MSc Surveying
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Performance Evaluation of the PrimeSense IR Projected Pattern Depth Sensor

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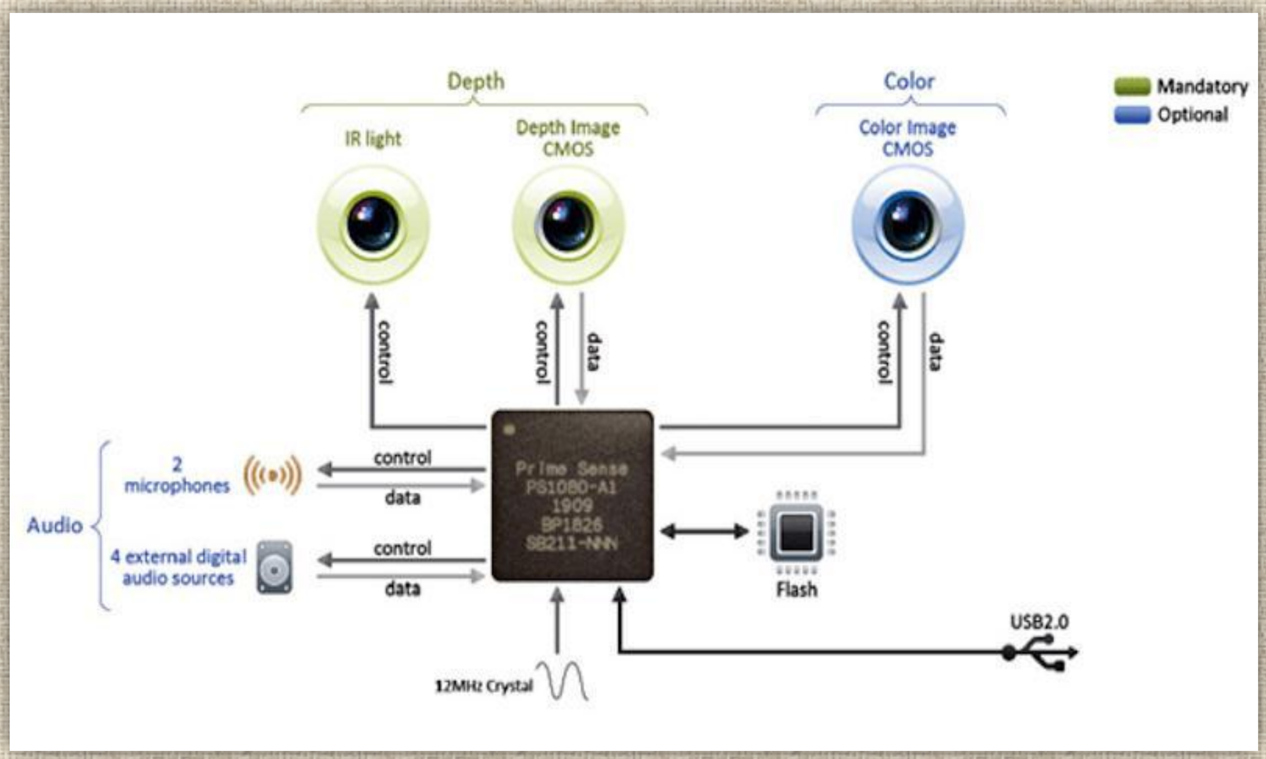
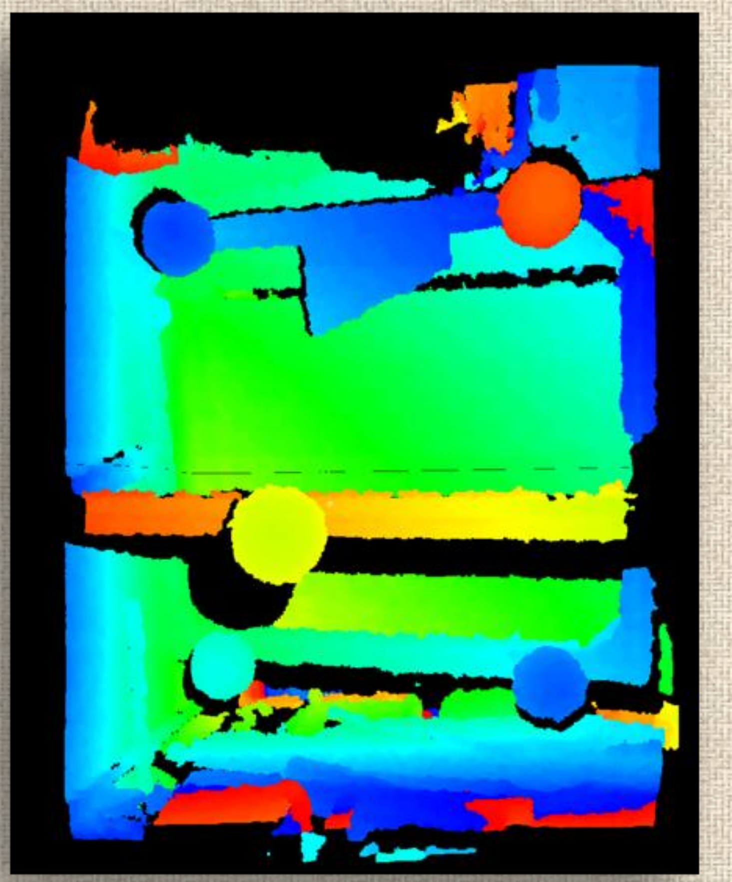
The PrimeSensor

A new depth sensor technology has been developed and introduced into the consumer electronics market; the PrimeSensor from PrimeSense producing 640x480 depth image information at 30fps, most commonly known for its appearance in the popular Microsoft Kinect, the Xbox peripheral. The sensors' primary ranging function, the true capabilities of which are to a large extent unknown, is of interest. As yet no research into the PrimeSensor which evaluates the resolution and accuracy performance has been documented. Performance and capabilities are explored of the PrimeSensor whilst developing an understand of the sensors method of operation.



The figure above from PrimeSense (2010) illustrates the fundamental components of the PrimeSensor. Of interest for the purpose of this research is the depth measurement component of the PrimeSensor system. The PrimeSensor operates a system of projected near infrared (IR) light which is read or received from the scene using a standard CMOS image sensor to produce the 640x480 depth image. PrimeSense (2010) state their sensor "works by coding the scene volume with near-IR light", a process they have termed "Light Coding". PrimeSense (2010) go further to explain their "SoC [System on Chip] chip is connected to the CMOS image sensor, and executes a sophisticated parallel computational algorithm to decipher the received light coding and produce a depth image". The significant component to the PrimeSensor depth measurement system is the system of IR light projection and detection. The system projects a speckle pattern of IR spots constant over time, the displacement of that said pattern to the embedded reference plane allows for depth estimation through a process of active triangulation.

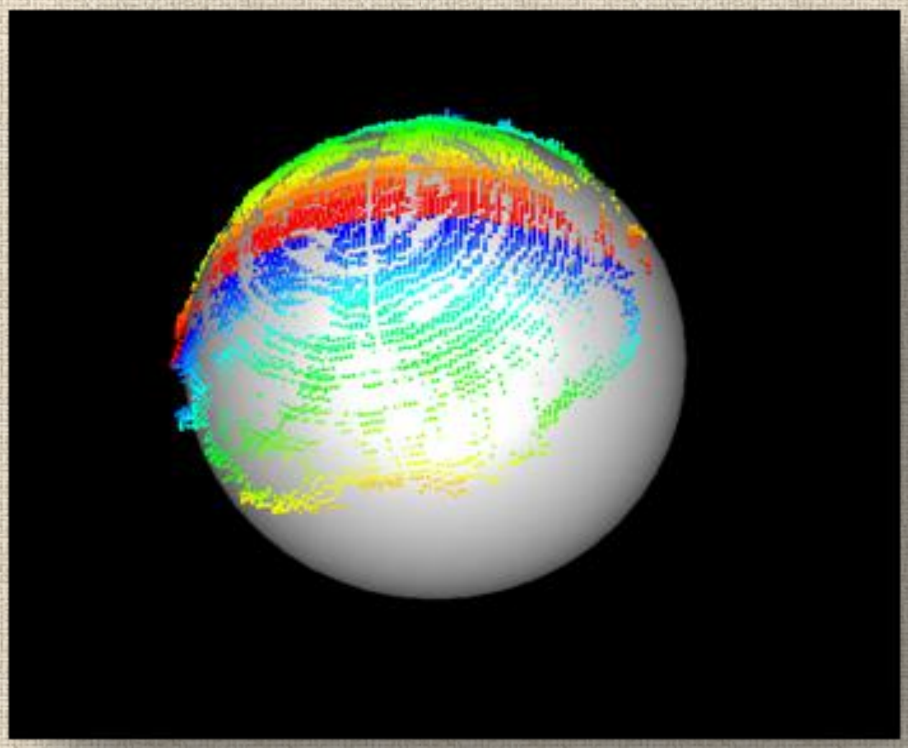
Performance Evaluation



Several aspects of the PrimeSensors operation were probed in order to test and evaluate the sensor performance:

- Spatial Resolution
- Depth Resolution
- Quality Parameter: Probing Error
- Quality Parameter: Sphere Spacing Error
- Depth Accuracy
- Planar Accuracy

One critical piece of literature with significant influence on the methodology of this research paper comes from VDI/VDE (2002). The VDI/VDE (2002) paper titled "Optical 3D Measuring Systems - Optical Systems Based on Area Scanning" outlines standard test protocol designed for the "acceptance and reverification of optical 3D measuring systems of various designs, degrees of automation and sizes". VDI/VDE (2002) state the test protocol applies to "3D measuring systems based on area scanning, whose function is based on triangulation" and the "sensor consists of one or more components such as one or more imaging sensors and one or several projection systems projecting structures on to the object surface to be measured, or a system serving to illuminate any existing surface texture".

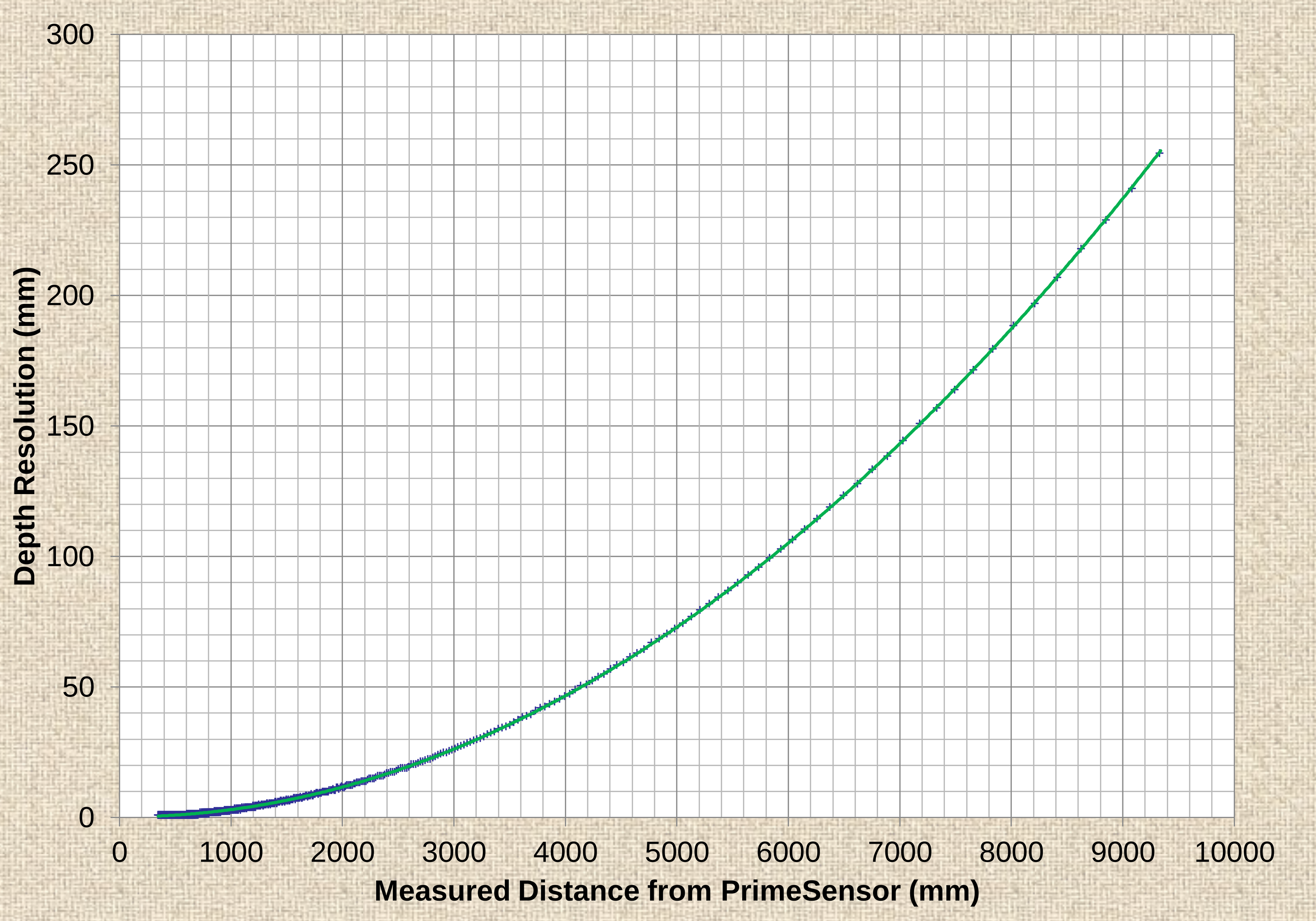


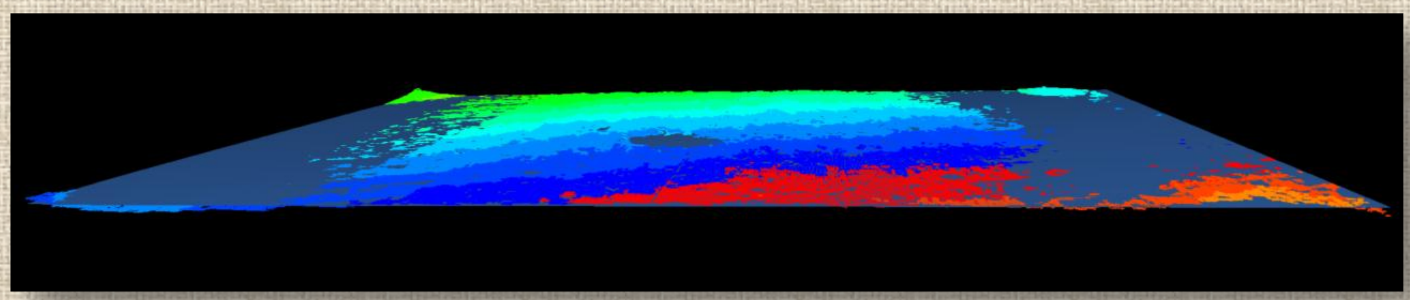
References

PrimeSense, 2010. [Pages at:] http://www.primesense.com/files/FMF_2.PDF [Last accessed: June 22 2011]

VDE/VDI, 2002. Optical 3-D Measuring Systems – Optical Systems Based on Area Scanning, *VDI/VDE-Richtlinen*, Part 2, Aug.

Chart 1. PrimeSensor Depth Resolution





The Leica Cyclone extract above illustrates the best fit plane over PrimeSense measured point cloud at the minimum observed range for this test of 0.5m. The standard deviation of measured points to best fit plane in this instance was 1.814mm. There are several noteworthy characteristics present upon inspection of the illustration, we can see a distinct warping effect of the plane at this (0.5m) range, the corners also display distinct warping effect with adjacent corners deviating in opposite directions on the z axis away from the best fit plane. We can also observe a circular hole in the PrimeSense point cloud were no depth data has been returned. Below are further illustrations of the best fit to plane test scenarios, at test distances of 1.5m (top), and 3.5m (bottom).

Several aspects of the PrimeSensors performance come to light as a result of the testing reported in the previous chapter. The depth resolution severely degrades beyond a depth of 3.5m. This severely limits the sensors ability to distinguish detail at depths beyond this 3.5m threshold. The degradation of depth resolution, as one would expect, has significant influence upon data quality at increased ranges as seen in planar testing were increased point cloud noise is introduced, edge distortion errors are largely more apparent, striping of points along z values

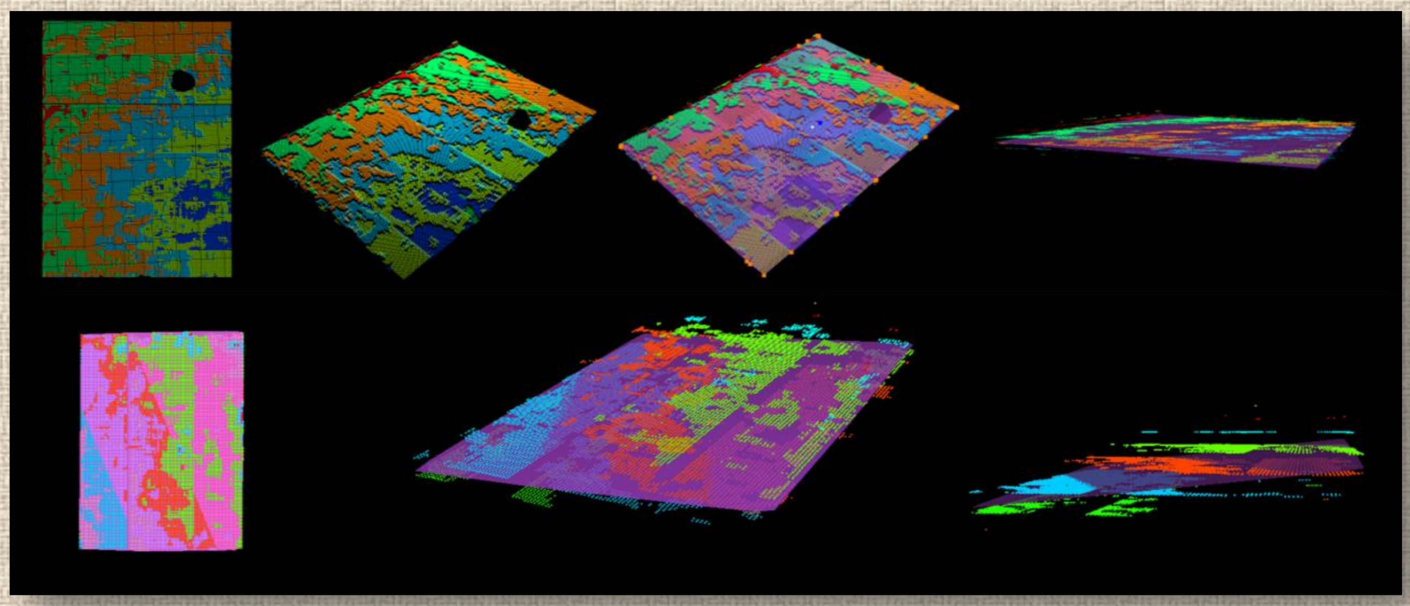
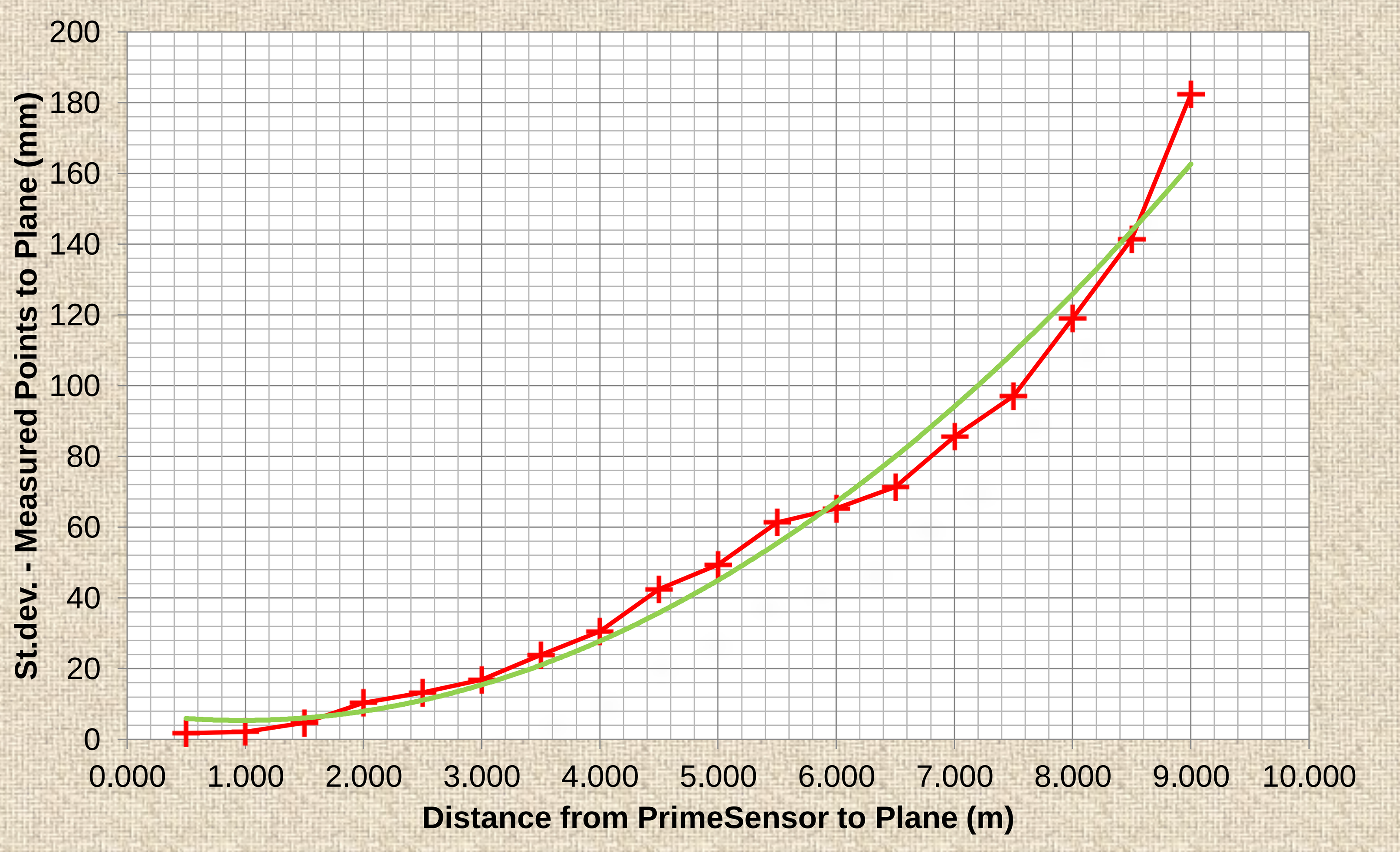


Chart 1. Standard Deviation of Measured Points to Best Fit Plane



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