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DEGLI STUDI
DI PADOVA

Development of a smart capture system for On-Orbit-Servicing with space robots

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Outline

1. Introduction
2. Tests on the robotic arm
3. The capture interface and its sensor
4. Future works

Introduction

The purpose of the work is to develop and test a capture system to catch space vehicles for On—Orbit—Servicing with robotic arm.

The capture is the first operation for missions aiming to extend or improve the life of orbiting satellites.

The use of space robots allows more flexibility during such operations

Brief recap

The work included two main parts:

- Establish a ground facility to test capture systems whose central technology is a custom robotic arm;
- Develop a capture interface.

The robotic arm

The tests performed on the robotic arm highlighted some unwanted behaviors:

Low precision: due to assembly errors → fixed by closing the control loop through the vision system.

Vibrations: due a suboptimal tuning of the controllers of the motors → fixed with a tuning of them, but further tests are required.

The capture interface

The tests on the robotic arm provided some drivers for its design:

Tolerate misalignments: due to the accuracy of the robotic arm → capture interface of type gripper.

Disc shaped target: reduce the degrees of freedom → small dimensions.

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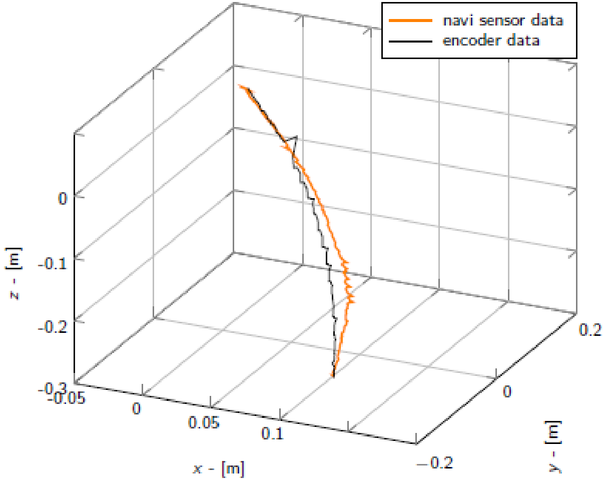
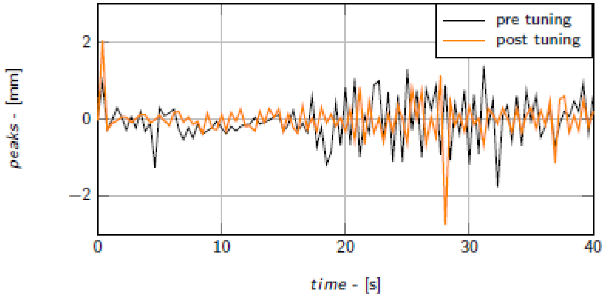
Test on vibrations

Vibrations were a crucial factor, then many attention was given in order to reduce them as possible.

They are caused by:

- a suboptimal tuning of the controllers of the motors (fixed);
- the length of the trajectory: the more it increases, the more the vibrations accumulates (especially at the end of it, as reported in the plots).

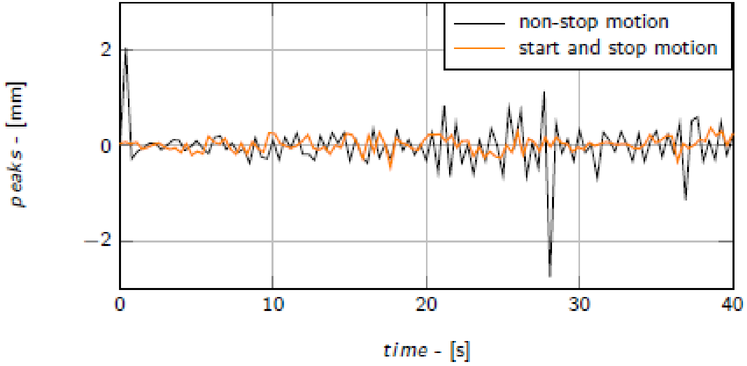




Trajectory traking

The trajectory has been divided into small segments.

Due to its stop—and—start nature, this method may lead to other vibrations, then series of tests have been performed.



The tests provided a range of accelerations, decelerations and velocities to keep the tracking error within 5mm, the same accuracy of its main navigation sensor represented by the vision system.

Now the robotic arm fits all the requirements to be employed as a positioning system and for testing capture tasks. Anyway, thanks to its high degree of customization it is always possible to convert it for other purposes.

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Mechanical design of the gripper

The tests performed with the joint action between the robotic arm and the vision system provides some cardinals drivers to design the capture system:

- it should tolerate lateral and angular displacements: 5mm for the lateral, 10 deg for the angular;
- it of gripper type, with each finger individually actuated to improve its ability to manage displacements;

Two other important properties of the gripper are:

- the use micro—controller that makes it independent from the main computer of the robotic arm;
- the use of a passive method to react to the failure of its actuation system (TBD).

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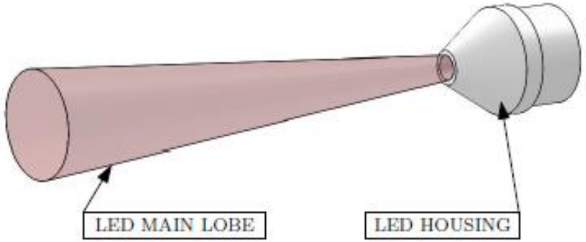
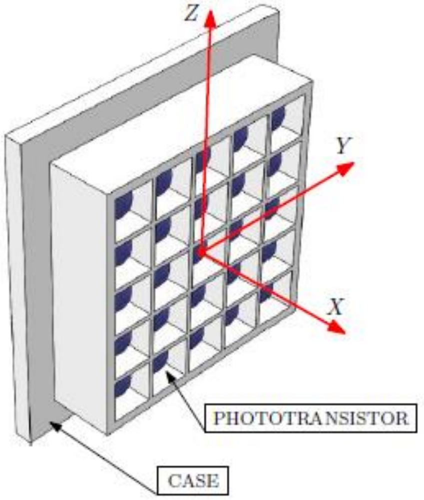
Sensor description – Physical design

The employed vision system is able to reconstruct the pose of the target until 60mm, then an additional sensor for the rest of the trajectory is needed. The sensor is composed by two main parts:

- the infrared LED whose beam can be considered a cone with an aperture of 20 deg and it will be mounted inside the target interface;
- the matrix of phototransistors (a custom 25 pixels CCD) able to reconstruct the position of the LED. It is a 33mm side square, the phototransistors are spaced 5mm and it will be mounted inside the gripper.



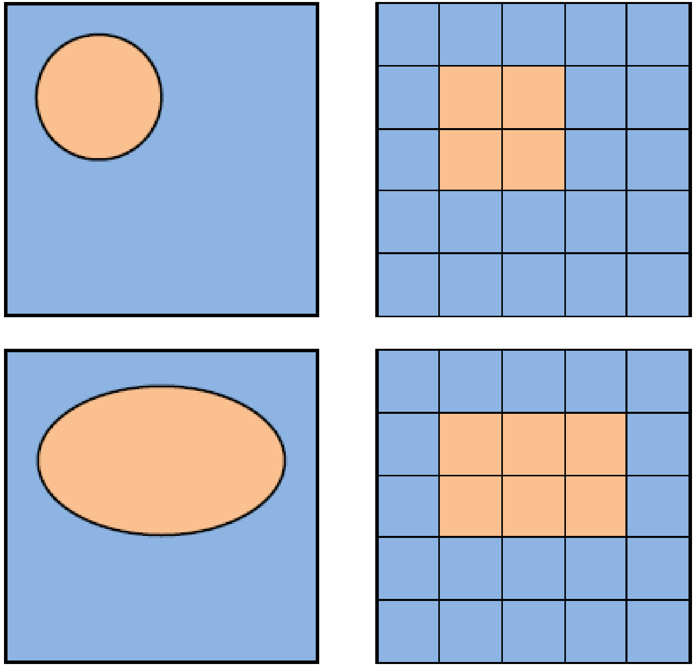


Sensor description – Working principle

The sensor exploits the geometric fact: when a plane intersects a cone, the shape on the plane depends on relative position and orientation between the cone and the plane:

if they are parallel, the projected figure is a circle, whose dimension increases with the distance between the plane and the vertex of the cone; otherwise, they are ellipses.

In the sensor the cone is represented by the beam of the LED and the plane is the custom CCD. Being the plane discrete, the circles become squares or diamonds and the ellipses become rectangles.

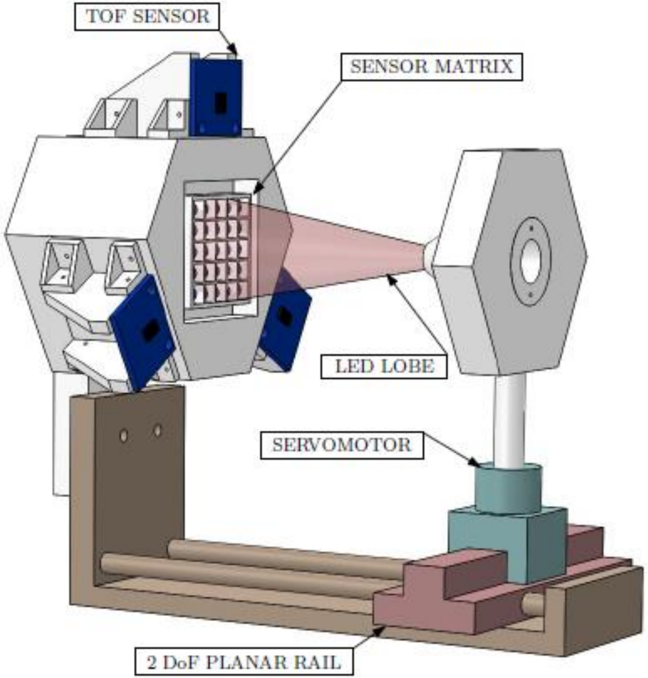


Sensor characterization – Setup

An experimental characterization is required to retrieve a relation between the distance of the LED and the number of active phototransistors.

The sensor was fixed on a 3 DoF slide equipped with encoders. The LED was mounted on the moving part of the slide in order to have a fixed position and orientation during the test.

Three Time—of — Flight sensors (ToF) measure both the distance and the orientation of the LED.

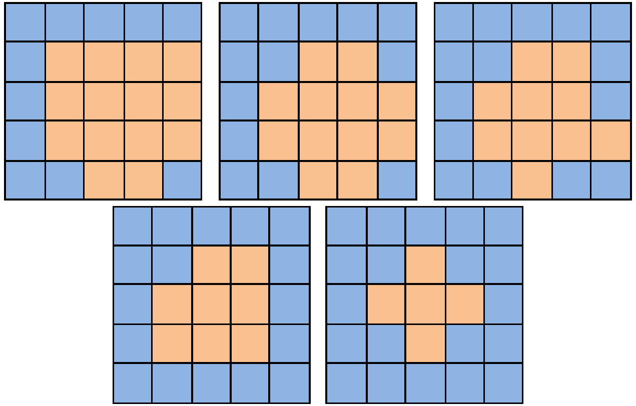


Sensor characterization – Results

The experimental characterization of the sensor provided the following outputs:

- the resolution on the plane the same as the distance between each phototransistor: 5mm;
- the relation between the distance of the LED and the number of the activated phototransistors reported in the table;
- after the initial part, the resolution along the x axis of the sensor is constant;
- at distances lower that 15mm the sensor is not able to tell if the target is tilted or not (it is not able to distinguish between small ellipses and circles).

#activated phototr.	Min d [mm]	Max d [mm]	Range [mm]
14	47.5	30.0	17.5
12	27.5	25.0	2.5
10	23.0	21.0	2.0
8	18.1	16.1	2.0
5	14.0	12.0	2.0



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Future works

The last year of the PhD will be dedicated to tests the smart capture system in different scenarios. The tests are going to be performed with an increasing level of difficulty:

- capture a fixed target: the gripper has to capture a target that is not moving. This tests has the purpose to test the navigation sensors;
- capture a floating target: the gripper has to capture a target free of moving on the low friction table. With this test also the ability of the gripper to avoid contacts with the target all will be test.

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Thanks for the attention

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