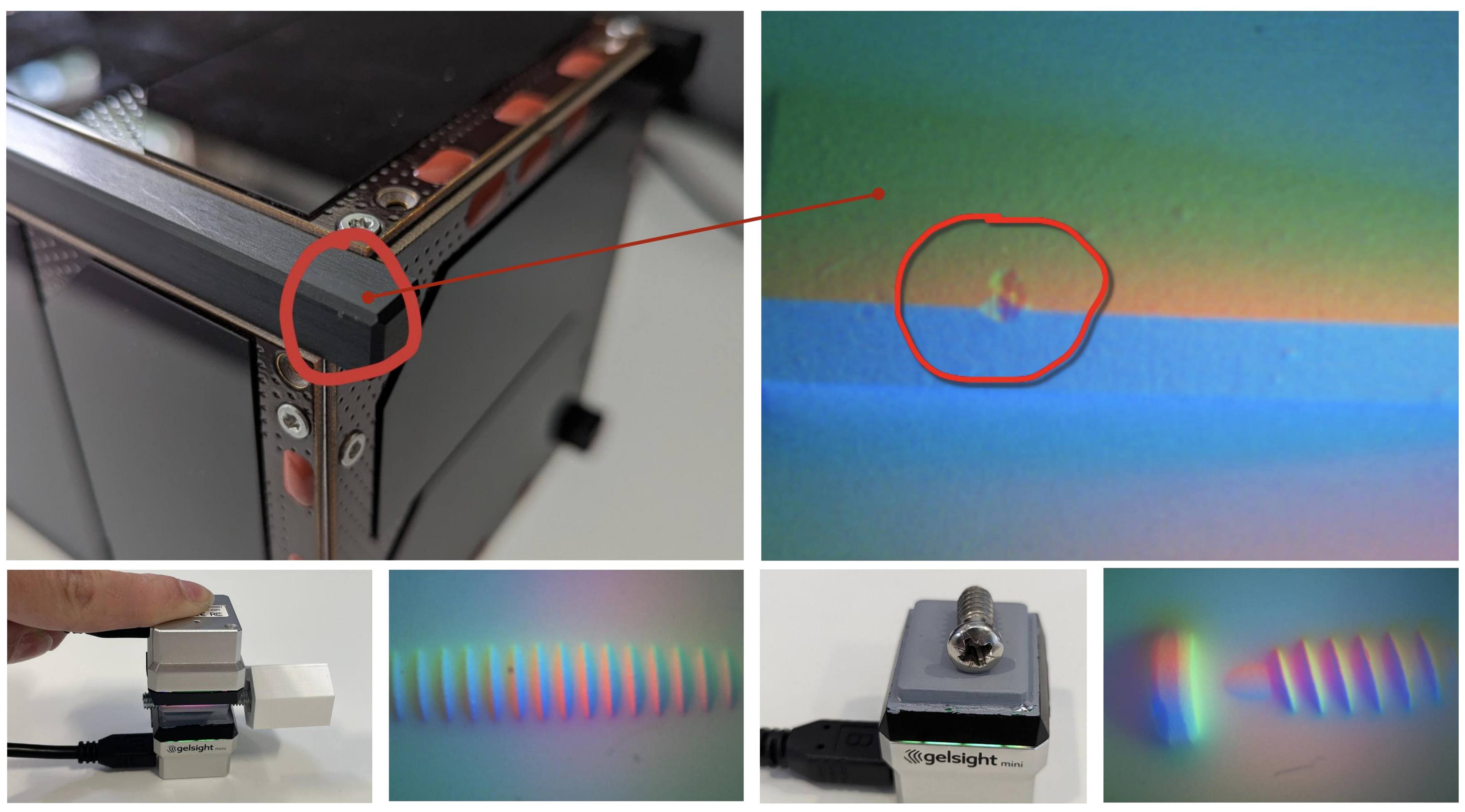

Fig. 3: Crack inspections, first row – CubeSat, second row - bolt