

Design and Implementation of SIFT Algorithm on FPGA for Autonomous Vehicle Vision Applications

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PROJECT OVERVIEW

- ◆ Introduction
- ◆ Motivation
- ◆ Background
- ◆ SIFT Algorithm
- ◆ MATLAB Model
- ◆ RTL Implementation
- ◆ Results and Analysis
- ◆ Future Work and Summary

INTRODUCTION

- 💧 Computer vision algorithms
- 💧 Video – Collection of Images
- 💧 Autonomous Vehicles – Real Time Processing



MOTIVATION

- ◆ To perform Real Time processing Of SIFT [3]
- ◆ Hardware Faster – Every millisecond counts
- ◆ Cost-Effective in the long run and Efficient

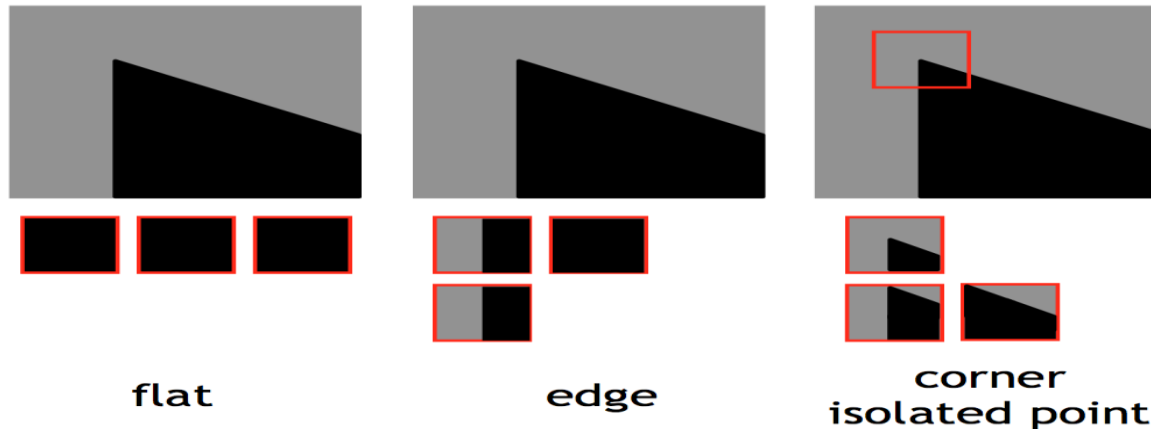
BACKGROUND

◆ David Lowe

- 1999 Invariant feature detection
- 2004 patented, distinctive Image Features [1]

BACKGROUND

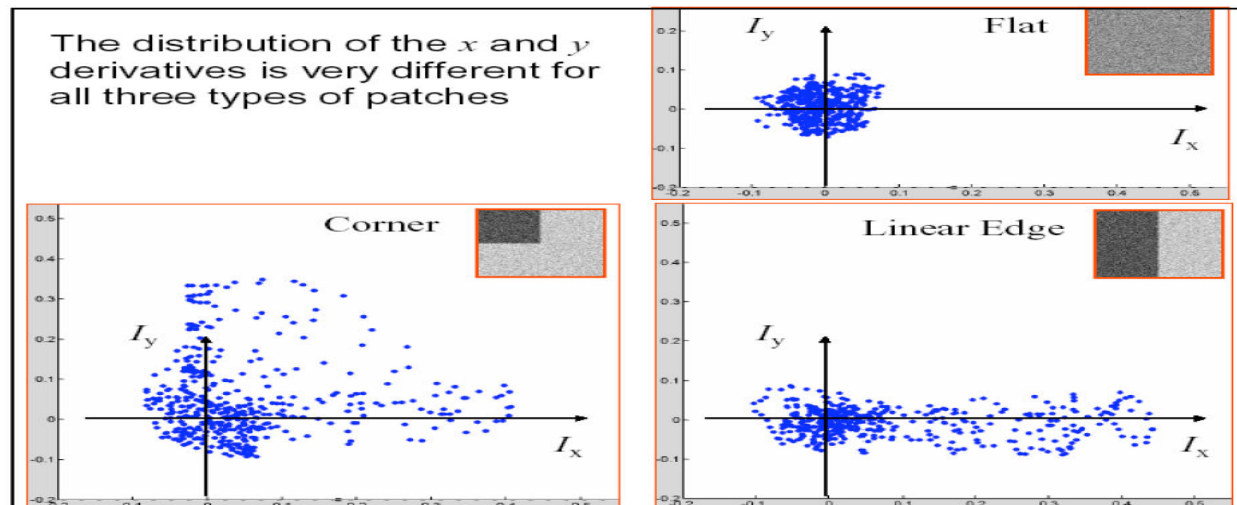
- ◆ Moravec Corner Detector , 1981 [2]
 - Shifting Window to compare Intensity levels
 - SSD (Sum of Squared Differences)



BACKGROUND

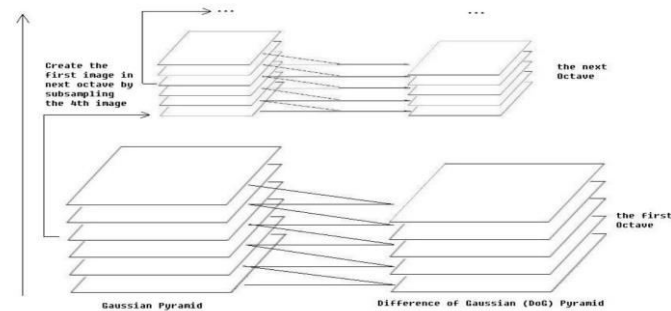
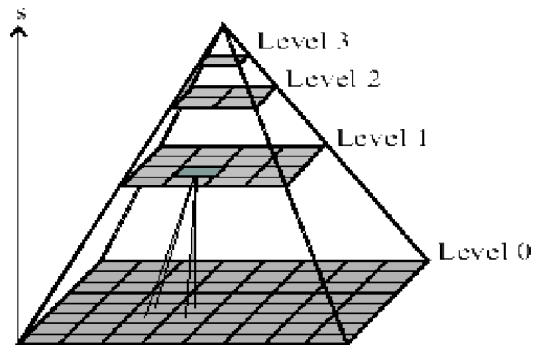
💧 Harris Corner Detector , 1988 [4]

- Differential gradients in X and Y directions in place of shifted rectangles

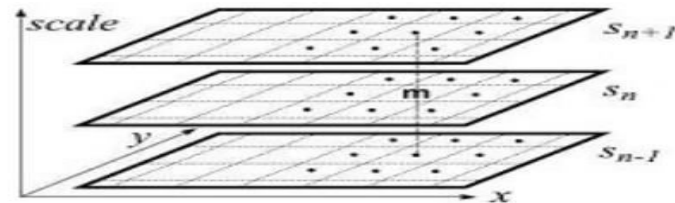


SIFT ALGORITHM [1]

Scale-space extrema detection – Gaussian, DOG

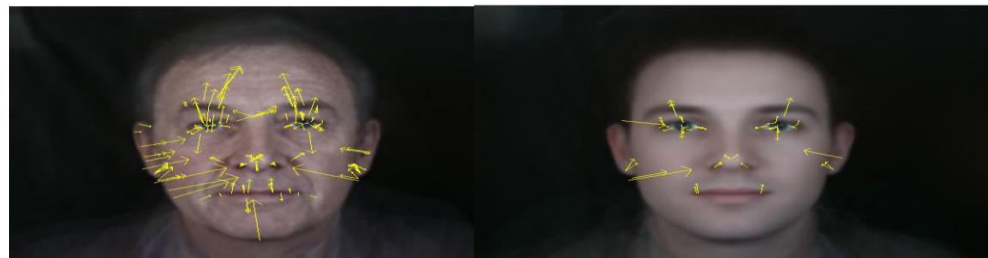
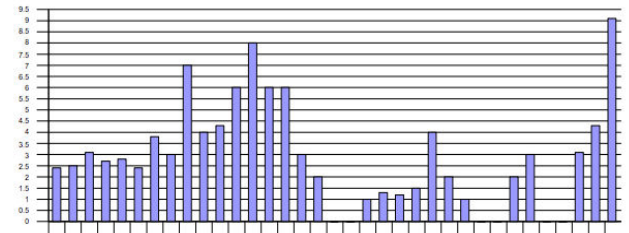
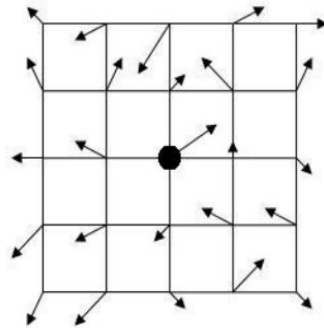


Keypoint localization – Local Extrema



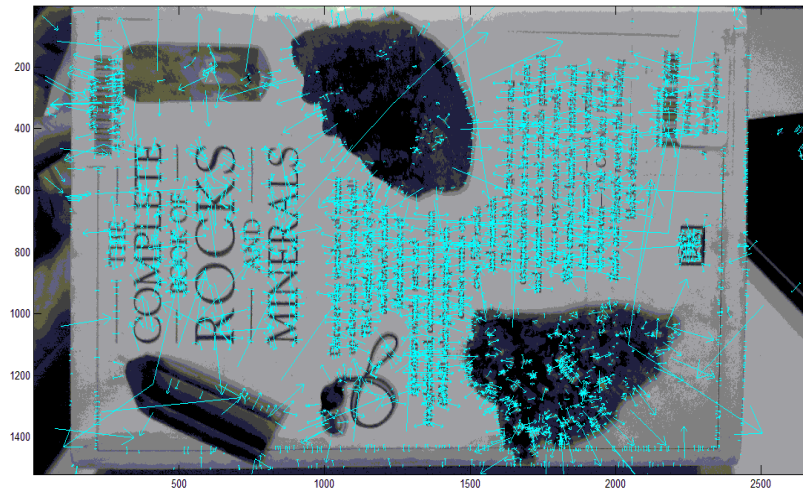
SIFT ALGORITHM

- Orientation assignment – Local Gradients
- Keypoint descriptor



MATLAB

- Implemented the whole SIFT process with image matching.



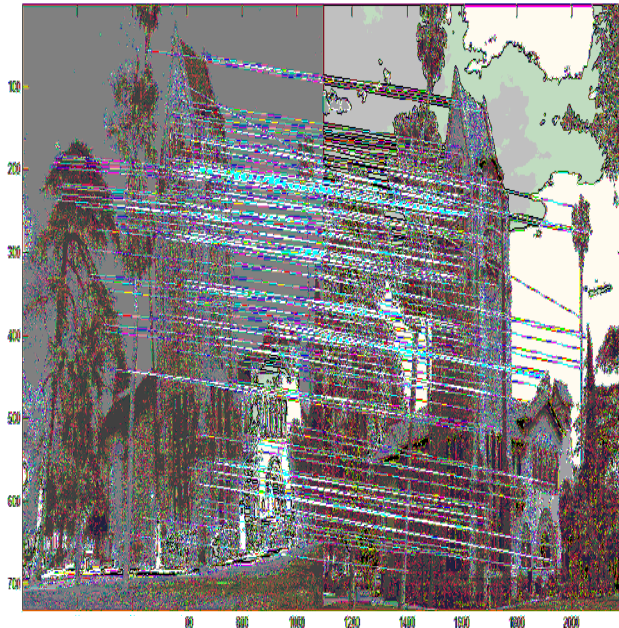
MATLAB



```
Finding keypoints...  
8934 keypoints found.  
Finding keypoints...  
3190 keypoints found.  
Found 50 matches.
```

```
num =  
  
    50
```

MATLAB

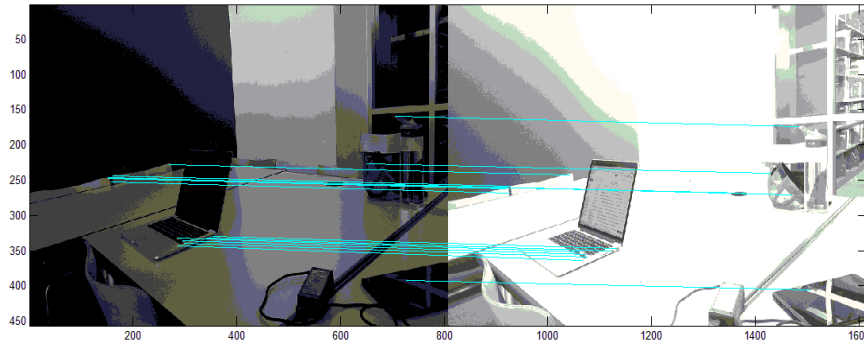


```
>> [num,lm0,lm1]=match2('Tower_Night.jpg','Tower_Day.jpg')  
Finding keypoints...  
4460 keypoints found.  
Finding keypoints...  
5003 keypoints found.  
Found 163 matches.
```

```
num =  
  
163
```


MATLAB

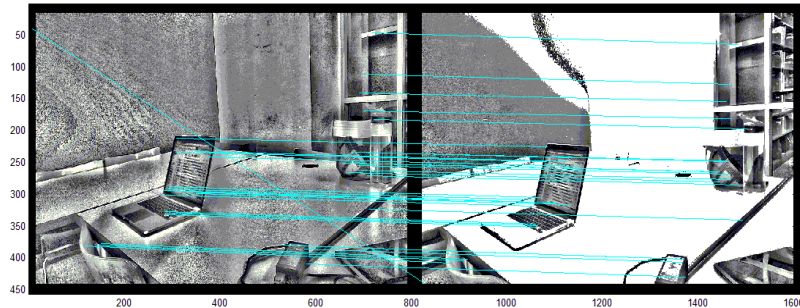
Matching without Pre-Processing



```
Finding keypoints...  
261 keypoints found.  
Finding keypoints...  
582 keypoints found.  
Found 24 matches.
```

```
num =  
  
24
```

Match with Pre-Processing

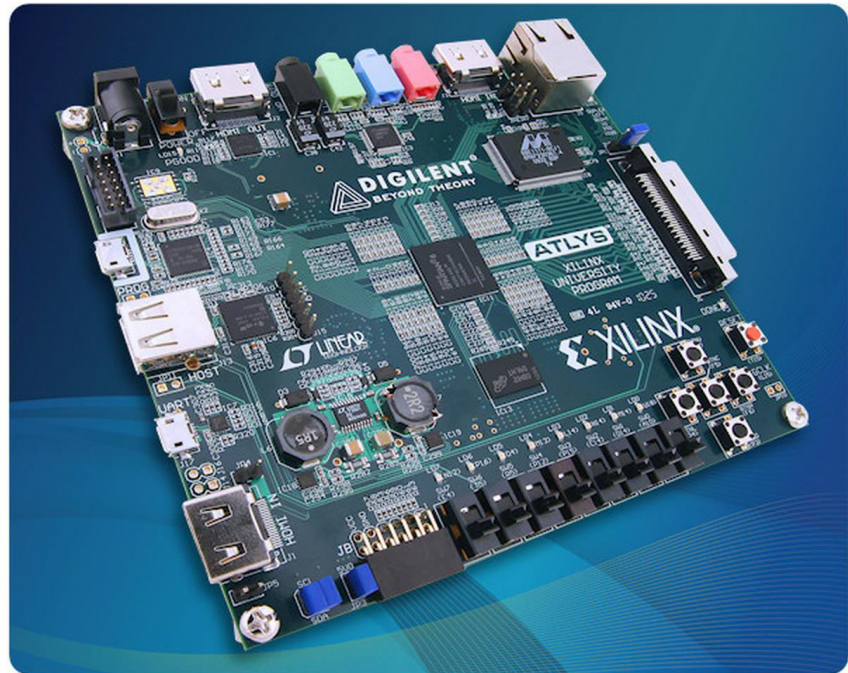


```
Finding keypoints...  
2034 keypoints found.  
Finding keypoints...  
1283 keypoints found.  
Found 39 matches.
```

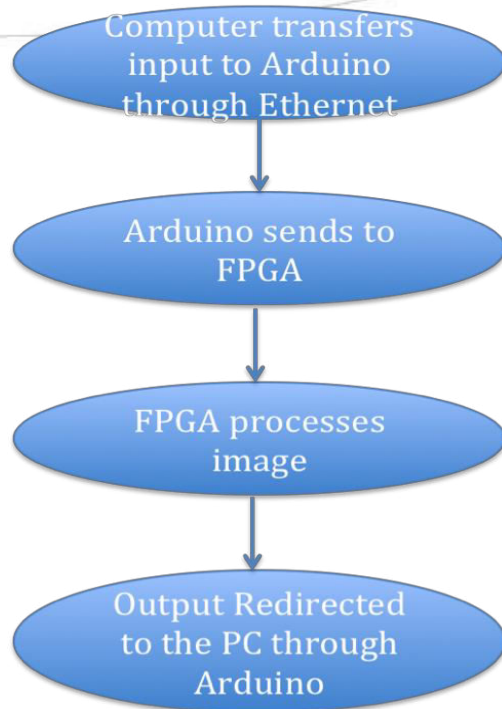
```
num =  
  
39
```

HARDWARE

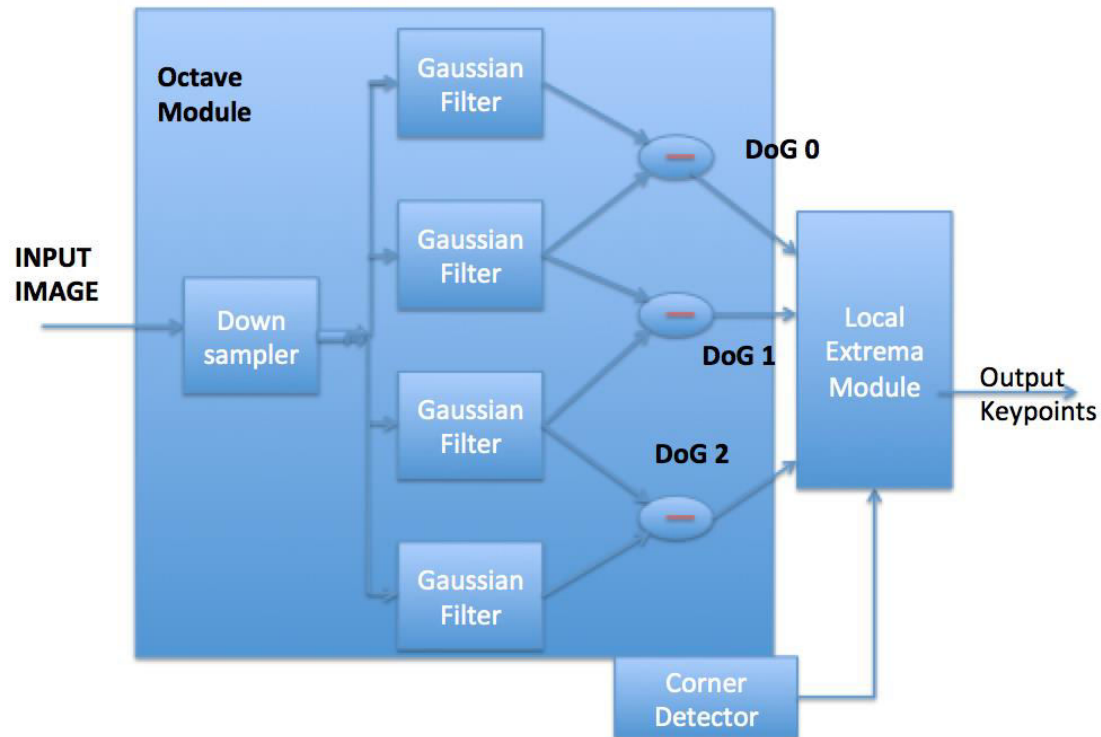
- 💧 Spartan 6 FPGA
- 💧 324 Pin Package
- 💧 6822 Slices
- 💧 2.1 Mbits of RAM
- 💧 58 DSP Slices



System Flow



RTL IMPLEMENTATION



RTL RESULTS

Input Image



DoG Output



DOG1.bmp



DOG2.bmp

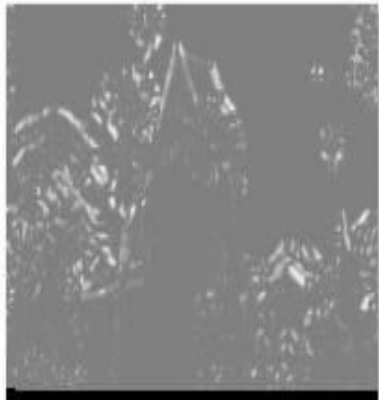


DOG3.bmp

RTL RESULTS



Harris Corner Output



corner1.bmp



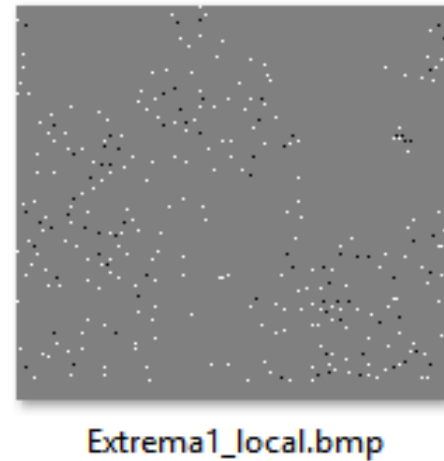
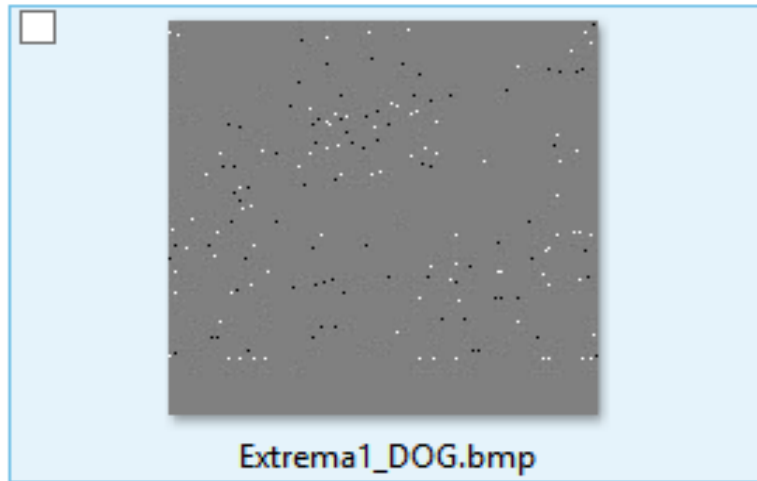
corner2.bmp



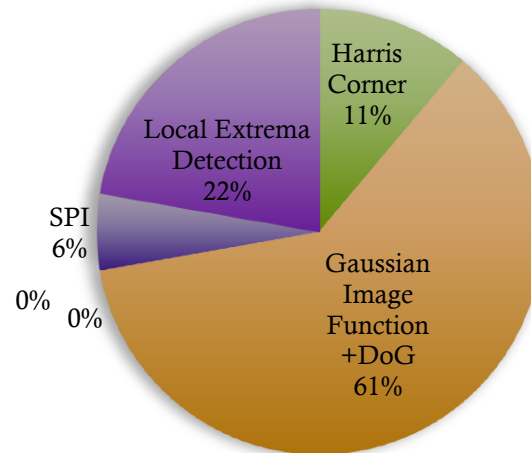
corner3.bmp

RTL RESULTS

Local Extrema Output

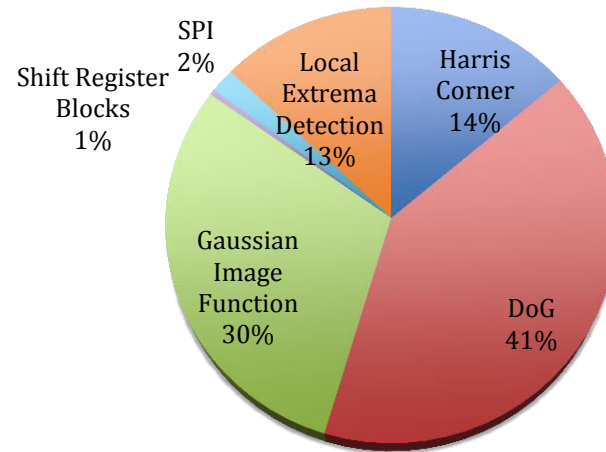


ANALYSIS



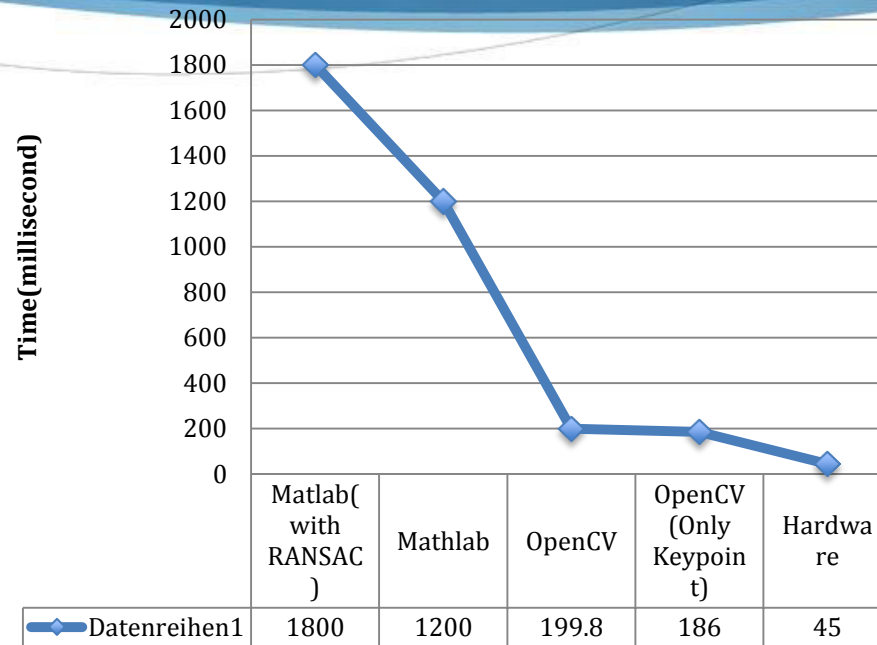
Computational Complexity per Module

ANALYSIS



Resource Utilization per Module

ANALYSIS



RUN TIME across different Implementations

FUTURE WORK AND APPLICATIONS

- ◆ Optimize Resources
- ◆ Object Tracking features
- ◆ More complex applications using this SIFT engine

SUMMARY

- ◆ Successful Implementation of the SIFT algorithm on an FPGA.
- ◆ Faster than software based approaches.
- ◆ Computationally intense part of SIFT as a hardware accelerator is beneficial

REFERENCES

- [1] D. G. Lowe, “Distinctive Image Features from Scale-Invariant Keypoints,” IJCV, 2004.
- [2] H. P. Moravec, “Obstacle avoidance and navigation in the real world by a seeing robot rover,” Ph.D. dissertation, Stanford University, Stanford, 1980.
- [3] Nathan Brummel & Tyler McAtee , "Implementation of scale-invariant feature transform (SIFT) " - December 11, 2013
- [4] C. Harris and M. Stephens, “A combined corner and edge detection,” in Proc. 4th Alvey Vis. Conf., 1988, pp. 147–151.

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THANK YOU



Q & A