Visual Odometry in Smoke Occluded Environments

Aditya Agarwal

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Outline

Introduction

Part 1 -

- Introduction to Svo
- Svo using RGBD
- Odometry Comparison with fovis

Part 2 -

- Introduction to Image Dehazing
- Examined Dehazing Methods
- Odometry Improvement using Dehazing

Conclusions

Future Work

Introduction : Micro Aerial Vehicles

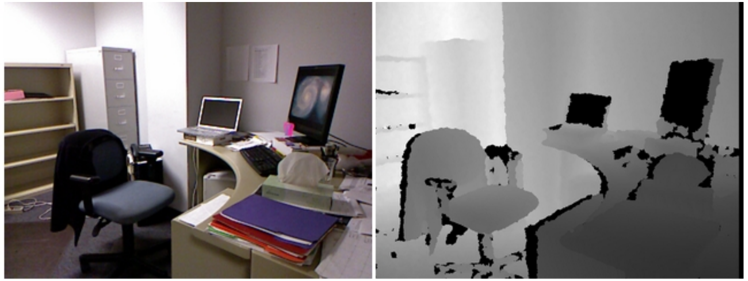
- Light and autonomous aerial vehicles
- MAVs have increasing applications

- Industrial inspection - Detect fires on a shipboard *[Shipboard project]*

Introduction : Visual Odometry

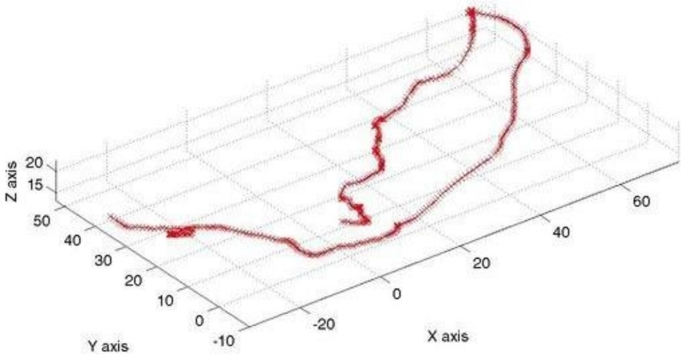
- Estimating pose of vehicle by examining sequence of images from onboard camera

Input



A sequence of RGBD images

Output

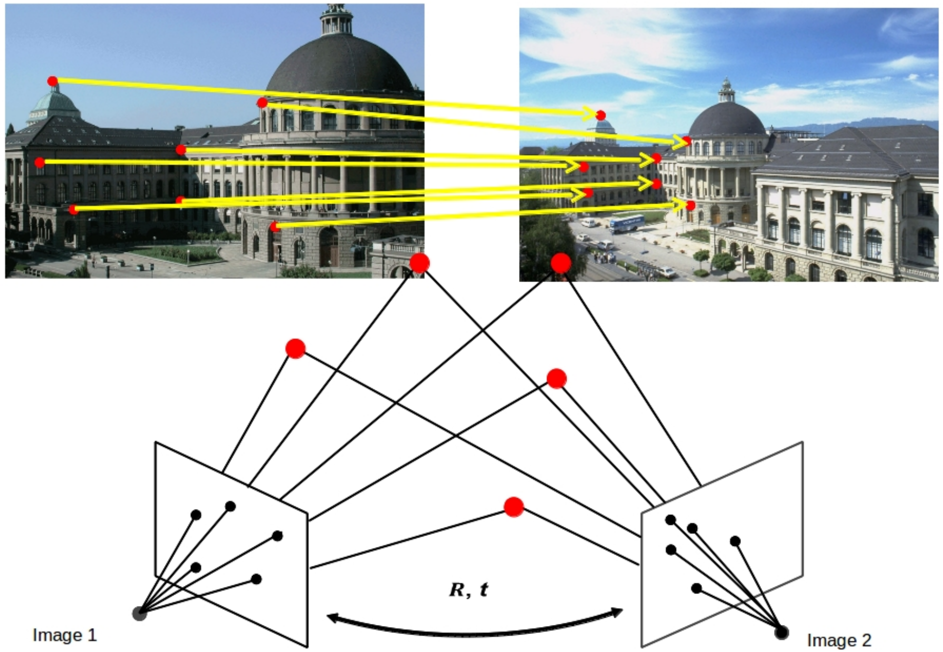


A sequence of transorms

Why use VO?

- An efficient tool for trajectory estimation on a shipboard
  - GPS denied environment
  - Light vehicle with limited hardware
  - Ineffectiveness of laser in smoke

How VO works?

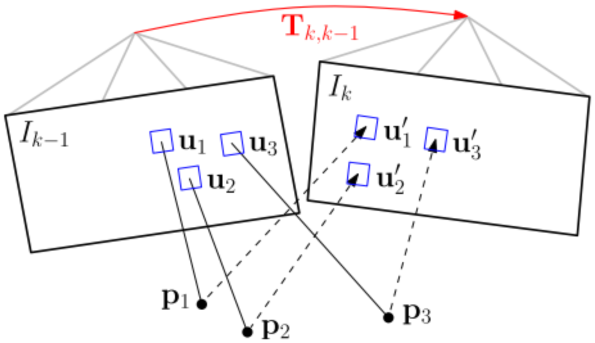


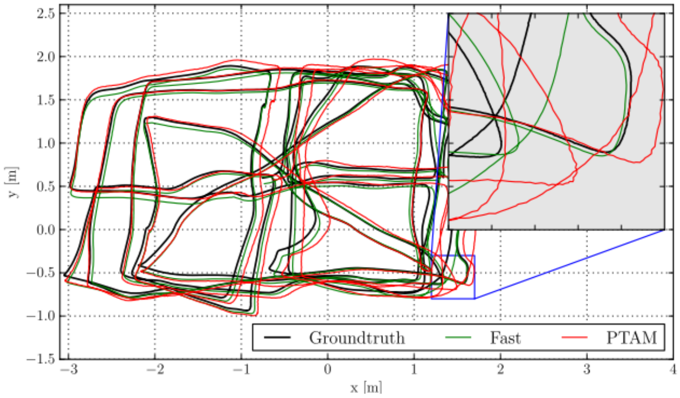
D. Scaramuzza and F. Fraundorfer, “Visual odometry [tutorial],” IEEE Robot. Autom. Mag. , vol. 18, no. 4, pp. 80–92, Dec. 2011

Part 1 : Svo as an odometry method

SVO : Fast semi-direct monocular visual odometry

- State of the art monocular visual odometry method
- Success factors of feature-based odometry methods
- Accuracy and speed of direct methods





Christian Forster, Matia Pizzoli, and Davide Scaramuzza. SVO : Fast Semi-Direct Monocular Visual Odometry.- Proc. IEEE Intl. Conf. on Robotics and Automation, 2014

Motivation : Svo using RGBD

- Monocular version fails for challenging scenes - motion blur, darkness, lack of keypoints, smoke
- Depth filters are unable to converge in a continually changing scene
- Reduce computation

Svo Modifications : Depth Filter

- Probabilistic depth-filter used to estimate depth of 2D features
- Depth filter is removed
- New 3D points are initialized directly when frame is captured

Svo Modifications : Map Initialization

- Svo uses a map containing a set of keyframes and 3D features
- Initial map triangulated from the first two keyframes
- Triangulation not required as depth data is available in initial frame
- Thus 3D map is initialized directly from the first frame

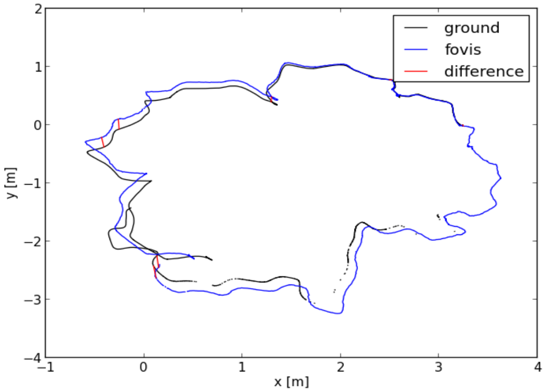
Svo Modifications : Keyframe Selection

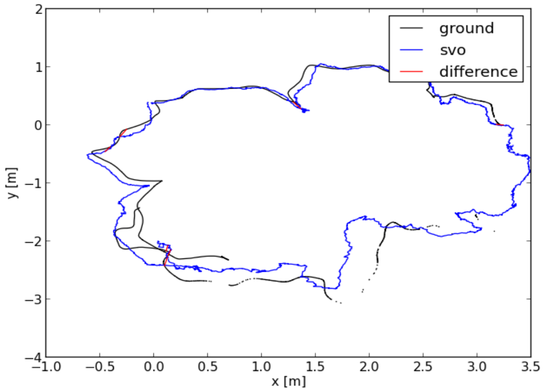
- Based on relative Euclidean distance to the previous frame.
- Impose additional condition of relative rotation

Comparisons

Used metrics from "A benchmark for the evaluation of RGBD slam systems" Sturm et al, 2012

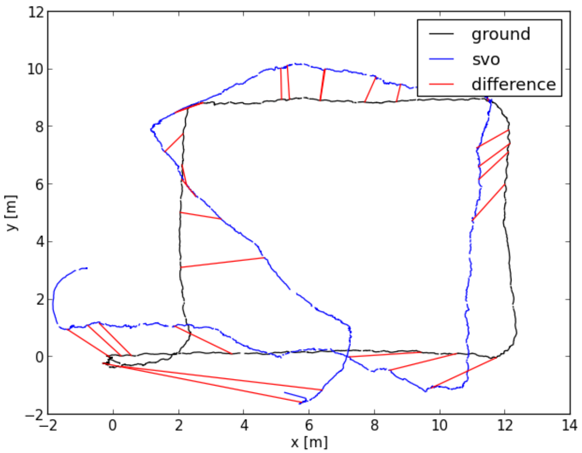
Method	fr2/desk			
	Translational (RMSE)	Translational (Standard dev)	Rotational (RMSE)	Rotational (Standard dev)
fovis	**0.0116**	0.0048	0.58	0.29
svo	**0.0139**	0.008	0.69	0.35

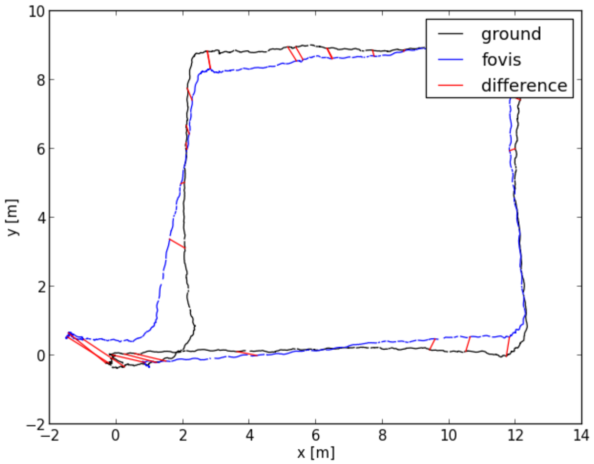




Comparisons

Method	shadwell/03_level2			
	Translational (RMSE)	Translational (Standard dev)	Rotational (RMSE)	Rotational (Standard dev)
fovis	**0.0178**	0.0105	1.435	0.946
svo	**0.0435**	0.0288	1.417	0.944





Computation

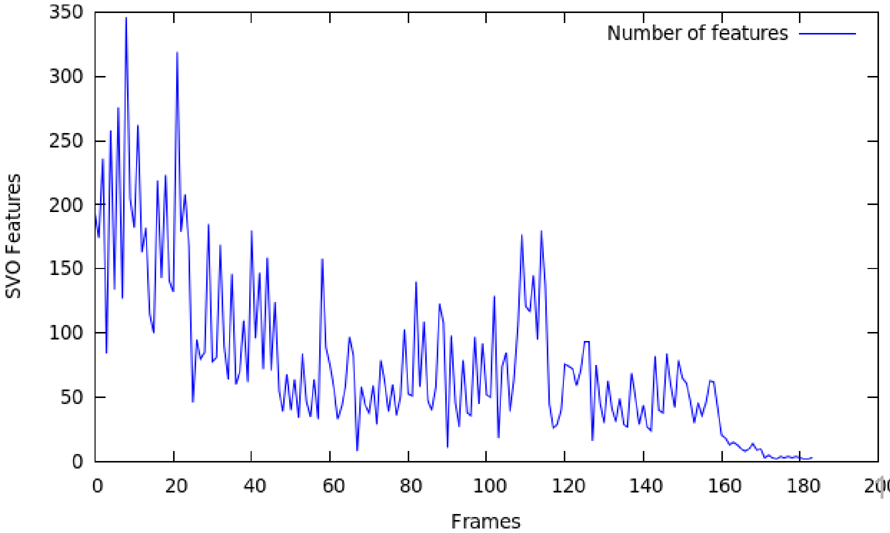
Method	Algorithm Runtime			Avg CPU Usage (%)
	Max (ms)	Min (ms)	Avg (ms)	
svo	19	0.7	**4**	25
fovis	78	4	**23**	20

Svo and fovis are both suitable odometry methods for a light MAV, fovis being the more suitable candidate if more accuracy is desired and svo if speed

Part 2 : Odometry in smoke occluded Environment

Why odometry fails in smoke?

- Loss of color contrast, precision and saturation
- Lack of distinguishing *features* in the image
- *feature matching* across frames is severely degraded
- *matching* for depth edges reduces significantly [Narasimhan2003]



Introduction : Image dehazing

- Restoration of images degraded by presence of turbid medium such as haze, fog or smoke
  - Light reflected by the surface is attenuated
  - Light reflected blends with *airlight*

Input

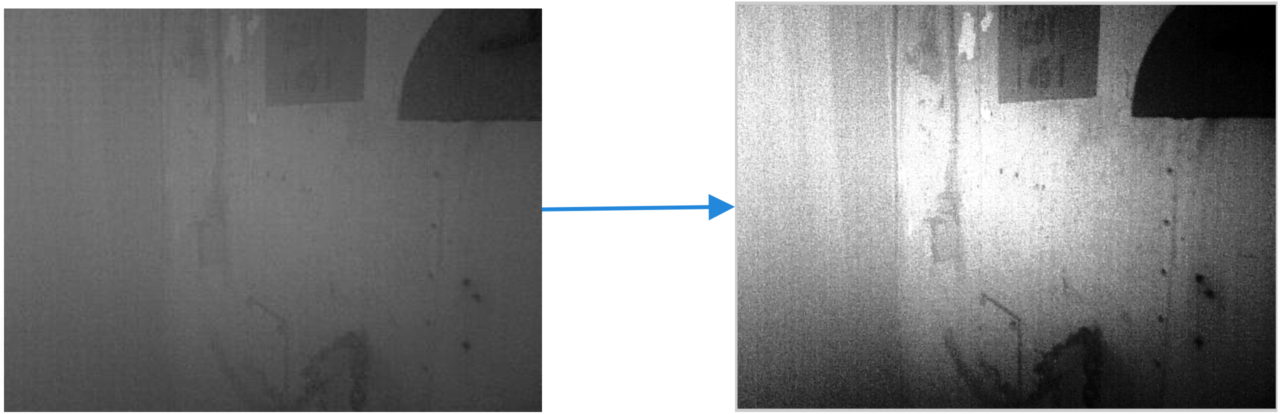
A single image or multiple images

Output

Restored or enhanced image

Why is dehazing difficult?

- Hazing is spatially variant
  - However traditional contrast enhancing methods act on the image as a whole



Histogram equalization

Why is dehazing difficult?

- Hazing is spatially variant
  - RGBD data may lack depth information in dense smoke

RGB Image

Depth image

Why is dehazing difficult?

- Existing dehazing techniques are for outdoor scenes affected by fog
- Image data is available in RGB

?

Related Work

- Several techniques have been proposed to remove atmospheric haze from outdoor scenes.
- The techniques can be grouped into :
  - Multiple Image based :
  - Single Image based :
    - Contrast enhancement based
    - RGB based
    - Model based

How to model image hazing?

$$I(x) = t(x)J(x) + (1 - t(x))A$$

$I(x)$ The observed intensity values of the hazy image

$J(x)$ The scene radiance or albedo, **actual colours** of the scene

$t(x)$ **The transmission along the light ray, causes attenuation**

$$t(x) = e^{-\beta d(x)}$$

$(1 - t(x))A$ A denotes the **ambient** atmospheric light

Examined Dehazing Methods

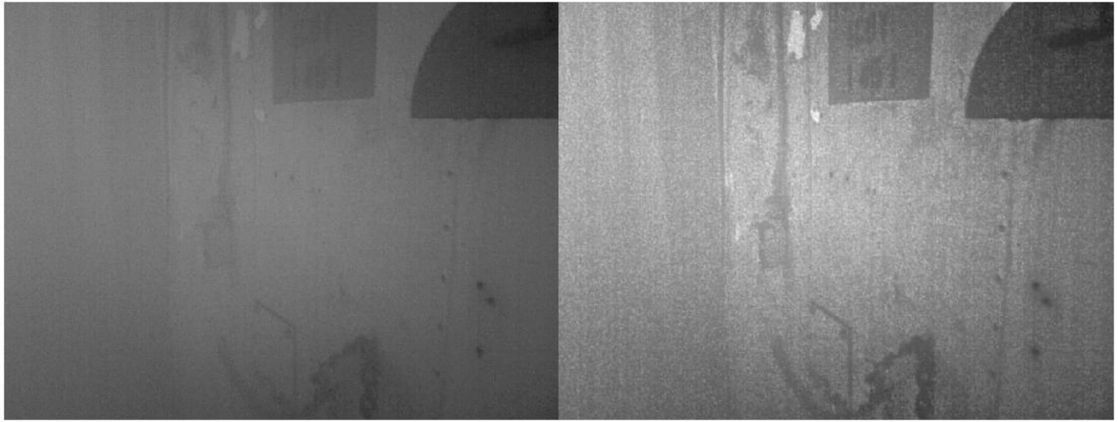
- **Multiple Image Based** [Donate2006]
  - Areas of image to are partially visible across different images of same scene
  - Color saturation and high frequency content in images used as a measure of smoke
  - *Not applicable for camera in constant motion*

Examined Dehazing Methods

- **Contrast Enhancement Based** [Fattal2014]
  - Color lines are one dimensional distributions of pixels in RGB space
  - Variation in color lines used to recover scene transmission
  - Employs new technique to estimate atmospheric light vector
  - *Slow for real time application*

Examined Dehazing Methods

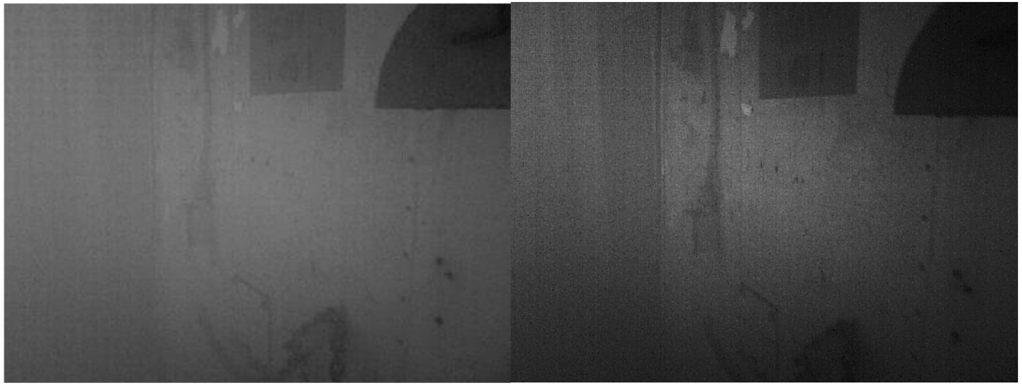
- **Contrast Enhancement Based** [Tarel2009]
  - Estimate airlight using a combination of median filters
  - Enhances overall contrast
  - Image is not darkened
  - *Slow for direct real time application*



Examined Dehazing Methods

RGB Based [He2010]

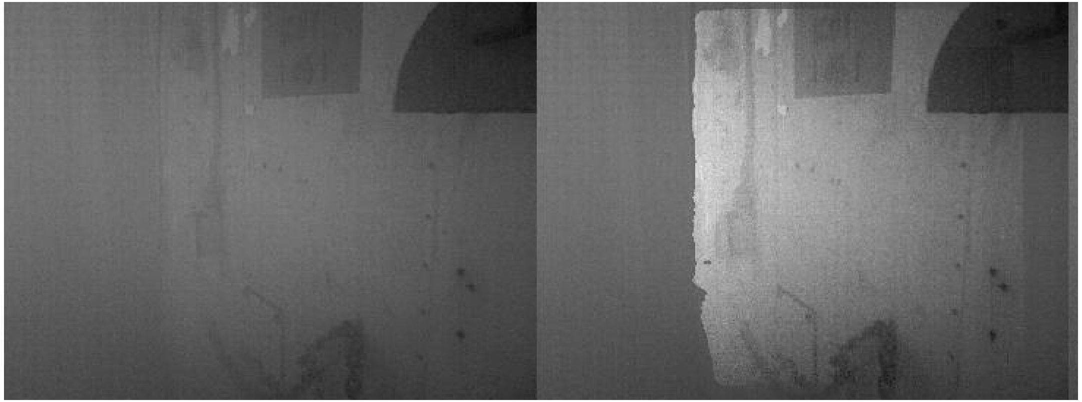
- Recovers approximate depth map
- Haze free image has dark pixels which have low intensity in atleast one channel (rgb)
- Uses an optional matting function that is not feasible in real time
- *Suitable for color images only*
- *Darkens overall image*



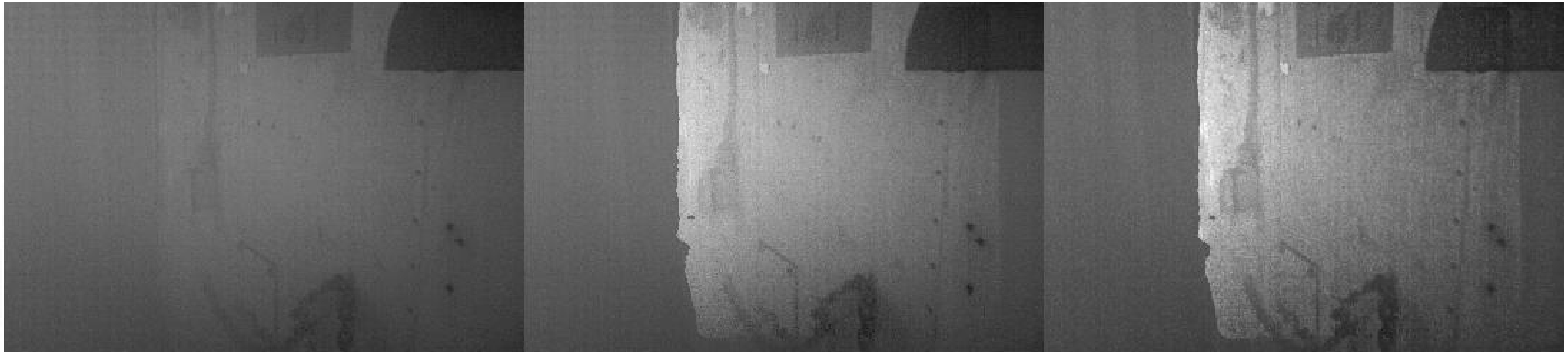
Examined Dehazing Methods

- **Depth Model Based** [Narasimhan2003]
  - Significant enhancement for depth available regions
  - Suitable for real time application
  - Uses depth data directly to estimate transmission
  - *Parameter values are taken as user input*
  - *No enhancement if depth data is unavailable*

$$t(x) = e^{-\beta d(x)}$$

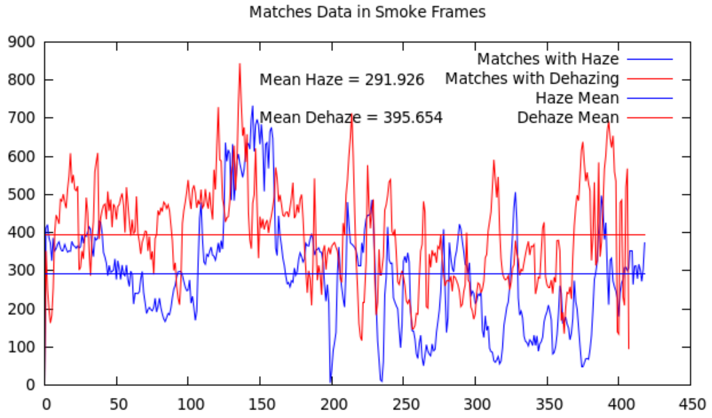


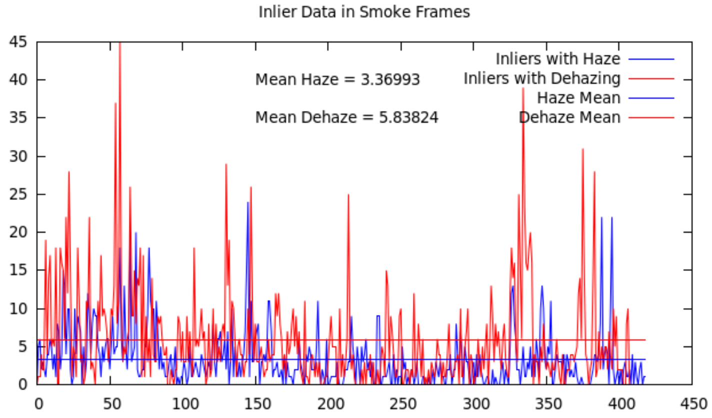
Proposed Dehazing Pipeline



Obtain depth and grayscale image data → Median filter on depth image → Depth model based dehazing → Contrast enhancement

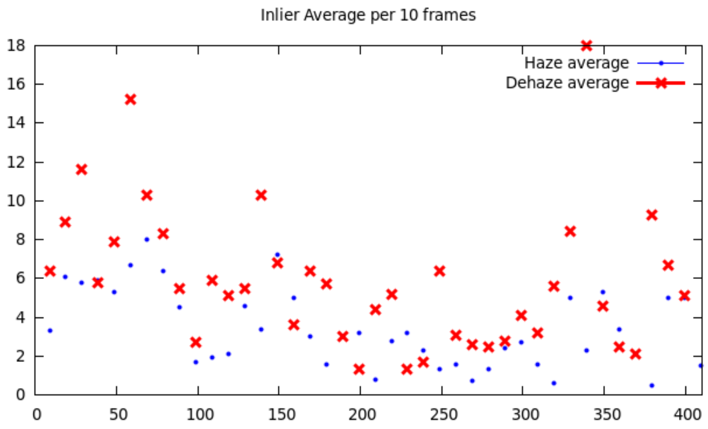
Running fovis on dehazed dataset





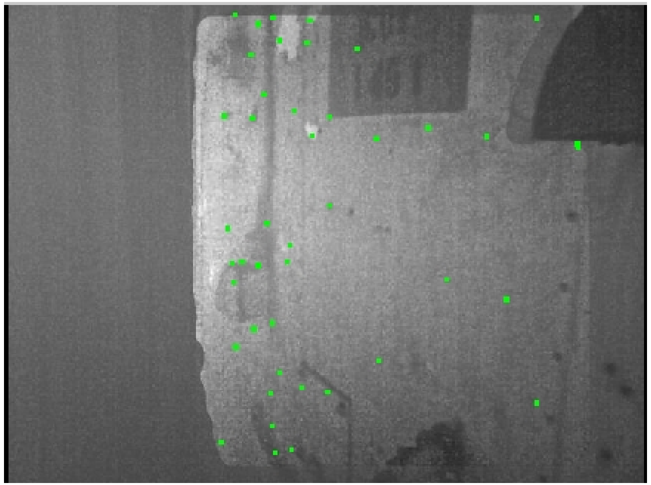
- Matching and inlier detection is improved
- Still insufficient for tracking

Running fovis on dehazed dataset



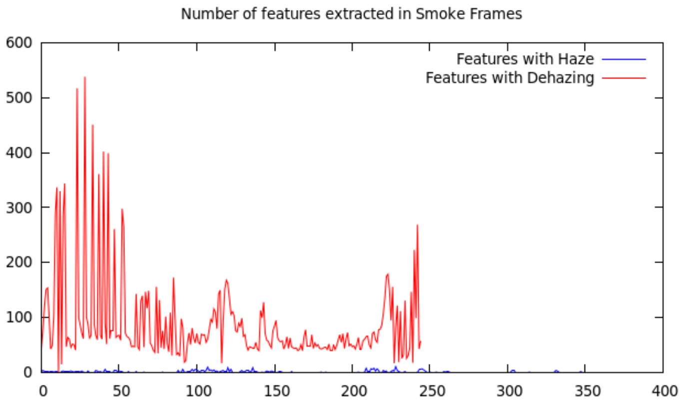
- Clearly more inliers are extracted after dehazing

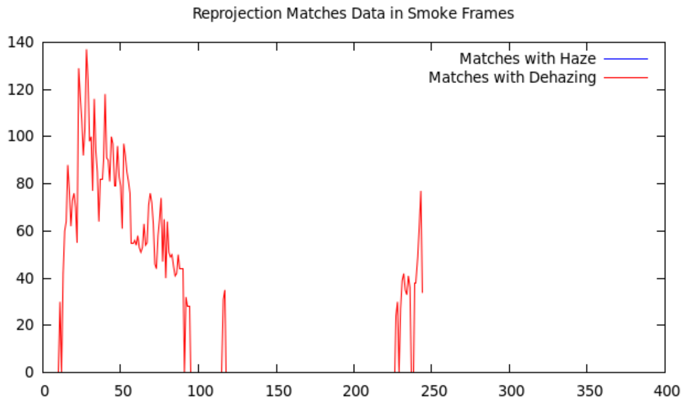
Running svo on dehazed dataset



- Feature extraction improve significantly after dehazing

Running svo on dehazed dataset





- No tracking at all in haze condition
- Intermittent tracking observed for dehazed data

Future Work

- Use RGB dataset
- Automatic selection of depth model dehazing parameters
- Adaptation of svo as an odometry method in haze/smoke conditions
- Recording more smoke datasets for testing

A combination of depth and contrast based dehazing can enhance input image and hence significantly improve performance of semi-direct odometry methods such as svo