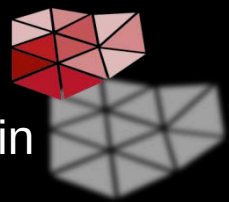
Uwe Hahne and Marc Alexa

DEPTH IMAGING BY COMBINING TIME-OF-FLIGHT AND ON-DEMAND STEREO

Computer
Graphics
TU Berlin

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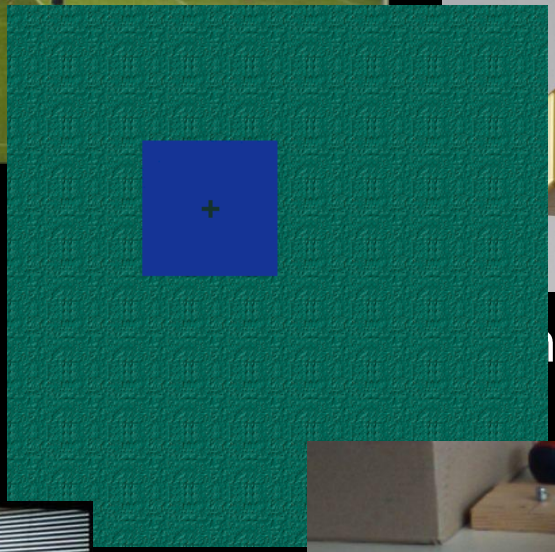
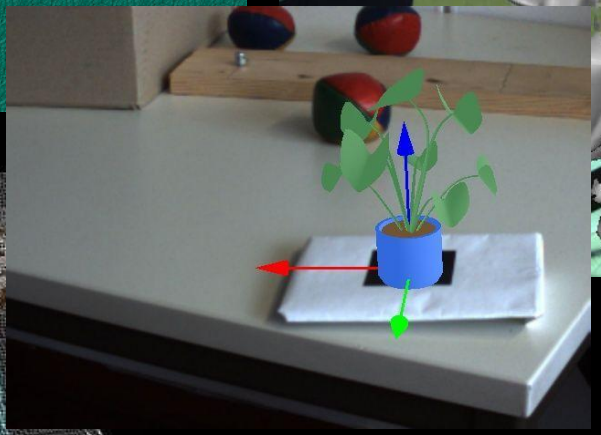
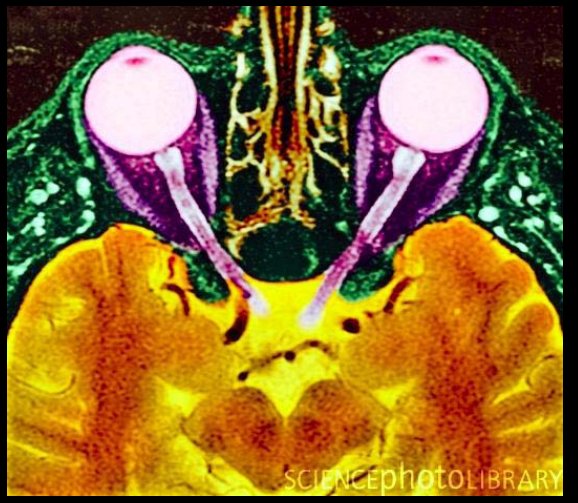


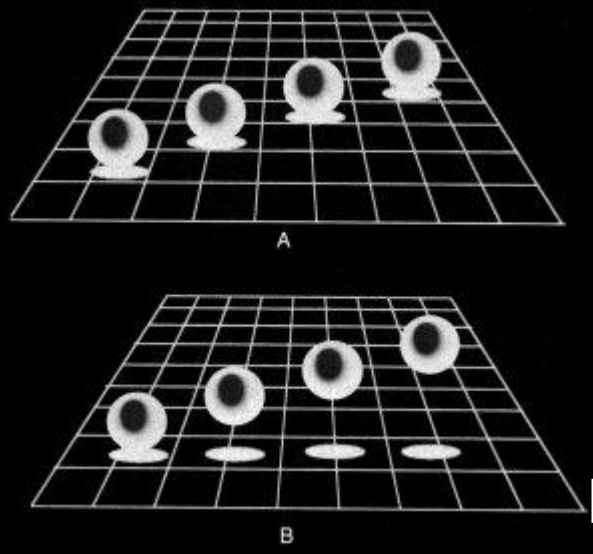


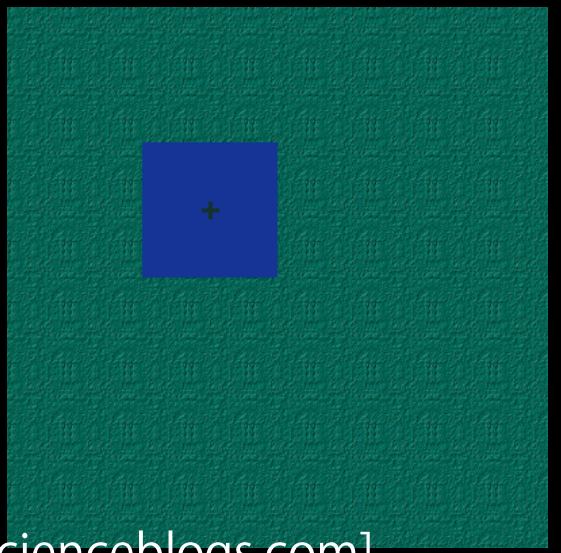
How do humans percept depth?

- Stereo optics
- Brain+memory
- Motion
- Monocular depth cues
  - e.g. occlusion

  and shadows

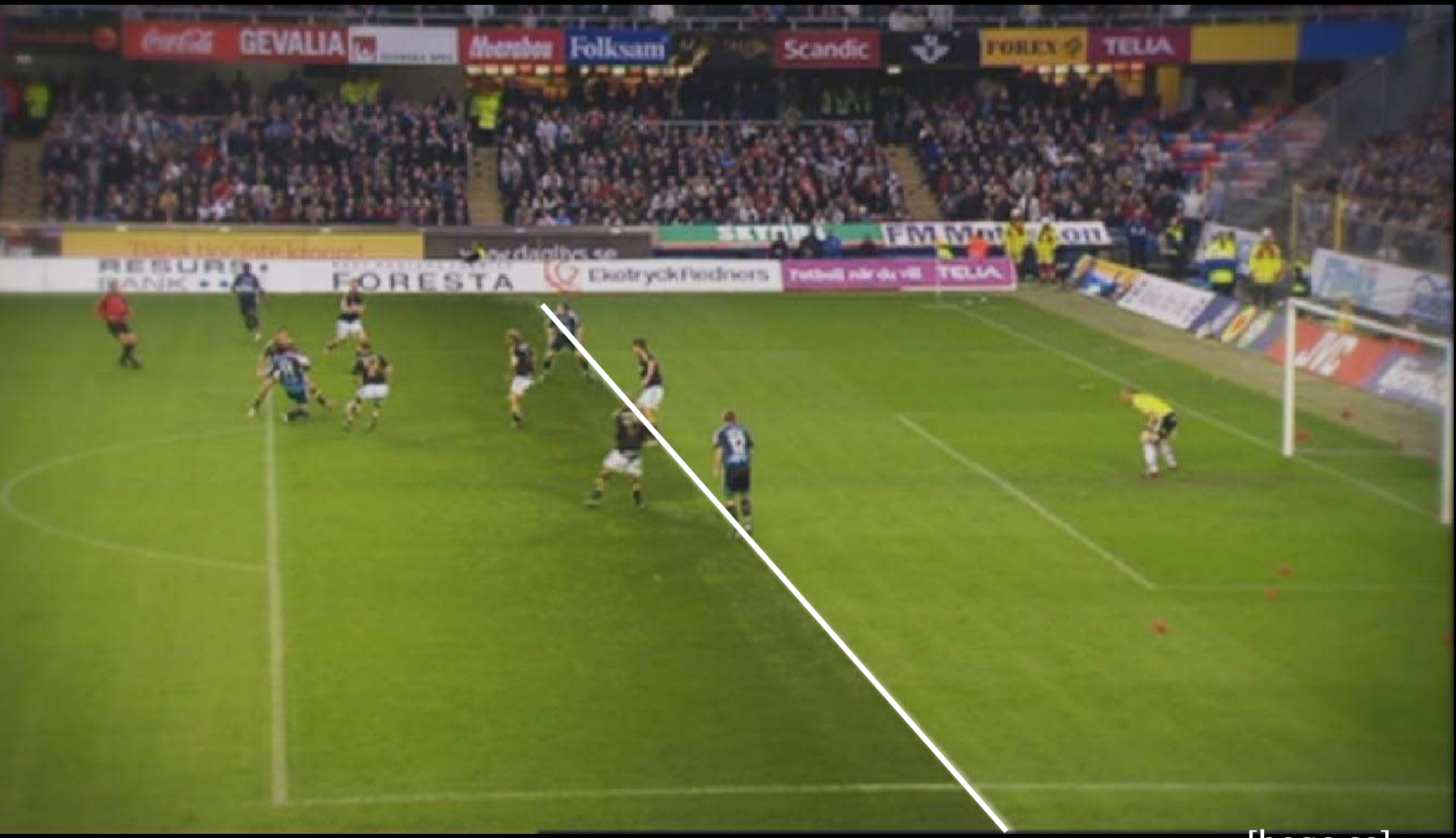






[scienceblogs.com]

Depth in TV



[hego.se]

Depth in Augmented Reality

[janfischer.com]

Going beyond reality

Technical realization

SETUP

Cameras in comparison

Stereo

- Human like vision
- Long history of algorithms
- Medium resolution
- Low dynamic range
- Fails for textureless regions
- Problems through semi-occlusion

Time-of-flight

- Bat like vision
- Still in development
- Very small resolution
- Active illumination
- Best for textureless regions
- Prefers diffuse reflecting objects

→ Fusion in order to balance properties

Setup

Camera fusion

- done by:

- [BBK07] Christian Beder, Bogumil Bartczak, and Reinhard Koch. A combined approach for estimating patchlets from PMD depth images and stereo intensity images. In F.A. Hamprecht, C. Schnörr, and B. Jähne, editors, Proceedings of the DAGM 2007, number 4713 in LNCS, pages 11–20. Springer, 2007.
- [GAL07] S. Guðmundsson, H. Aanæs, and R. Larsen. Fusion of stereo vision and time-of-flight imaging for improved 3D estimation. In International workshop in Conjunction with DAGM'07: Dynamic 3D Imaging., volume 1, pages 164–172, sep 2007.
- [HA07] Uwe Hahne and Marc Alexa. Combining time-of-flight depth and stereo images without accurate extrinsic calibration. In International workshop on Dynamic 3D Imaging,pages 78–85, Heidelberg, September 2007.
- [KS06] Klaus-Dieter Kuhnert and M. Stommel. Fusion of stereo-camera and pmd-camera data for real-time suited precise 3d environment reconstruction. In IEEE/RSJ International Conference on Intelligent Robots and Systems, pages 4780–4785, October 2006.
- [LKH07] M. Lindner, A. Kolb, and K. Hartmann. Data-fusion of pmd-based distance information and high-resolution rgb-images. In International Symposium on Signals, Circuits and Systems (ISSCS), 2007.
- [LLK07] M. Lindner, M. Lambers, and A. Kolb. Sub-pixel data fusion and edge-enhanced distance refinement for 2d/3d images. In Dynamic 3D Imaging (Workshop in Conjunction with DAGM'07), Heidelberg, Germany, September 2007.
- [NMCR08] C. Netramai, O. Melnychuk, J. Chanin, and H. Roth. Combining pmd and stereo camera for motion estimation of a mobile robot. In The 17th IFAC World Congress July, 2008. accepted.
- [Reu06] R. Reulke. Combination of distance data with high resolution images. In ISPRS Commission V Symposium 'Image Engineering and Vision Metrology', 2006.
- [ZWYD08] Jiejie Zhu, Liang Wang, Ruigang Yang, and James Davis. Fusion of time-of-flight depth and stereo for high accuracy depth maps. In IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR), 2008.

Technical realization

ALGORITHM

Algorithm

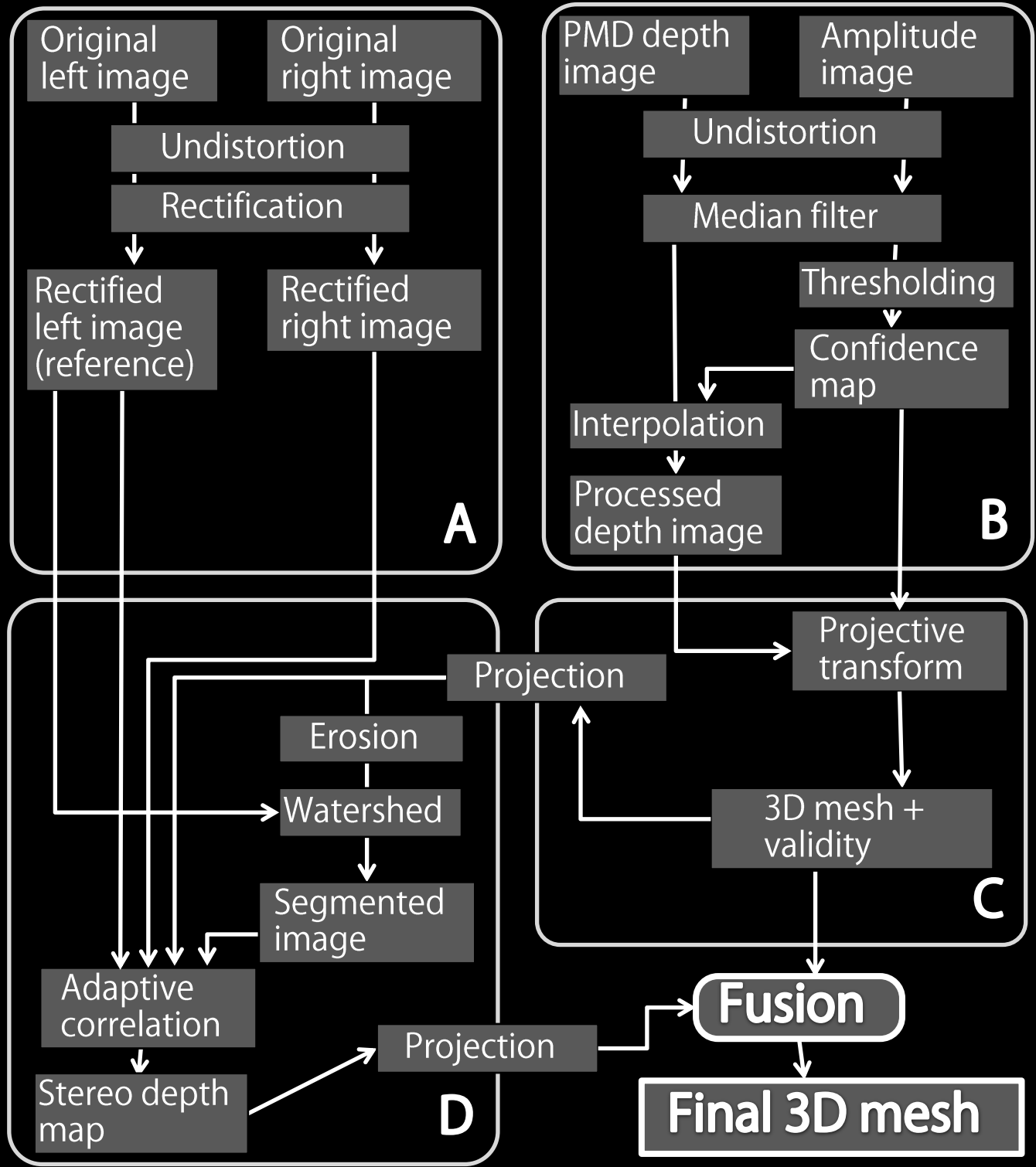
A: Stereo cam

B: PMD cam

C: 3D data

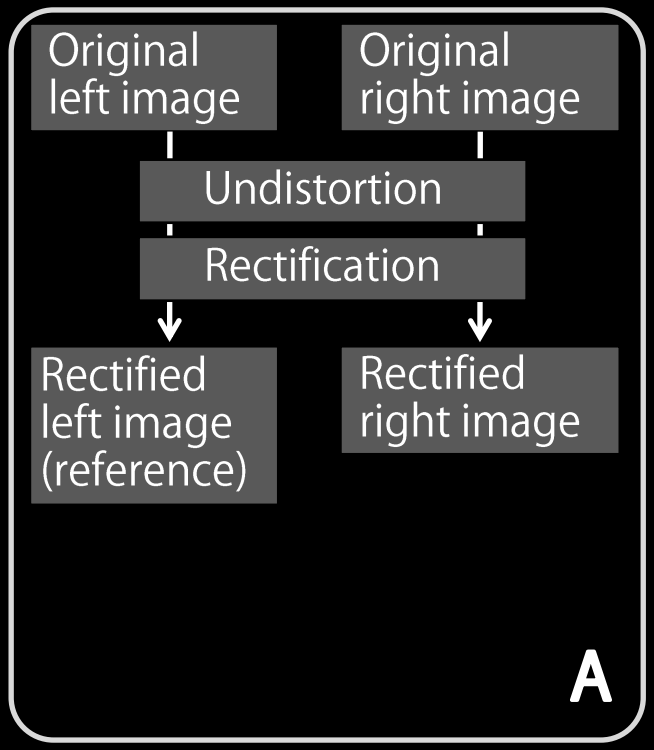
D: Color image

→ Fusion



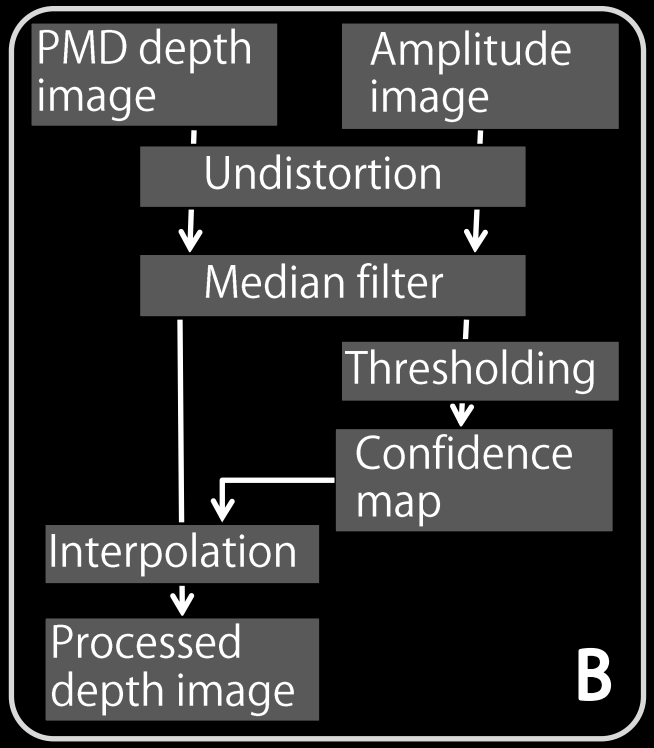
Algorithm

A: Stereo cam



- Using a PointGrey Bumblebee2
  - → it all comes for free

Algorithm



B: PMD camera

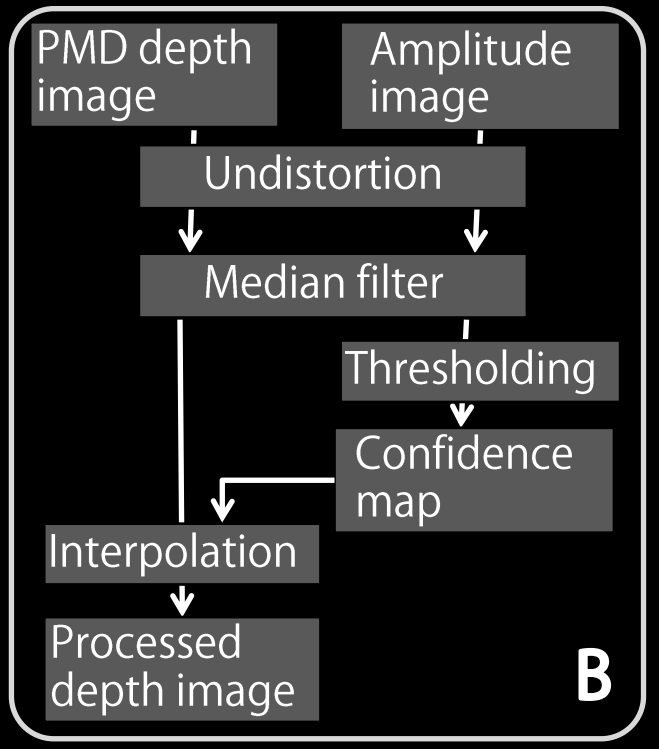
- Filtering
- Use amplitude as **confidence value**

depth image

amplitude image

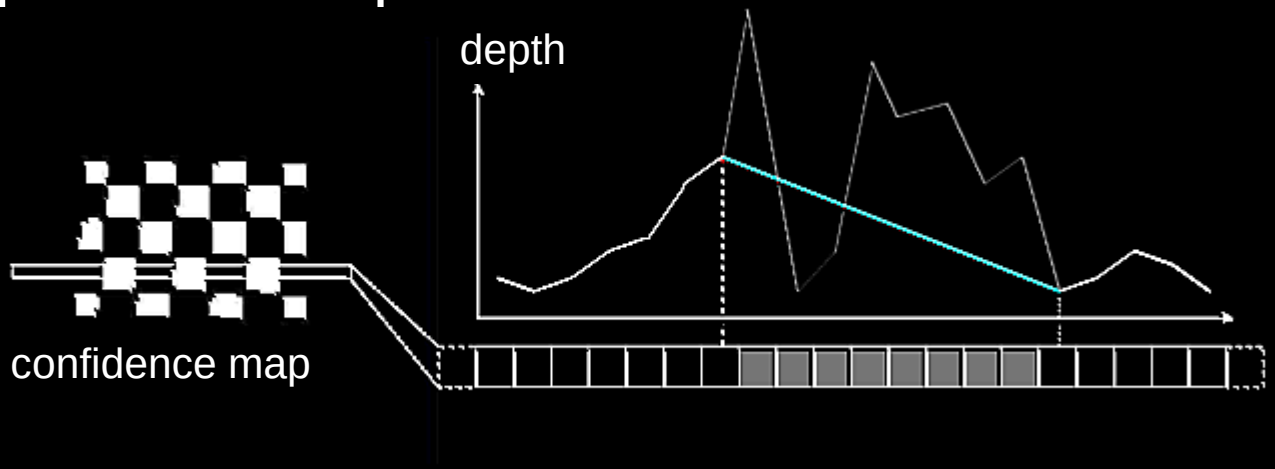
binary confidence map

Algorithm

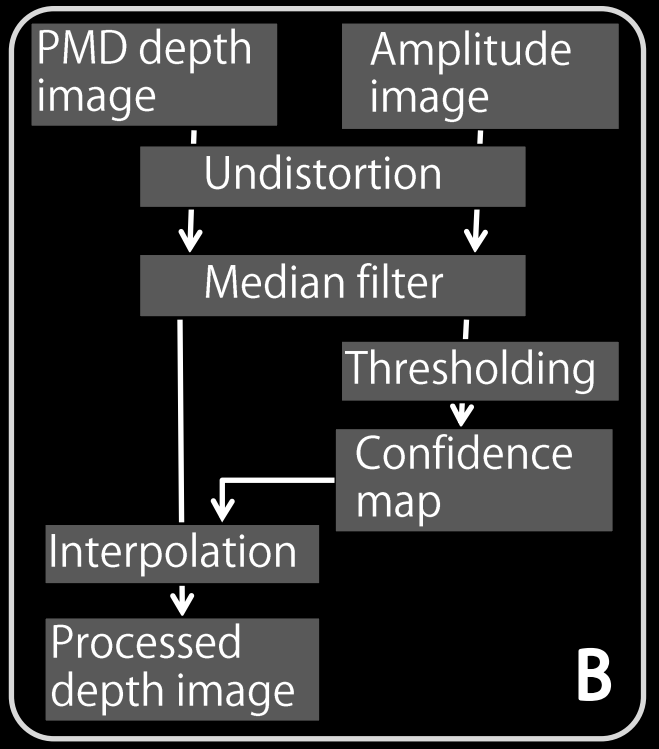


B: PMD camera

- Filtering
- Use amplitude as **confidence value**
- Interpolate bad pixels



Algorithm



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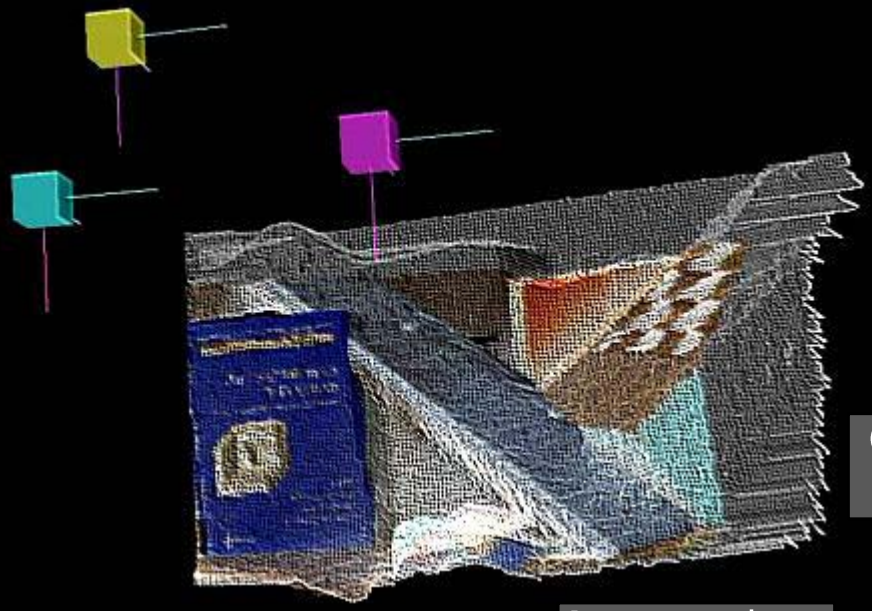
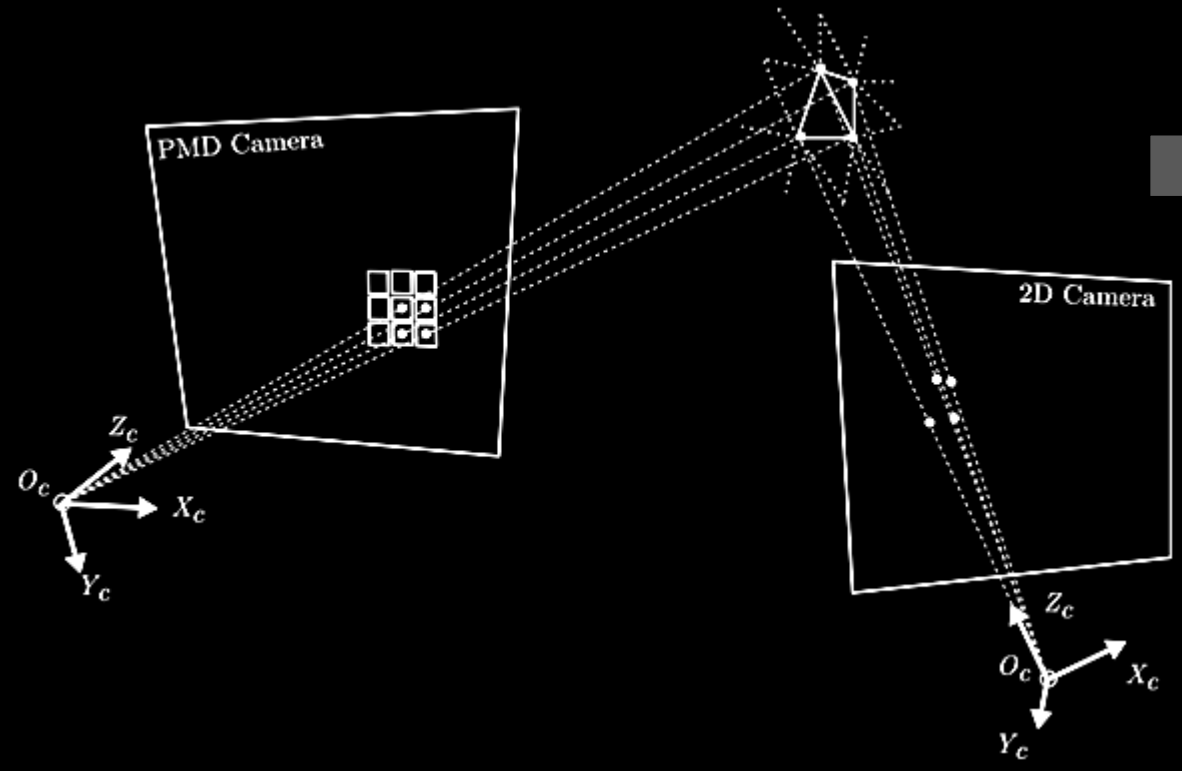
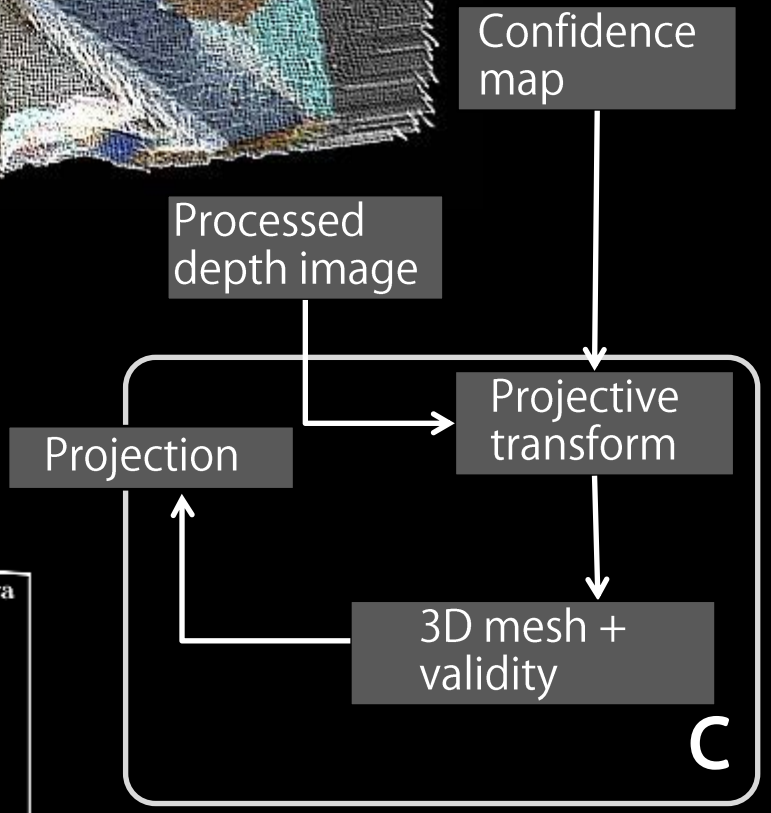
Algorithm



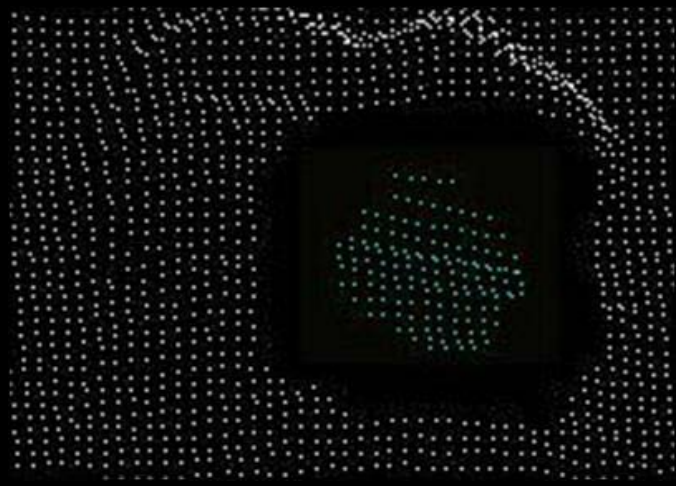
C: 3D data

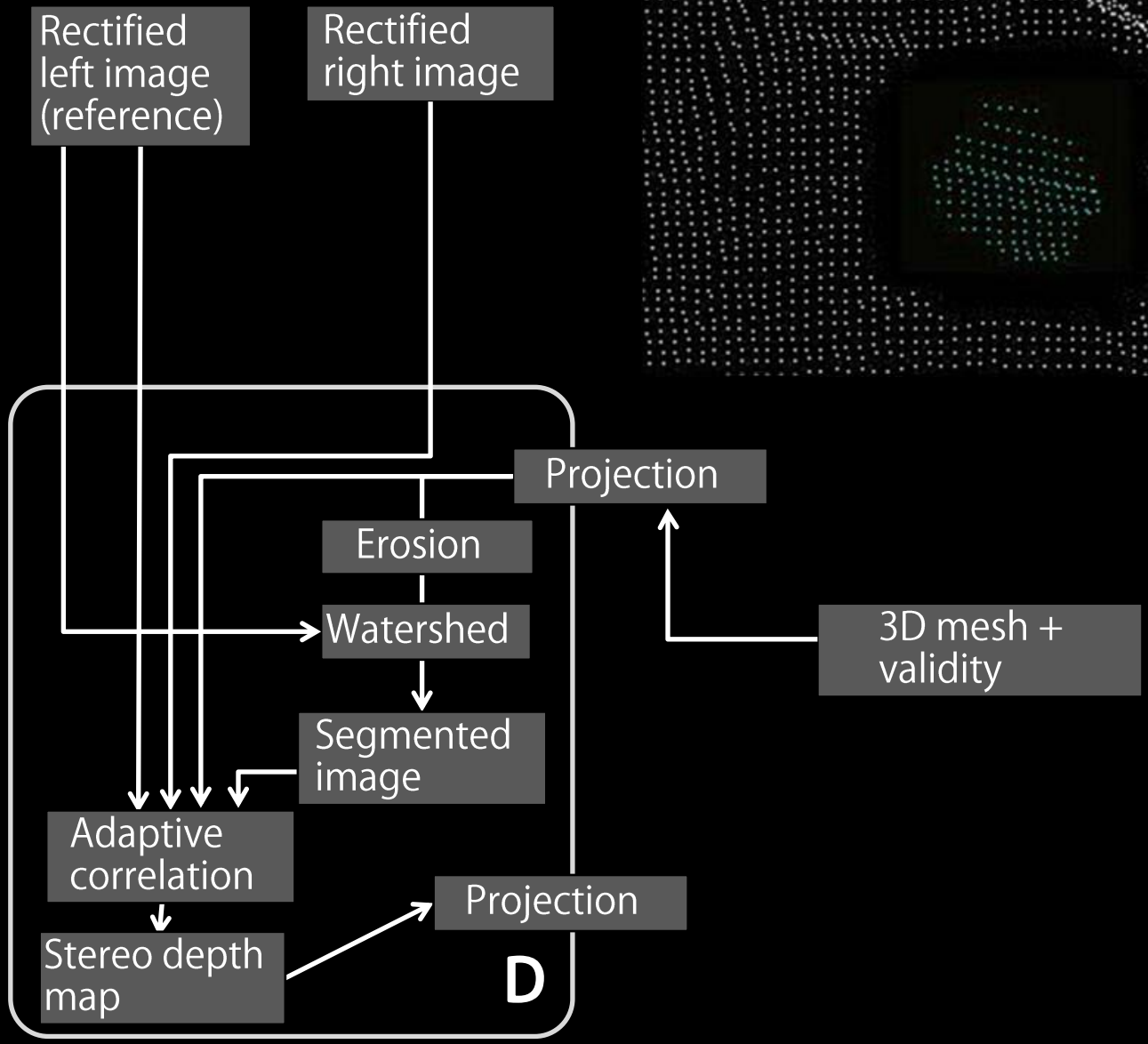




Algorithm

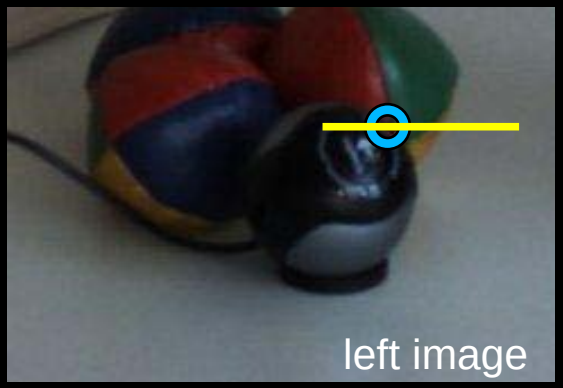
D: Color image

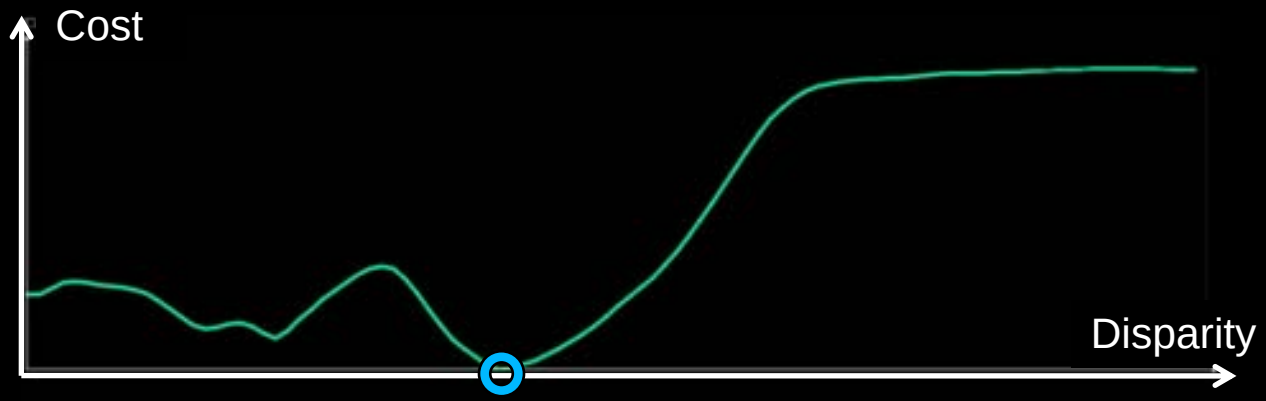




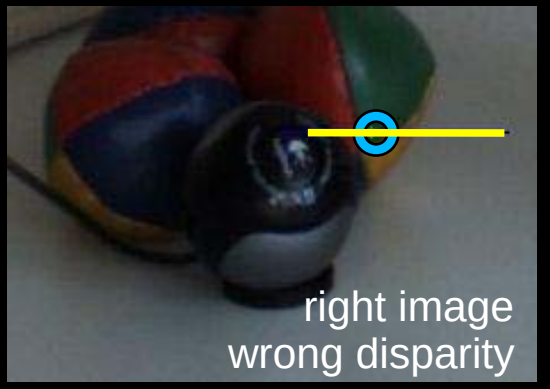
Algorithm

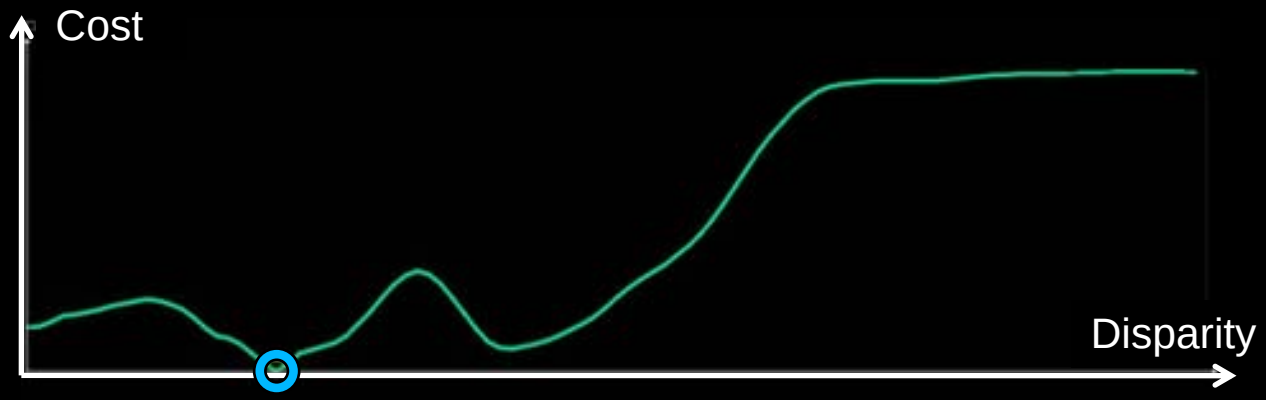
- On-demand stereo



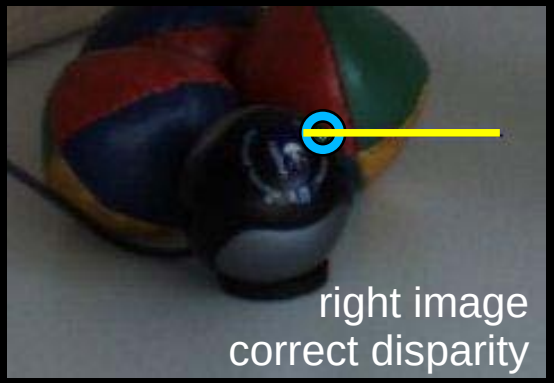


Static correlation window



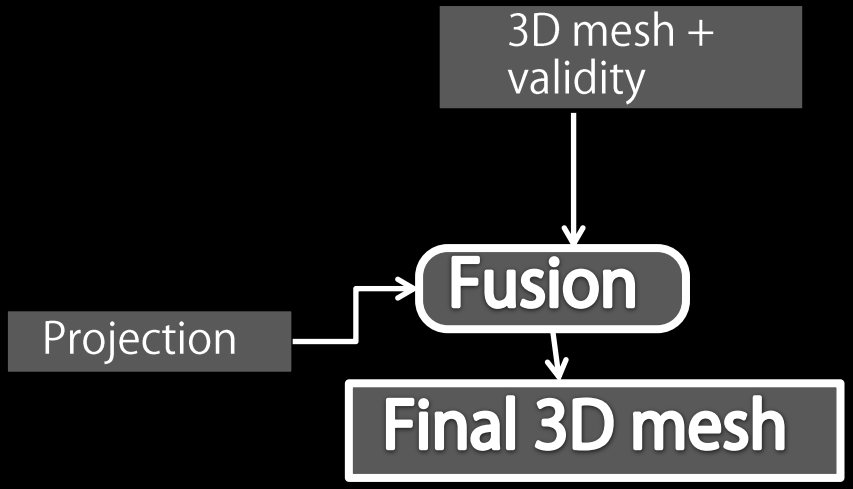


Adaptive correlation window



Algorithm

→ Fusion



Technical realization

RESULTS

More realism...

Occlusions

interactions...

Collisions

and applications.

Painting Interaction

Conclusions and future work

RESULTS

Still work to do...

- Stereo on demand can ressolve problems with higly textured regions
- PMD captures depth where stereo does not work in principle
- Exact fusion is hard through different error characteristics
- Find a confidence measure for depth from stereo
- Find more overlaps where both systems can support each other

Thanks to Antoine Mischler.

Thank you for listening.

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