Computer Vision in an Automotive Context: High Dynamic Range Imaging with a Dual Camera System

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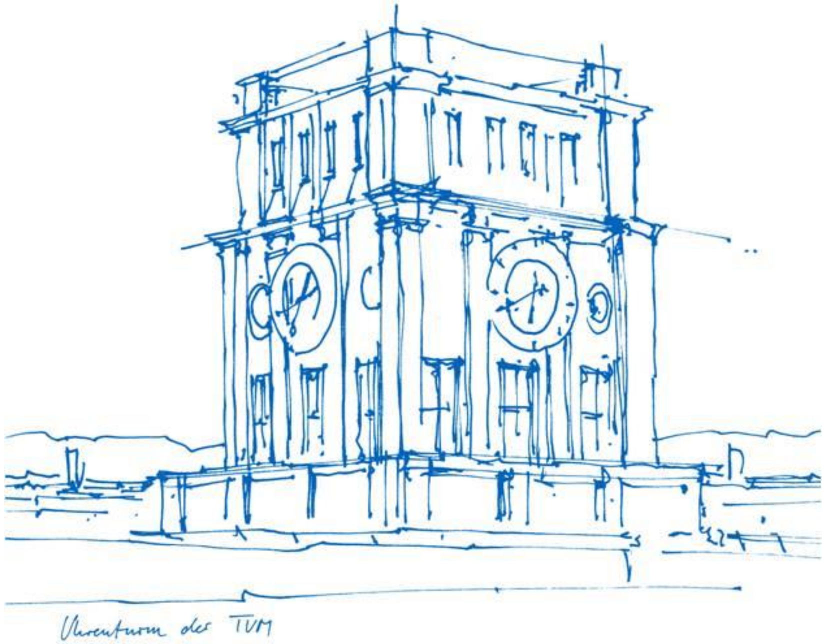
Guangzhou, 2017-12-20



Low Dynamic Range (LDR)

➡ No details in darkest / lightest parts of image!

Limitations of Low Dynamic Range (LDR)

- Eight Bit per color channel

-> 16.7 million different colors

BUT:

only 256 values for each pixel of one channel

HDR

LDR

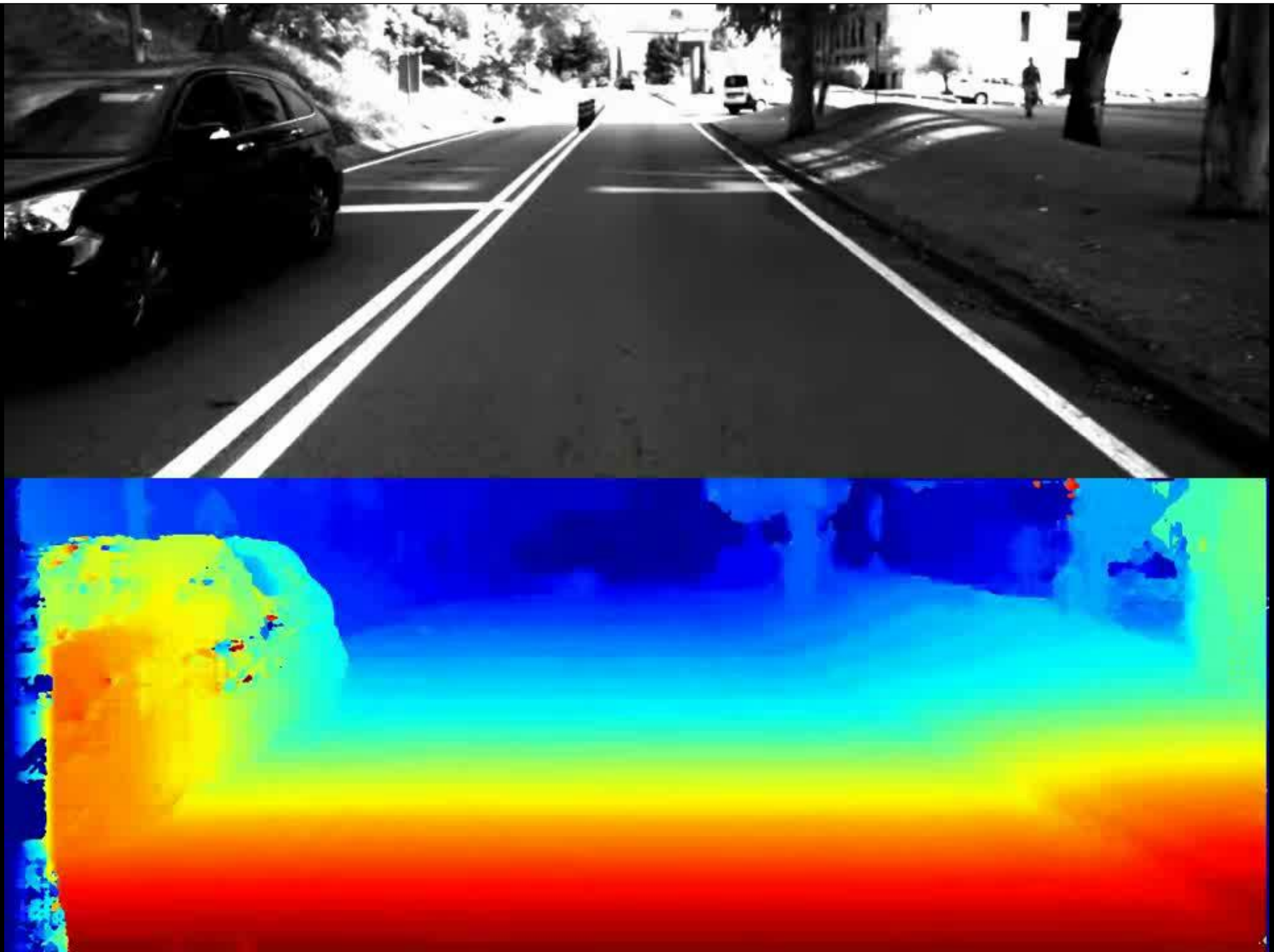
Dominik Urbaniak (TUM)

HDR beneficial for Computer Vision?

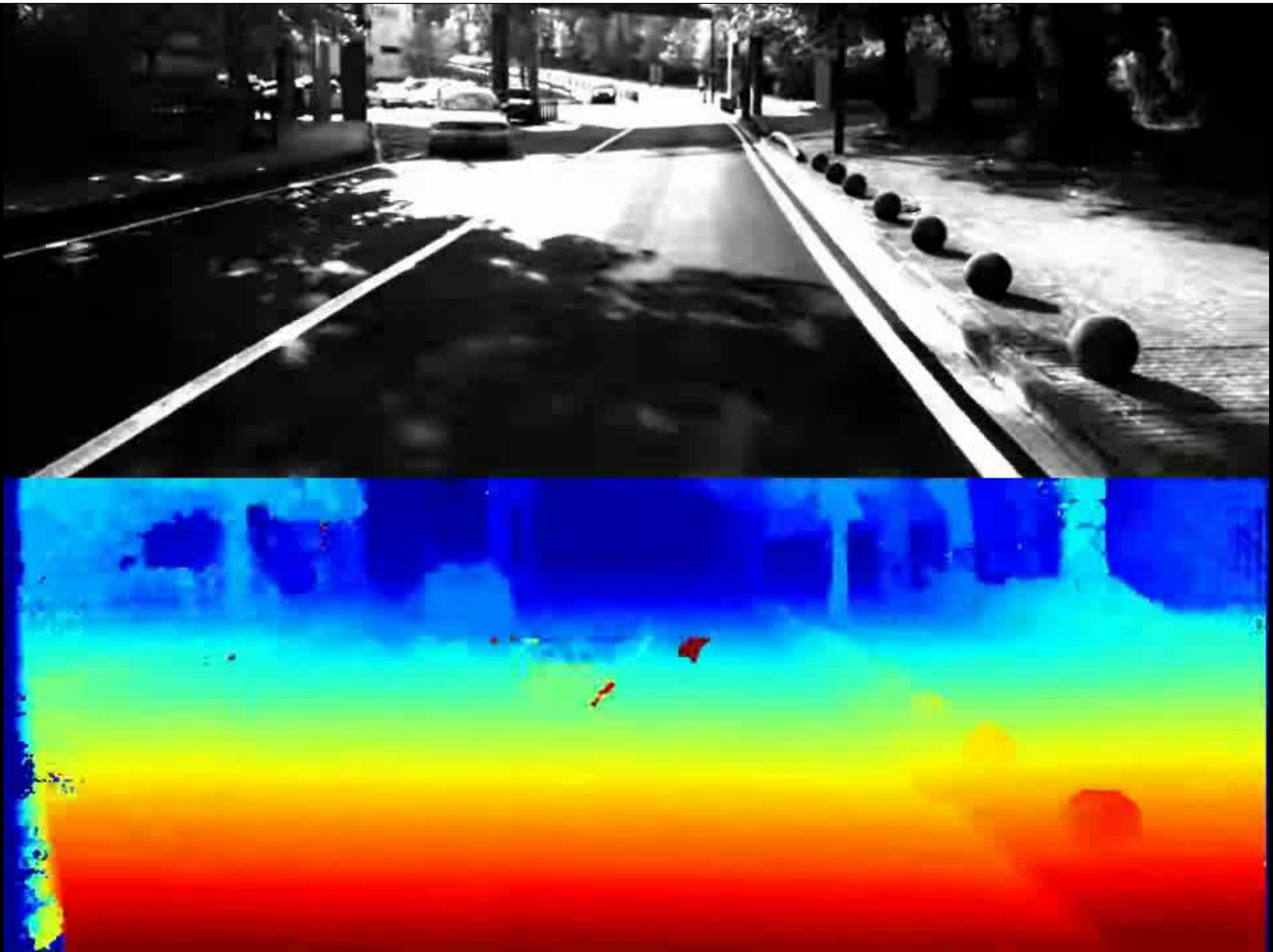
Crash of Tesla Model S with Truck in May 2016

Embedded Real-Time Stereo Estimation

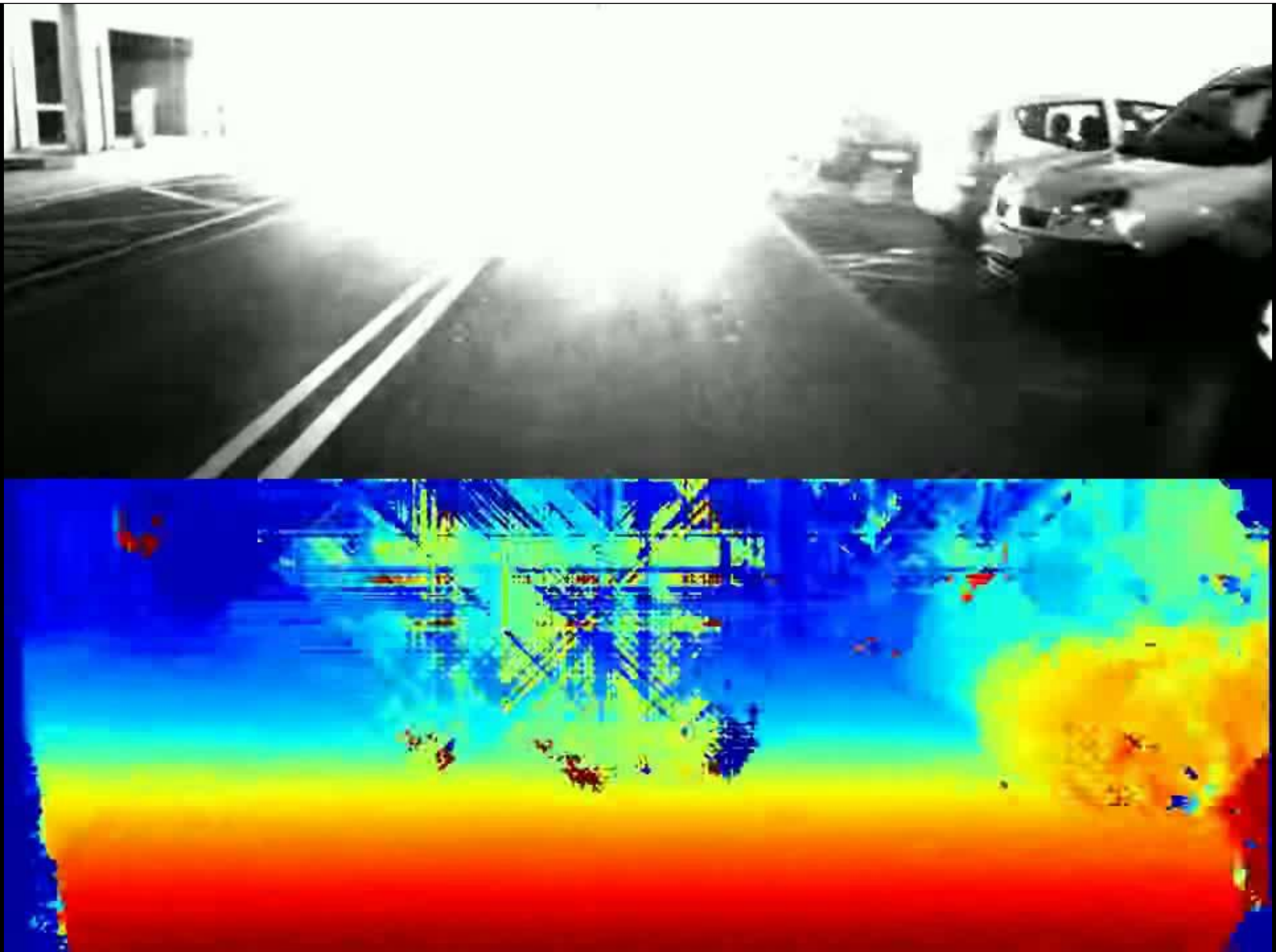
D. Hernandez-Juarez, A. Chac´on, A. Espinosa, D. V´azquez, J. C. Moure, and A. M. L´opez
Universitat Autonoma de Barcelona, Barcelona, Catalonia, Spain



Camera facing sun and sun reflections



Camera facing the exit of a tunnel



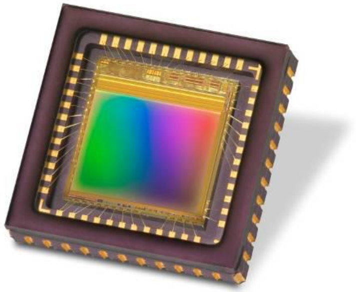
Project Goal

Improve **disparity maps** under **difficult light** situations using **HDR imaging**

Equipment

Hardware

- Two Kowa lenses
- Two e2v image sensors
- Altera FPGA and Nios II processor

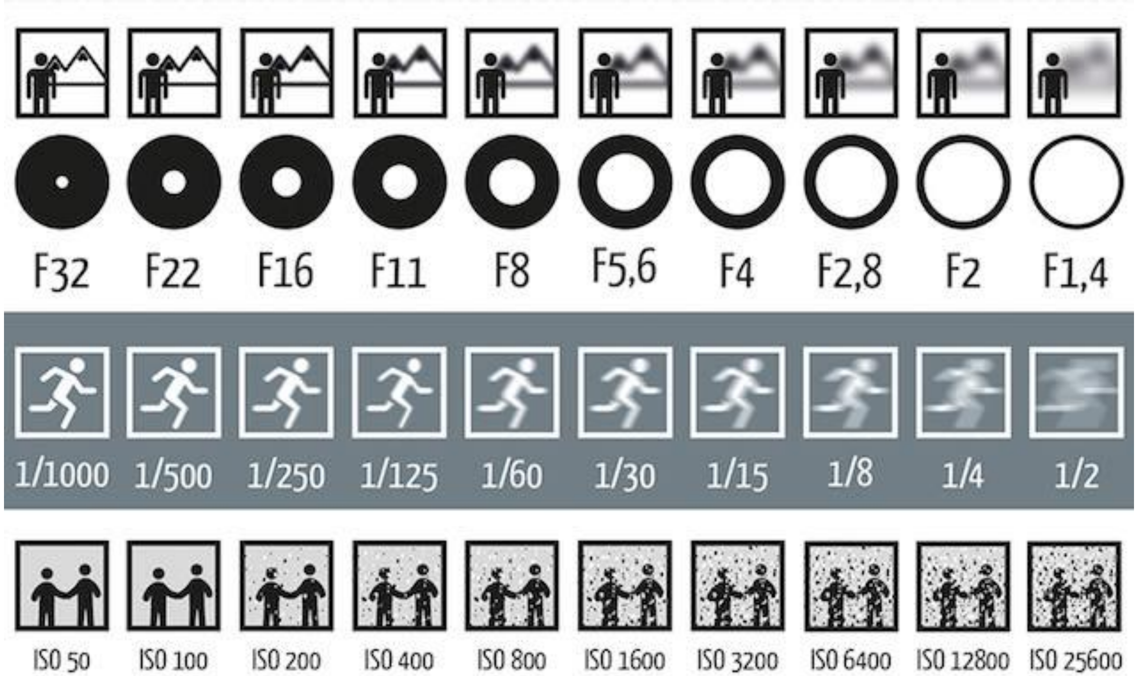


Software

- OpenCV with Visual Studio
- Matlab
- Quartus Prime (FPGA)
- Eclipse (Nios II)

Major Challenges

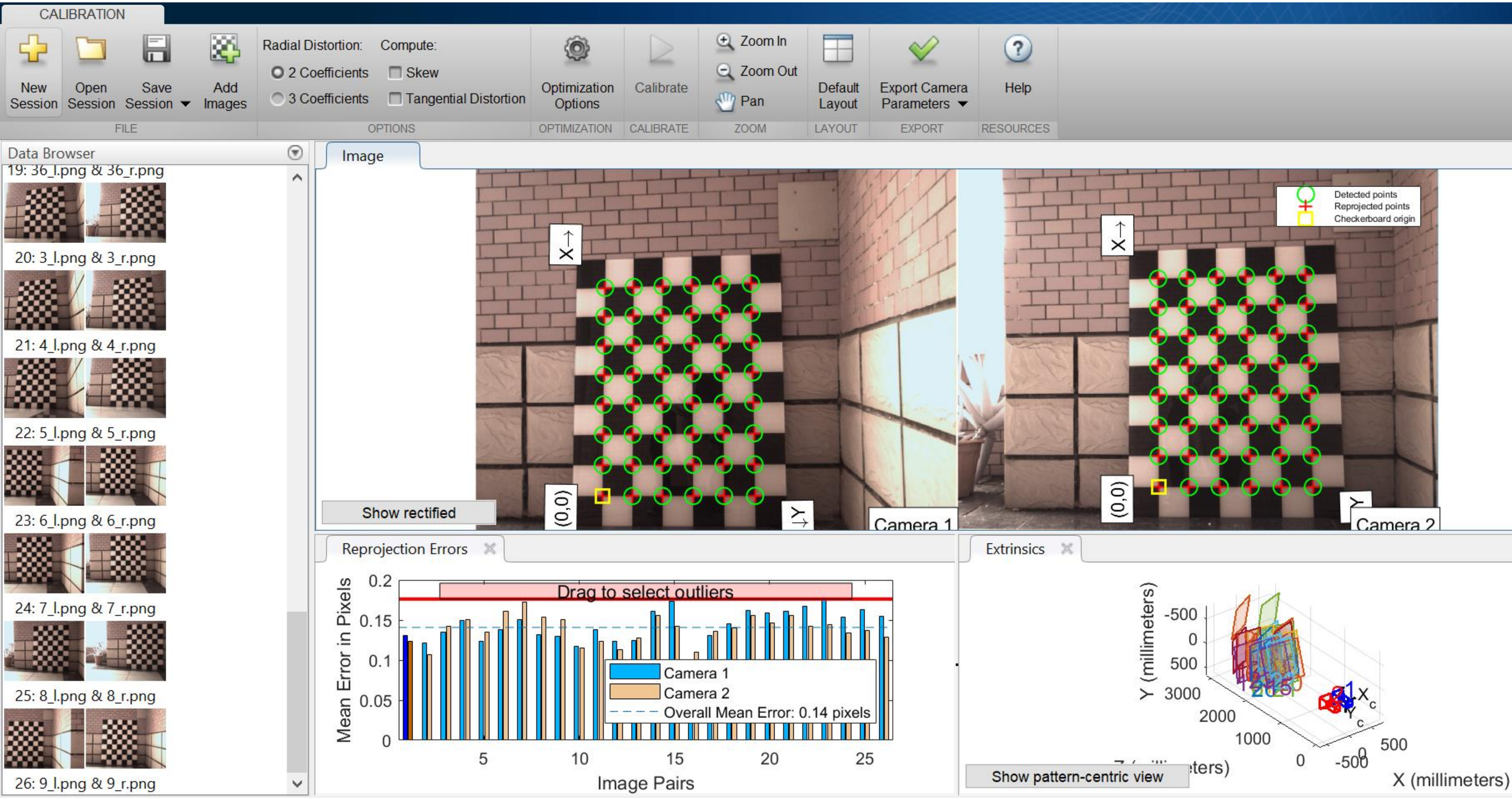
- **High computational effort**
  -> Edit images offline
- **Low exposure time vs. good image quality**
  -> Parameters to influence exposure time:
  - Aperture
  - Analog gain
  - Digital gain



Procedure with Nios II

1. Automatic exposure time adjustment
2. Image output with alternating exposure times

Matlab - Stereo Camera Calibrator



Transfering Camera Parameters to OpenCV

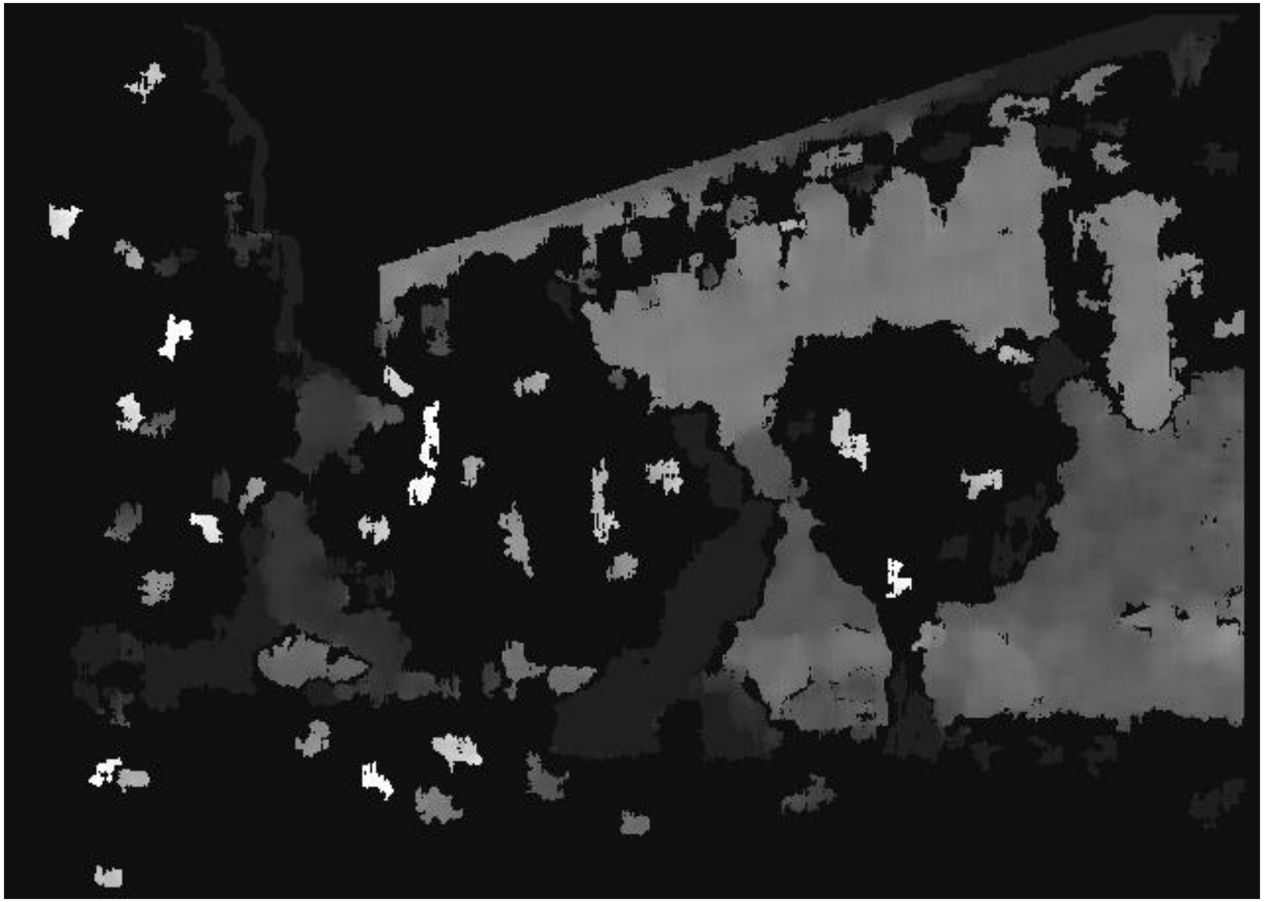
Parameters

- Translation & rotation matrices **T** & **R**
- Both Camera matrices **K1** & **K2**
- Distortion Coefficients of both Cameras **D1** & **D2**

➡ Input parameters to OpenCV function and rectify images

SGBM Disparity Map Results

First decent result



SGBM Disparity Map Results

Good for +25 meters

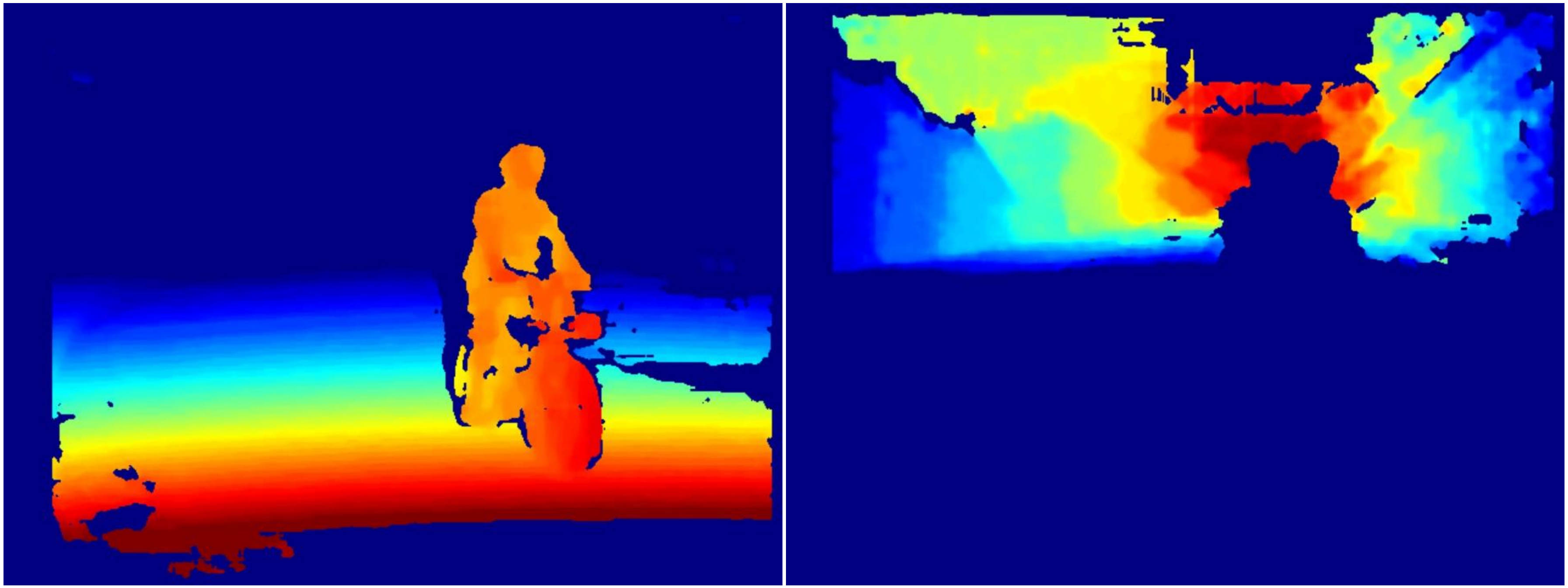
SGBM Disparity Map Results

Eliminating noise in the foreground

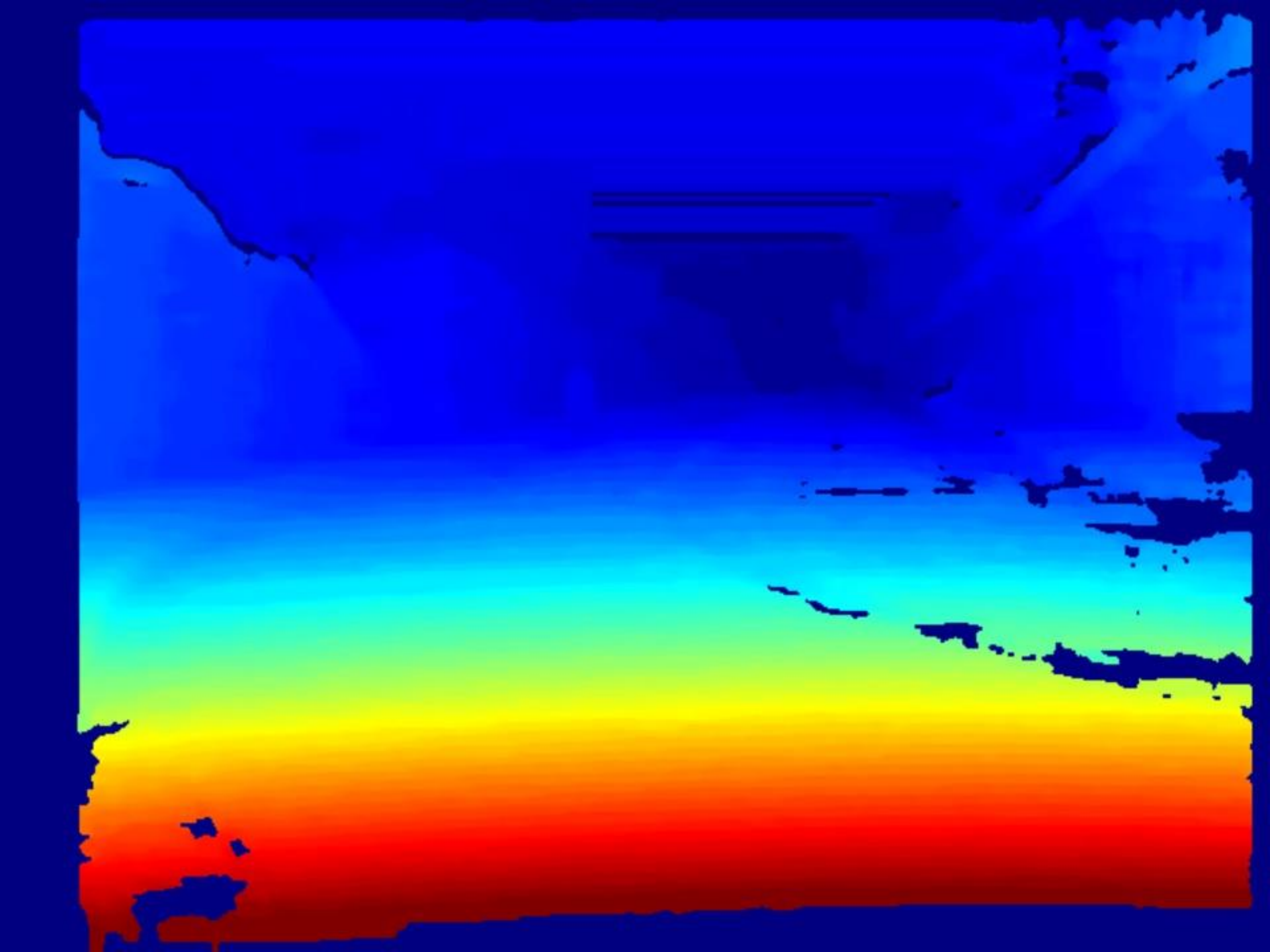
SGBM Disparity Map Results

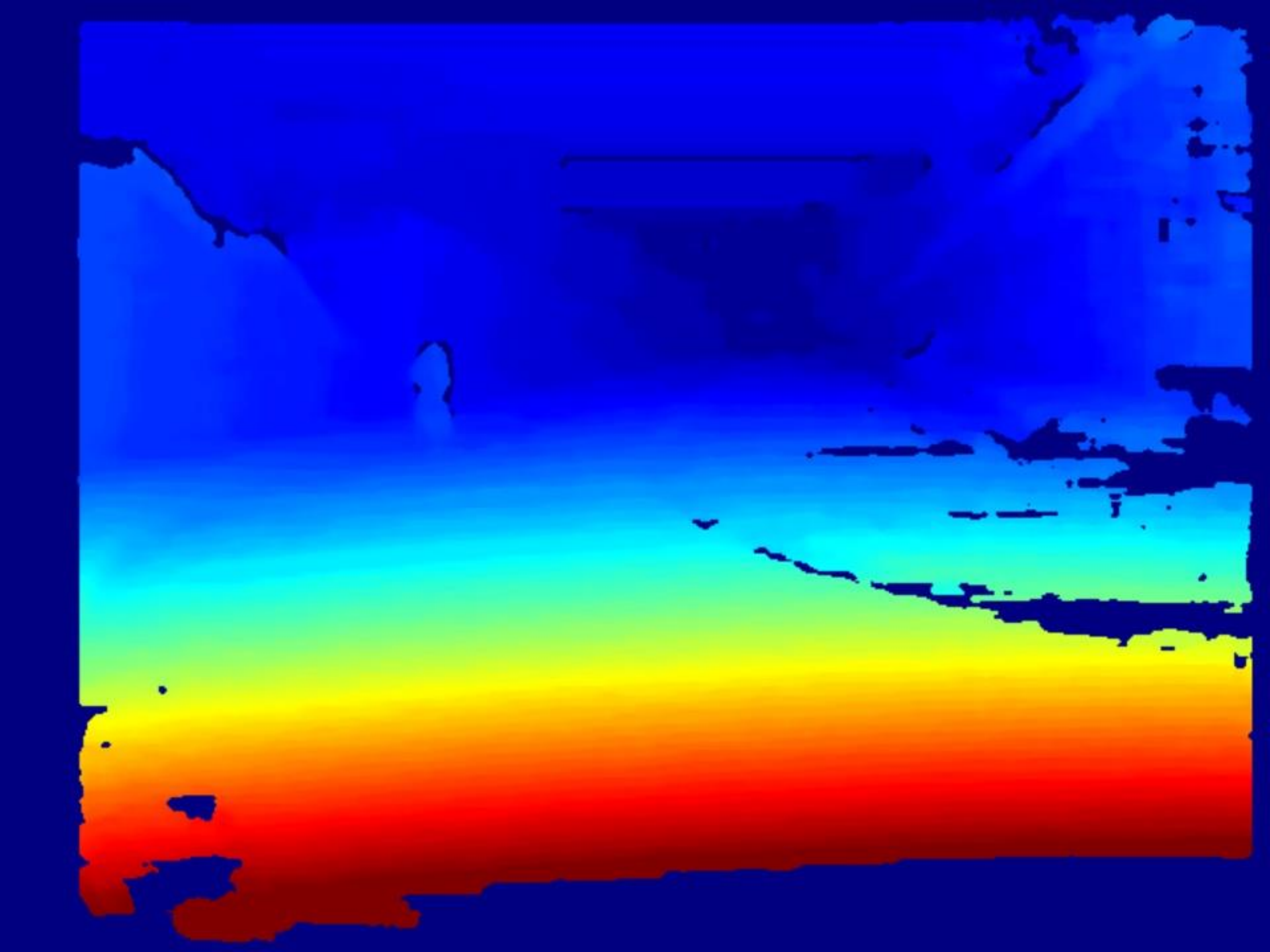
Interchanging left and right image shifted disparity map to foreground

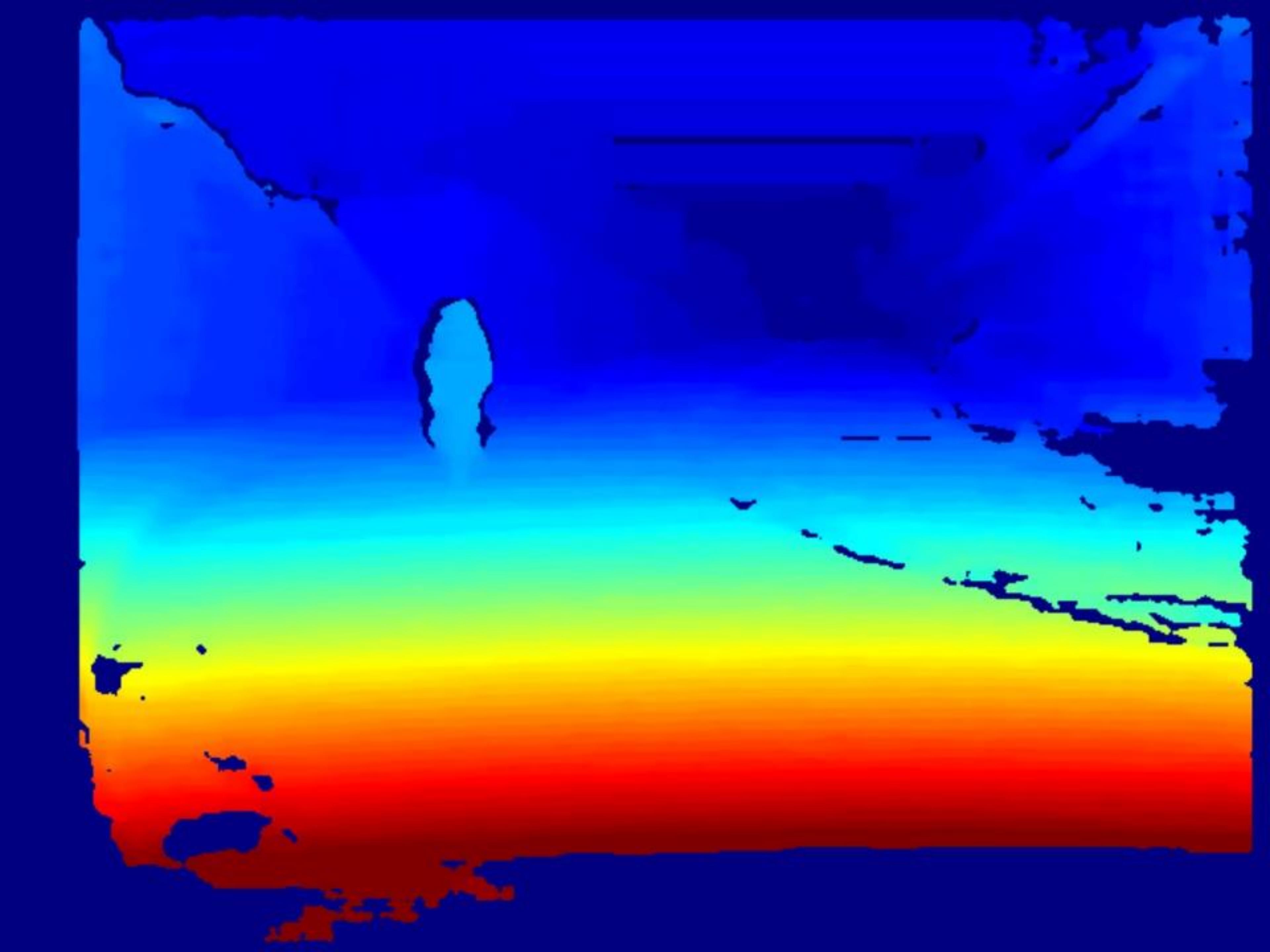
SGBM Disparity Map Results

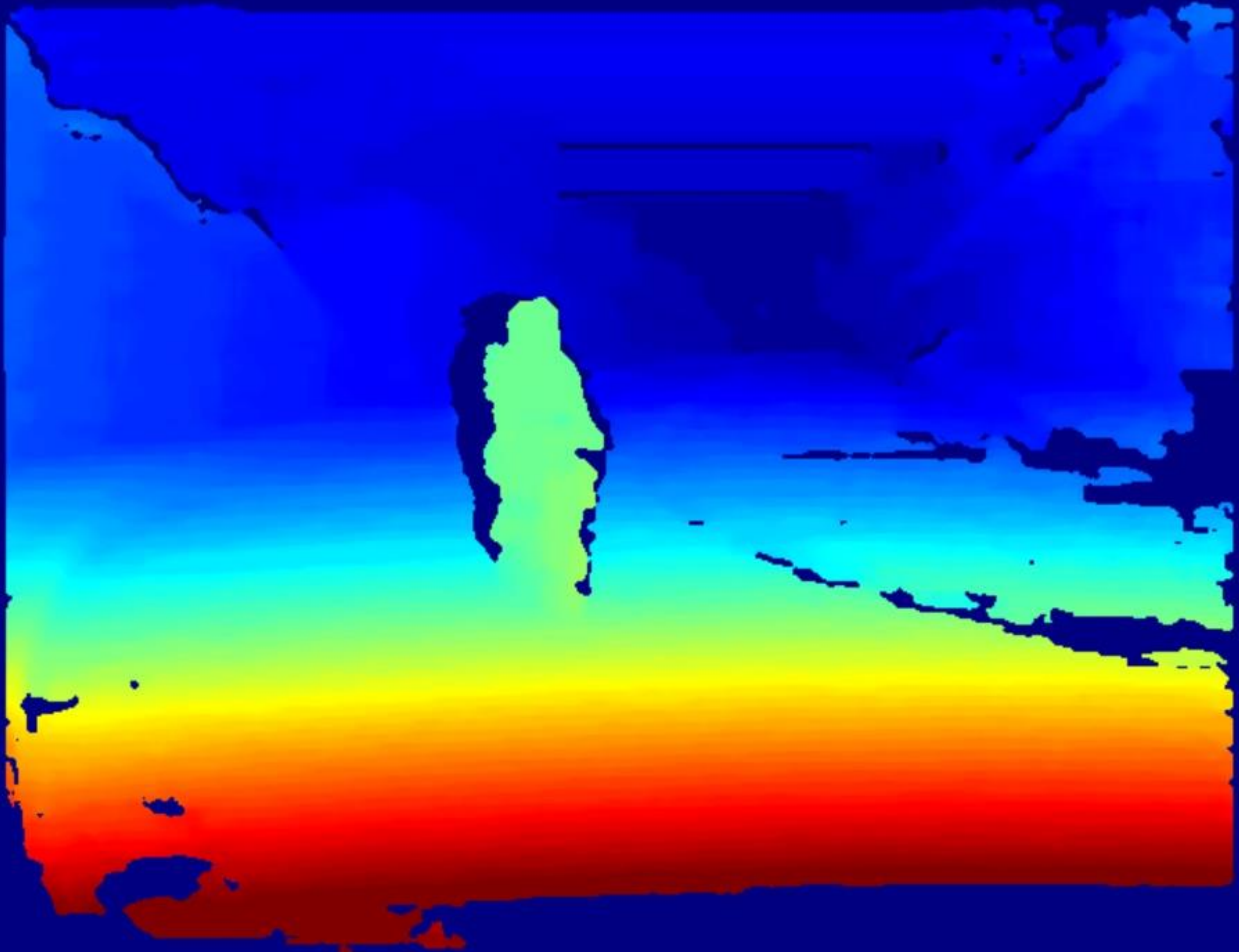


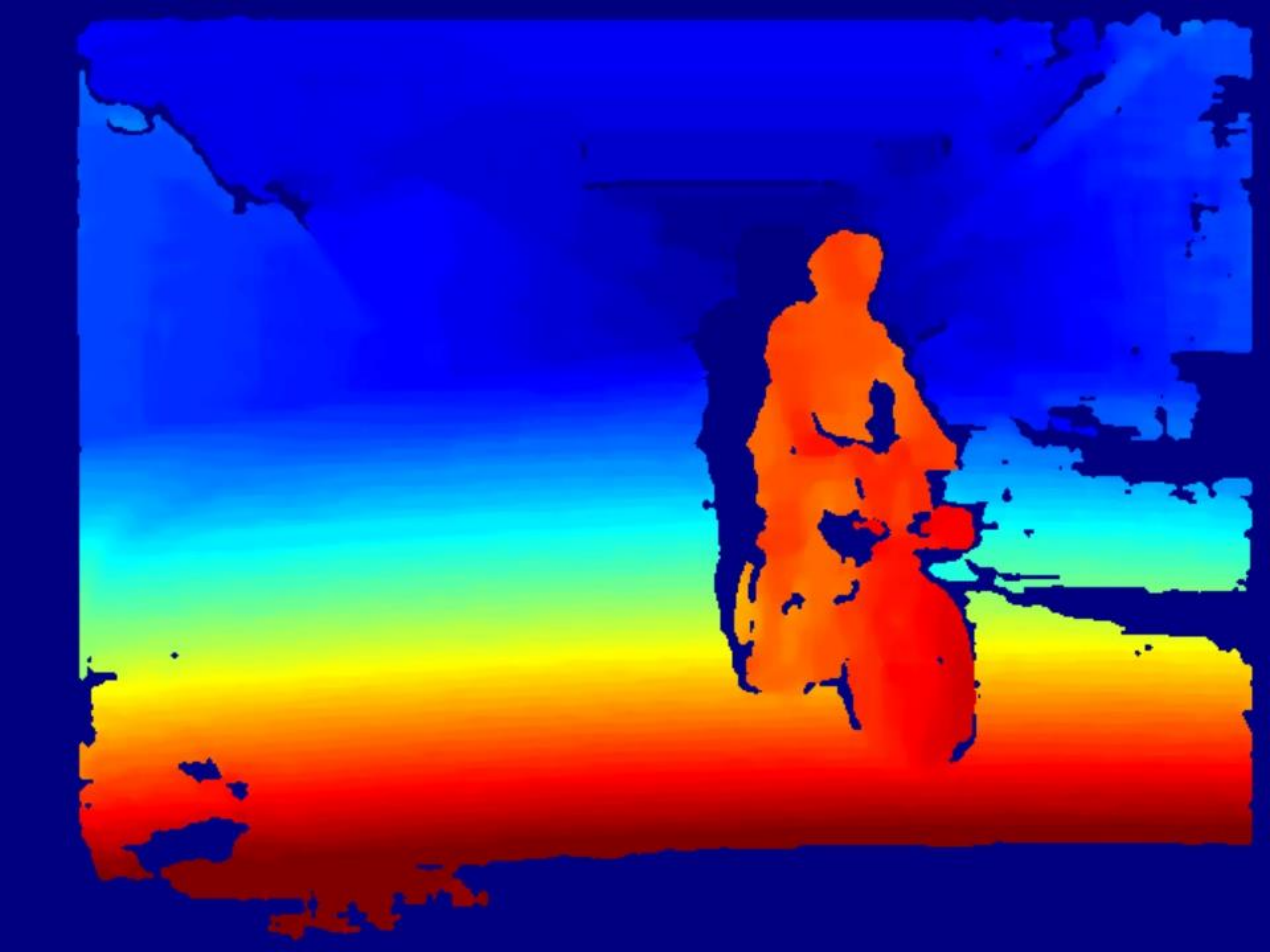
How to mix both parts to one image?
-> before disparity map is converted to 8 bit image, **all values** are contained **in one image**, negative values get lost
-> compress all values to 8 bit before conversion











HDR Creation with OpenCV

Simply calling OpenCV functions
- Aligning images
- Merging images
- Tonmapping images
  -> Reinhard algorithm

Challenge

Always darker image first

HDR Alternative with Merge Mertens

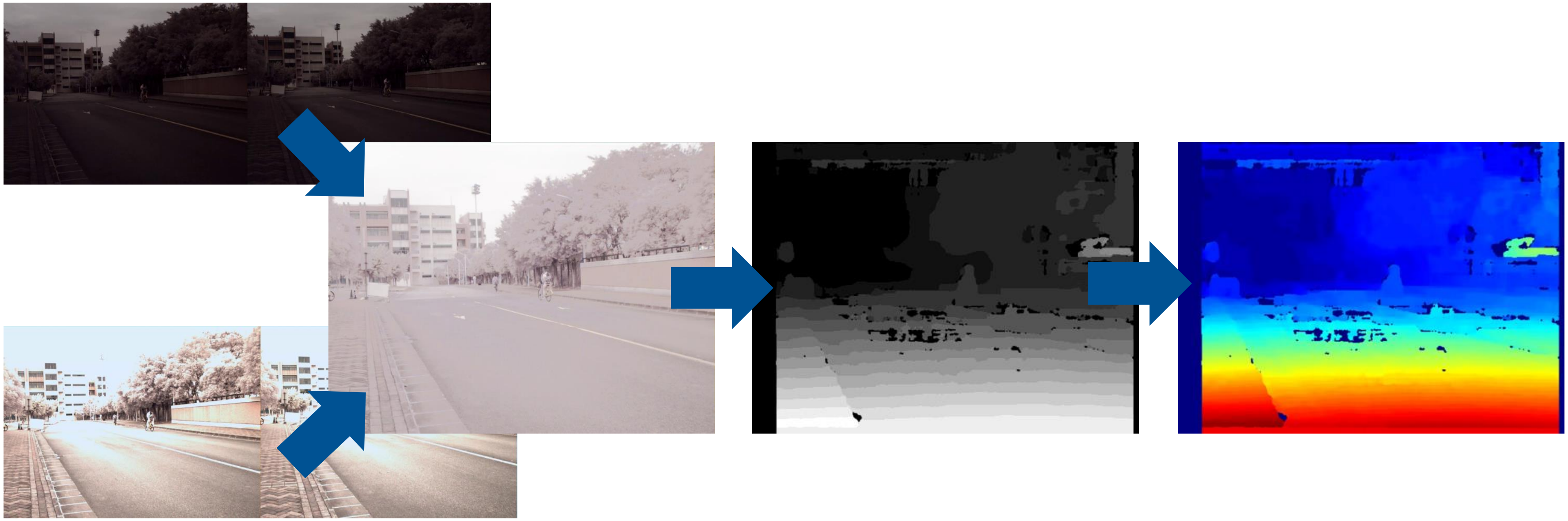
Simply calling OpenCV functions

- Aligning images
- Merging images
- No Tonemapping

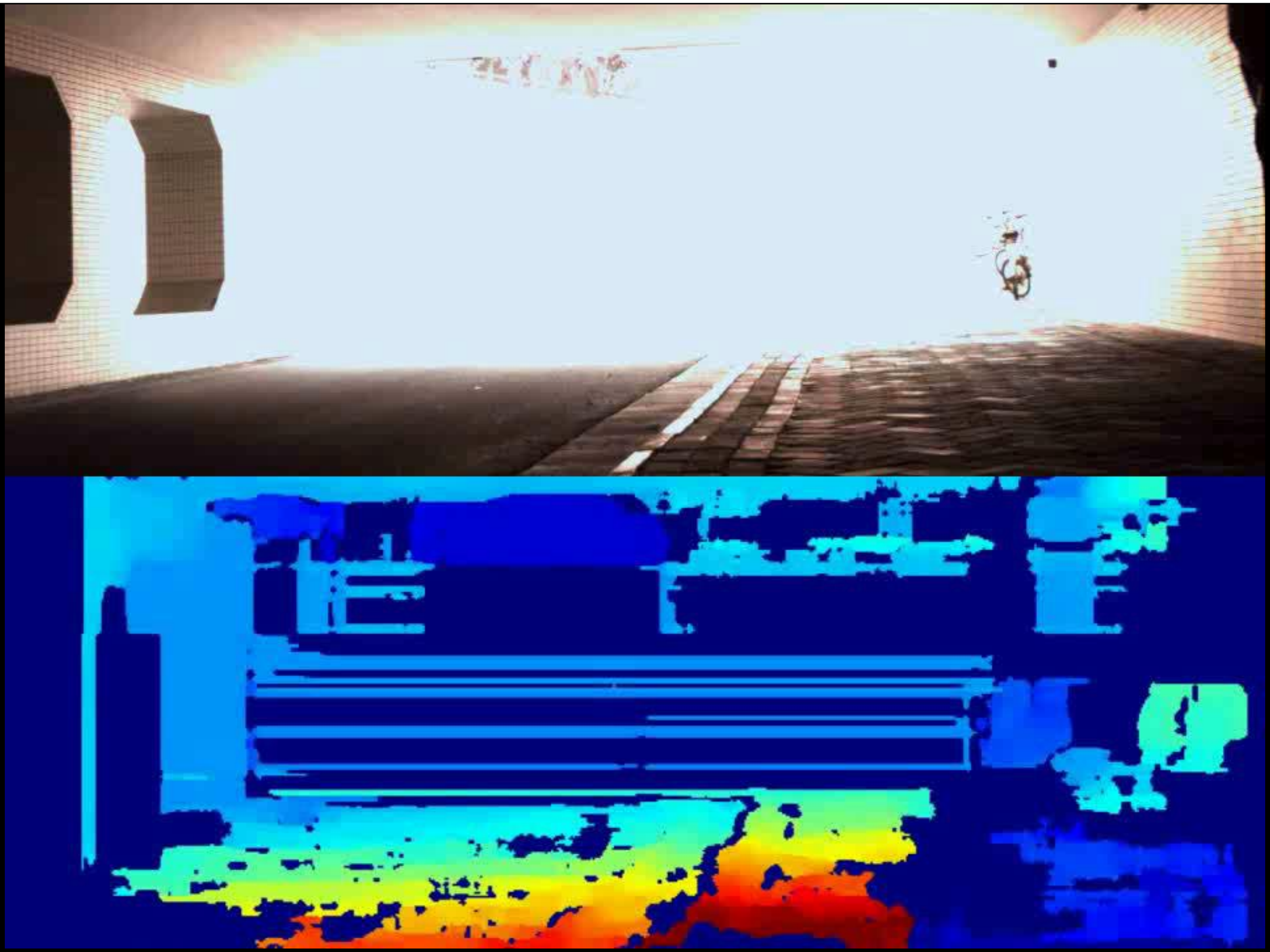
  -> faster

Overall Process

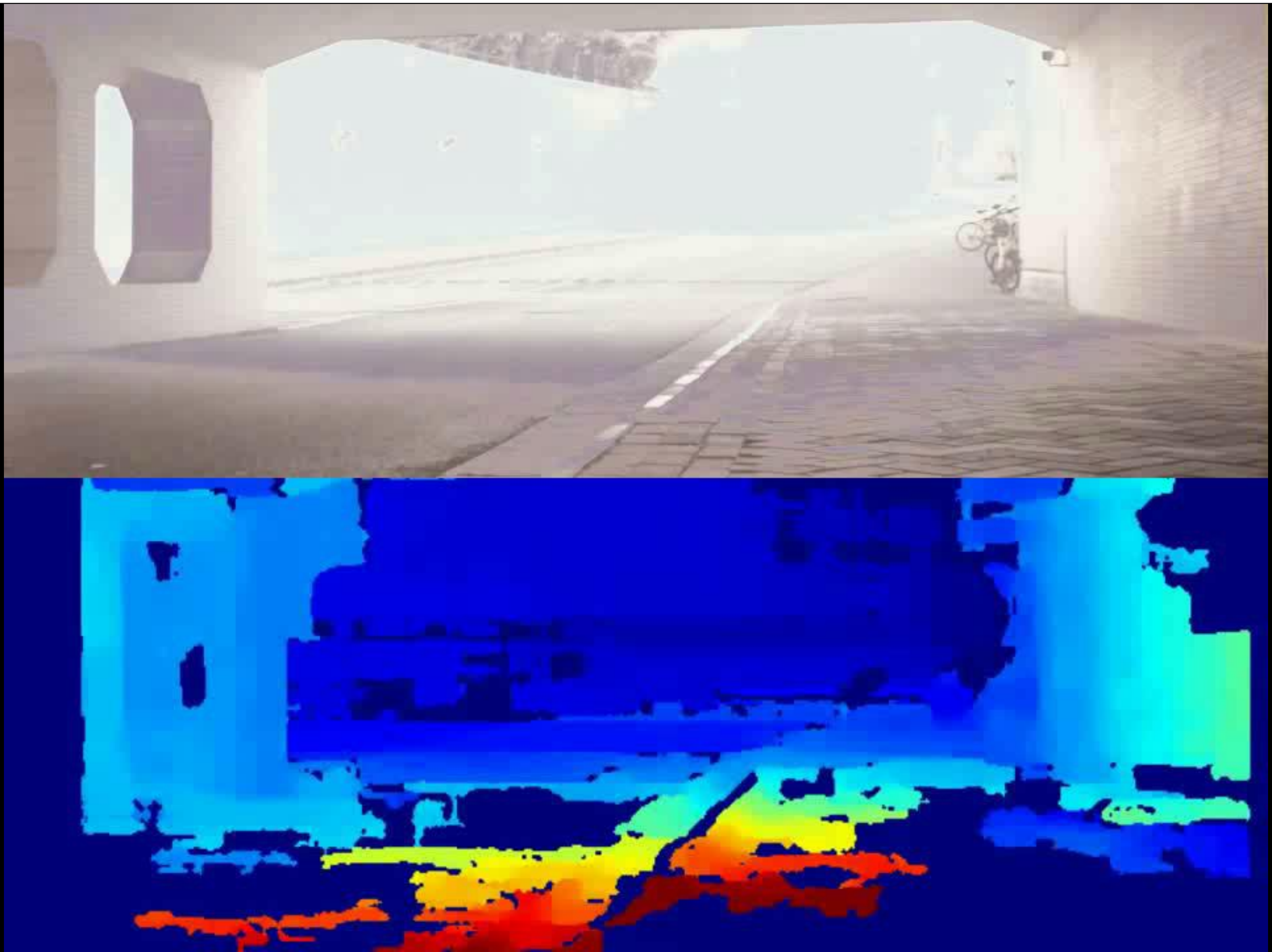
1. Input: One Image displaying frame from left and right camera
2. Turn one darker and one lighter image to a **HDR image**
3. Create **Disparity Map** from left and right frame
4. Apply Color Map for better visibility



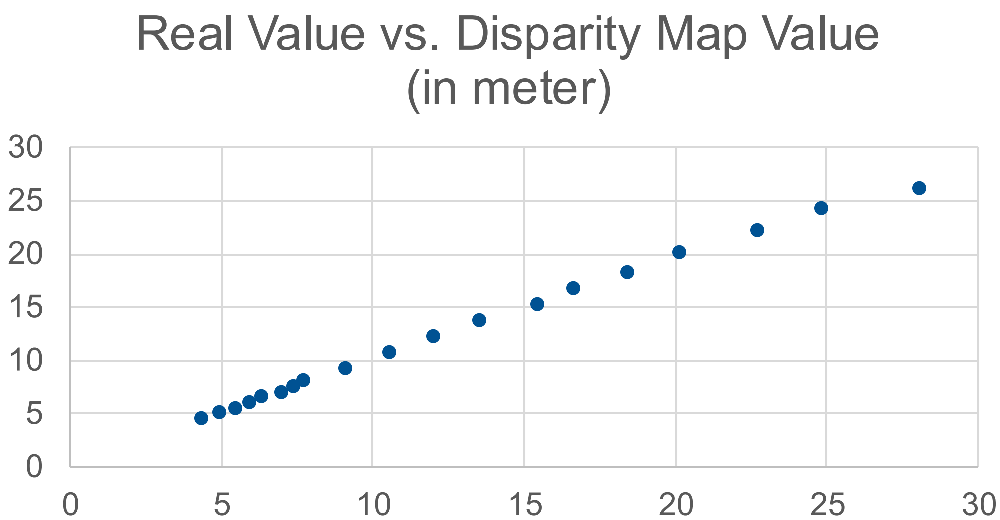
14 meters inside a tunnel, **no HDR**

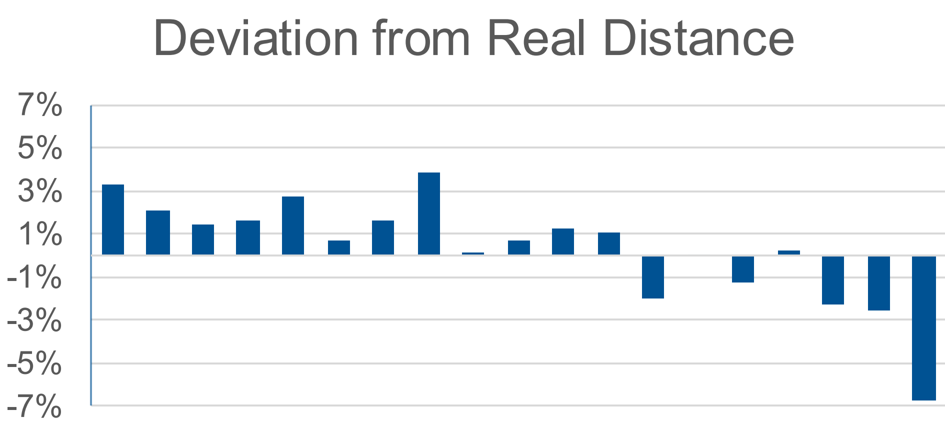


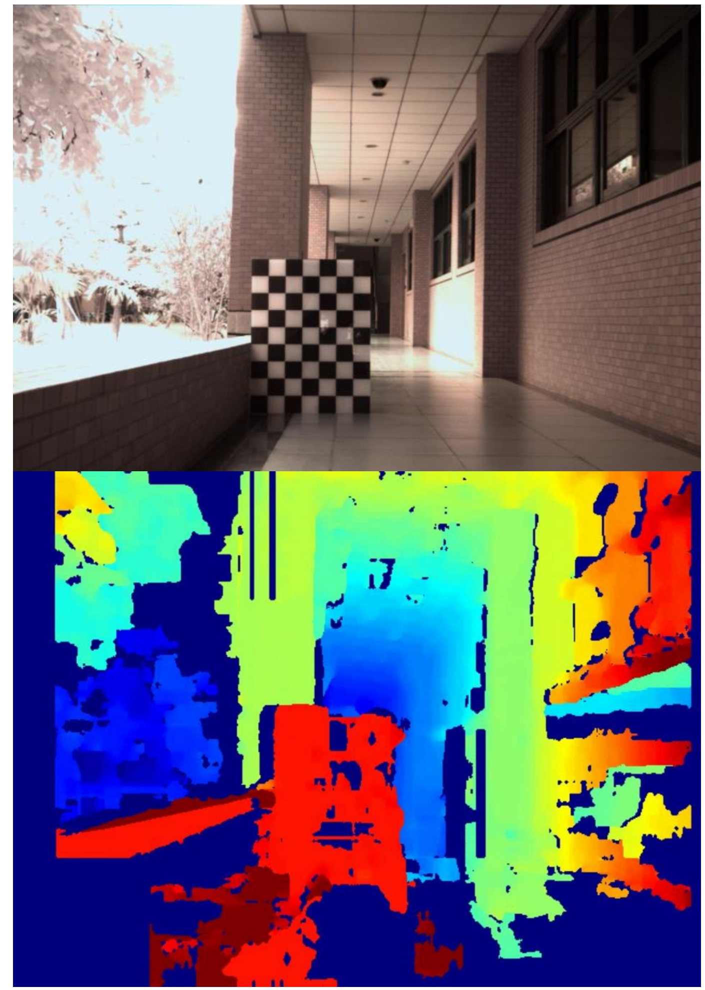
Exposure time of lighter image **16 times** longer



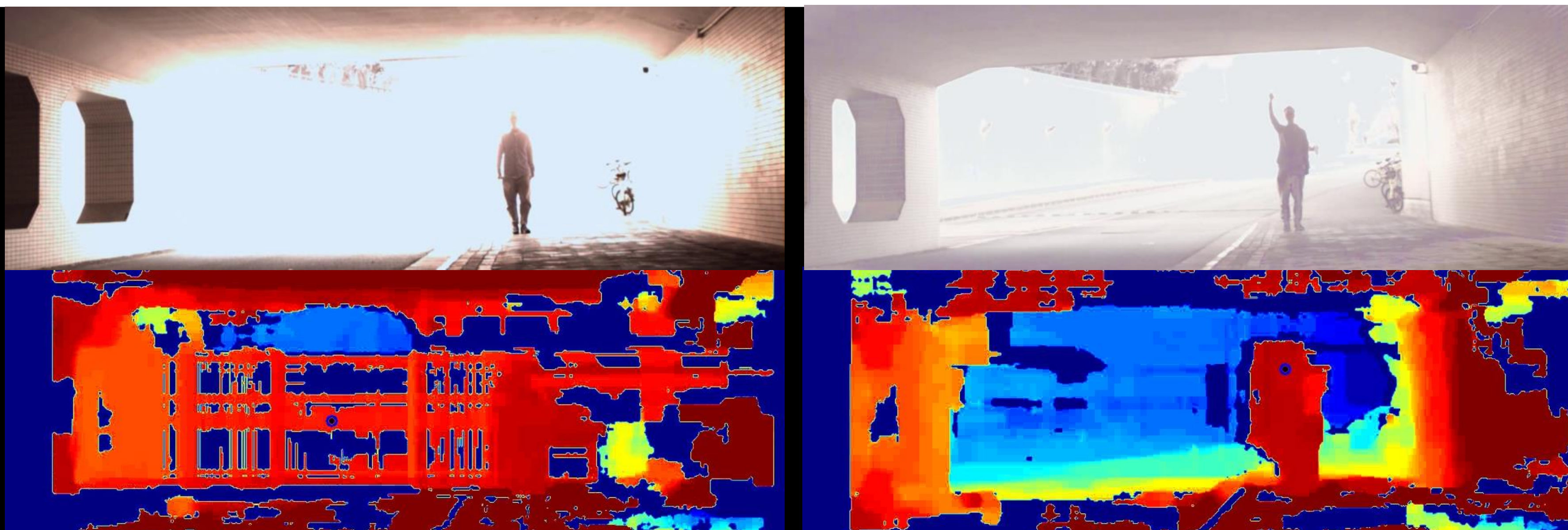
Distance Measurement







Comparison at 14m: LDR, HDR, Lidar (VLP-16)

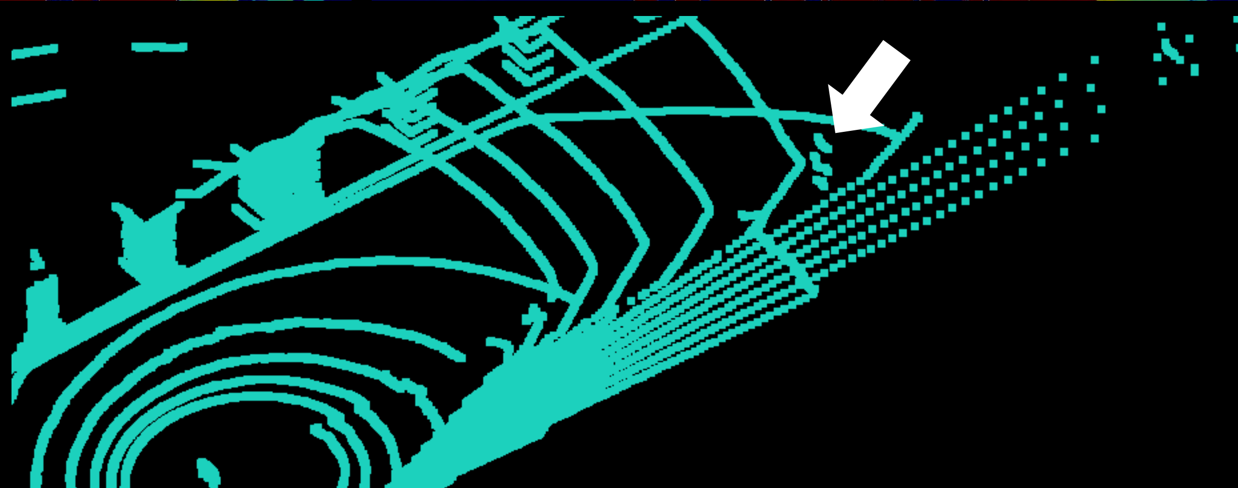


LDR Disparity Map

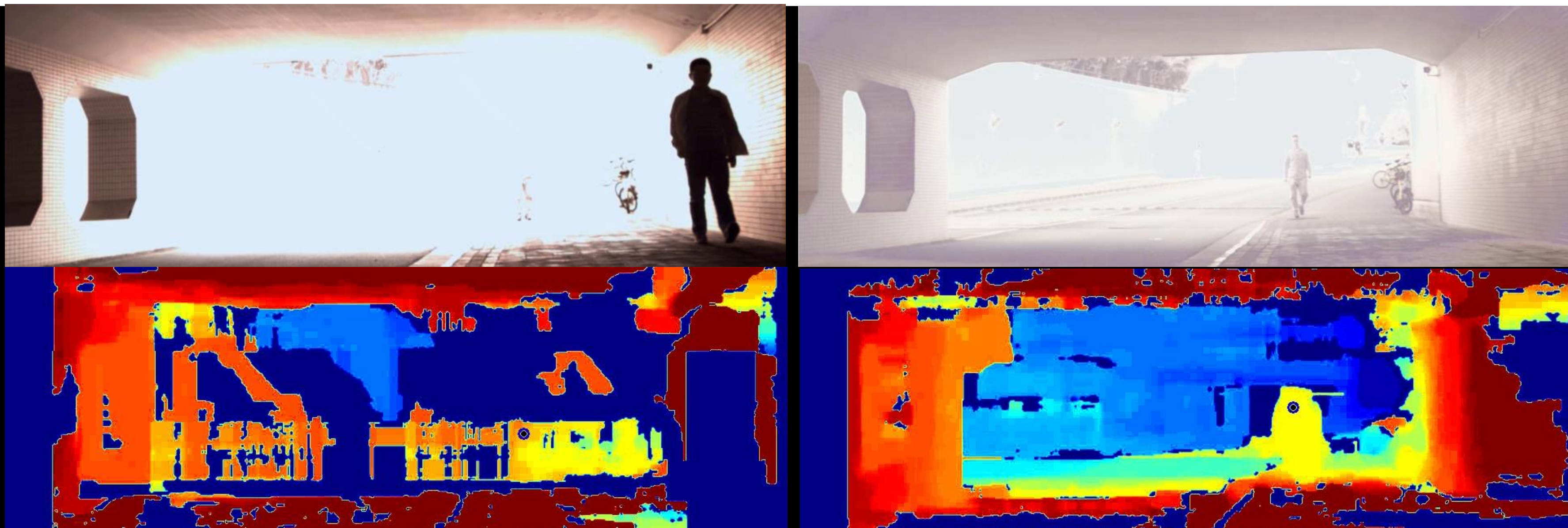
-> draws “wall”

Lidar

-> only three laser



Comparison at 20m: LDR, HDR, Lidar (VLP-16)

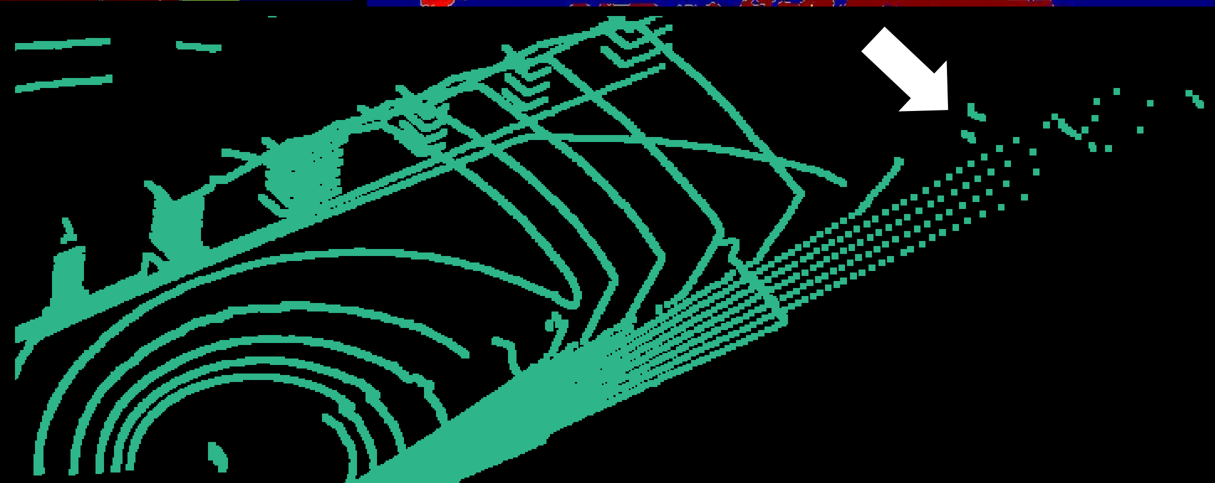


LDR Disparity Map

-> not recognizable

Lidar

-> only two laser



✓ Project Goal Achieved

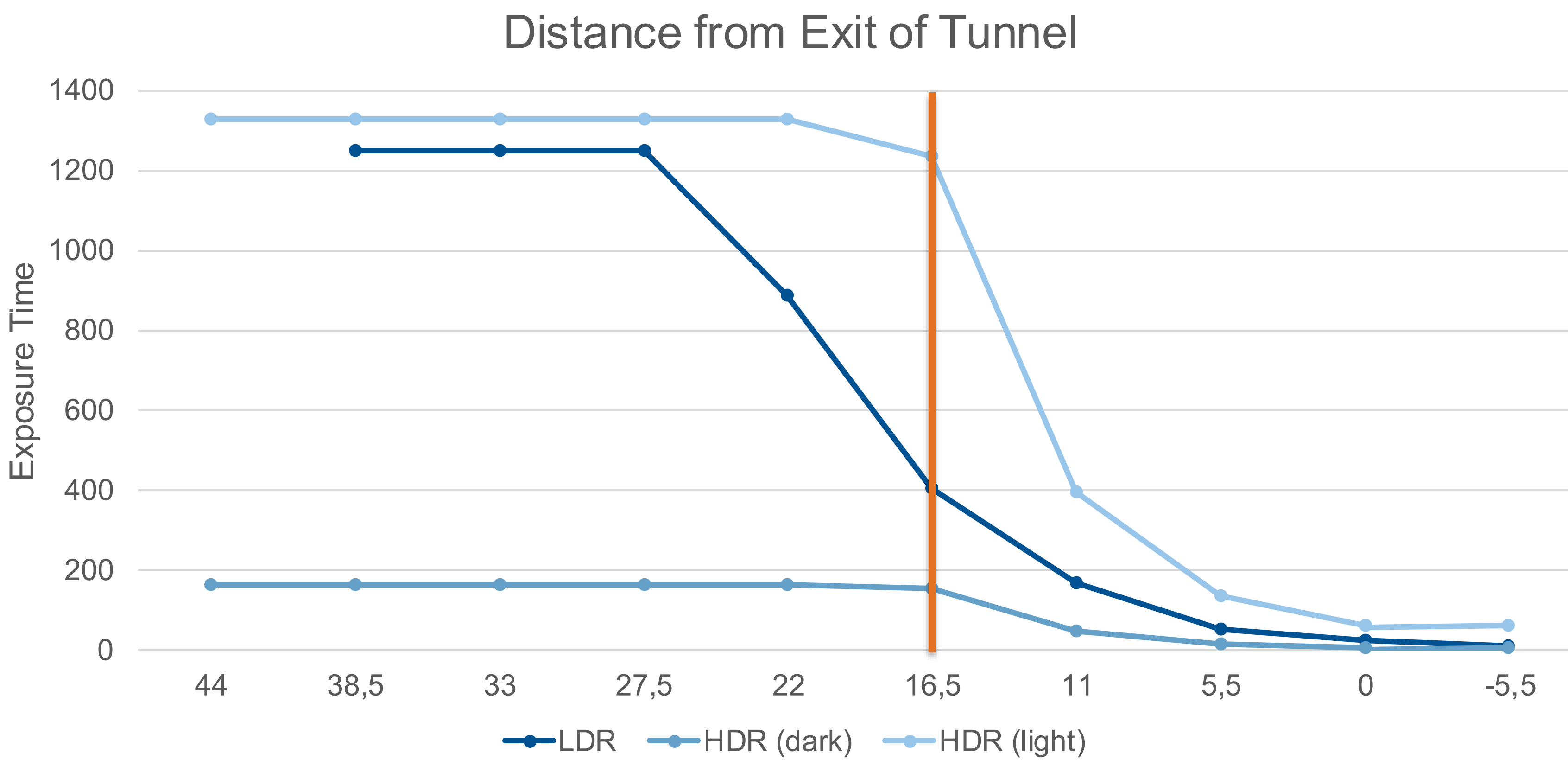
Disparity maps under **difficult light** situations improve using **HDR imaging**

BUT:

Master Limitations for use in Automotive Application

- **Light**
- **Performance**

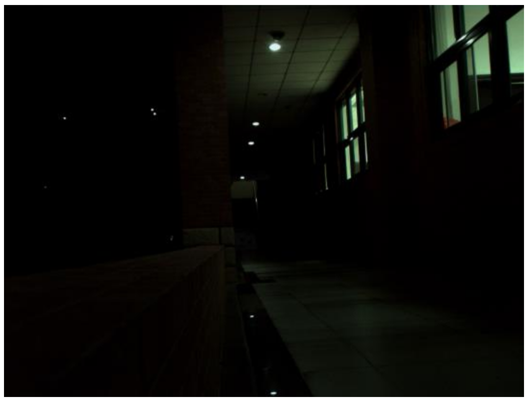
Light Limitations



-> With HDR, more than 20m into the tunnel will **decrease quality of disparity map**, due to use of **analog** and **digital gain**

No Gain

AG = 2, DG = 0



with Analog & Digital Gain

AG = 4, DG = 0

AG = 6, DG = 0

AG = 6, DG = 31

AG = 6, DG = 63

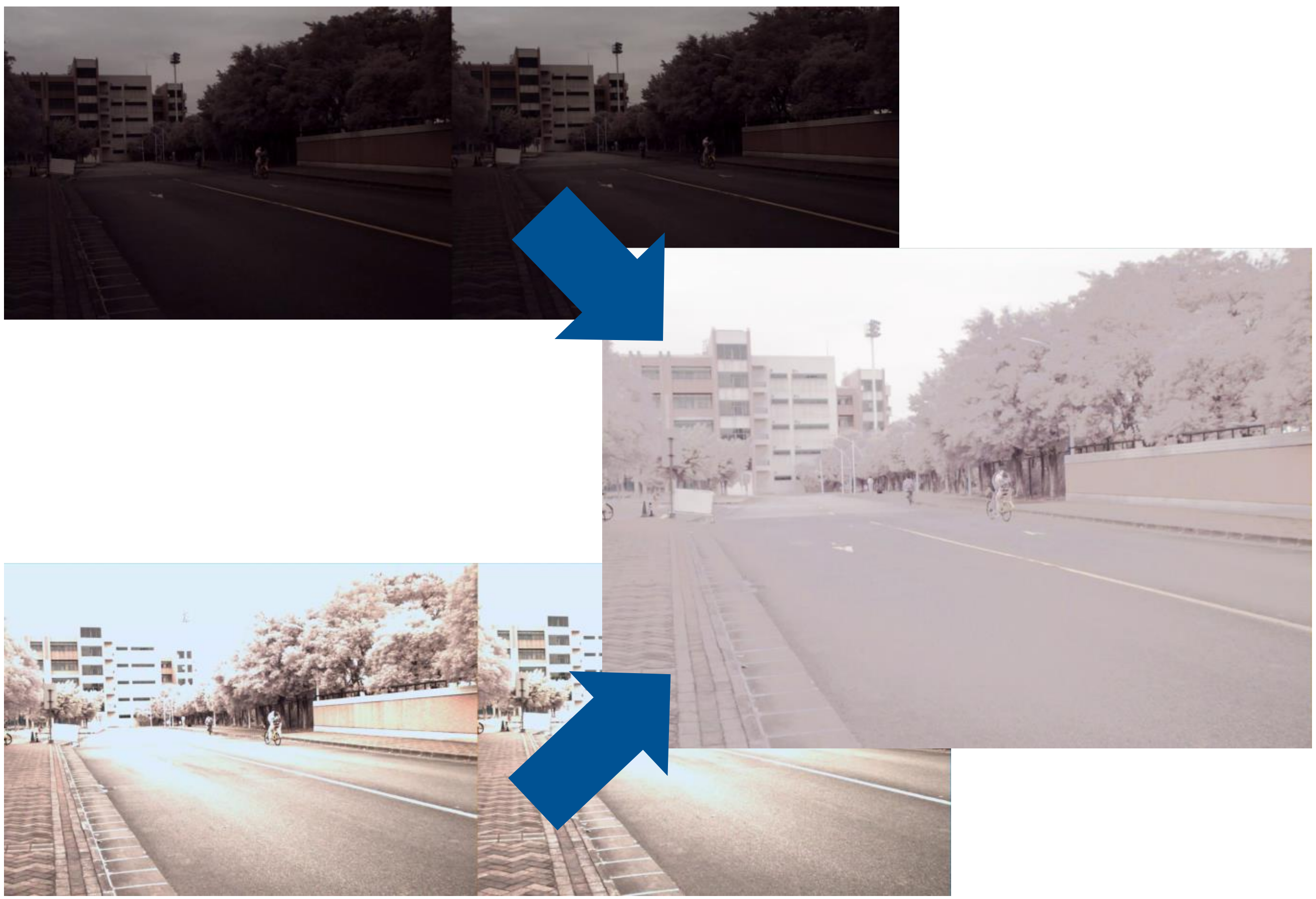
- Image becomes brighter
- Black turns into gray

-> Max AG = 4

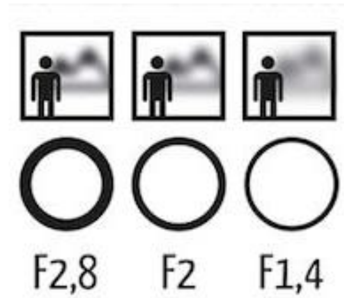
-> Max DG = 63

Influence of HDR on Frames per Second (fps)

Two images are combined to **one** -> fps will be **divided by two**!



Possible Measures against Light Limitations



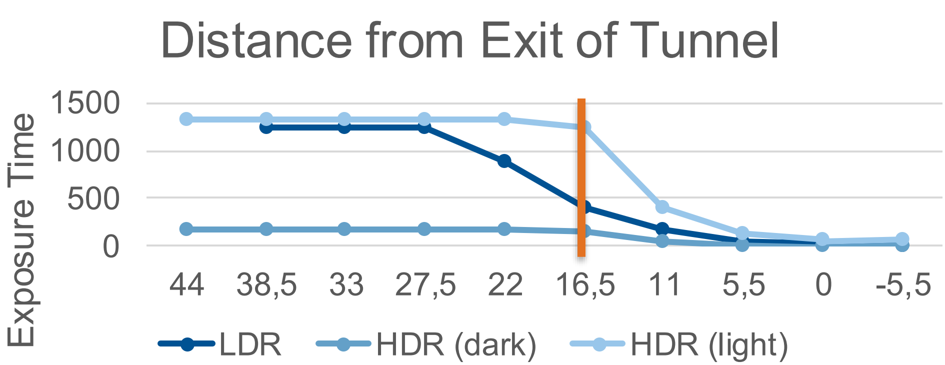
1. Lenses with lower Aperture (< f2.8)

   -> more expensive

2. Bigger and more light sensitive image sensors

   -> more expensive

3. Limit use of HDR to smallest difference in exposure times as possible



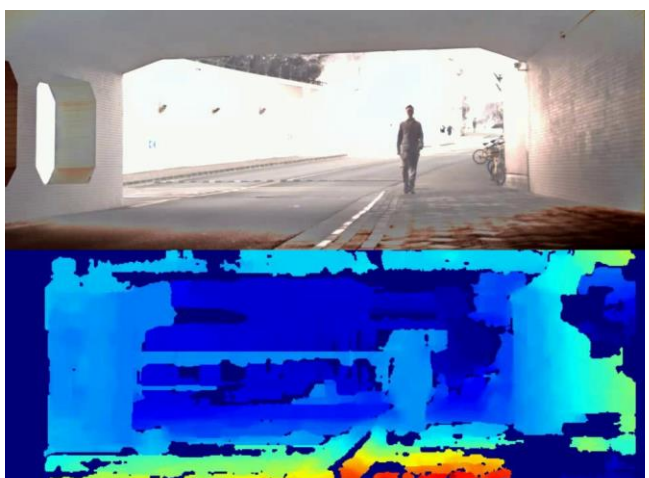
Possible Measures against Performance Limitations

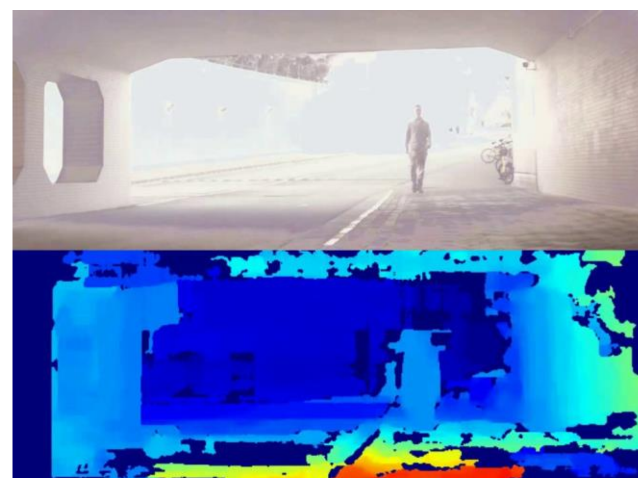
Additional HDR computation takes about **threefold** the computation time of LDR disparity maps

1. Faster Hardware

   -> more expensive

2. Analyse whether disparity map from merged images is sufficient





Future Work

In situations that decrease the quality of the disparity map due to difficult light:

-> Automatic use of HDR to improve disparity map
-> Finding optimum difference factor of exposure times

Might turn out fisible with improved/cheaper hardware

Questions?