Use of tactile feedback to control robotic palpation to characterize object hardness Zhe Su

Introduction: Palpation is a procedure used by physicians to gather clinical data for diagnostic purposes, such as detecting and characterizing hard lumps in soft tissue (e.g. breast or abdominal organs). Small changes over time may be important but the procedure tends to produce mostly subjective impressions. A robotic system with tactile sensors might be more effective, but only if it can replicate the adaptive and well-controlled exploratory movements that humans tend to make. We have developed a haptic robot platform consisting of a Barrett hand-wrist-arm system whose three fingers have been equipped with novel multimodal BioTac® sensors (www.SynTouchLLC.com). In this paper, we present algorithms for the control of human-like exploratory movements for pressing on and characterizing objects with various hardnesses (durometer values). When the robot gradually presses its fingertip into compliant rubber samples, it uses the sensory feedback from the tactile sensors to control both normal and tangential contact forces and to adjust the orientation of its fingertip to account for the potentially unknown orientation of contact surfaces and internal discontinuities such as buried lumps. The BioTac senses the distributed deformation of its own compliant, liquid-inflated skin, which depends on the compliance of the object that it contacts.

Materials and Methods: Similar to the human fingertip, the BioTac sensors are sensitive to tangential as well as normal forces. When performing a compliance movement it is desirable to apply forces normally and symmetrically to the object. For the haptic robot, this means servoing its end-effectors in the pitch and roll directions to orient a flat portion of the core of the BioTac (Fig. 1A). The sensory feedback is provided by four adjacent electrodes on this flat region whose impedance depends on compression of the skin against the electrode surface and the displacement of the conductive liquid between the skin and core. These four adjacent electrodes are labeled electrode 7, 8, 9, and 10 on the electrode array map (Fig. 1B). The pair of electrodes along the x-direction (8 and 9) and the pair of electrodes along the y-direction (7 and 10) are used for servocontrol of the pitch and roll, respectively, of the robotic fingertip. When the tactile sensor detects inequalities between these pairs of electrodes, the error is corrected by adjusting the pitch or roll of the fingertip of the robot. The total contact force during indentation is estimated from the sum of impedance changes on all four electrodes. When pressing into a compliant object, the object has a tendency to wrap around the finger and the resulting forces can be measured by other electrodes lateral to the flat surface (such as 17). Comparing this change with the relative magnitude of impedance changes in the central four electrodes can yield substantial information about the compliance of the object. Additional information can be obtained from the fluid pressure.

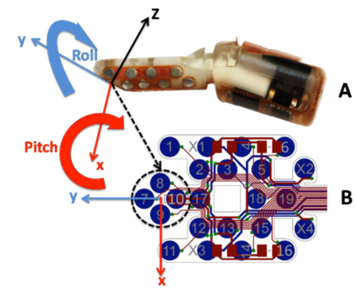

Figure 1. A. Orientations on BioTAC: the finger local coordinate frame has its origin in the center of the two electrode pairs and is coplanar with the flat surface of the core B. Electrode array map

Results and Discussion: The BioTac actually measures the current admitted into the electrode from a test pulse applied to various reference electrodes distributed in the fingertip, so a decrease in measured voltage from an initial value reflects an increase in electrode impedance. For the lateral electrode #17, the impedance initially increased similarly for all materials as increasing force was applied at the fingertip and the skin deformed, but the curves diverged as the more compliant materials deformed and enveloped the skin further from the centroid of contact. The reorientation movement that the robot made to correct pitch to maintain normal force resulted in the transients in lateral electrode impedance at ~5s in Fig. 2, which were particularly pronounced for the hard materials. After the robot corrected its orientation and reached its maximal contact force, the resting voltage on the lateral electrode reflected the compliance of the object.

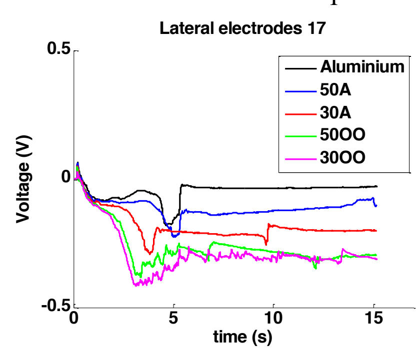

Figure 2. Typical BioTac lateral impedance electrode feedback from pressing on different compliant surfaces.

Conclusions: The preliminary results show that tactile sensory signals available in the BioTac can be used to measure compliance of objects, but only if there is accurate control of the exploratory movement. In this paper, the BioTac was controlled to explore flat compliant objects. Compliant objects that have curved surfaces or inhomogeneities in material properties will generate different responses in the sensors, whose interpretation may require additional exploratory movements.