OUTDOOR AND INDOOR NAVIGATION
WITH MICROSOFT KINECT

Diana Pagliari
Livio Pinto
• 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
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.
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

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

<table>
<thead>
<tr>
<th></th>
<th>X [mm]</th>
<th>Y [mm]</th>
<th>Z [mm]</th>
<th>omega [rad]</th>
<th>phi [rad]</th>
<th>kappa [rad]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>51.7</td>
<td>1.27</td>
<td>2.38</td>
<td>-0.0065</td>
<td>-0.0012</td>
<td>-0.0039</td>
</tr>
<tr>
<td>St. Dev.</td>
<td>1.46</td>
<td>0.89</td>
<td>1.26</td>
<td>0.0025</td>
<td>0.0026</td>
<td>0.0032</td>
</tr>
</tbody>
</table>
Integrate **Depth Data** (co-registered with IR camera) and **RGB images** in order to reconstruct **Kinect trajectory**:

- Investigate motion tracking algorithm
- **KLT** (Kanade Lucas Tomasi) algorithm has been modified 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-translation between $PC_i$ and $PC_{i+1}$ and determination of the approximate trajectory

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

\[
X_{i+1} = R_{i+1}^{i*} X_{i*}
\]

\[
X_i = (R_i^{i*})^{-1} X_{i*}
\]
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

<table>
<thead>
<tr>
<th>RGB camera lever-arm</th>
<th>X [m]</th>
<th>Y [m]</th>
<th>Z [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>-0.016</td>
<td>0.771</td>
<td>-0.087</td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>0.018</td>
<td>0.004</td>
<td>0.005</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IR camera lever-arm</th>
<th>X [m]</th>
<th>Y [m]</th>
<th>Z [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>-0.075</td>
<td>0.773</td>
<td>-0.090</td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>0.021</td>
<td>0.006</td>
<td>0.007</td>
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</table>
RECONSTRUCTING TRAJECTORY WITH THE KINECT

- 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
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.

- 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
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!