3D Photography Using Shadows

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Goal: 3D reconstruction
State of the art

• Accurate
• Bulky
• Complicated
• Cost: >10k$

Weak structured lighting system
The idea

The geometry

\[ \Pi = \cap (O, P) \cap \Pi \]
The geometry

\[ \Lambda = (O, \lambda) \cap \Pi_d \]
\[ \Pi = (S, \Lambda) \]
Spatio-temporal processing

Temporal processing

\[ t_p(p) = 133.27 \]

Spatial processing

\[ t_p(p) = 133.27 \]

\[ x_{ref} = 130.6 \]

Time \( t \)

Camera calibration

- Position of the desk plane
- Internal parameters of the camera

Camera calibration

[Tsai’87, Abdel-Aziz and Karara’71]
Lamp calibration

Vertical plane calibration

\[ \{\Pi_d, \lambda_l\} \rightarrow \Pi_v \]
Angel experiment

Accuracy: 0.1mm over 10cm ~ 0.1% error

Skull experiment

Accuracy: 0.1mm over 10cm ~ 0.1% error
Textured objects

Other objects
Pot-pourri scan

Accuracy: 0.5mm over 50cm ~ 0.1% error

Scanning with the sun

Accuracy: 1mm over 50cm ~ 0.5% error
Scanning with the sun

Accuracy: 1cm over 2m
~ 0.5% error

Error analysis

\[ \sigma_Z^2 \propto \frac{1}{d^2} \cdot \frac{1}{\nabla I^2} \cdot \sigma_l^2 \]

- Variance of the error in depth estimate
- \( d \): distance of the shadow plane \( \Pi \) to the camera optical center
- \( \nabla I \): shadow edge sharpness (image gradient)
- Image brightness noise

[Bouguet'99]
Real-time implementation

- **Performance**: 30Hz, 320x240, Pentium II 300MHz
- **Single shadow pass**: 20 - 30 seconds (600-900 frames)
- **Refined scanning**: 1 - 2 minutes

Conclusions

- ✔ Low cost and simple technique for dense 3D shape acquisition
- ❌ Does not work with specular or dark objects
What’s next?

• Registration of multiple scans complete models [Turk’94, Curless’96]

References (1)

Space-time analysis:

• B. Curless and M. Levoy, “Better optical triangulation through spacetime analysis”, ICCV95, pages 987-993, June 1995

Camera calibration:

References (2)

Multiple view registration:

• B. Curless and M. Levoy, “A volumetric method for building complex models from range images”, SIGGRAPH ’96, 1996

Shadow scanning:

  available at: http://www.vision.caltech.edu/bouguetj/ICCV98/
  available at: http://www.vision.caltech.edu/bouguet/

References (3)

Related work on shape from shadows: