Depth Measurement using Phase Shifting Interferometry
- a vision structured light system for 3D head tracking

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Abstract

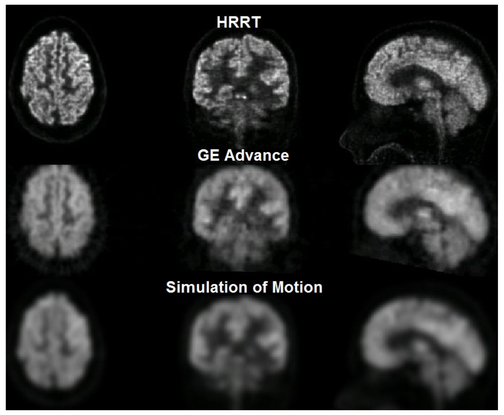
A new proposal of a 3D head tracking system for high resolution PET brain imaging is demonstrated. A prototype of a tracking system based on structured light is setup on a model of the HRRT PET scanner. Methods to reconstruct a 3D point cloud of simple surfaces based on phase-shifting techniques are implemented. A calibration of the system is partly implemented.

Motivation

Patient movements are damaging for the image quality especially for high resolution PET scanners.

The special dedicated brain scanner, High Resolution Research Tomograph (HRRT) has a resolution down to 1.4mm. Serious errors may therefore occur on high resolution PET brain images, if no corrections for patient head movements are performed.

An external tracking system is needed to register the position of the patient during the scanning.



Comparison of the HRRT PET brain scanner (Top) and a normal clinical scanner, GE Advance (center).

Bottom: simulation of a slow motion during the PET acquisition (Gauss filtration of HRRT images).

Setup

A vision system of a DLP projector and a CCD camera has been setup on a HRRT scanner model. The camera and projector are connected to a PC and synchronized through software controlled from Matlab.

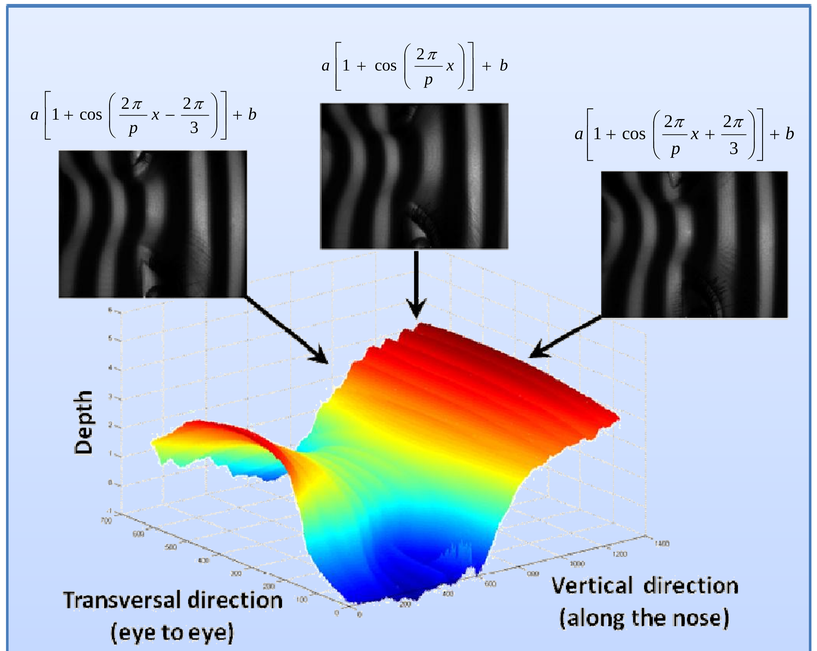
The projector projects patterns onto the face of a mannequin head or a reference plate and the CCD captures images of the projected patterns.

Four patterns are captured for each point cloud reconstruction. Three shifted

sinus patterns and a center line cross to generate an absolute phase-map.

Three Phase-Shift Interferometry

Phase-shifting interferometry is a method to find the depth of 3D objects. Corresponding CCD pixels and lines on the DMD (digital micromirror device) are associated by the absolute phase-map.



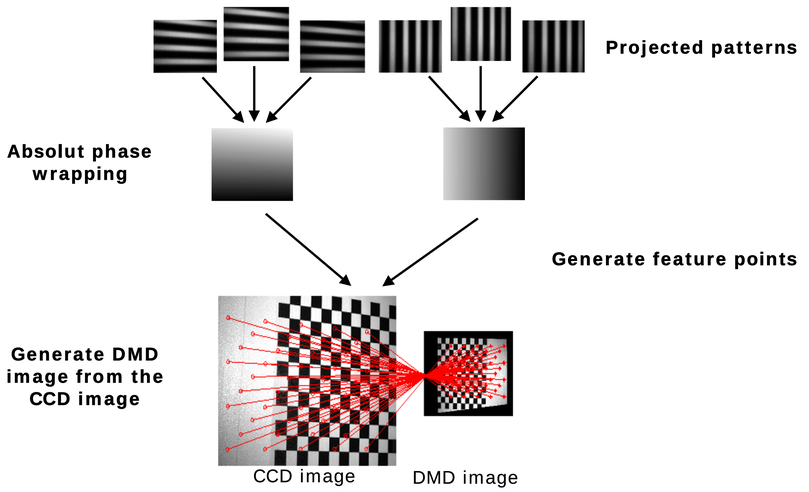
1. **Patterns generation**
2. **Patterns capture** $I_k(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y)+\delta_k]$
3. **Phase wrapping** $\phi(x,y) = \tan^{-1}\left(\sqrt{3}\frac{I_1(x,y)-I_3(x,y)}{2I_2(x,y)-I_1(x,y)-I_3(x,y)}\right)$
4. **Phase unwrapping**
5. **Phase-map to 3D coordinates conversion**

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = A^{-1}b$$

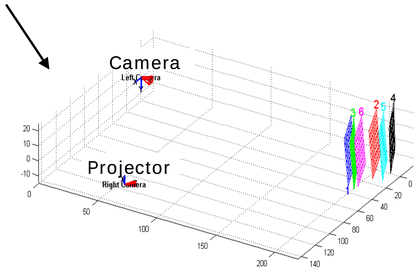
where *A* and *b* are linear combinations of the calibration parameters.

System Calibration

The stereo calibration between the camera and the projector is obtained by creating images that look like they have been grab by the projector (DMD image). The camera images of the calibration object is warped from the camera CCD location to the projector DMD location, using the three phase-shifting method on a set of vertical and horizontal patterns.



A standard stereo camera calibration can then be obtained from a set of CCD and DMD images.



Conclusion

A 3D head tracking prototype was setup and tested. The principal of the phase-shifting method for reconstruction of 3D points clouds was demonstrated.

References

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