DICA-Dept. of Civil and Environmental Engineering
Geodesy and Geomatics Section

POLITECNICO DI MILANO





OUTDOOR AND INDOOR NAVIGATION WITH MICROSOFT KINECT

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OUTLINE

- *The Microsoft Kinect sensor*
- *The improvements of Kinect v2*
- *Indoor Navigation with Microsoft Kinect sensor*
  - *Integration of depth maps and RGB images for indoor navigation*
  - *Kinematic test*
- *Work in progress: Outdoor Navigation with Microsoft Kinect sensor*
- *Conclusions*

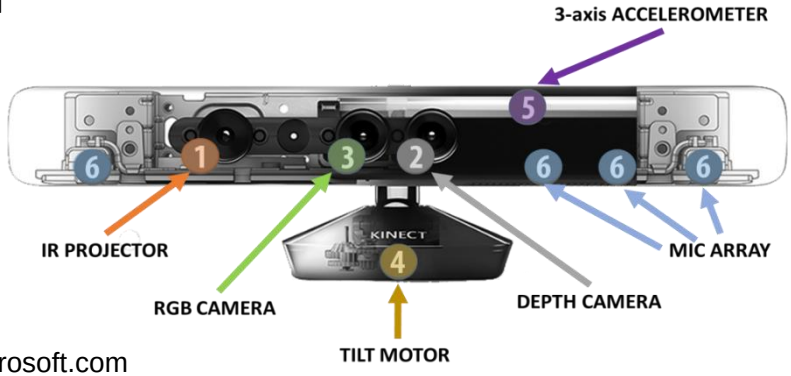
INDOOR POSITIONING WITH PHOTOGRAMMETRY: MICROSOFT KINECT

The Kinect 1.0 sensor is an **active 3D camera** developed by Microsoft and Prime Sense.

- It allows to play and completely control the Xbox360 console.
- During the game the **gestures** of the player are **continuously tracked** and the player's avatar is moving accordingly to the user motions
- Kinect 1.0 is based on speckle pattern technology

On summer 2014, a **new generation** of Kinect based on **time-of-flight** technology has been released

www.microsoft.com



www.microsoft.com

https://www.wired.com

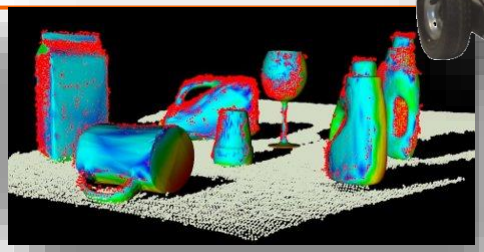
MICROSOFT KINECT AS A LOW-COST SENSOR

Shortly after Kinect 1.0 launch on the market Software Development Kits (SDKs) have been realized allows to use the device as a **low-cost measurement system**.

- Allows acquisition of RGB, IR and depth images up to 30 fps
- Skeleton tracking

The Kinect has attracted researchers from different fields, from Computer Vision to robotics or biomedical engineering

http://lara.unb.br/~antonio/files/publis/bo_embc2011.pdf

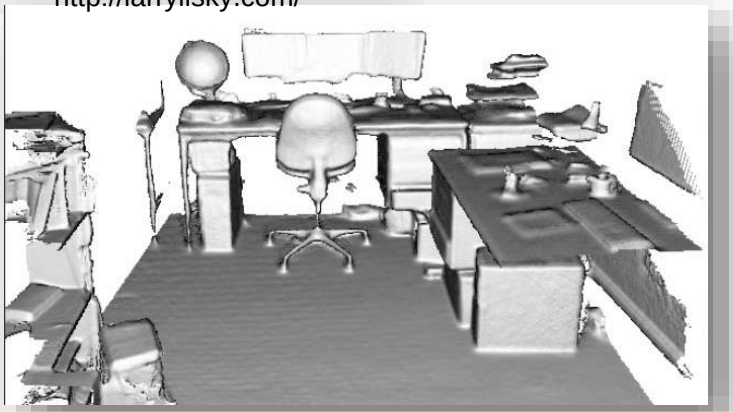


http://larrylisky.com/

http://www.superdroidrobots.com

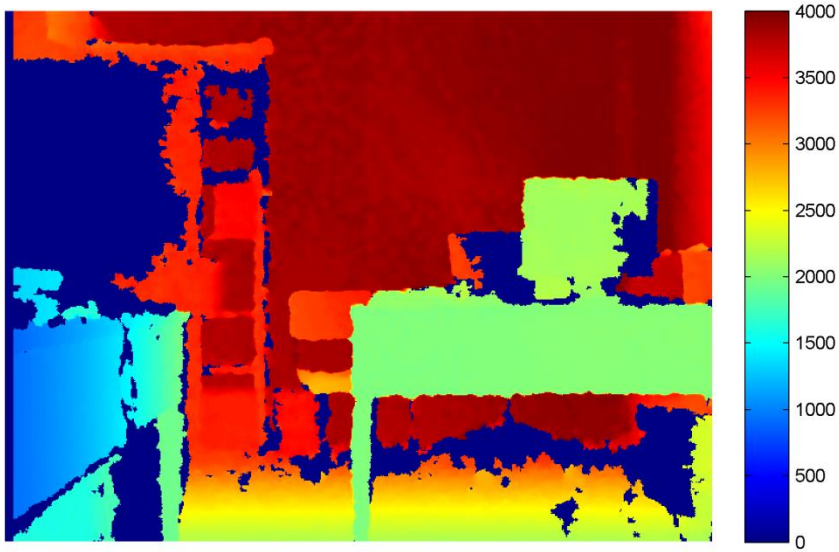
In March 2013 the Kinect Fusion Libraries have been released: these libraries allow to quickly produce meshed model just moving the sensor around the scene

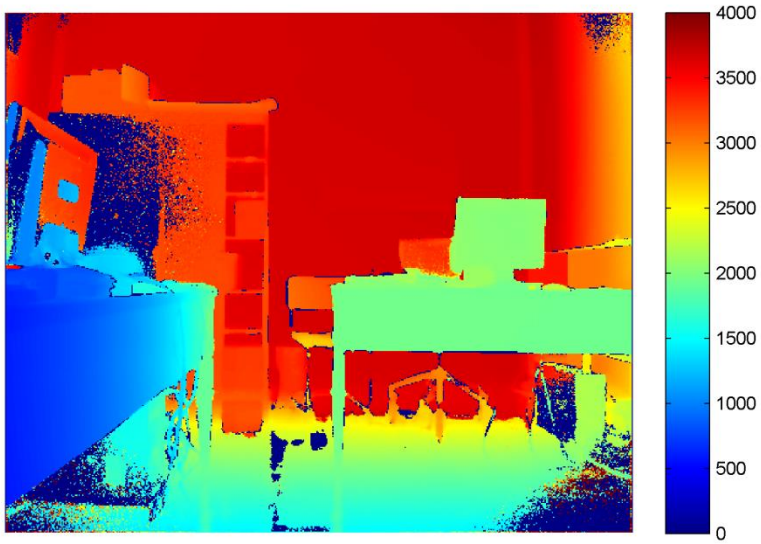
http://3dart.it/



http://www.youblob.com/node/194

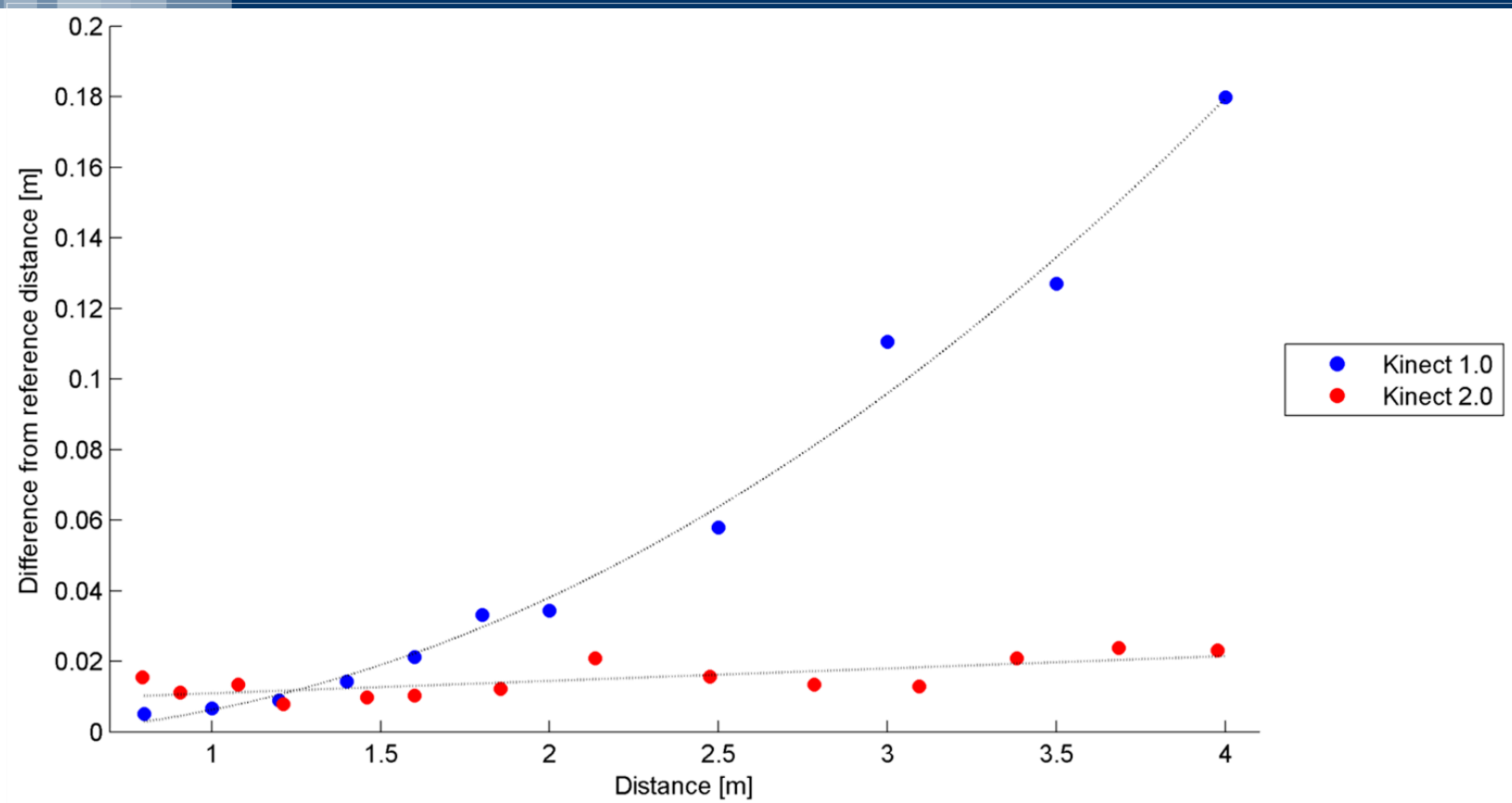
KINECT V1 vs KINECT V2





The depth maps deliverable with the **second generation** of Kinect are **more complete** and cover a wider view. The number of no-data are smaller and the border of the **objects** are **better defined**

KINECT V1 vs KINECT V2 – DEPTH MEASUREMENTS

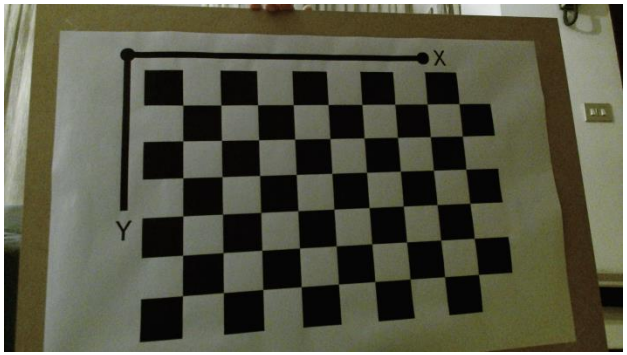


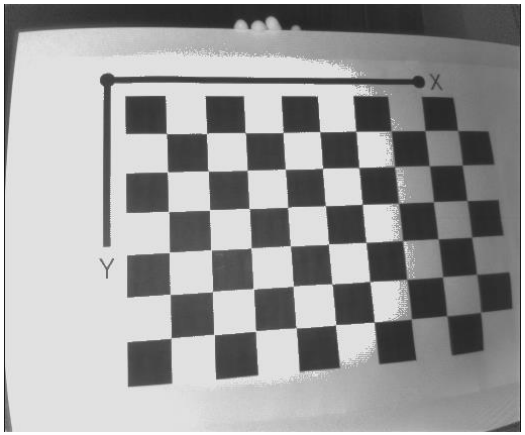
$$dZ = -\frac{Z}{b}db_x - \frac{X-b}{b}db_z - \left(\frac{Z^2}{b} + \frac{X^2}{b}\right)d\varphi_1 + \frac{XY}{b}d\omega_1 - \frac{YZ}{b}d\kappa_1 + \left(\frac{Z^2}{b} + \frac{(X-b)^2}{b}\right)d\varphi_2 + \frac{(X-b)Y}{b}d\omega_2 - \frac{YZ}{b}d\kappa_2$$

$$dZ = \frac{-Z}{f_{mod}}df_{mod} + \frac{Z}{2n\pi + \phi}d\phi$$

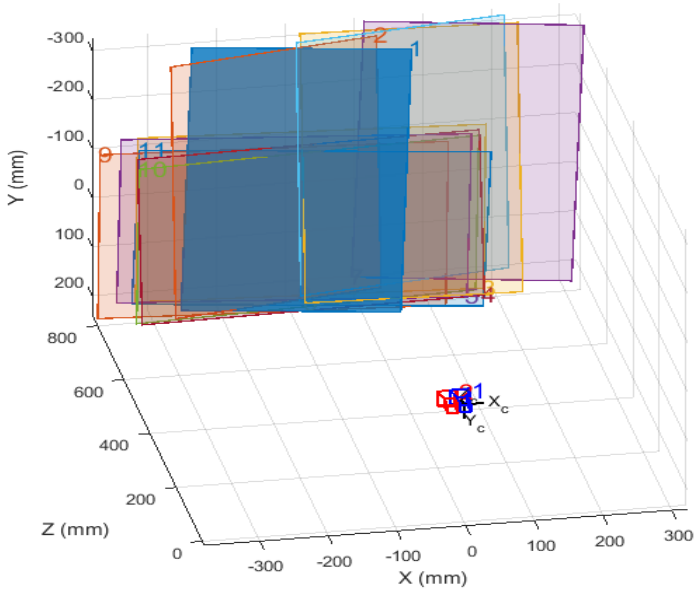
The new generation of Kinect is much more accurate.

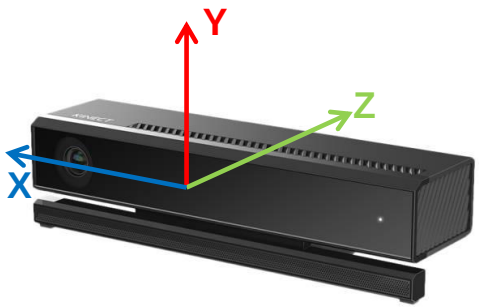
IR-RBG CAMERA CALIBRATION





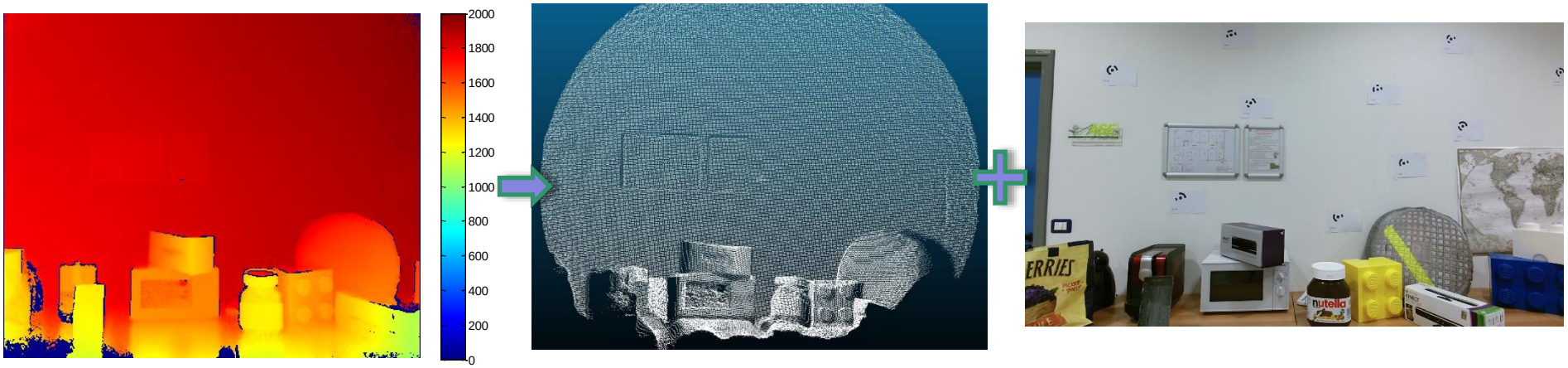
- RGB and IR camera calibration using Matlab ® Calibration App → chessboard has emerged as the best solution for IR camera calibration
- Stereo calibration in Matlab® to define the **relative orientation between the two cameras**





	X [mm]	Y [mm]	Z [mm]	omega [rad]	phi [rad]	kappa [rad]
Mean	51.7	1.27	2.38	-0.0065	-0.0012	-0.0039
St. Dev.	1.46	0.89	1.26	0.0025	0.0026	0.0032

INDOOR NAVIGATION WITH THE KINECT



Integrate **Depth Data** (co-registed with IR camera) and **RGB images** in order to reconstruct **Kinect trajectory**:

- Investigate motion tracking algorithm
- **KLT** (Kanade Lucas Tomasi) algorithm has been modify in order to track points extracted with more reliable interest operator (SIFT, SURF)

Part of this research has been carried out during a stage at 3DOM (3D Optical Metrology) – FBK (Bruno Kessler Foundation)

RECONSTRUCTING TRAJECTORY WITH THE KINECT

Acquisition of RGB images and Depth Maps

↓

Depth Maps distance correction and Point Cloud Generation

↓

Features extraction (SIFT, SURF) and KLT tracking

↓

Tie points re-projection on Point Clouds

↓

Estimation of Roto-traslation between PC_i and PC_{i+1} and determination of the approximate trajectory

$$\underline{X}_{i*+1} = \underline{\underline{R}}^{i*}_{i*+1}\underline{X}_{i*}$$

↓

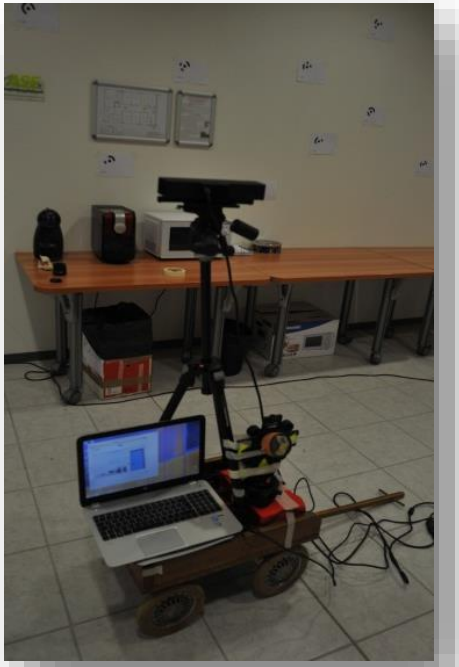
ICP estimation of Roto-traslation correction between PC_i and PC_{i+1} and determination of the corrected trajectory

$$\underline{X}_{i} = \left(\underline{\underline{R}}^{i}_{i*}\right)^{-1}\underline{X}_{i*}$$

CART GEOMETRIC CALIBRATION

To compare the Kinect trajectory recovered with the reference one it is necessary to **define** the **vectors** that connected in space the cameras and the center of the prism.

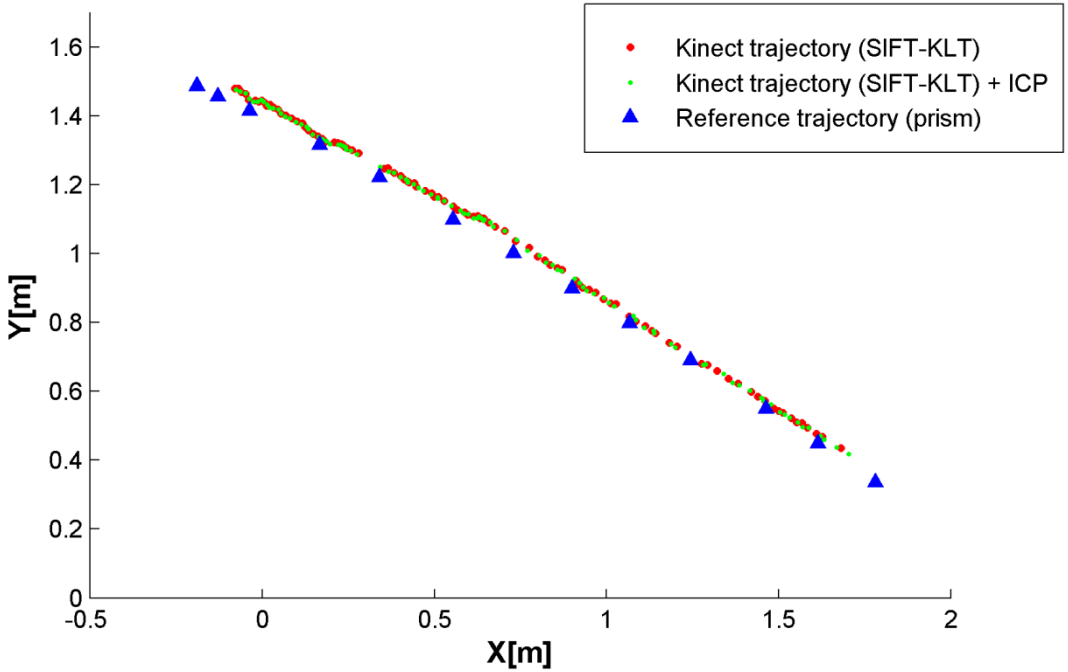
- **stop and go survey**, acquiring IR and the RGB images
- For each one of the stationed points, the coordinates of the reflective prism have been acquired too



RGB camera lever-arm	X [m]	Y [m]	Z [m]
Average	-0.016	0.771	-0.087
Standard deviation	0.018	0.004	0.005

IR camera lever-arm	X [m]	Y [m]	Z [m]
Average	-0.075	0.773	-0.090
Standard deviation	0.021	0.006	0.007

RECONSTRUCTING TRAJECTORY WITH THE KINECT

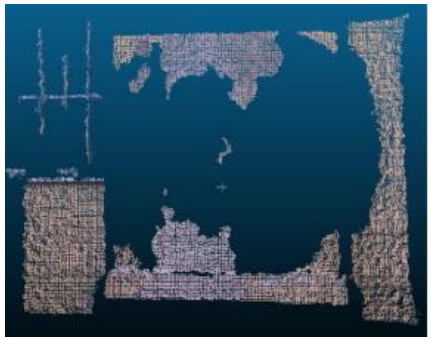


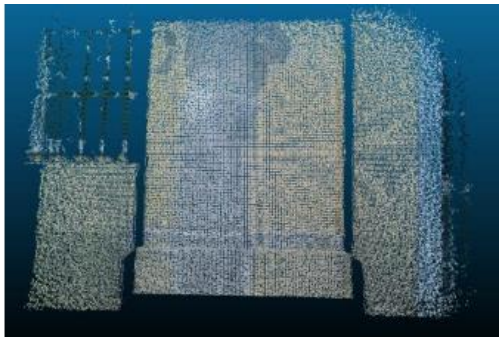
	RMSe KLT-SIFT Kinect 2.0 trajectory [m]	RMSe KLT-SIFT Kinect 2.0 trajectory + ICP [m]
X	0.047	0.046
Y	0.035	0.030
Z	0.038	0.029

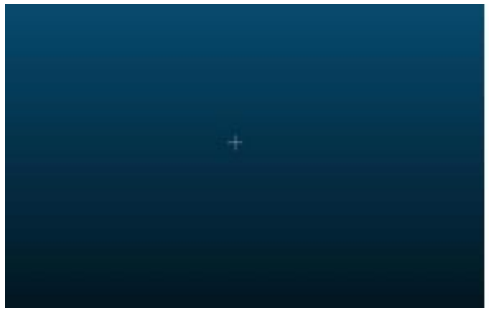
- RMSe of the discrepancies in all the coordinates are **lower than 0.05 m** in all direction (in agreement with the precision that have been reached, during cart calibration phase)
- **ICP corrections** are **not significant** because they were of the same order of magnitude of the error committed by Kinect 2.0 sensor when it is used as a depth measuring system

OUTDOOR NAVIGATION WITH THE KINECT: WORK IN PROGRESS

The Kinect v2 seems to be **able to acquire depth data** even under direct **sunlight**. For this reason it can be interesting also for outdoor navigation, but also to solve the problem of **passing from indoor to outdoor**







(Zennaro, 2014)

- Calibrate the **depth sensor also outdoor** in order to define accuracy, precision and operative range
- Evaluate the influence of the reflective material and weather conditions
- **Integrate** the **Kinect** data (RGB and depth) and **GNSS**

CONCLUDING REMARKS AND OUTLOOK

- The new generation of Kinect represent an important improvement. The sensor acquires **more accurate** and **precise depth data**, RGB image in HD and is capable of acquire **data** even **outdoor** or **under** few centimeters of **water**.

- It can be very useful for passing from outdoor to indoor environments

- **Indoor Navigation** :
  - Integrated use of RGB and depth images allowed to recover the followed trajectory with 0.05 m of error

- **Outdoor Navigation** :
  - Calibration of the depth camera outdoor (different illumination conditions)
  - Test to evaluate the effects of the reflection of the different materials to evaluate the completeness of point clouds
  - Integrate the RGB+DEPTH solution with GNSS data (low-cost receivers)

THANKS FOR YOUR ATTENTION!