Movidius
an Intel company

MDK Disparity Map Example

Application Note

v1.0

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1 Software Architecture

1.1 Introduction

Disparity Map is a cross-compilable example that runs on Myriad 2 chip and PC.

1. Myriad 2 project

   `mdk/examples/Demo/DisparityMap/myriad`

   The dense depth map is computed for each pair of left and right images captured by IMX208 sensors of 640x480 resolution. A rectification is applied on the right image for a better quality of the disparity map.

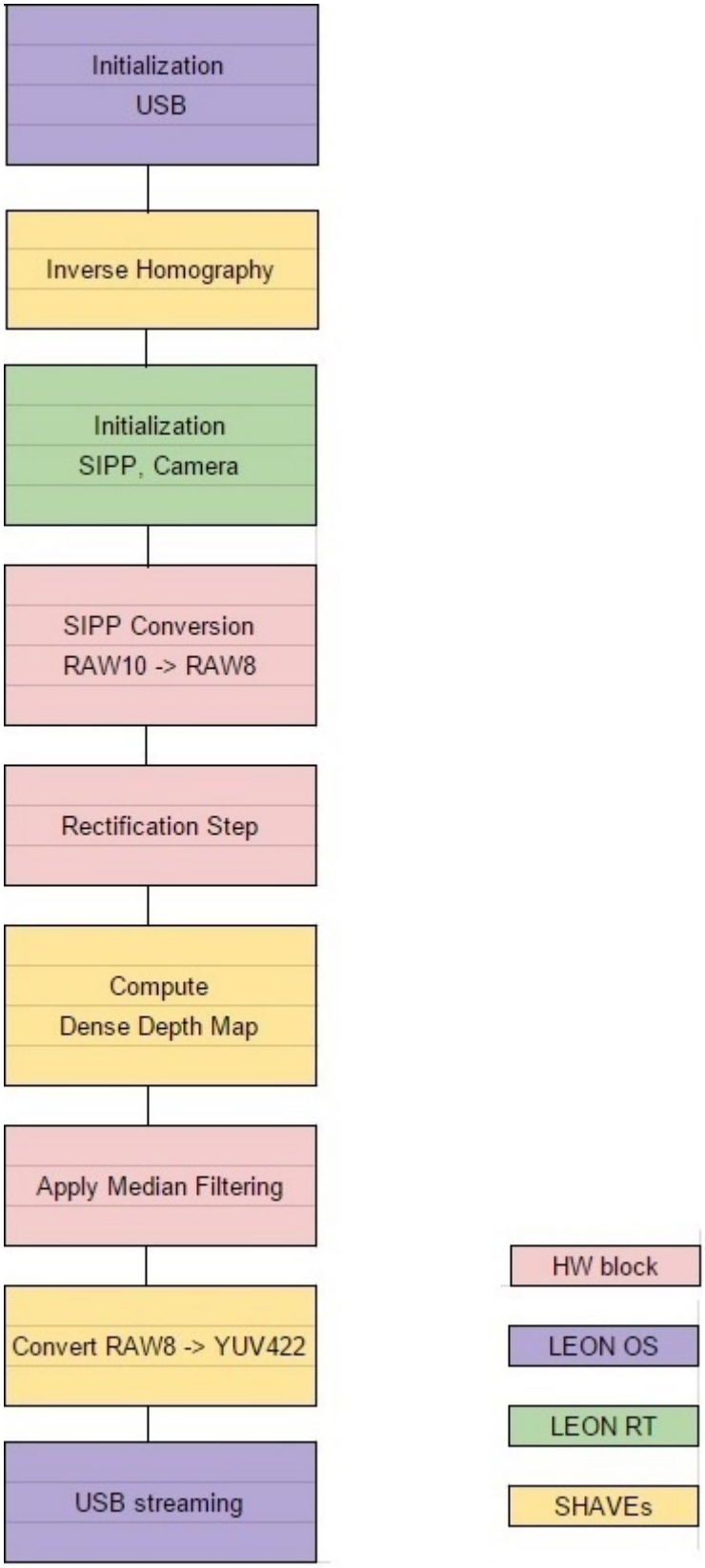
   The output is converted to YUV422 and streamed via USB.

2. PC project

   `mdk/examples/Demo/DisparityMap/pc`

   The dense depth map is computed for one pair of left and right images from the Middlebury dataset of 640x480 resolution.

1.2 High Level Architecture



2 Detailed Architecture

2.1 Requirements

The rectification step requires a Homography that is computed offline using OpenCV's function `findHomography()` after having detected the corners in both left and right images.

2.2 Camera Configuration

The IMX208 stereo sensor is connected in the following way:

- sensor 1 – CIF (RAW10).
- sensor 2 – SIPP MIPI (RAW10).

Sensor's resolution is 968x548 and images are center cropped to 640x480.

Camera runs at 30Hz and is configured in BINNING mode.

2.3 SIPP Conversion RAW10 → YUV400

A Lookup Table is used for converting the camera input from RAW10 to YUV400 needed for the algorithm.

2.4 Rectification Step

Rectification is done by a hardware block and consists in translation, rotation and warping.

The inverse of the precomputed Homography is needed, H^-1

$$L * H^{-1} = R$$

Rectification is applied on the right image in order to align the left and right images on the horizontal axis. This alignment offers the possibility to search in a range of maximum 64 disparities.

2.5 Disparity Map Computation

4 SHAVE processors are used and each one processes a patch of 640x130 of the image. Leon RT is in charge of splitting the image into 4 patches and reconstructing the final disparity map out of patches.

Disparity Map is computed by applying the following transformations to the images:

1. Census Transform (5x5 block) for left image
2. Census Transform (5x5 block) for right image
3. Census Cost
4. Census Minimum – Winner Takes All
5. Median Filtering

2.6 Conversion RAW8 → YUV422

An asm function is used to convert YUV400 algorithm's output to YUV422 to be streamed on USB.

2.7 USB Streaming

When a frame is finished being processed the USB is notified that he can stream it.

2.8 Memory footprint

The configured system frequency is 500MHz.

Processors used:

- LEON OS for USB code.
- LEON RT for camera streaming and managing image patches.
- SHAVES 0-3 for Depth Map computation.
- SHAVE 0 for preprocessing(H^-1) and postprocessing(YUV422 conversion).
- SHAVE 4 for SIPP internal lines.

Memory map:

1. CMX

   Each SHAVE requires ~70 KB for internal line buffers.

2. DDR

   Buffers for frame cameras, rectification, disparity maps and USB are located in DDR.

3 Performance

3.1 Optimized design

The processing is optimized in order to obtain 30 FPS:

- Frame N: capture frames.
- Frame N-1: rectification step.
- Frame N-2: dense depth map computation.

3.2 Performance

The table below shows performance for major processing steps.

Algorithm step	Measured ms @500Mhz
Preprocessing (H^-1)	0.01
Conversion RAW10 → YUV400	3.35
Rectification	16.24
Disparity Map Computation	22.13
Median filtering	0.82
Conversion YUV400 → YUV422	1.60