SIMULATION OF A TACTILE SENSOR USING SOFT CONTACTS FOR ROBOT GRASPING APPLICATIONS*

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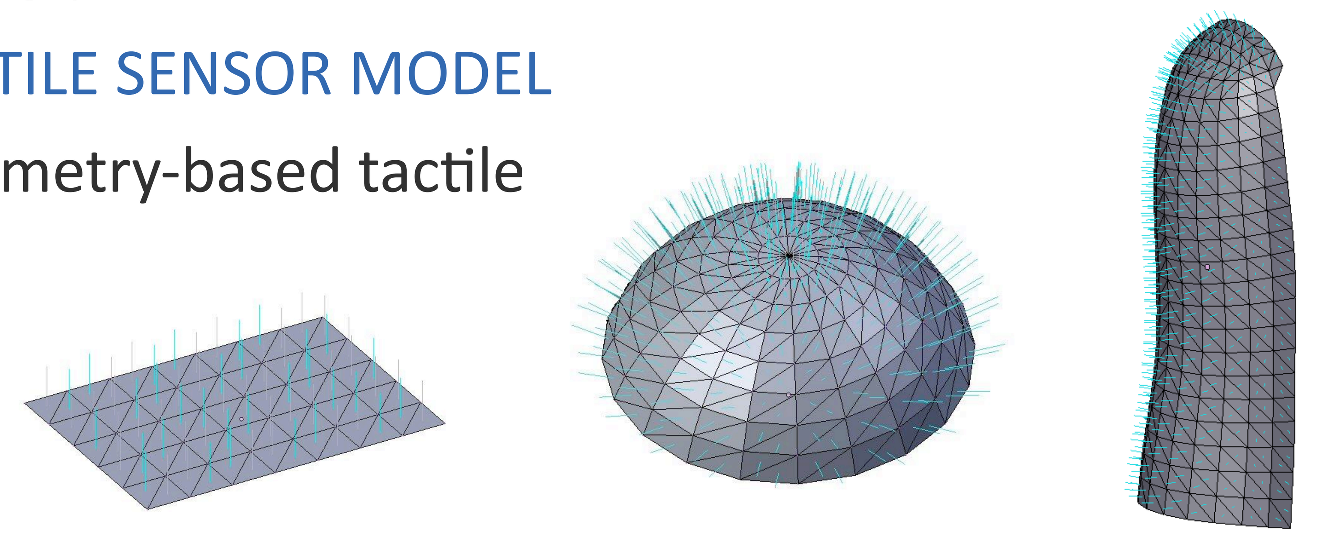
INTRODUCTION

In the context of robot grasping and manipulation, realistic simulation requires accurate modeling of contacts between bodies and, in a practical level, accurate simulation of touch sensors.

- This paper addresses the problem of simulating a tactile sensor considering soft contacts and full friction description.
- The developed model consists of a surface contact patch described by a mesh of contact elements.
- For each element, a full friction description is built considering stick-slip phenomena.
- The model is then implemented and used to perform typical tasks related to tactile sensors. The performance of the simulated sensor is then compared to a real one. It is also demonstrated how it can be integrated on the simulation of a complete robot grasping system

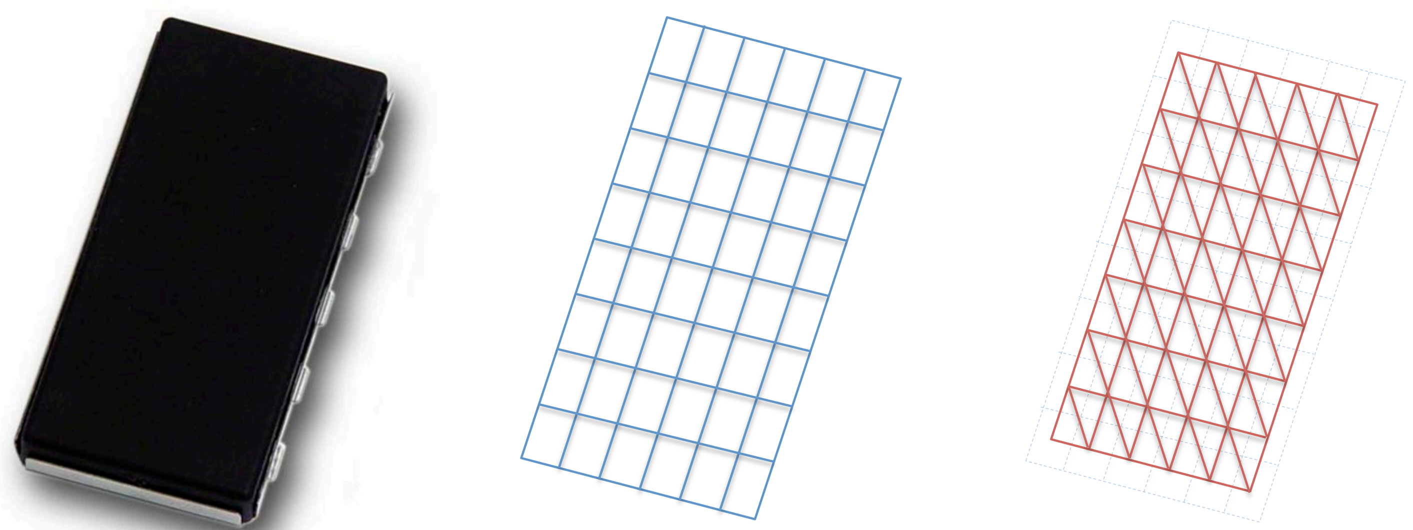
TACTILE SENSOR MODEL

Geometry-based tactile



(a) (b) (c)

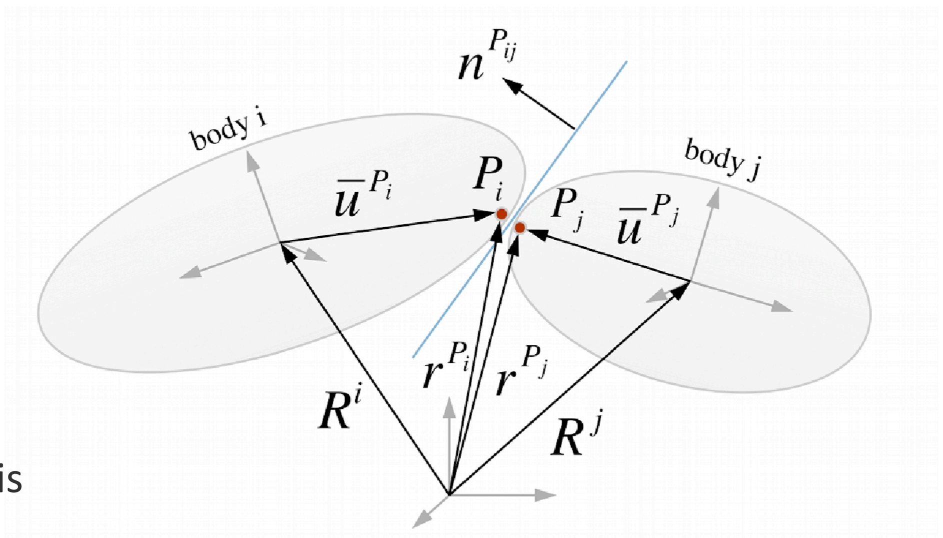
Example of tactile sensor geometries: (a) a simple grid, (b) a spherical surface and (c) human fingertip surface.



(a) (b) (c)

Example of a simulated tactile sensor construction: (a) real tactile sensor, (b) geometry of the sensor and (c) simulated tactile sensor elements

Contact Force Model



Contact forces are described using the soft contact approach which allows small penetration between contacting bodies taking into account local deformations. The amount of this penetration is calculated accordingly with the maximum penetration defined for each sensor.

On each contact point, the contact force (FC) can be written as:

$$F_C = F_n + F_t$$

F_n: **normal force produced by the soft contact**

It can be written as a linear spring-damper element

$$F_n = -(kd + c\dot{d})n^{P_{ij}} = f_n n^{P_{ij}}$$

k and c are spring and damping coef.

$n^{P_{ij}}$ normal vector of the contact plane

F_t: **tangential force represented by friction**

It is evaluated using the LuGre friction model which accounts for both static and sliding phenomena based on a bristle deflection interpretation.

The LuGre model captures the dynamic behavior of the contact surface using the first order differential equation for bristle deflections:

$$\dot{z} = \dot{s}_t - \sigma_0 \frac{|\dot{s}_t|}{g(\dot{s}_t)} z$$

z: bristle deflection

σ_0: stiffness coef. of the contacting surfaces.

$g(\dot{s}_t)$: is used to capture the Stribeck effect in order to describe stick-slip phenomena

$$g(\dot{s}_t) = \alpha_0 + \alpha_1^{-(\frac{\dot{s}_t^T \dot{s}_t}{\dot{x}_0^2})} \qquad \alpha_0 = F_n \mu_d \qquad \alpha_1 = F_n(\mu_s - \mu_d)$$

$$F_t = \sigma_0 z + \sigma_1 \dot{z} + c\dot{s}_t$$

σ_1 is the friction damping coefficient.

Having these equations, the forces and torques can be calculated on each contact point. These forces are applied to the body where the tactile sensor is attached as well as to the body that the tactile sensor is colliding with. They are also used to retrieve sensor feedback information.

IMPLEMENTATION

The tactile sensor model has been implemented using **OpenRAVE**, a planning architecture developed at the Carnegie Mellon University Robotics Institute.

It was created as a sensor plugin and it is available in **OpenGRASP** (a simulation toolkit for grasping and dexterous manipulation)

http://opengrasp.sourceforge.net/

In order to produce reliable results on force/ pressure, the collisions in the physic engine are disabled between the sensor and objects, allowing the tactile sensor to solve the forces using soft contacts. That way, the pressure detected and the pressure applied are identical.

Algorithm 1: How to construct a simulated tactile sensor and obtain the sensor data

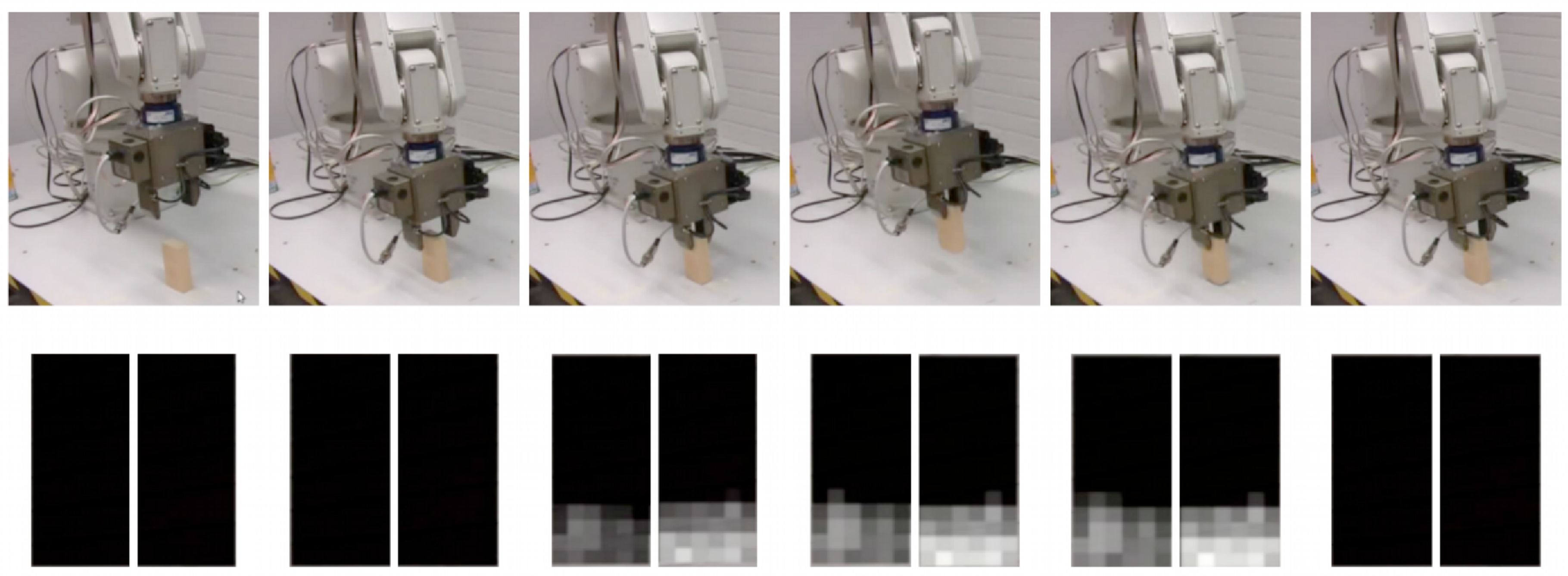
```
Result: Tactile Sensor Data
begin
    Create a mesh representing the real sensor geometry (see Fig.2b);
    Create the simulated sensor elements by placing a vertex on the
    center of each of the mesh polygons (see Fig. 2c);
    Parametrize the sensor elements with the maximum penetration and
    the values needed to calculate friction (k, c, μs, μd, σ0, σ1, α1);
    for each vertex of the simulated sensor element do
        Place a vector pointing to the vertex, with a magnitude equal
        to the maximum penetration;
    for each time-step do
        for each vertex do
            Calculate the intersection of the vector with the target
            objects;
            if they are in collision then
                Create a contact point on the intersection;
        for each contact point do
            Calculate the contact force in the normal direction (8);
            Calculate the tangential friction (13) ;
            Add these two components to get the total contact force.;
        for the sensor's body and each target body do
            Calculate and apply the forces (14,13) and torques (16,
            17);
        Convert the forces to tactile values;
end
```

EXPERIMENTS ON ROBOT GRASPING

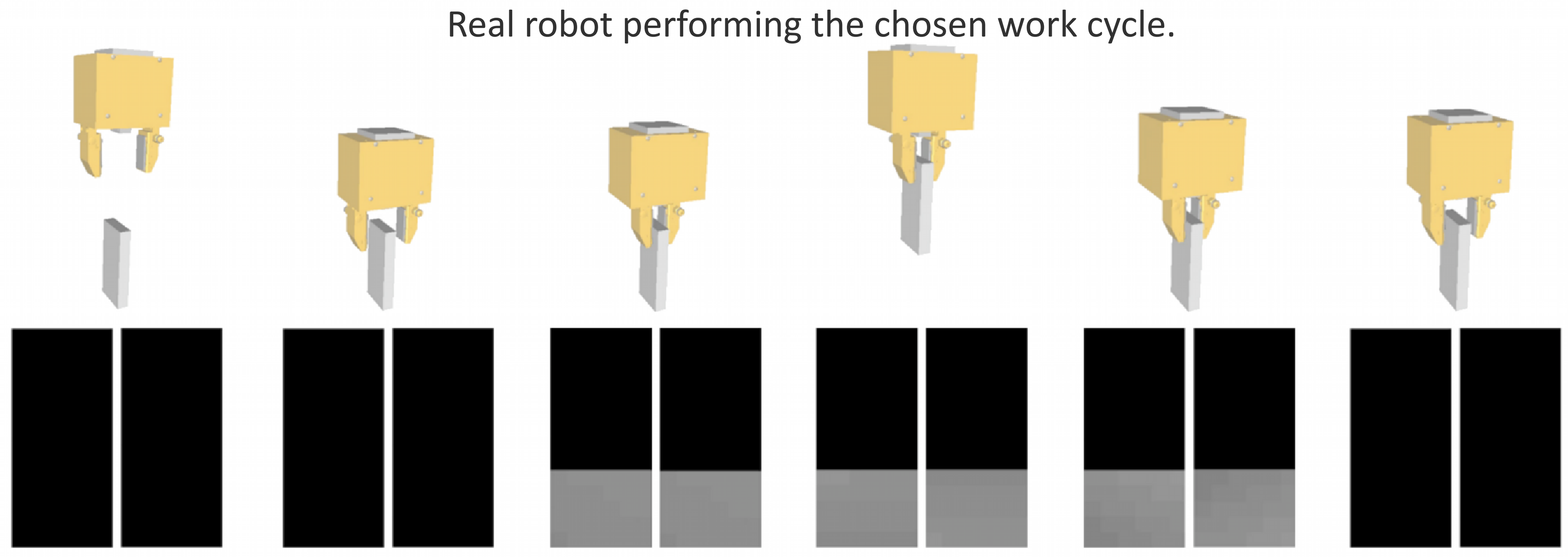
Comparison of a simple grasping action

A simple task of grasping and picking up a cube using a Schunk PG70 parallel jaw gripper was selected as the test scenario.

- Each finger of the gripper had a Weiss Robotics DSA 9205 tactile sensor attached to it.
- The tactile sensor feedback was used to control the grasping force and to determine the stability of the grasp.
- The idea was to perform the same task using this robot and compare the results with the ones obtained by executing the same actions in the simulator. In order to accomplish this, a high level controller was implemented using an abstraction architecture, which allows to switch between real and simulated hardware transparent from the controller point of view.



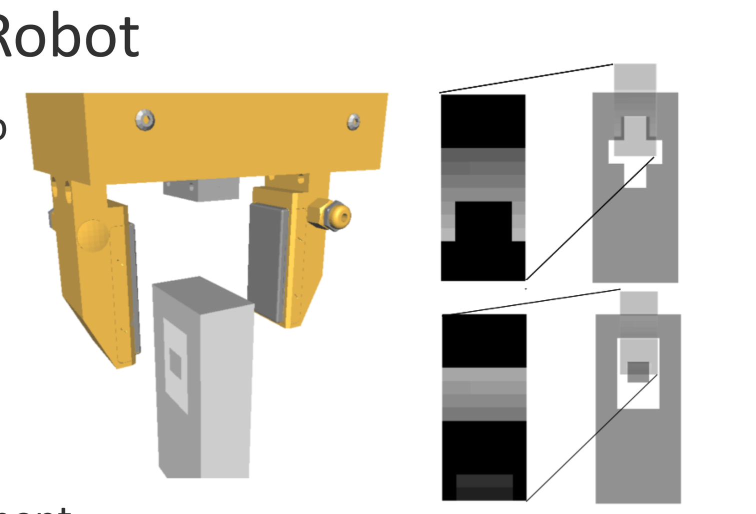
Real robot performing the chosen work cycle.



Simulated robot performing the chosen work cycle

Shape Recognition Using the Simulated Robot

The simulated robot was further tested by running a scenario where the simulated tactile sensor was used to recognize object shapes given that this is one of the main applications of this type of sensor. The tactile sensors give out consistent results.



FUTURE WORK

- Validate the sensor with a more complex dynamic environment.
- Test the performance of the tactile sensor with more tactile geometries, like the human finger/hand.
- Test the scalability of the sensor when the number of vertices increases.
- Further explore tactile feedback without the real hardware limitations
- Use the finger geometry for human contact research

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