Low Light Depth Enhancement for UAV Applications

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[1] M. Chu, “Edmonton LRT Tunnel,” *Flickr*, 02-Sep-2013. [Online]. Available: https://www.flickr.com/photos/mikechu/9648389099. [Accessed: 03-Dec-2022].

[2] D. Uria, “Drones to the Rescue: Public Safety Officials Invest in UAVs,” *UPI*, 11-Mar-2019. [Online]. Available: https://www.upi.com/Top_News/US/2019/03/11/Drones-to-the-rescue-Public-safety-officials-invest-in-UAVs/3181551831983/. [Accessed: 03-Dec-2022].

Problem Definition

A prototype unmanned aerial vehicle (UAV) tasked with autonomously mapping and exploring its environment using stereo depth estimation.

Environments include mine shafts, light rail tunnels (LRTs), search and rescue, and unstable infrastructure

Motivation

Suboptimal mapping and exploration performance in low lighting conditions

Various depth modes from camera unavailable with current firmware

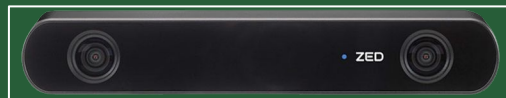
Introduction

Depth Estimation → Autonomous Navigation → Driverless Cars, UAVs etc.

[4] (*Google Researchers Released New State-of-the-Art Method For Depth Estimation from Single Image*, n.d.)

LiDAR

[5] (*3D LiDAR Sensors | MRS1000 | SICK*, n.d.)



[6] *ZED 2 - AI Stereo Camera | Stereolabs*, n.d.)

[7] The next Step in Machine Learning: Deep Learning - University of York, n.d.

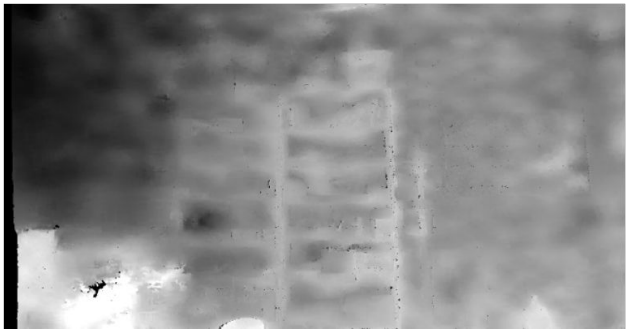
Related Work

The study done by Rafael, Nicola and Nicolai proposed a stereo matching method called MTStereo 2.0 for limited resource systems that require efficient and accurate depth estimation. It is based on a Max tree hierarchical representation of image pairs which is used to identify matching regions among image scanlines. The proposed approach was tested on several benchmark datasets like KITTI, Driving, Flyingthing 3D and achieved competitive accuracy and efficiency. [8] (Brandt et al., 2020)

Amit, Noam, David and Ron proposed a refinement network for depth estimation and processed Depth rather than Disparity. This depth refinement of stereo matching algorithms attempts to tackle and reduce the quadratic relation between the depth and the error within the depth estimate. [9] (Bracha et al., 2021)

Data Collection

Ultra Depth Mode



Neural Depth Mode

Stereo Image

Zed 2 stereo camera from Stereolabs to collect low light, left and right stereo image pairs in addition to low light, low quality depth images and high light high quality depth images.

Factory Claim regarding depth image qualities: "*The new Neural Depth mode generates a dense, high-fidelity depth map up to 2k resolution. The map is able to accurately capture challenging environments such as reflective surfaces and untextured areas. It also delivers high Depth completeness with unprecedented edge accuracy for advanced spatial segmentation*. [3]"

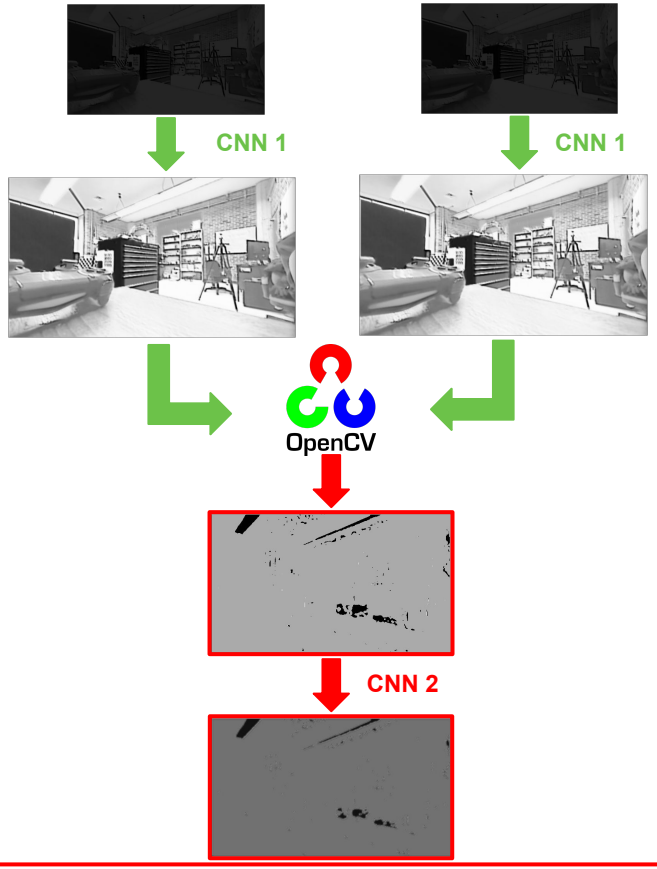
Depth Range: 0.5 m to 20 m

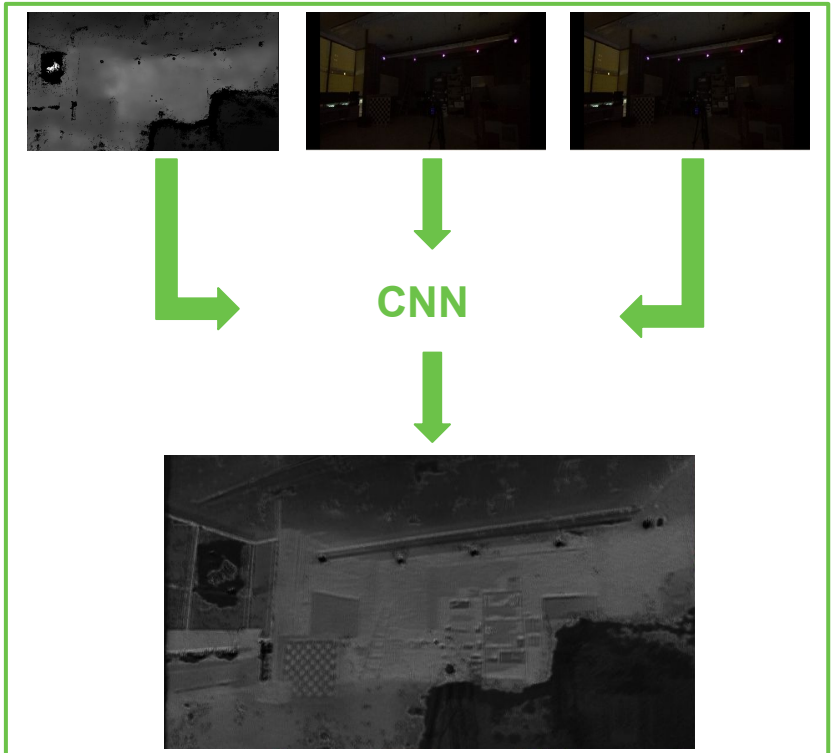
Depth Data Type: 32 bit floating point

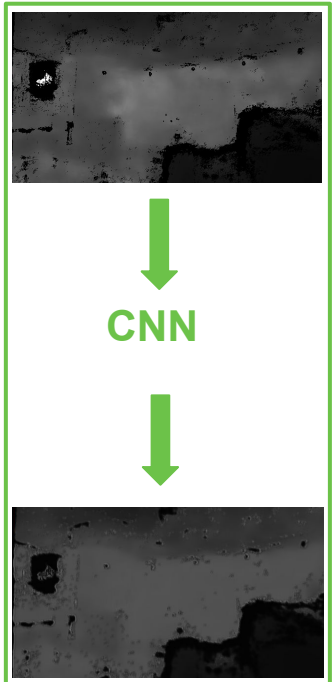
Left/Right Stereo Image Pairs: 8 bit 4 channel integers

Images: 100 - 80% Training 20% Testing

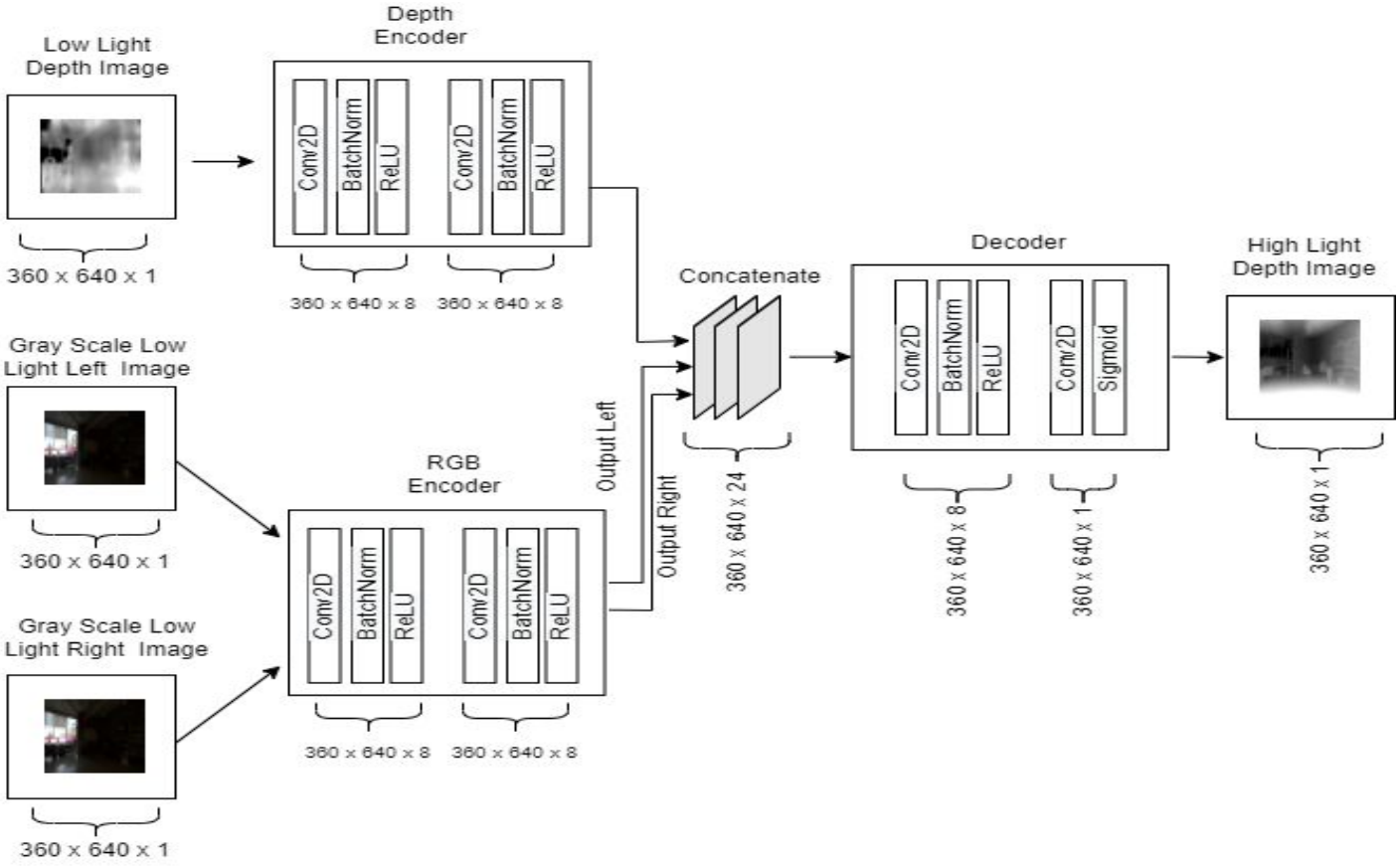
Evolution of CNN Models





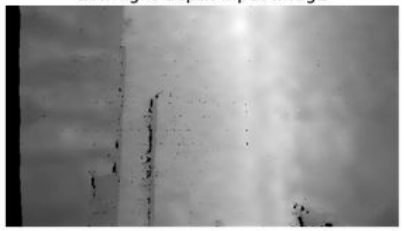


Model Architecture



Results

Low-light depth input image



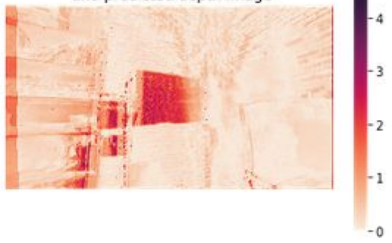
Low-light left input image

Low-light right input image

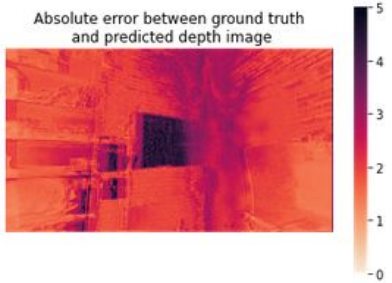
Output of the model

Ground truth depth image

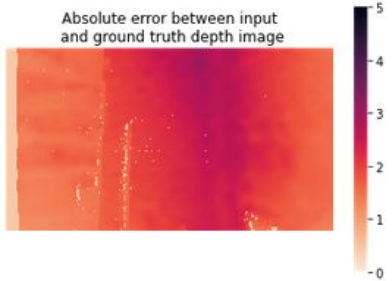
Absolute error between input and predicted depth image



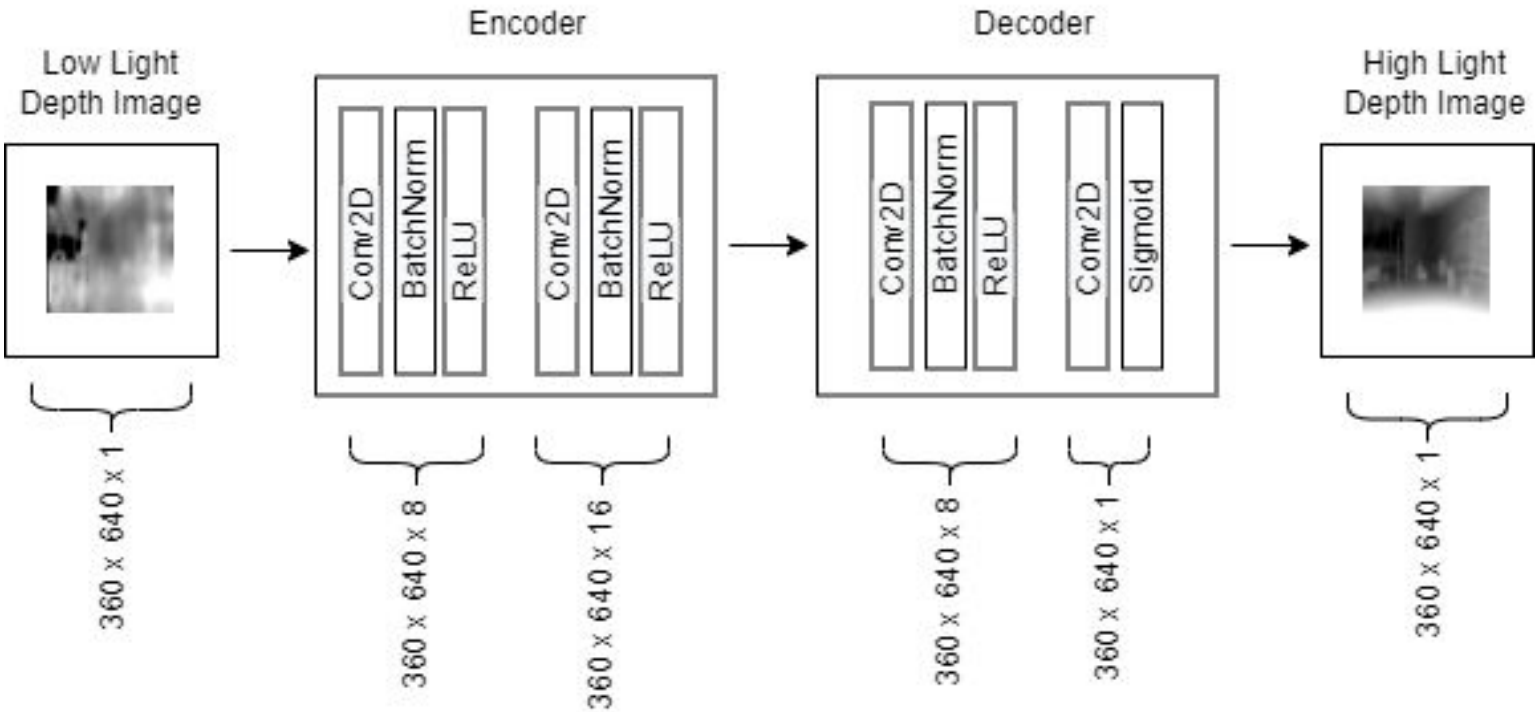
Absolute error between ground truth and predicted depth image



Absolute error between input and ground truth depth image

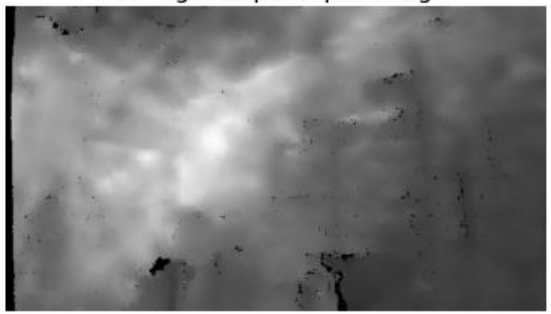


Model Architecture



Results

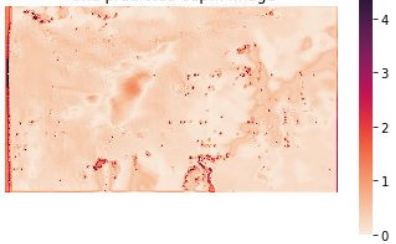
Low-light depth input image



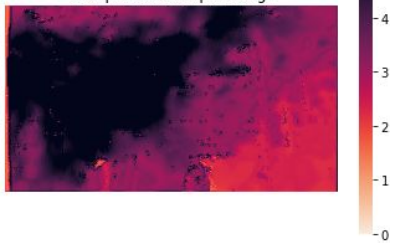
Output of the model

Ground truth depth image

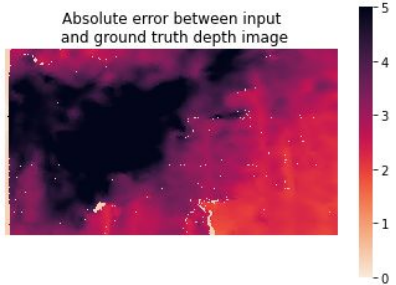
Absolute error between input and predicted depth image



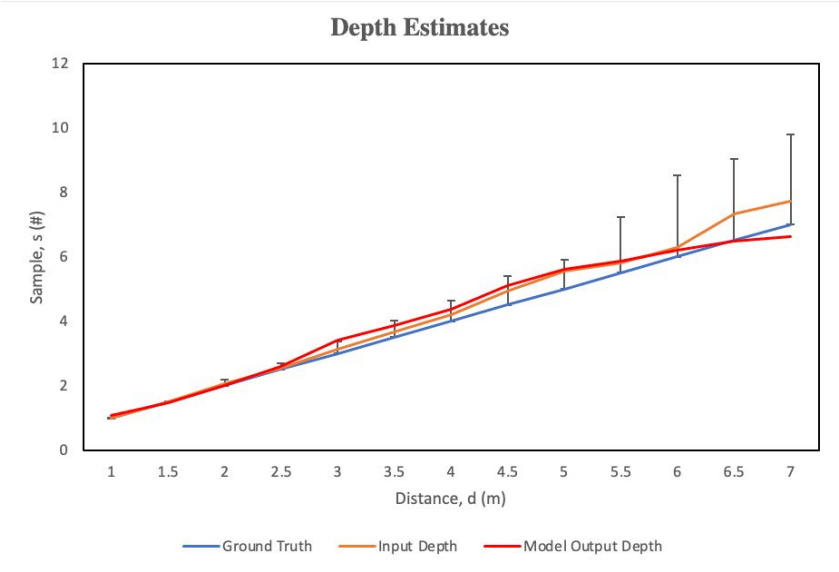
Absolute error between ground truth and predicted depth image

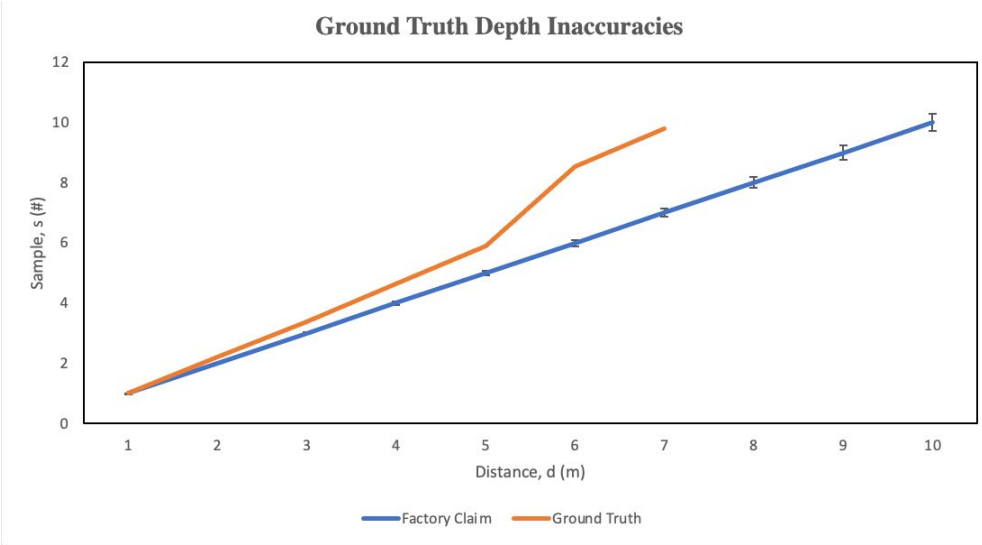


Absolute error between input and ground truth depth image



Results Continued





Ground Truth: The **high** light, **high** quality image
Input Depth: The **low** light, **low** quality image
Model Output Depth: The CNN **predicted** output depth

Stereolabs claims that the Zed 2 camera can report depth accuracies **within 1%** of the true depth at low distances. Additionally, This error will and will increase exponentially **up to 9%** at high depths.

Real Time Implementation

Hardware

Software

PyTorch

Python 2.7 + Python 3

C++

ROS
Robot Operating System

ubuntu

QGroundControl

Real Time Implementation Continued

References

[1] M. Chu, “Edmonton LRT Tunnel,” *Flickr*, 02-Sep-2013. [Online]. Available: https://www.flickr.com/photos/mikechu/9648389099. [Accessed: 03-Dec-2022].

[2] D. Uria, “Drones to the Rescue: Public Safety Officials Invest in UAVs,” *UPI*, 11-Mar-2019. [Online]. Available: https://www.upi.com/Top_News/US/2019/03/11/Drones-to-the-rescue-Public-safety-officials-invest-in-UAVs/3181551831983/. [Accessed: 03-Dec-2022].

[3] “Introducing next-generation stereo depth sensing,” *Stereolabs*, 29-Sep-2022. [Online]. Available: https://www.stereolabs.com/blog/neural-depth-sensing/. [Accessed: 07-Dec-2022].

[4] Google Researchers Released New State-of-the-art Method For Depth Estimation from Single Image. (n.d.). Retrieved December 6, 2022, from https://neurohive.io/en/news/researchers-from-google-released-new-state-of-the-art-method-for-depth-estimation-from-single-image/

[5] 3D LiDAR sensors | MRS1000 | SICK. (n.d.). Retrieved December 6, 2022, from https://www.sick.com/ca/en/detection-and-ranging-solutions/3d-lidar-sensors/mrs1000/c/g387152

[6] ZED 2 - AI Stereo Camera | Stereolabs. (n.d.). Retrieved December 6, 2022, from https://www.stereolabs.com/zed-2/

[7] The next step in machine learning: deep learning - University of York. (n.d.). Retrieved December 6, 2022, from https://online.york.ac.uk/the-next-step-in-machine-learning-deep-learning/

[8] Brandt, R., Strisciuglio, N., & Petkov, N. (2020). MTStereo 2.0: improved accuracy of stereo depth estimation withMax-trees. http://arxiv.org/abs/2006.15373

[9] Bracha, A., Rotstein, N., Bensaïd, D., Slossberg, R., & Kimmel, R. (2021). Depth Refinement for Improved Stereo Reconstruction. http://arxiv.org/abs/2112.08070

Questions?

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