Performance Assessment and Calibration of the Kinect 2.0 Time-of-flight Range Camera for Use in Motion Capture Applications

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Motivation

- 3D geometric information is increasingly used
  - Deformation analyses
  - Pre-mission or as-built surveys
  - Motion capture
- Time-of-flight (ToF) range cameras offer several advantages
  - Single sensor (thus, often cheaper)
  - Do not require retro-reflective targets or markers
  - Video framerate
Microsoft Kinect 2.0 Sensor

- Provides an affordable (≈ $200 USD) ToF ranging sensor with a large image resolution (512 x 424)
- Effective range of approximately 5 m with a framerate of 30 FPS
- Necessary to quantify the performance characteristics of the sensor in order to use it.

Experiments

- Performed in a temperature controlled room at the University of Calgary
- Kinect 2.0 set at fixed distances away from reflective plates (white and black Spectralon)
- Large field of targets used for self-calibration
Sensor Warm-up Time

Distance and Reflectivity
Self-Calibration for Systematic Errors

<table>
<thead>
<tr>
<th>Residuals</th>
<th>Before Calibration</th>
<th>After Calibration</th>
<th>Percent Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>x [pix]</td>
<td>1.98</td>
<td>0.26</td>
<td>87%</td>
</tr>
<tr>
<td>y [pix]</td>
<td>2.43</td>
<td>0.26</td>
<td>89%</td>
</tr>
<tr>
<td>range [mm]</td>
<td>66.1</td>
<td>12.6</td>
<td>81%</td>
</tr>
</tbody>
</table>

Conclusions

- Sensor has negligible warm-up time compared to other ToF cameras on market
- Precise motion capture with the Kinect 2 is possible, with some considerations
  - Ideal range at 1.0 m – 2.5 m
  - Highly reflective targets are desirable
  - See full paper for more details
- Calibration for interior systematic effects can produce significant (> 81%) improvement on residuals
**Self-Calibration – Additional Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_p$ [pix]</td>
<td>-4.74</td>
<td>0.15</td>
</tr>
<tr>
<td>$y_p$ [pix]</td>
<td>-3.48</td>
<td>0.14</td>
</tr>
<tr>
<td>$c$ [pix]</td>
<td>366.45</td>
<td>0.23</td>
</tr>
<tr>
<td>$k_1$ [pix$^{-1}$]</td>
<td>$6.518 \times 10^{-7}$</td>
<td>$9.536 \times 10^{-9}$</td>
</tr>
<tr>
<td>$k_2$ [pix$^{-4}$]</td>
<td>$-1.226 \times 10^{-11}$</td>
<td>$9.562 \times 10^{-14}$</td>
</tr>
<tr>
<td>$d_0$ [mm]</td>
<td>-16.9</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Vignette Effect