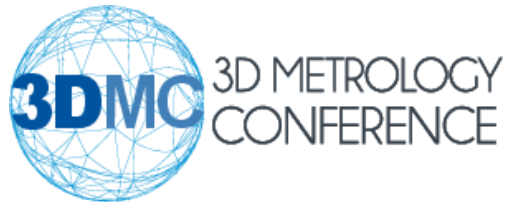


Image-based Measurement of Concrete Surface Roughness

Barış Özcan, Raimund Schwermann, Jörg Blankenbach, Thomas Fischer





3DMC - Hamburg
17th October 2018



Outline

1. Introduction to Roughness
2. Research Project: Image-based measuring system
 - Structure from Motion
 - Dense Image Matching
3. Conclusion

Arrangement system for shape deviations (DIN 4760)

Gestaltabweichung (als Profilschnitt überhöht dargestellt)	Beispiele für die Art der Abweichung	Beispiele für die Entstehungsursache
1. Ordnung: Formabweichungen 	Geradheits-, Ebenheits-, Rundheits- Abweichung, u.a.	Fehler in den Führungen der Werkzeugmaschine, Durchbiegung der Maschine oder des Werkstückes, falsche Einspannung des Werkstückes, Härteverzug, Verschleiß
2. Ordnung: Welligkeit 	Wellen (siehe DIN 4761)	außermittige Einspannung, Form- oder Laufabweichungen eines Fräasers, Schwingungen der Werkzeugmaschine oder des Werkzeuges.
3. Ordnung: Rauheit 	Rillen (siehe DIN 4761)	Form der Werkzeugschneide, Vorschub oder Zustellung des Werkzeuges
4. Ordnung: Rauheit 	Riefen Schuppen Kuppen (siehe DIN 4761)	Vorgang der Spanbildung (Reißspan, Scherspan, Aufbauschneide), Werkstoffverformung beim Strahlen, Knospenbildung bei galvanischer Behandlung
5. Ordnung: Rauheit Anmerkung: nicht mehr in einfacher Weise bildlich darstellbar	Gefügestruktur	Kristallisationsvorgänge, Veränderung der Oberfläche durch chemische Einwirkung (z. B. Beizen), Korrosionsvorgänge
6. Ordnung: Anmerkung: nicht mehr in einfacher Weise bildlich darstellbar	Gitteraufbau des Werkstoffes	

Roughness

Parameters for Description

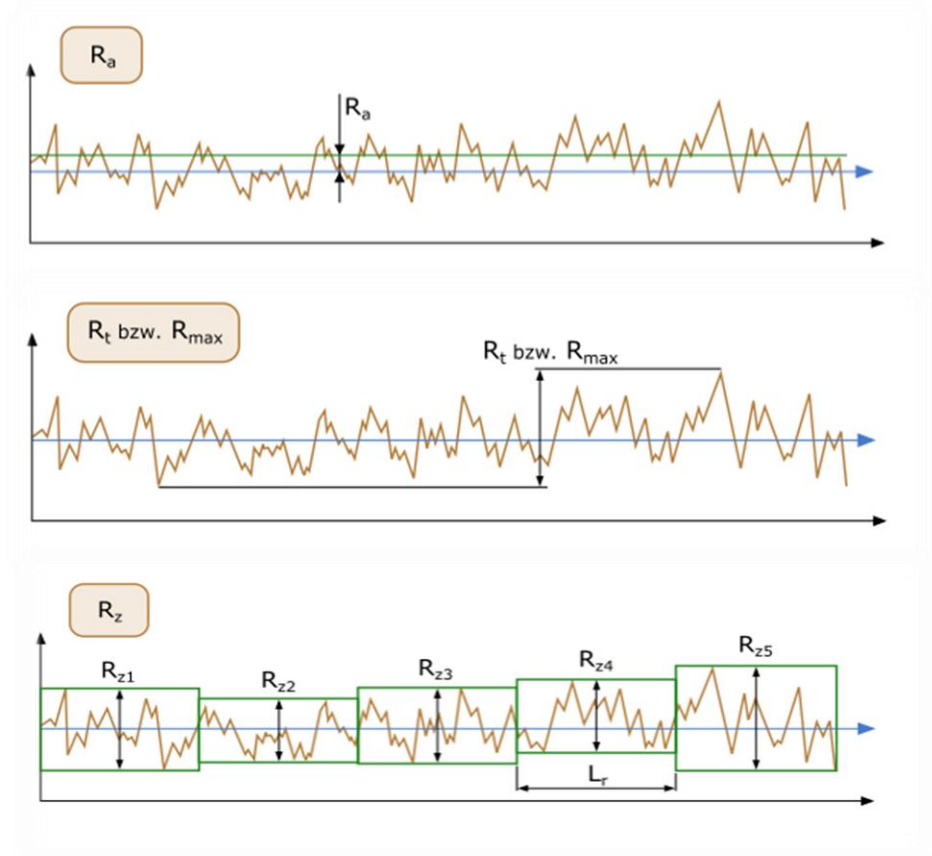
- Arithmetical mean height

$$R_a = \frac{1}{l} \sqrt{\int_0^l y(x) dx}$$

- Total height

- Mean height

$$R_z = \frac{1}{5} (R_{z1} + R_{z2} + R_{z3} + R_{z4} + R_{z5})$$

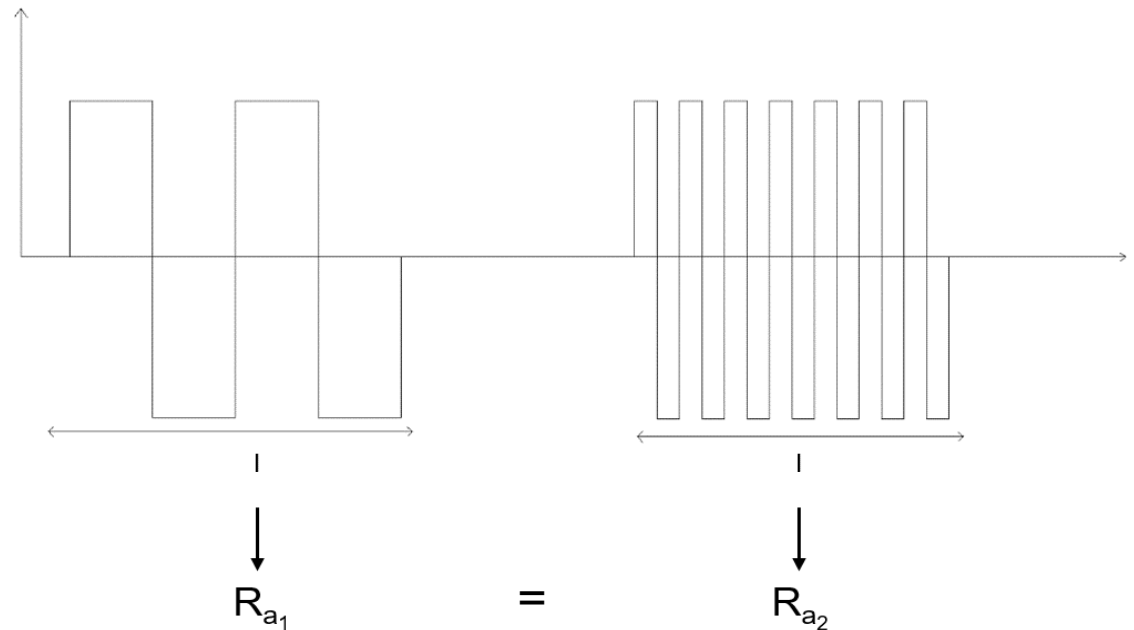


Roughness

Parameters for Description

- Arithmetical mean height

$$R_a = \frac{1}{l} \sqrt{\int_0^l y(x) dx}$$



But not same rough!

Roughness

Present Measuring Methods

- Sand patch test
- Skid depth gauge
- Laser triangulation
- Stylus instruments



$$R_{t\text{Kaufmann}} = \frac{4 \cdot V}{\pi \cdot d^2}$$

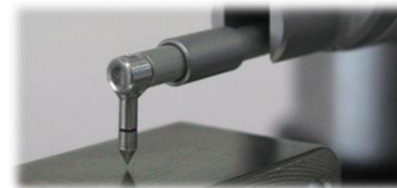
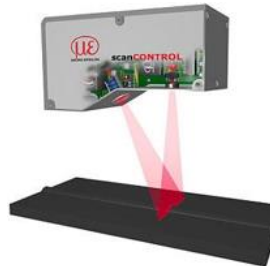


Image-based measuring system

Automatic Determination of Concrete Surface Roughness based on digital optical technology

in cooperation with our industrial partner



Nedo GmbH & Co. KG
Dornstetten

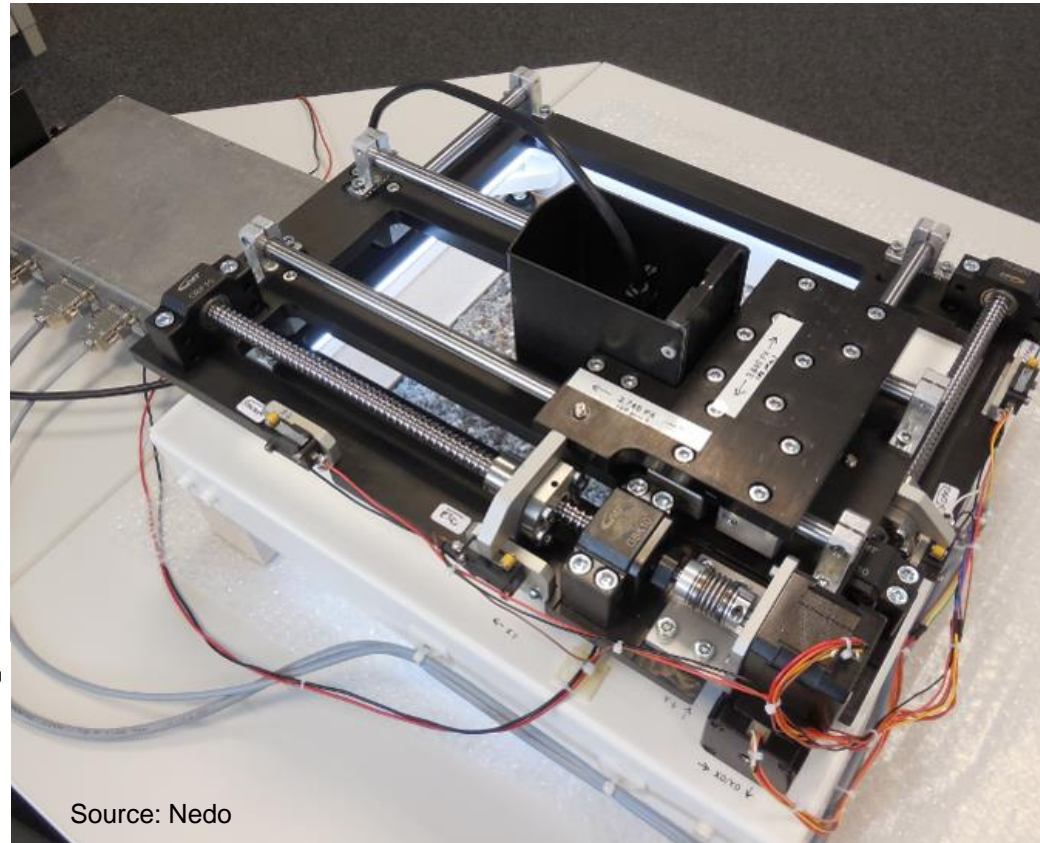


**Geodetic Institute
of RWTH Aachen**

Image-based measuring system

Automatic Determination of Concrete Surface Roughness based on digital optical technology

Hardware prototype:



Source: Nedo

Image-based measuring system

3D reconstruction

Initial tests with a DSLR with macro lens



3D reconstruction based on overlapping images

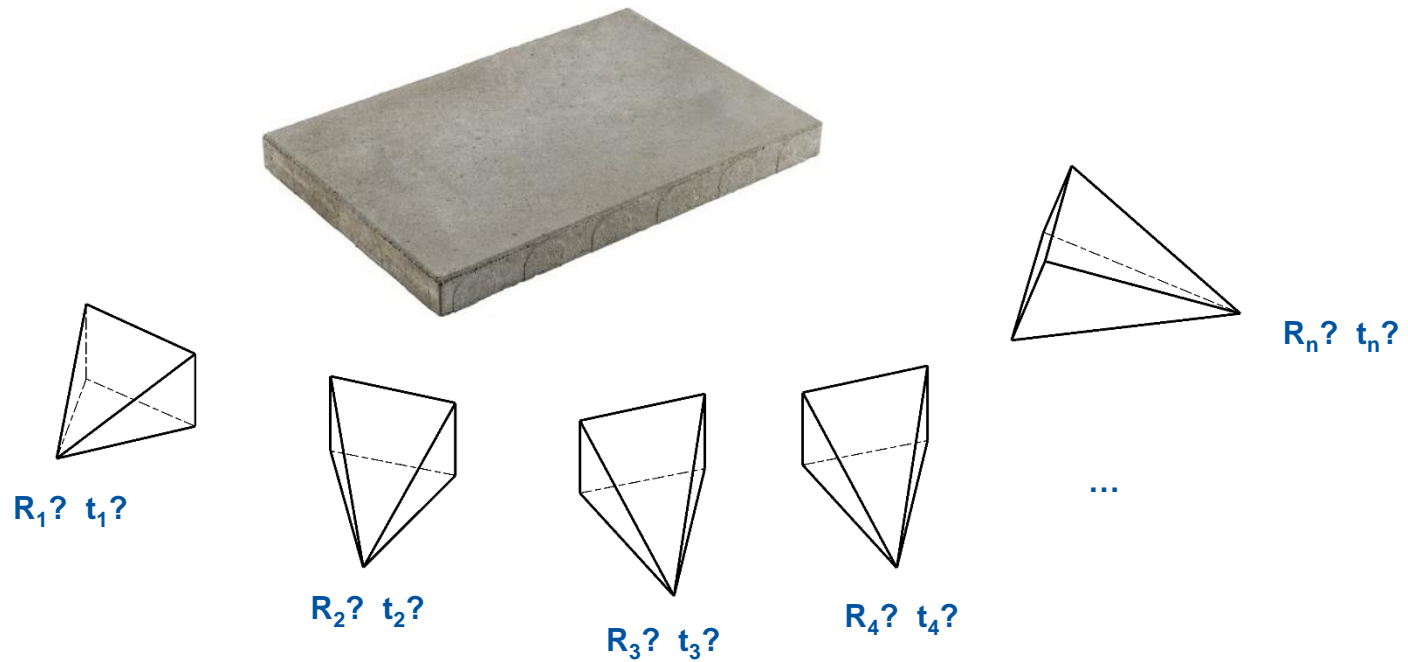
1. Structure from Motion (SfM)
2. Dense Image Matching (DIM)



Structure from Motion

Goal:

- Reconstruct the orientations of the cameras



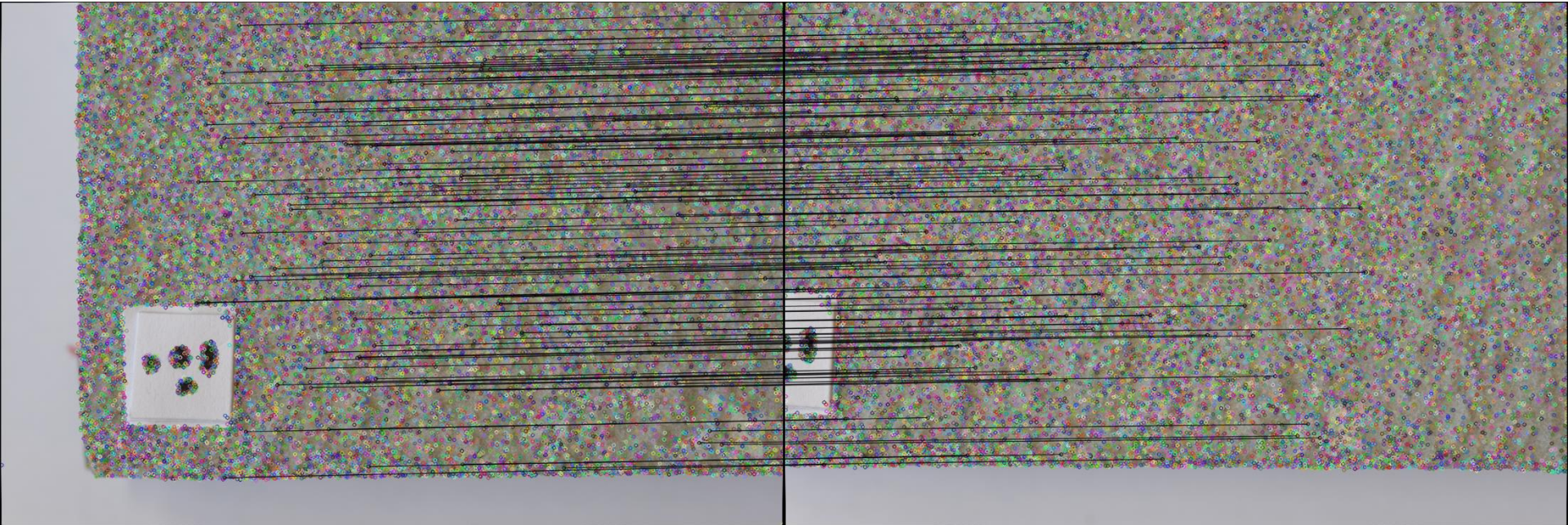
Structure from Motion

1. Feature Detection



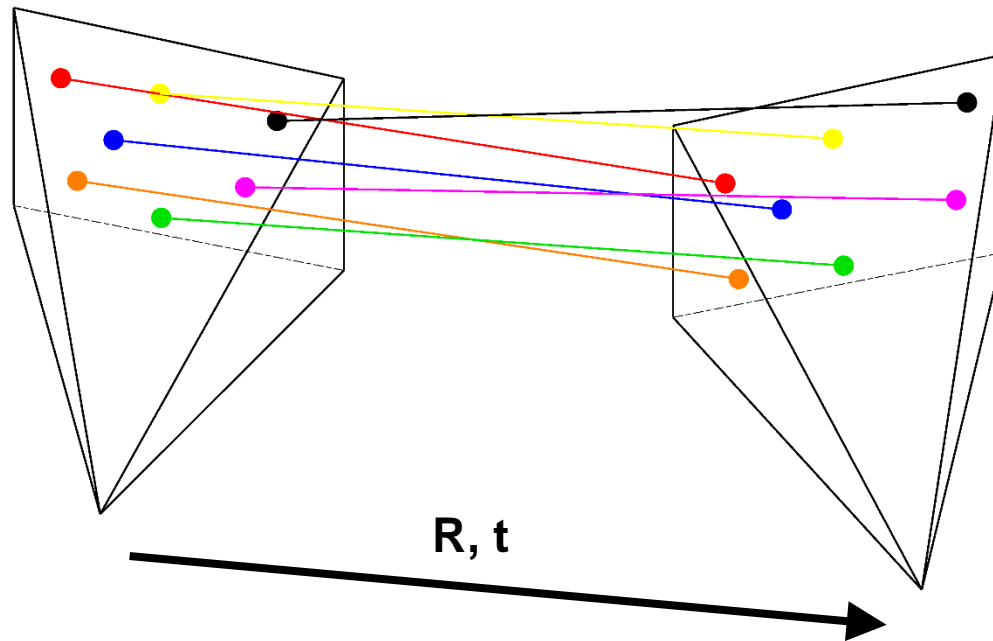
Structure from Motion

2. Feature Matching

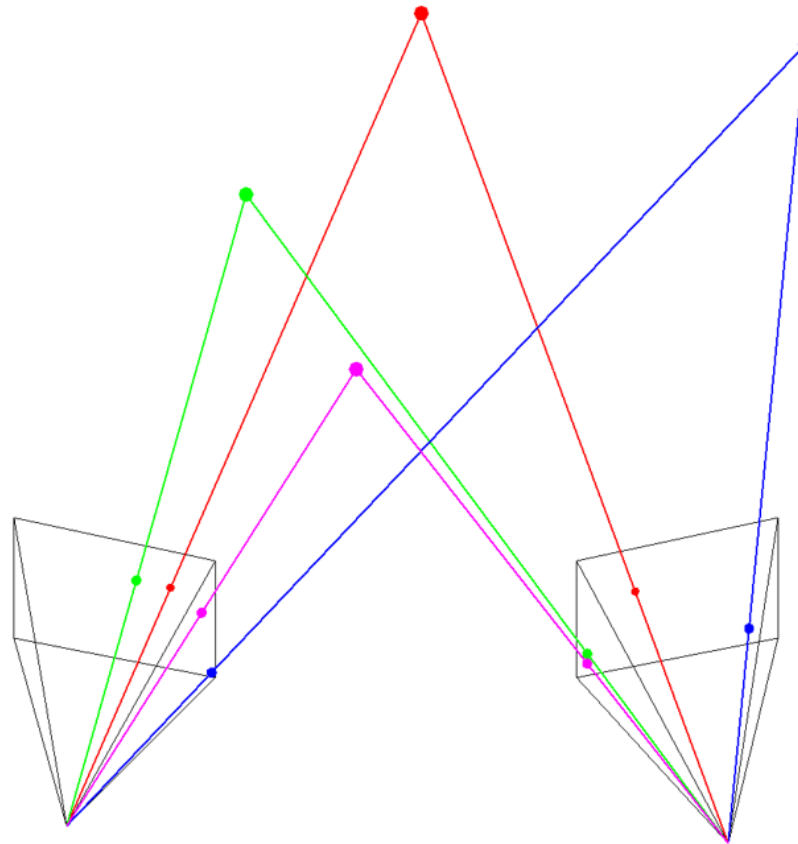


3. Calculation of the relative Orientation

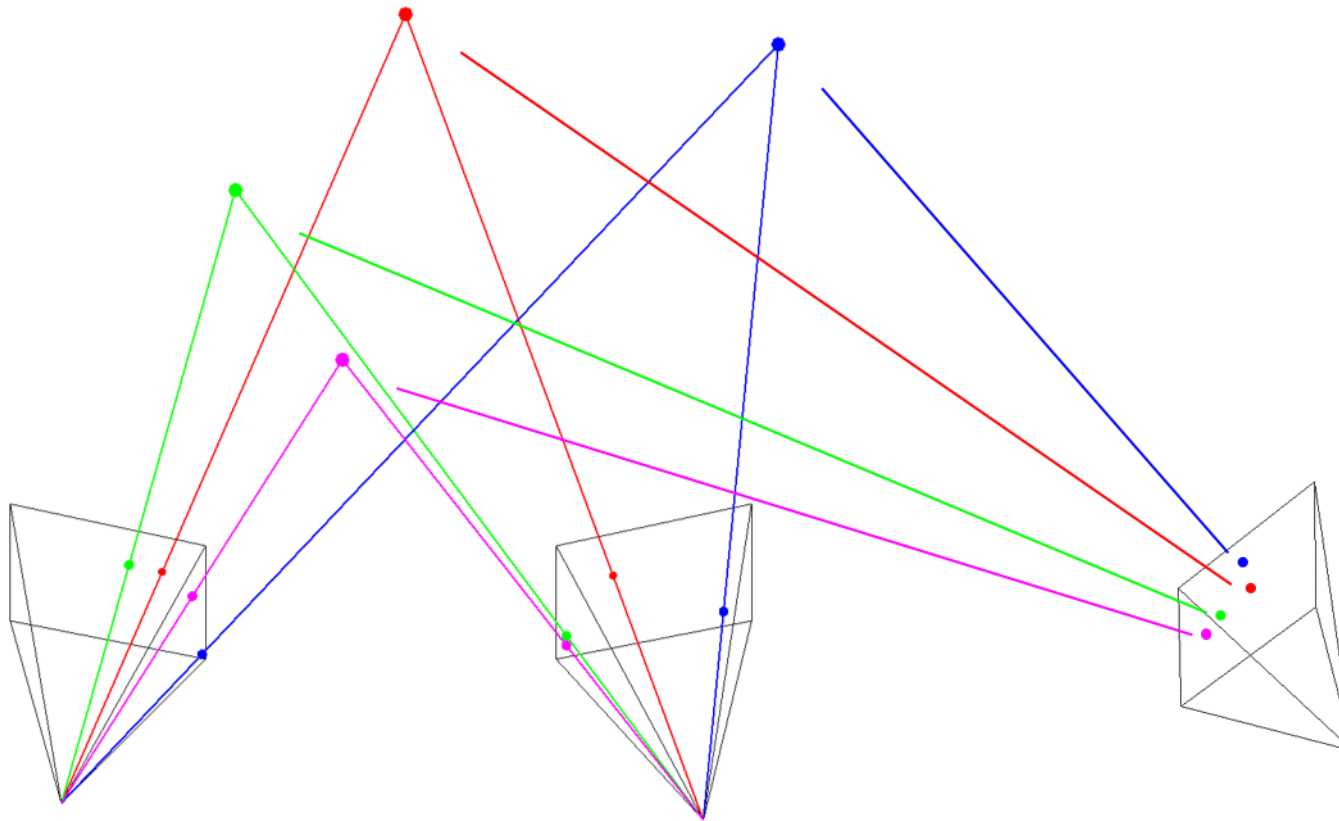
- i. Calculation of the fundamental matrix (or essential matrix)
- ii. Determining R, t



4. Triangulation

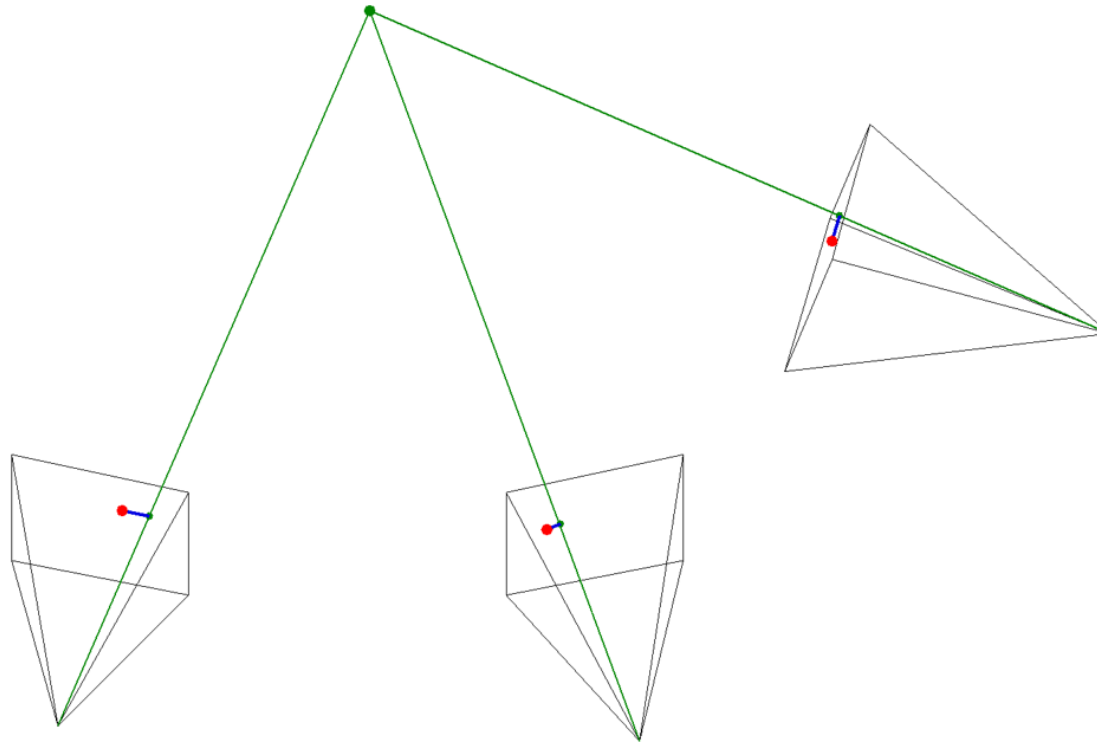


5. Pose Estimation / PnP Problem



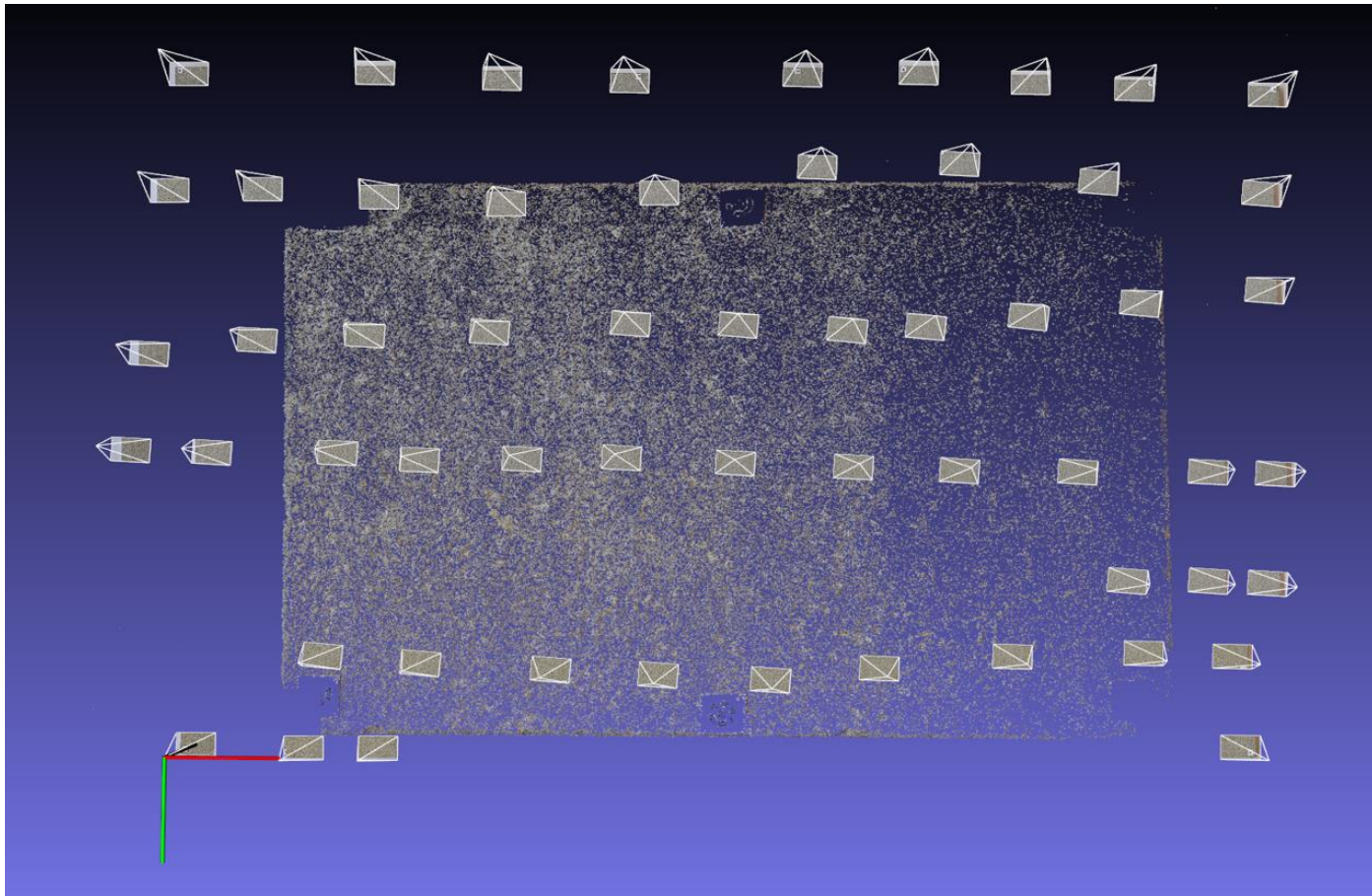
6. Bundle Adjustment

$$\min_{\hat{P}_i, \hat{X}_j} \sum_{i=1}^m \sum_{j=1}^n d(x_{ij}, \hat{P}_i, \hat{X}_j)^2$$



Structure from Motion

Outcome



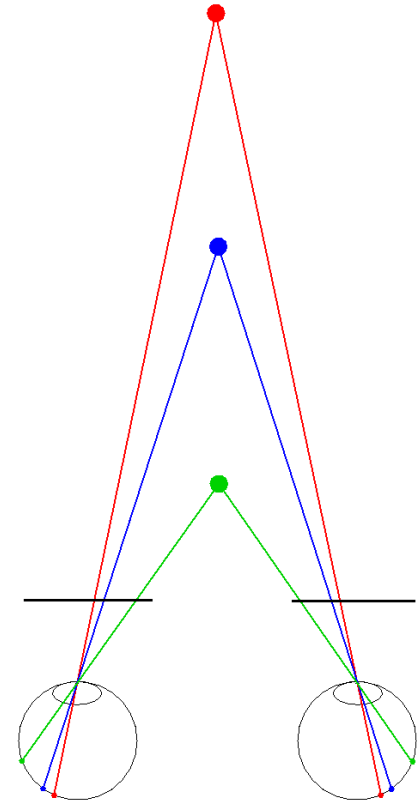
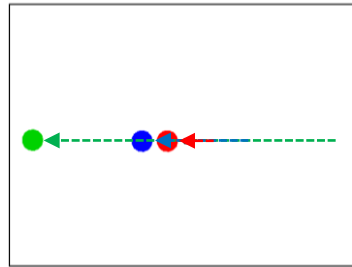
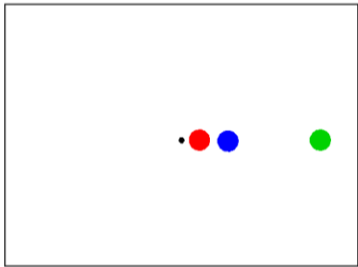
Dense Image Matching

Goal:

- Determine the depth for each image point of an image

Principle

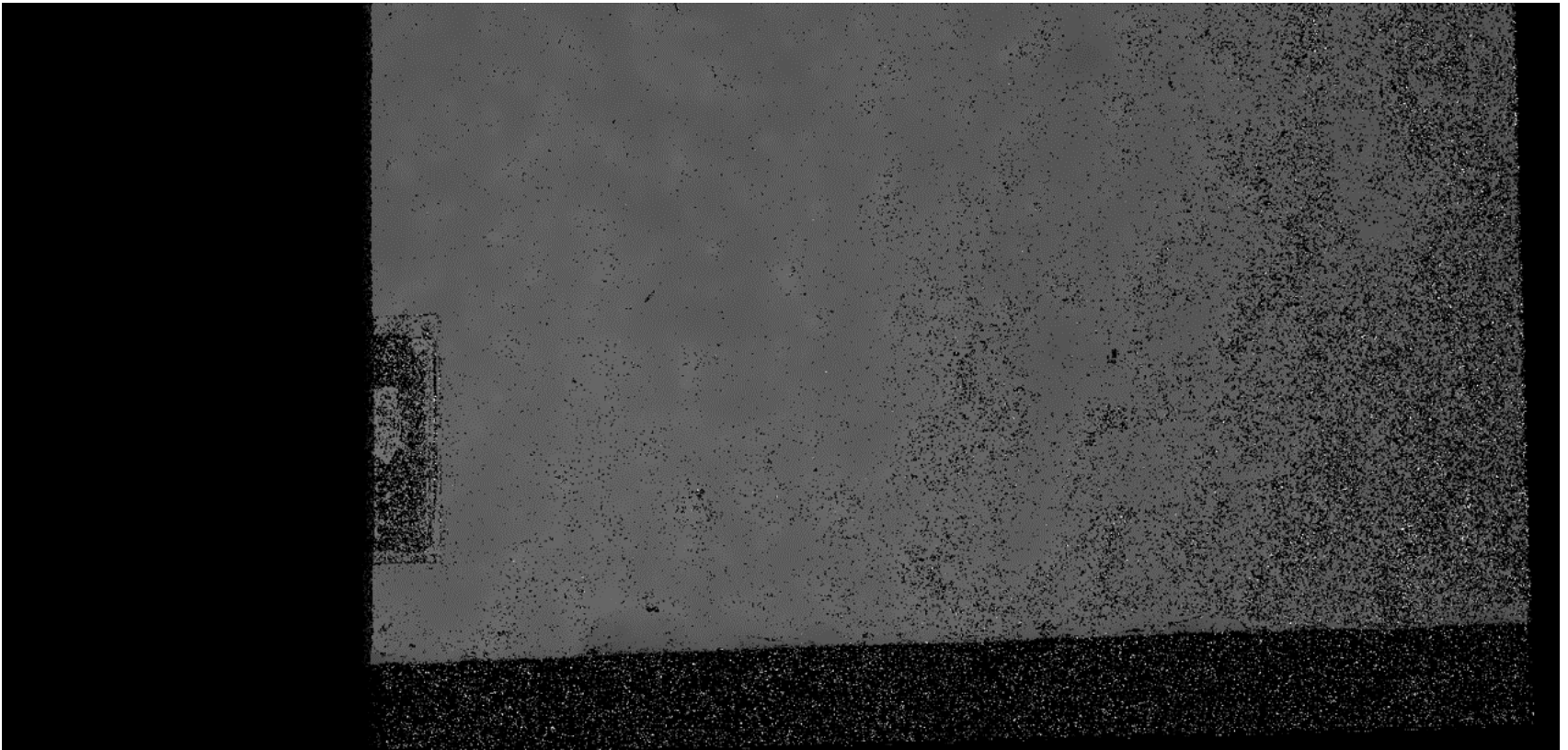
- Human depth perception



Dense Image Matching

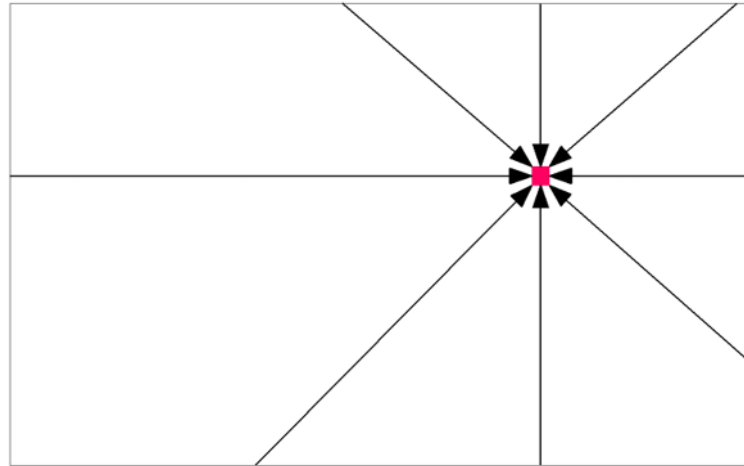
Stereo Block Matcher (SBM)

Disparity map



Semi-Global Matching (SGM)

- Optimization based on several 1D paths

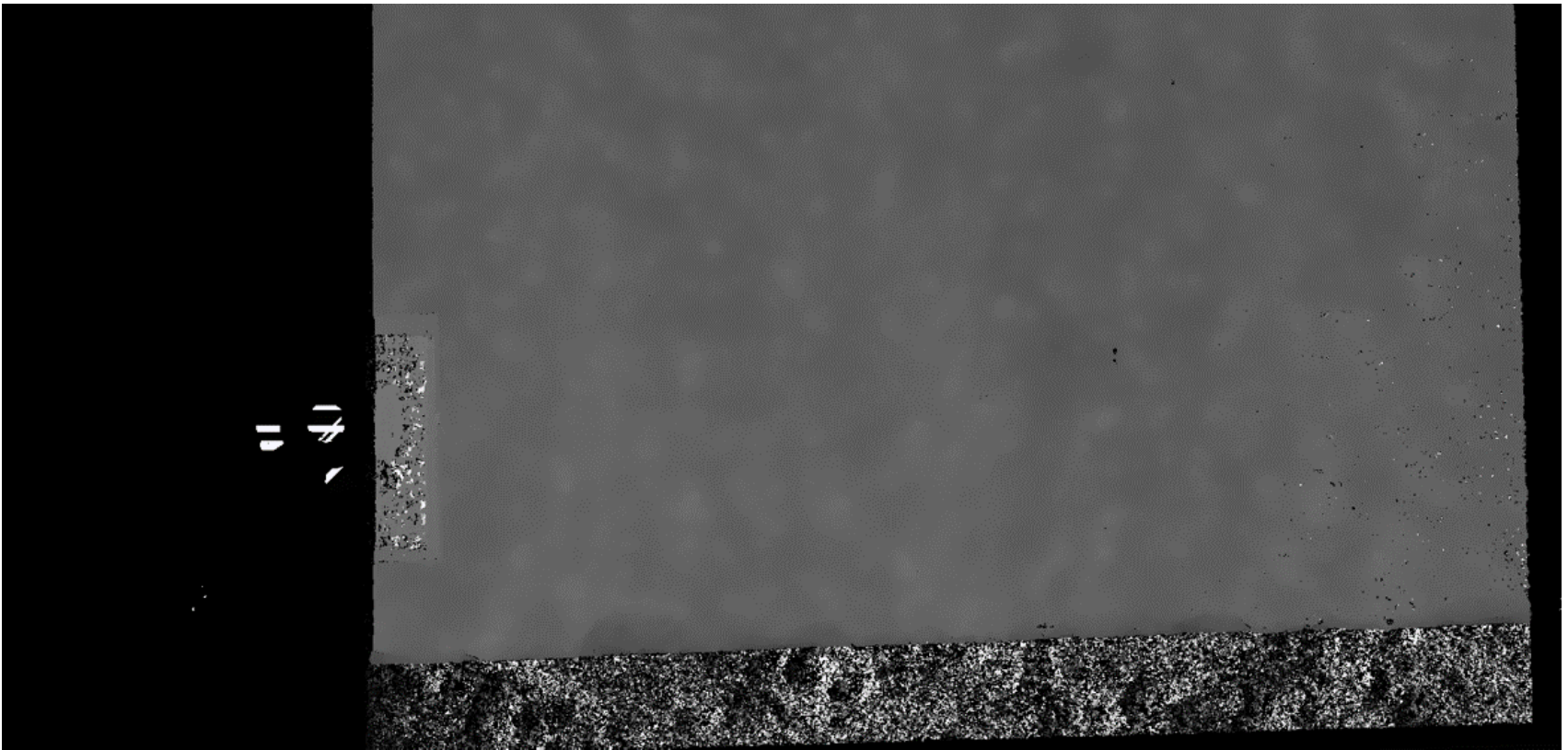


$$L_r(p, d) = C(p, d) + \min \begin{cases} L_r(p - r, d) \\ L_r(p - r, d - 1) + P_1 \\ L_r(p - r, d + 1) + P_1 \\ \min_i L_r(p - r, i) + P_2 \end{cases} - \min_k L_r(p - r, k)$$

Dense Image Matching

Semi-Global Matching (SGM)

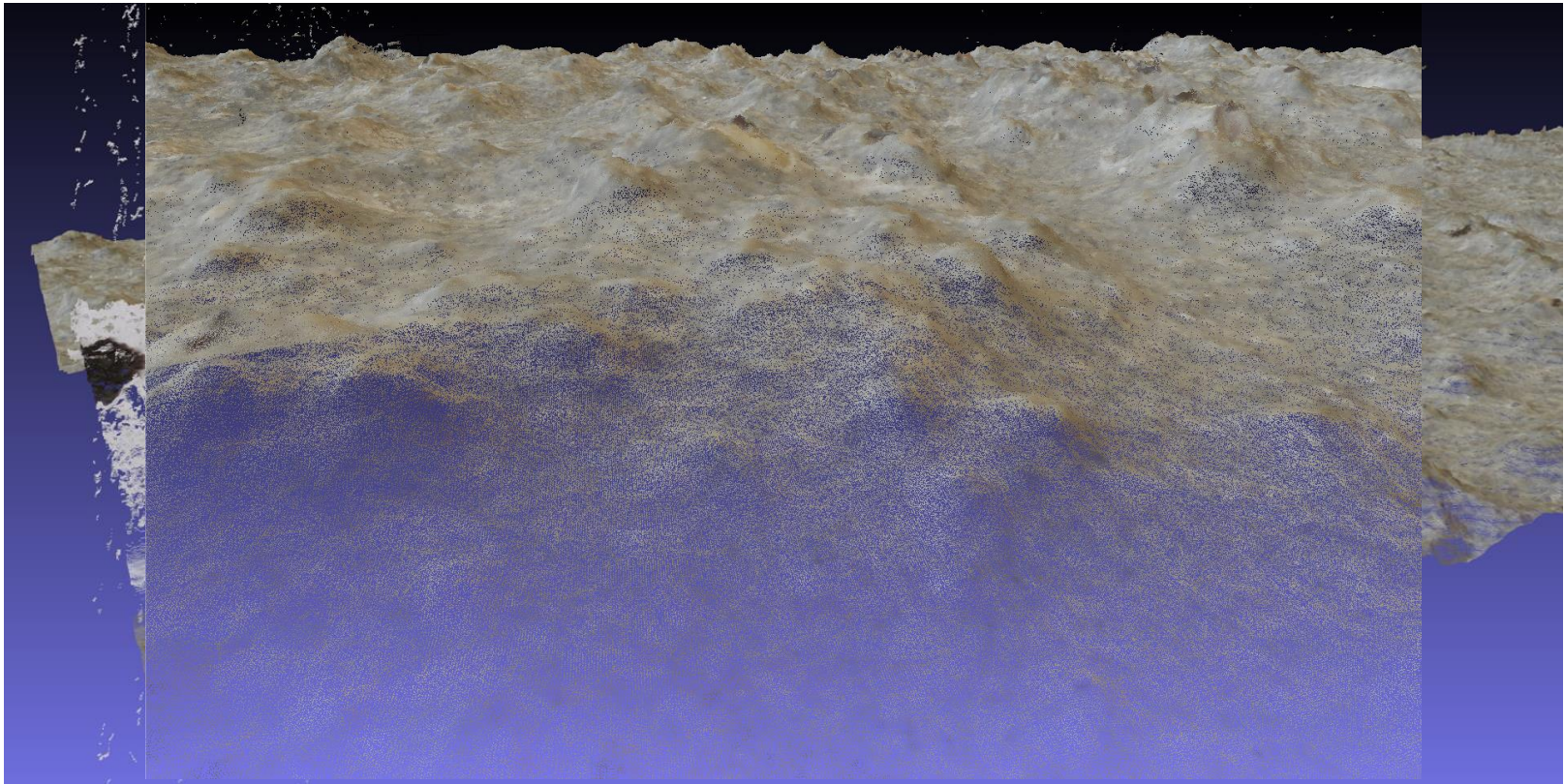
Disparity map



Dense Image Matching

Semi-Global Matching (SGM)

3D point cloud



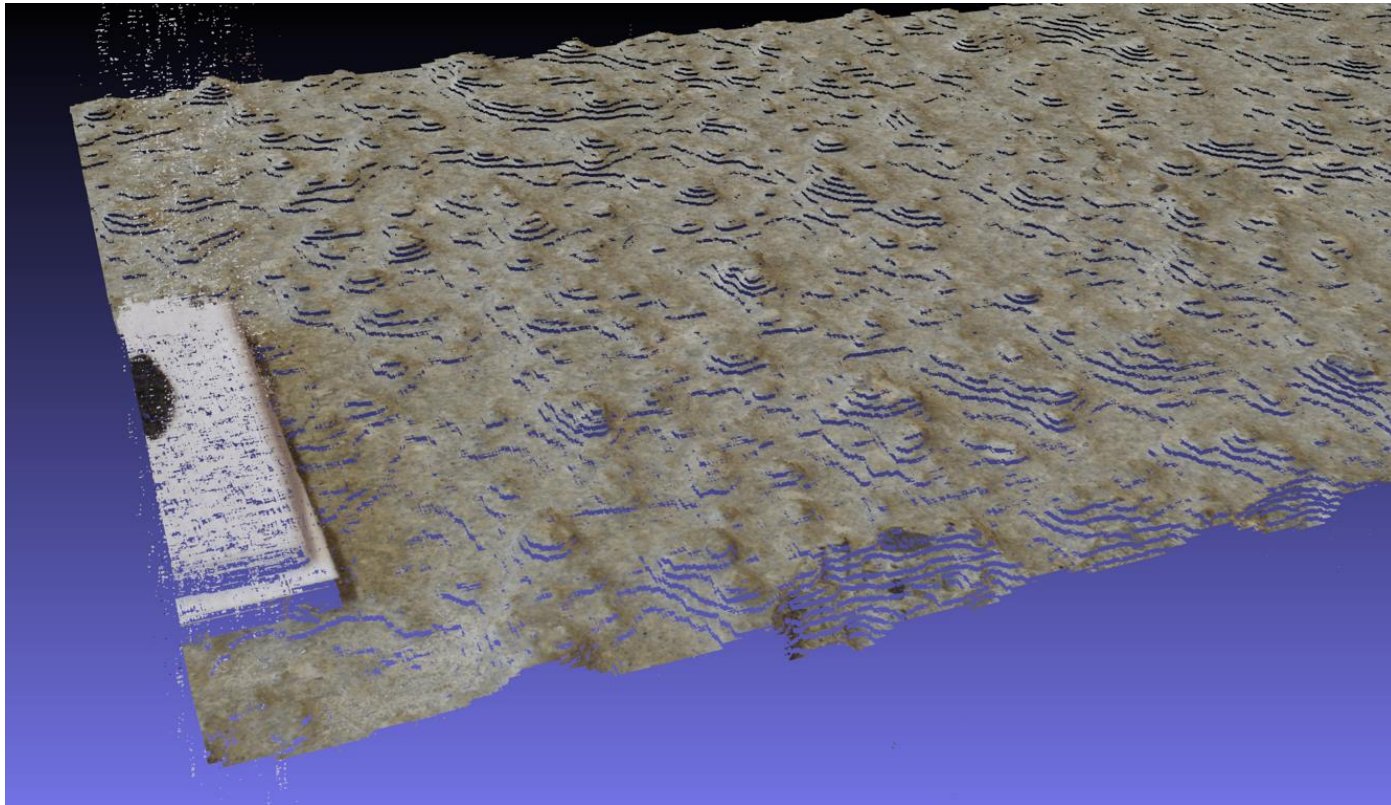
GPU-Implementation of SGM

- For real-time requirements
 - Using CUDA
- Tests on High-End Graphics Card (GeForce GTX 1080 Ti)
 - 3584 CUDA-Cores (Processing Units)
 - 11 GB RAM
 - 11.3 TFLOPS (10^{12} Floating Point Operations / s)

Dense Image Matching

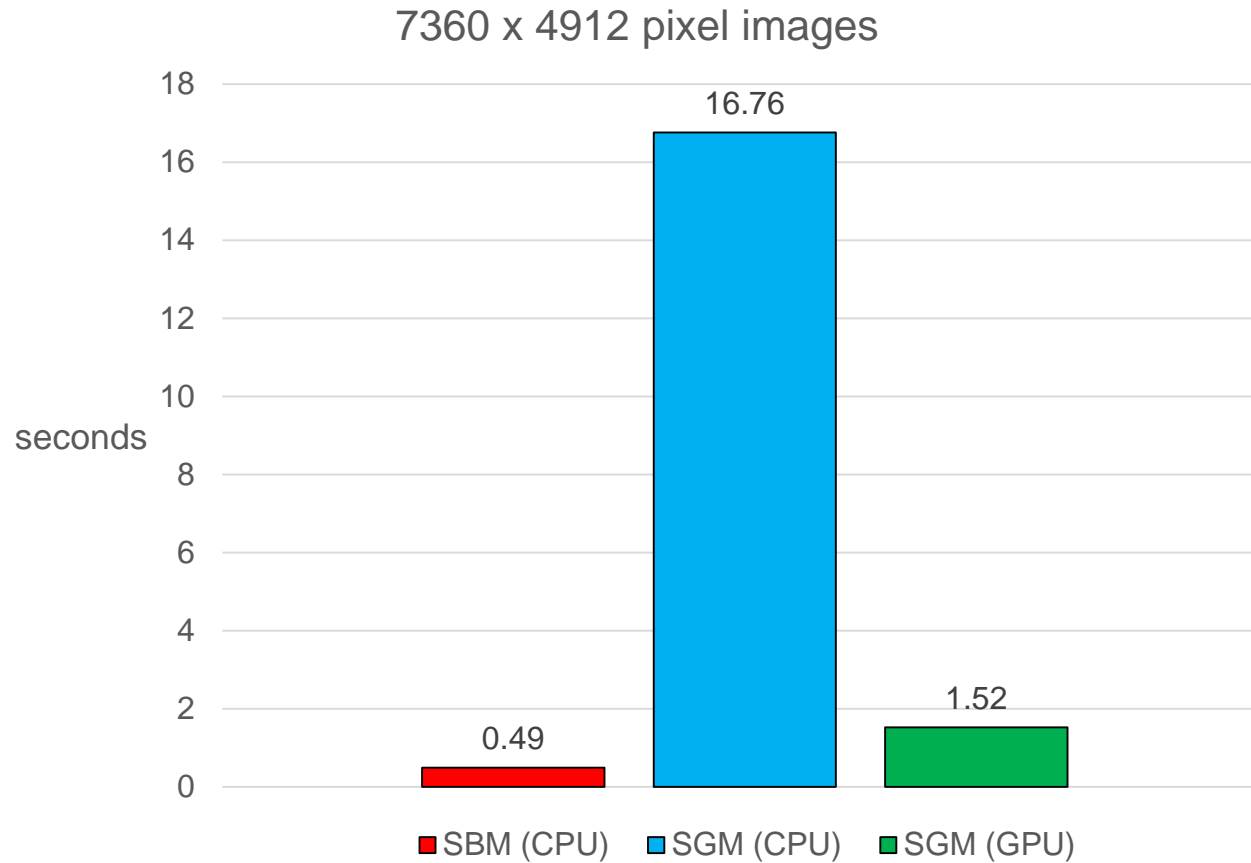
GPU-Implementation of SGM

3D point cloud



Conclusion

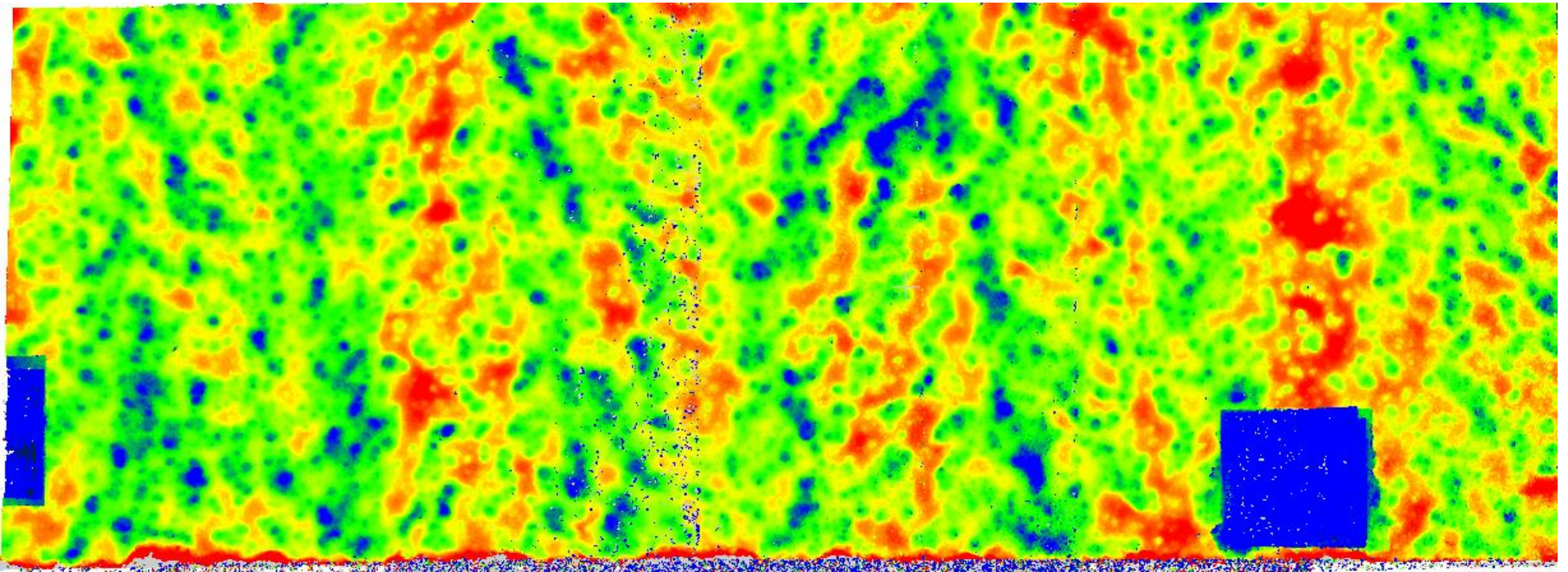
Runtime Comparison of DIM



Conclusion

Preliminary Result

Height map



Conclusion

Benefits of the method

- new area-based analyzation of the surface roughness
- quantitative evaluation
- optical
- passive (light)
- contactless / non-destructive
- portable
- cheap (basically just camera)

→ promising method

Conclusion

Challenges

- Image acquisition
 - Macro lens \Rightarrow small depth of field
- Dense reconstruction
 - Computationally intensive
 - High number of matchings at Dense Image Matching
 - Memory-consuming SGM
 - $M_{\text{SGM}} \approx H * W * D$

Conclusion

Outlook

- Method optimization
- Evaluation
 - Comparison with other methods
 - Repeatability
- Adapting old and new roughness parameters

Thank you for your attention

Bariş Özcan

oezcan@gia.rwth-aachen.de