Automatic Matching and 3-D Reconstruction of Free-Form Linear Features from Stereo Images

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Introduction

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- Automatic matching of free-form linear features is a groundbreaking problem to solve because of it's applications in 3-D reconstruction problem.
- We tried to implement one of the older algorithms to incorporate the concepts of parallelization in sequential algorithms.

Problem Statement

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Given a pair of images, we have to do the following :

- Calculate the **Fundamental matrix**.
  - It defines the relationship between the sterio pairs.
- Perform 3-D reconstruction using that matrix.

Our Approach

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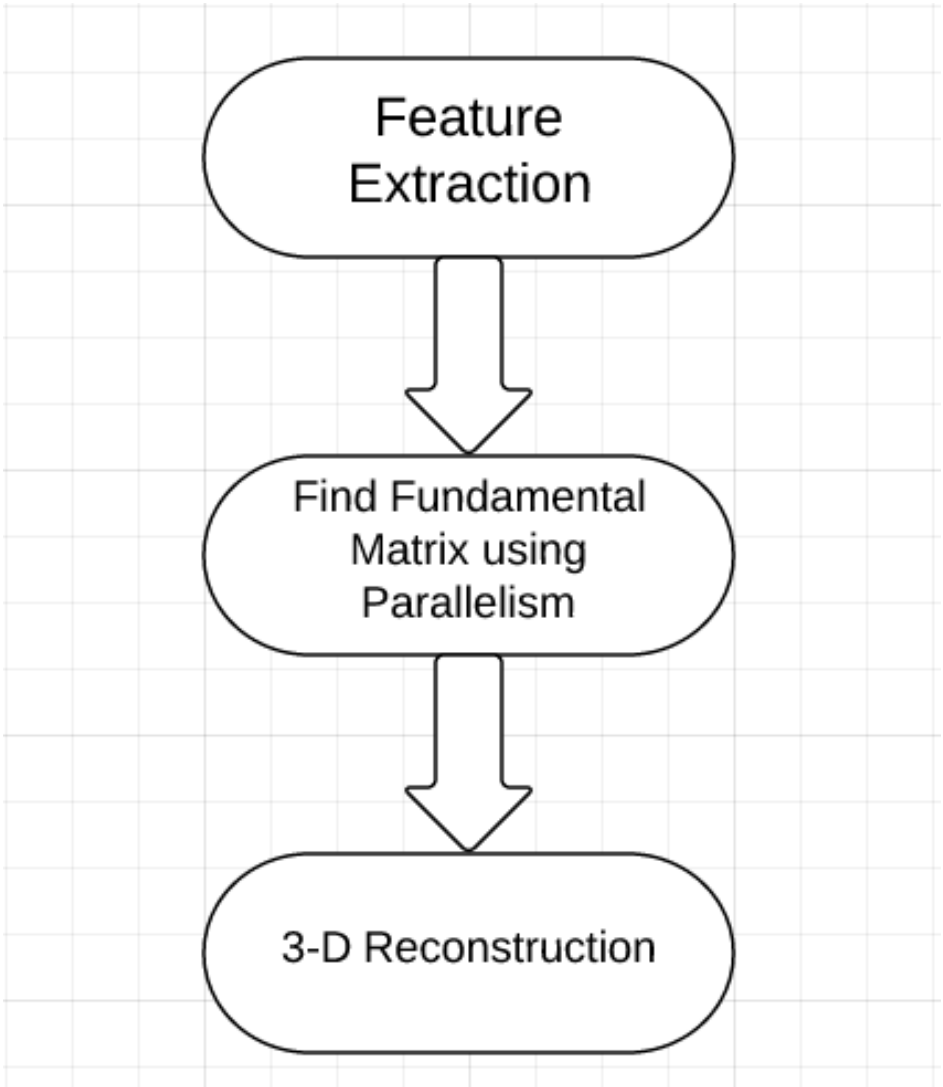

Feature Extraction (SIFT)

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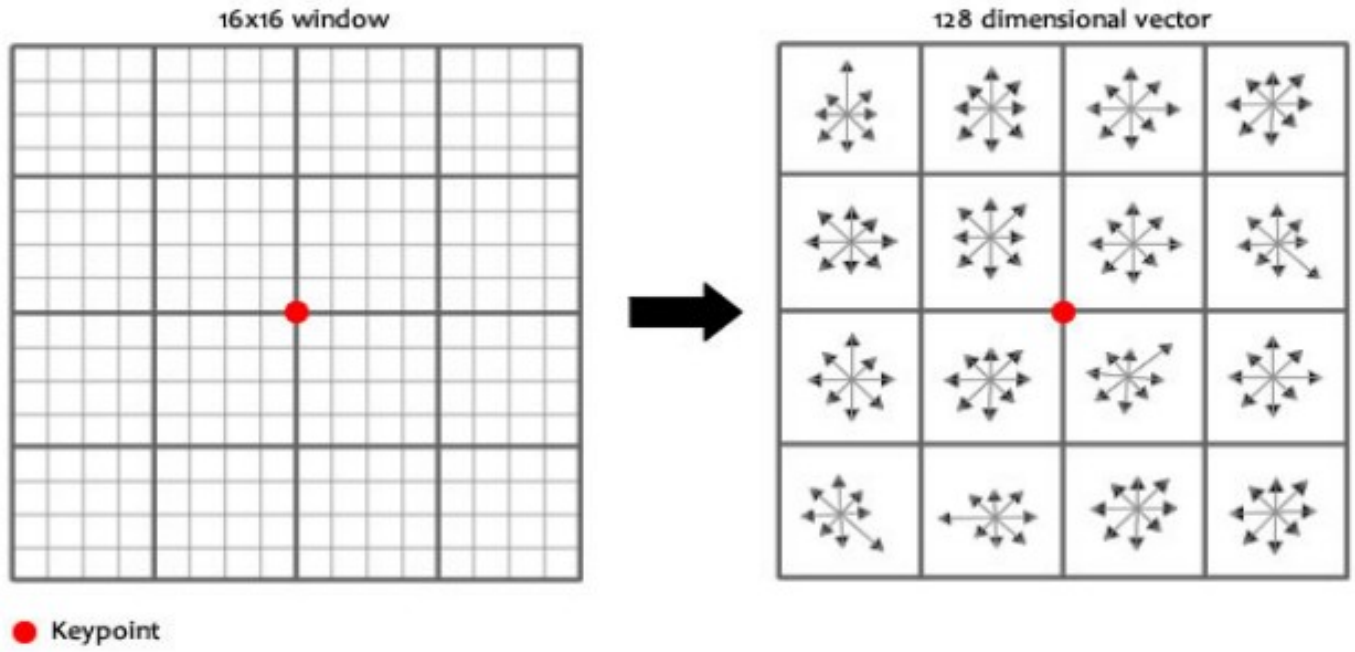
- SIFT(Scale Invariant Feature Transform) is used as the feature extracting algorithm to extract feature points for the two given images.
- These features are invariant to image translation, scaling and rotation.
- This invariance is due to the difference fo Gaussians function applied to scale space to a series of smoothed and resampled images.
- These features are quite robust and more stable for image matching and recognition.

Feature Extraction (SIFT)



- Feature points from both the stereo images form the respective keypoints set.
- These keypoints are used to calculate the entities of **fundamental matrix**.

Finding Fundamental Matrix

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- Fundamental matrix defines a relationship between the pair of sterio images.

$$x'^T F x = 0$$

- x' and x are the conjugate points on the left and right stereo images respectively.
- Fx corresponds to the epipolar line on which x' on the other image should lie.

Parameter Calculation

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- One parameter is calculated at a time.
- Randomly initialize the matrix.
- Take every possible pair of matching hypotheses (every pair of points : one from keypoint_1 and one from keypoint_2).
- For every pair of matching hypotheses, we calculate a particular parameter of the fundamental matrix.
- Now for every pair of matching hypotheses, we obtain a value and check to what bin of the accumulator array does it belong.

Parameter Calculation

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- After taking every matching hypotheses into consideration , take the bin with the max number of elements in the accumulator array.
- All those matching hypotheses who contribute to that accumulator array , are considered as possible matches and the value of the accumulator array is assigned to the parameter.
- In this way we solve for every parameter of the fundamental matrix and also get the possible matches for the stereo images.

Parallelism

- One dimensional block.
- Block Size = 256
- Number of blocks = $\frac{n_1 \times n_2}{256}$
  - n1 and n2 are the number of elements in repective keypoint sets.
- Index i and j are defined as follows for their repective sets :
  - $i = idx \mod n_1$
  - $j = (int)\frac{idx}{n_1}$
- The set of variables is calculated in parallel.

Parallelism

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- Using them another **intermediate matrix** is calculated that is then further used to calculate the **fundamental matrix**.
- The structures copied on the **device memory** include :
  - KeyPoint Arrays
  - Array to store the variables.
  - An intermediate array to store the intermediate values.
  - Some Variables.

3-D Reconstruction

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- Obtain the fundamental Matrix.
- Compute the **Essential Matrix** and then compute the **rotation and translation matrix** (matrix describing the orientation between the two cameras).
  - Essential Matrix :

$$E = K' T.F.K$$

  - More general form of fundamental matrix as essential matrix can only be used in relation to calibrated cameras since inner camera parameters must be known.
- Then we use the inbuilt functions to obtain the disparity map of the stereo images.

Results

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On 21.tiff, 22.tiff from the given dataset :



Results

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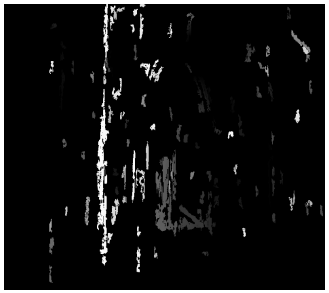
On w1.tiff, w2.tiff from the EPFL website:





References

- Automatic Matching and Three-Dimensional Reconstruction of Free-Form Linear Features from Stereo Images, Ayman F. Habib, Young-ran Lee, and Michel Morgan, 2003.
- Open CV Documentation : `http://docs.opencv.org/`
- Cuda Documentation : `http://docs.nvidia.com/cuda/`