

Unsynchronized Structured Light

for 3D scanning

Daniel Moreno Fatih Calakli Gabriel Taubin









Cameras are omnipresent



Pattern Projector + Camera = 3D Sensor



KDBE

Structured Light



Sponsored by

KOBE

Synchronized projection and capture



Without Synchronization





Rolling Shutter Cameras





Structured Light Algorithms



- Existing algorithms fail to correctly binarize





Unsynchronized Structured Light





Model Variables







Unsynchronized Model





Algorithm Steps





Estimate t_e, t_f, t_r, and t₀ Estimate pattern values: P₁, ..., P_M





(1) Time Variables Estimation



We make P₁, ..., P_M known by adding a constant color pattern subsequence





(1) Time Variables Estimation



- We minimize this energy:

$$E(t_e, t_f, t_r, t_0) = \frac{1}{2} \sum_{n} \sum_{x,y} \left[P(x, y)^T V_{ny} h(t_e, t_f, t_r, t_0) - I_n(x, y) \right]^2$$

- Constrained Non-Linear Minimization
- Example initial values:

$$t_e = 1, \ t_f = 1.1 t_e, \ t_r = 0.0001, \ t_0 = 0.5$$



(1) Timing Calibration Result











Image 1





SIGGRAPH

ASIA 2015

KDBE

Calibrated Model





Sponsored by

SA2015.SIGGRAPH.ORG

(2) Pattern Values



Regularized Linear Energy Minimization:

$$E(P) = \frac{1}{2} \sum_{n=1}^{N} \left[h^{T} V_{ny}^{T} P(x, y) - I_{n}(x, y) \right]^{2}$$
$$+ \frac{\lambda}{2} \sum_{m=1}^{M} P_{m}(x, y) \left[1 - P_{m}(x, y) \right]$$
$$- 0 < P_{m} < 1$$
$$- 1 \text{Independent for each pixel}$$

Results: decoded patterns



Input Image Sequence



Output Pattern Sequence



Results: decoded patterns





Comparison with Synchronized SL









Result: Example 3D Model





Limitations: global illumination







SA2015.SIGGRAPH.ORG

Summary



- SL without software/hardware synchronization
- Global and rolling shutter cameras
- Results comparable to synchronized
 SL
- Global Illumination is a challenge
- Application: enable cell phones and cameras to operate as 3D cameras

Thank you!





Daniel Moreno

daniel_moreno@brown.edu

fatih_calakli@brown.edu

Fatih Calakli

Gabriel Taubin

taubin@brown.edu





SA2015.SIGGRAPH.ORG

Thank you!





Daniel Moreno: daniel moreno@brown.ed U Fatih Calakli: fatih calakli@brown.edu Gabriel Taubin: taubin@brown.edu



