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Faculdade de Ciências e Tecnologia
Universidade de Coimbra

HANDLE

Representation framework of perceived object softness characteristics for active robotic hand exploration

Ricardo Martins

rmartins@isr.uc.pt   -   www.isr.uc.pt/~rmartins

PhD Advisor:
Prof. Jorge Dias
ISR - Institute of Systems and Robotics
University of Coimbra

Objectives

- The elementary spatial representation of perceived softness is described as a probabilistic combination of softness description of reference sample materials;
- The perceived softness is represented based on previous experience and knowledge, to incorporate uncertain and to be progressively updated;

Haptic memory – perceived softness model of the reference materials

- Characteristic signature of each of the reference materials, m, is modeled by:

$$C_P^m(C_D) = a_1^m C_D^{\frac{3}{2}} + a_2^m \qquad C_P^m(C_A) = a_3^m C_A^{\frac{3}{2}} + a_4^m$$

- The curve parameters (a_1, a_2, a_3, a_4) for each reference material, m, can be learnt by performing several human demonstrations of unaxial palpation of the test materials.

- The parameters (a_1, a_2, a_3, a_4) for each reference material, m, are estimated by least square estimate

- **Reference materials contact interaction signature:**

- **Reference materials:**

Material $_1$ Material $_2$
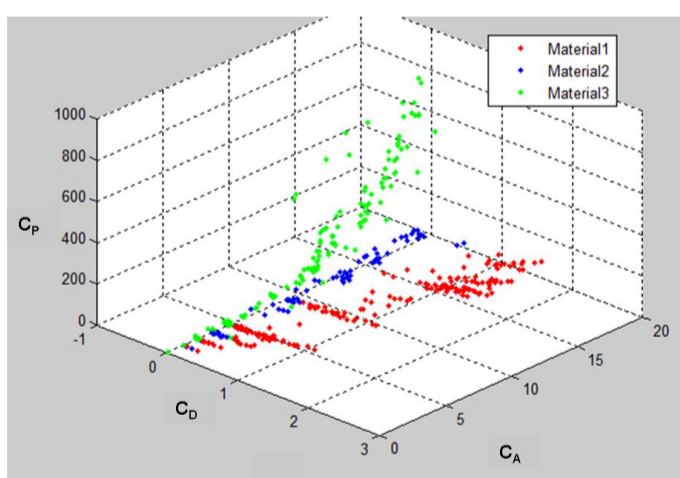
Material $_3$

C_P- Contact Intensity
C_A- Contact area
C_D – Contact indentation in the object normal surface
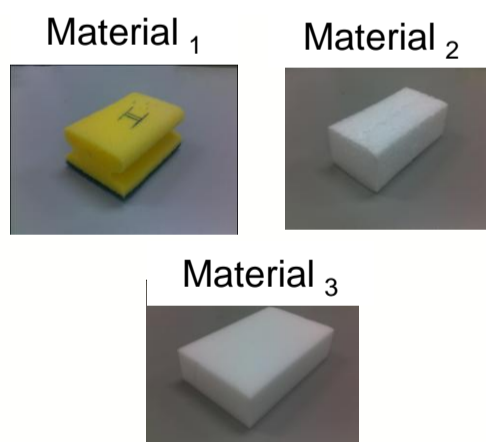
TABLE I: Model parameters estimation for each reference material

Reference Material	a_1	a_2	a_3	a_4
$Material_1$	68.1	19.73	3.30	16.05
$Material_2$	365.6	16.01	2.77	7.64
$Material_3$	1832.00	7.57×10^{-6}	9.309	5.92×10^{-6}

Novel objects progressive representation update

- Volumetric discrete grid;
- The knowledge about the softness of a voxel, m_l, after n batches of measurements is modeled trough a probability distribution function:

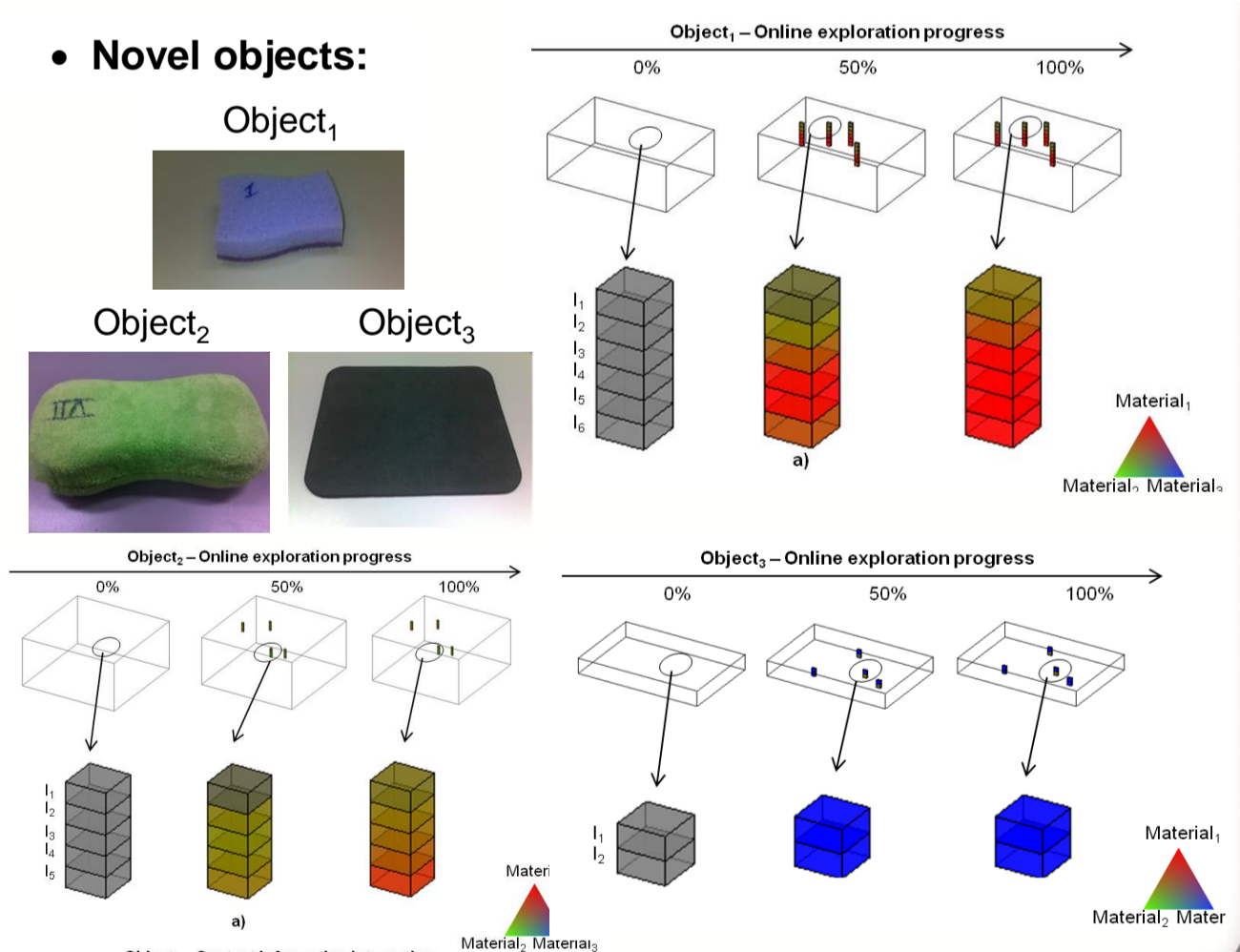$$p(m_l|\mathbf{D}_n^l) : m_l \in \{Material_1, Material_2, \ldots, Material_M\}$$

- For each voxel l, the set D_{n-1}^l contains the $n-1$ measurements influencing that voxel

$$p(m_l|\mathbf{D}_n^l) = \beta_1\beta_2 \prod_{i=1}^{n} p(m_l|\mathbf{D}_j^l) = \beta_1\beta_2 p(m_l|\mathbf{M}_i^l)p(m_l|\mathbf{D}_{n-1}^l)$$

- $p(m_l|\mathbf{M}_{i.}^l)$ converts the measurements $\mathbf{M}_k = (C_P, C_A, C_D)$ in estimation of softness values m_l of voxel l.

- **Novel objects representation update during exploration:**

- **Novel objects:**

Object $_1$

Object $_2$ Object $_3$