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FRAUNHOFER INSTITUTE OF OPTRONICS, SYSTEM TECHNOLOGIES AND IMAGE EXPLOITATION

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# REAL-TIME ON-BOARD OBSTACLE AVOIDANCE FOR UAVS BASED ON EMBEDDED STEREO VISION

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Motivation

- The increase in the use of UAVs requires an improvement of their usability and safety

- UAVs are equipped with multiple sensors to monitor their surrounding, e.g. obstacle avoidance

- EU Project TULIPP: Development of an ecosystem for low-power real-time embedded image processing systems

Contribution

- System for real-time obstacle avoidance running on an embedded Xilinx Zynq Ultrascale+

I_{left}, I_{right} — Disparity estimation — D — Obstacle avoidance
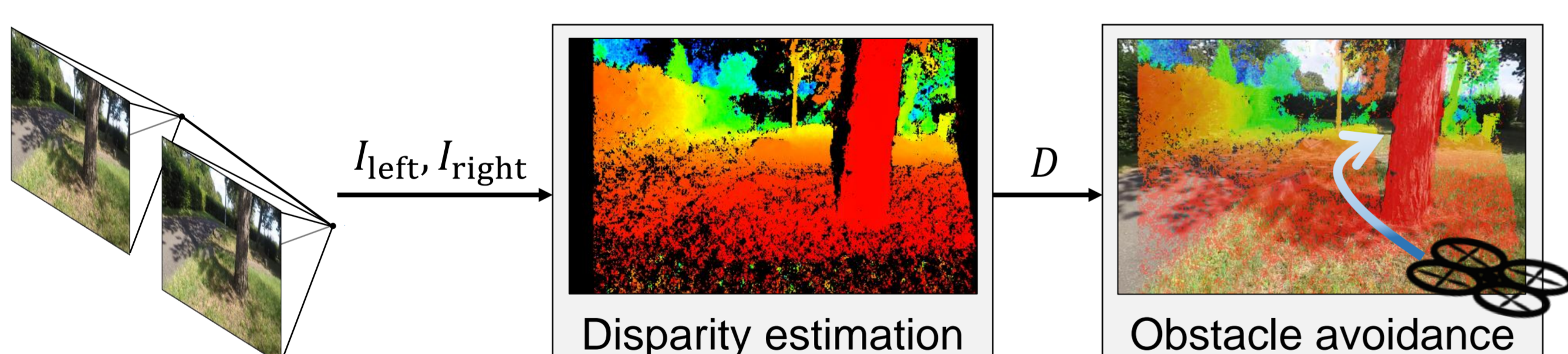
Disparity Estimation

- Stereo disparity estimation based on SGM (Hirschmueller, 2008), directly synthesized form C/C++ with HLS and deployed on embedded FPGA

  1. Image rectification and matching

  2. 4-path SGM optimization, adopted for streamed processing

  3. Left-Right check and Median filtering

Obstacle Avoidance

- Reactive obstacle avoidance algorithm computing shortest path around obstacle based on disparity map

  1. U- / V-Map computation (Oleynikova et al. 2015)

  2. Binary filtering and contour detection

  3. Obstacle extraction and waypoint computation

Experiments

- Runtime measurements

Operation	Time [ms]	Avg. Time [ms]
Disparity Estim. (FPGA)	31.4 – 36.1	34.5
Obstacle Avoid. (CPU)	2.7 – 11.0	4.2
Total	34.1 – 47.1	38.7

200 MHz

- Up to 29 Hz and a latency of 28.5 ms at a frame size of 640x360 pixel and 60 disparities

- Evaluated Sum of Absolute Differences and Census-Transform with 5x5 support region

- Quantitative results on KITTI Stereo 2015 benchmark (Menze et al., 2015)

Cost function	Density	Correct pixels
Sum of Abs. Diff.	64.1 %	76.0 %
Census Transform	74.2 %	95.4 %

- Obstacle avoidance deployed on ARM quad-core CPU running at up to 1.5 GHz

  - Hardware-in-the-Loop testing with DJI flight simulator

Future Work

- Perform experiments in the real-world with the embedded system mounted to the UAV

- Evaluate the algorithm w.r.t. energy consumption on embedded FPGA, CPU and GPU architectures

Literature

Hirschmueller, H., 2008. Stereo processing by semiglobal matching and mutual information. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 30(2), pp. 328–341.

Oleynikova, H., Honegger, D. and Pollefeys, M., 2015. Reactive avoidance using embedded stereo vision for mav flight. In: *Proc. IEEE International Conference on Robotics and Automation*, pp. 50–56.

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