NRI: FND: Optoacoustic Material and Structure Pretouch Sensing (OMASS) at Robot Fingertip

PI: Dezhen Song, co-PI: Jun Zou, Texas A&M University, College Station, TX 77843

http://telerobot.cs.tamu.edu/material-sensing/

Project Overview

The objective of this project is to develop systems and algorithms to create a new type of miniature fingertip-mounted sensors that can contactlessly detect and map object material type, shape, close-to-surface interior structure at close proximity. Building upon the working principle of optoacoustic effect, acoustic waves generated by modulated laser pulses will be used to probe material type and structure based on the acoustic spectrum, time-of-flight, and intensity analyses of the received optoacoustic signals. The proposed sensor will be enabled by new and efficient material recognition and surface/interior structure mapping algorithms so that the recommended grasping points and force range will be available before robot fingers are closed.
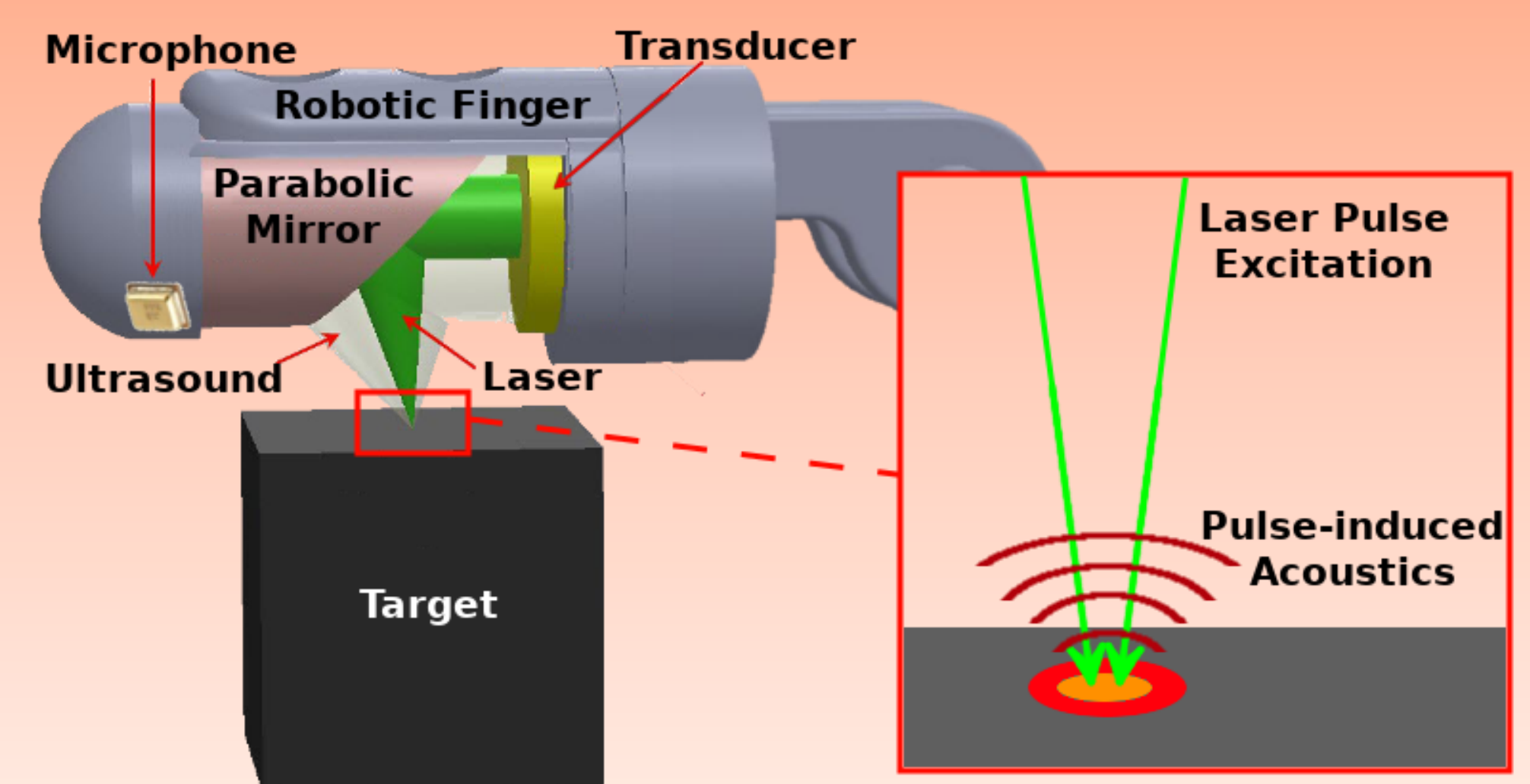

Fig. 1 An illustration of how an OMASS device functions.

Challenges & Motivation

Reliable grasping of unknown objects is a grand challenge for robotics. When robots move from factory floors to a wider service market, it is imperative to enable robots to grasp objects with no prior knowledge. Contactless detection of object material type, shape, close-to-surface interior structure can provide vital information such as friction coefficient and applicable grasping force for planning for successful grasps. Unfortunately, no existing sensors can achieve this. Imaging and ranging devices such as cameras/LIDARs can neither see through surface nor distinguish material type. Tactile sensing requires physical contacts between the robot finger and the object surface, which may risk damaging the object or changing configuration of the object. Either case may lead to grasping failure.

Scientific Impact

Due to the fundamental importance of grasping, the OMASS project fits well into the ubiquitous co-robots theme by benefiting almost all four sub-themes. The most directly related one is *customizability*, because being able to grasp unknown objects can drastically reduce setup time for different tasks under different situations. Robots equipped with the OMASS devices will be able to handle a variety of tasks in a variety of situations with minimal or no changes to hardware or software. For lowering the barrier to entry, both hardware and software developed in this project will be disseminated over the Internet with a library of acquired material signatures.
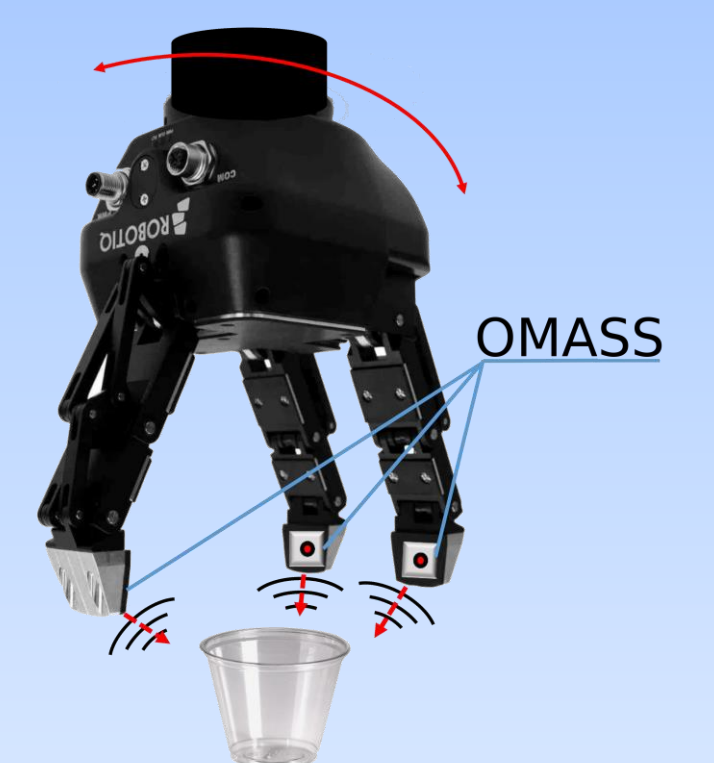

Fig. 2 A conceptual illustration of how OMASS works under a multi-finger configuration.

Solutions

Our OMASS project will focus on the following aspects:

- Development of OMASS devices: The objective of this task is to develop new compact bi-modal OMASS devices with pulse-echo ultrasound ranging and optoacoustic material/structure sensing capabilities in a pre-touch fashion. We will address the miniaturization and integration issues by capitalizing upon new device technologies and innovative integration approaches.

- Pretouch perception algorithms: The main tasks of perception algorithms are threefold: recognition, mapping, and planning, which have to be finished before the robot finger touches the object. We will develop efficient and novel sensor fusion algorithms to fully exploit the multi-modalities of the OMASS device.

- Material database and testbed construction: We will develop a database of material properties under the optoacoustic setup, which includes both raw signals and extracted signatures. We will also develop a testbed to verify algorithm and system developments based on our evaluation plan.
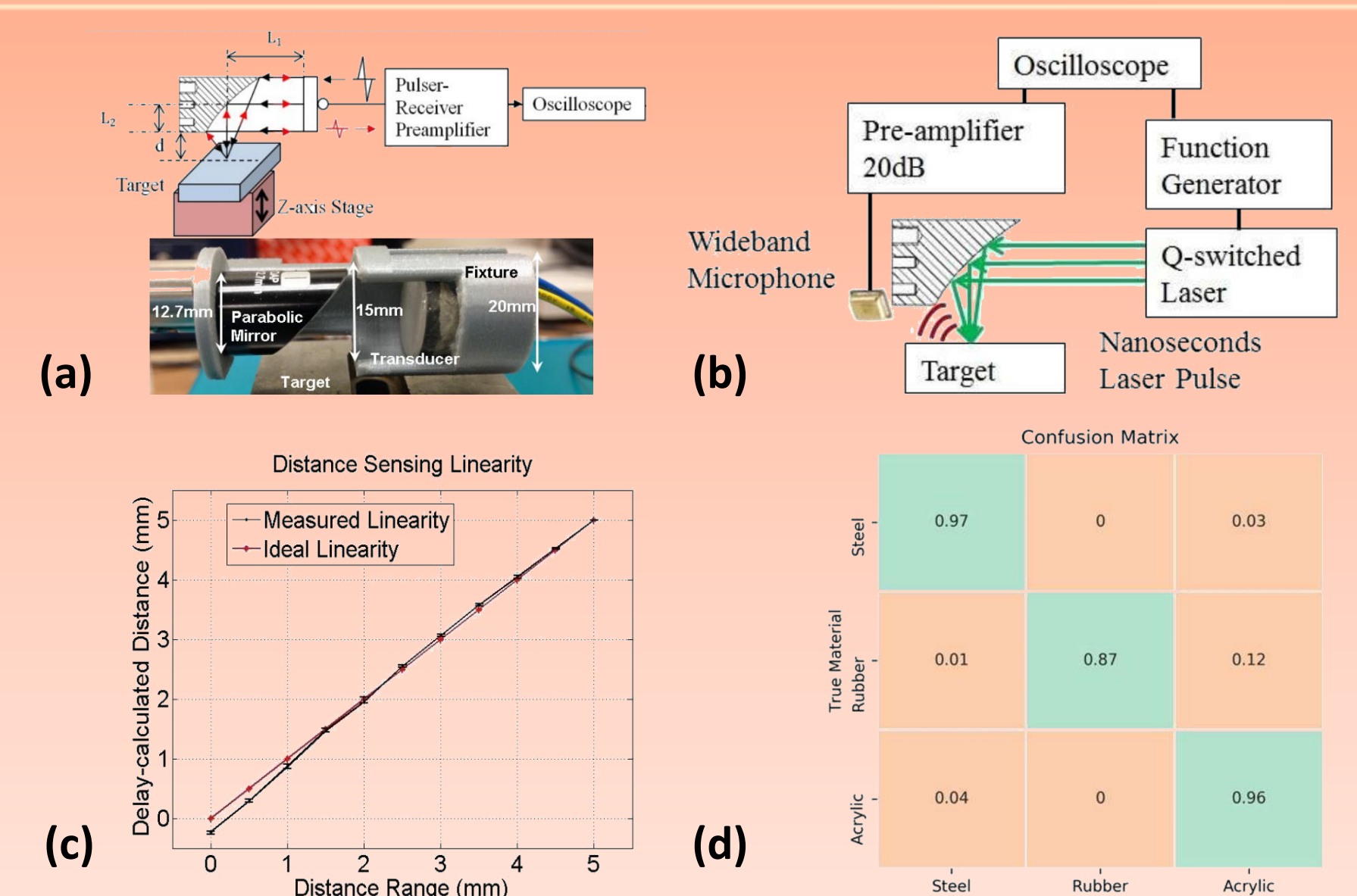

Fig. 3 (a) Diagram and prototype of ultrasound distance ranging setup; (b) Diagram of dense solid materials differentiation setup; (c) Ultrasound distance ranging result; (d) Classification confusion matrix of steel, acrylic and rubber.

Broader Impacts

The OMASS project will benefit a wide range of robotic applications that require grasping and manipulation such as manufacturing, service robots, search & rescue, etc. As we develop the OMASS device, we will share our development and educational efforts via journal and conference publications, seminars, research experience for undergraduates and teachers, open-house activities, and the Internet to scientists, students, underrepresented groups, and the public worldwide. The OMASS project will demonstrate the state-of-the-art robotics to the public. We will distribute hardware designs, source codes (e.g. cROS stacks), APIs, experimental data, and documentation via the project website so that other groups can learn from our experience.