Indirect Visual Odometry with Optical Flow

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Overview

1. Introduction

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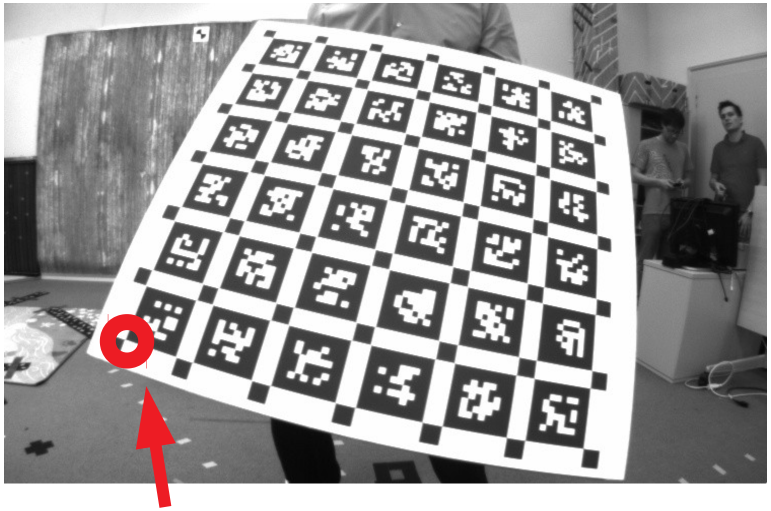
1 Introduction

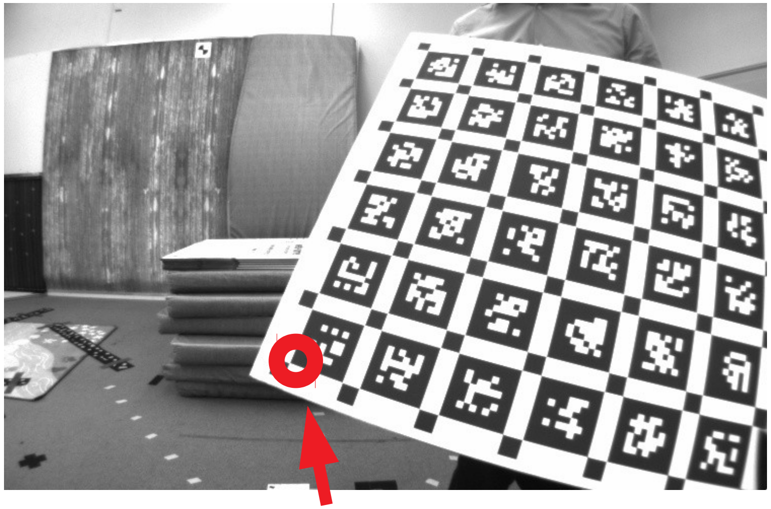
1.1 Lukas Kanade method for optical flow

Input: two images, key points in one image

Output: the key points in the other image



Input key point position in one image

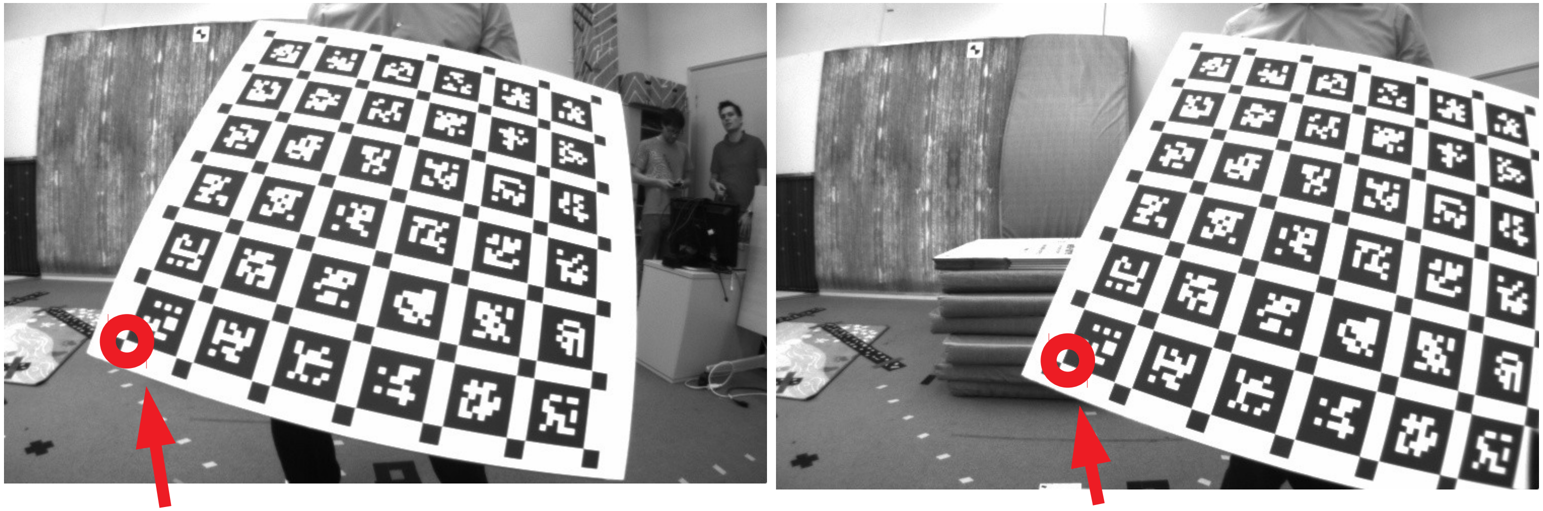


Output key point position in the other image

1 Introduction

1.1 Lukas Kanade method for optical flow

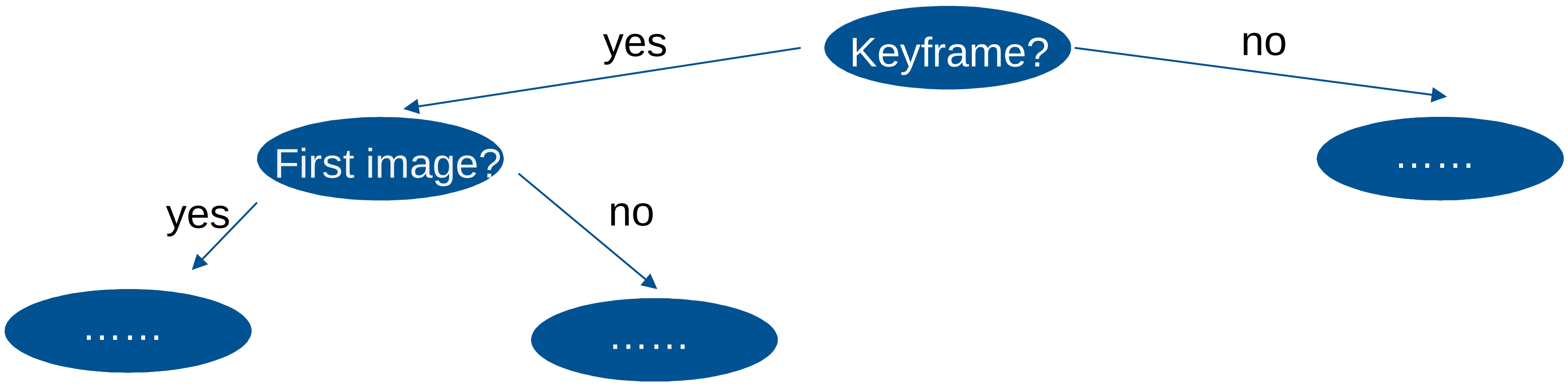
Inspiration in SLAM:
replace feature descriptors matching with optical flow method!



Input key point position in one image

Output key point position in the other image

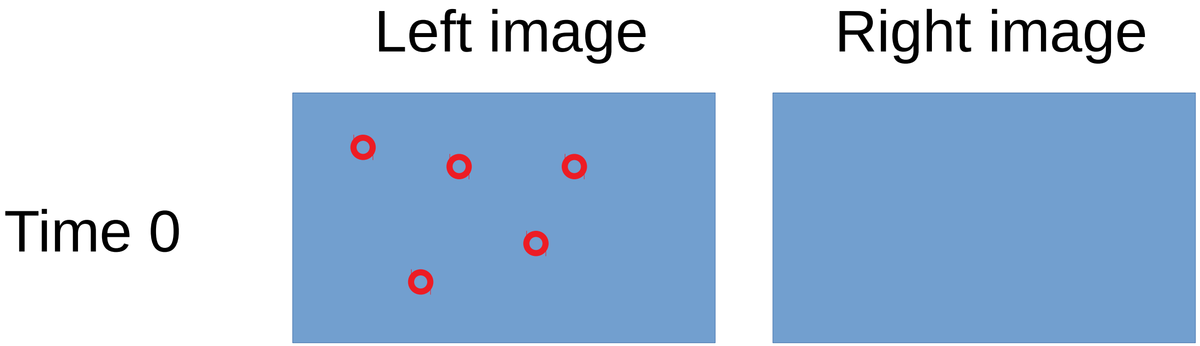
1 Introduction



1 Introduction

1.2 Project pipeline: first key frame

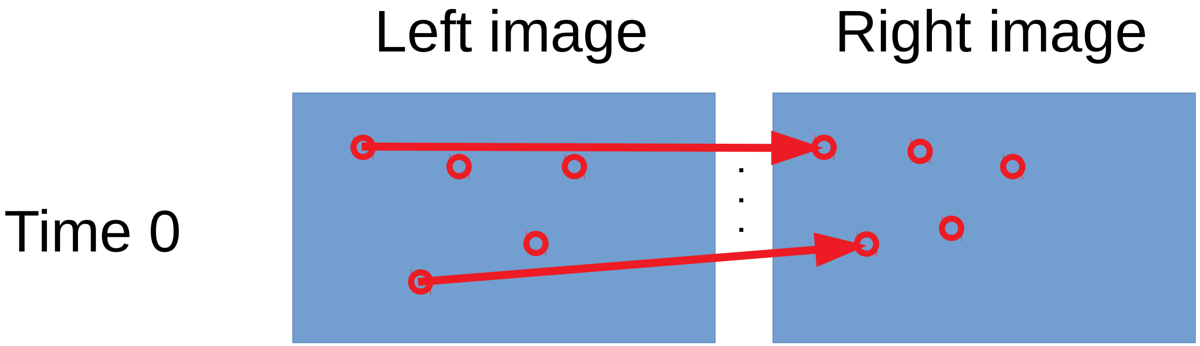
Step 1: detect key points in left image



1 Introduction

1.2 Project pipeline: first key frame

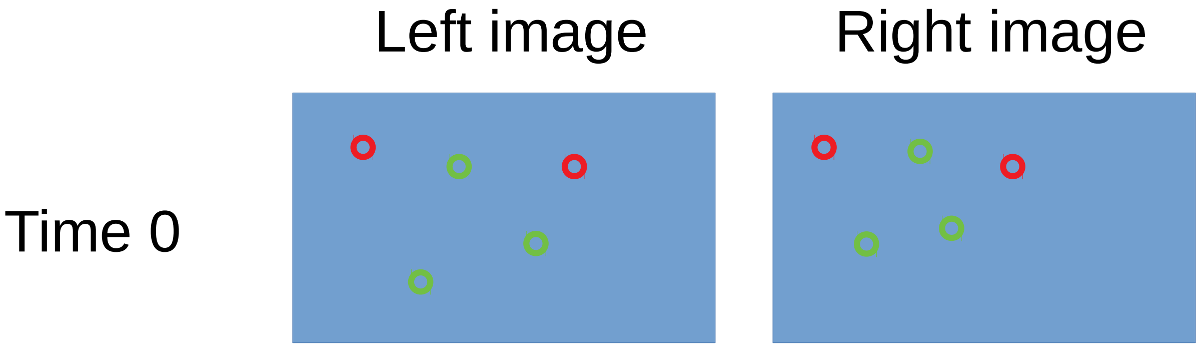
Step 2: optical flow to right image



1 Introduction

1.2 Project pipeline: first key frame

Step 3: check epipolar constraint and find inlier



Left image

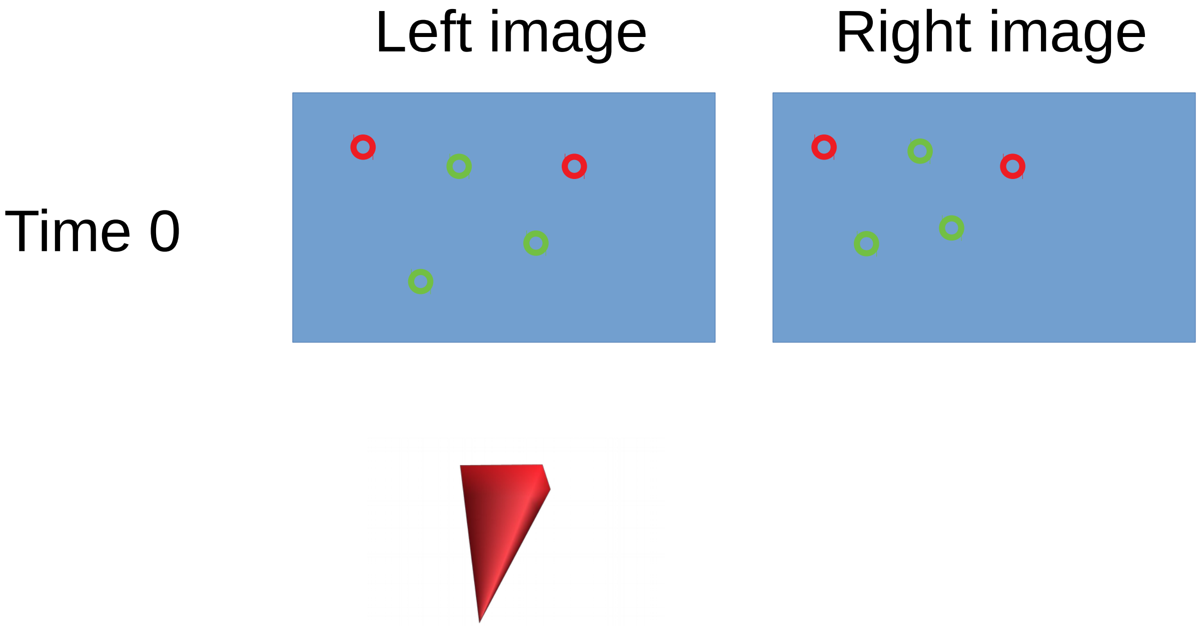
Right image

Time 0

1 Introduction

1.2 Project pipeline: first key frame

Step 4: localize camera



Left image

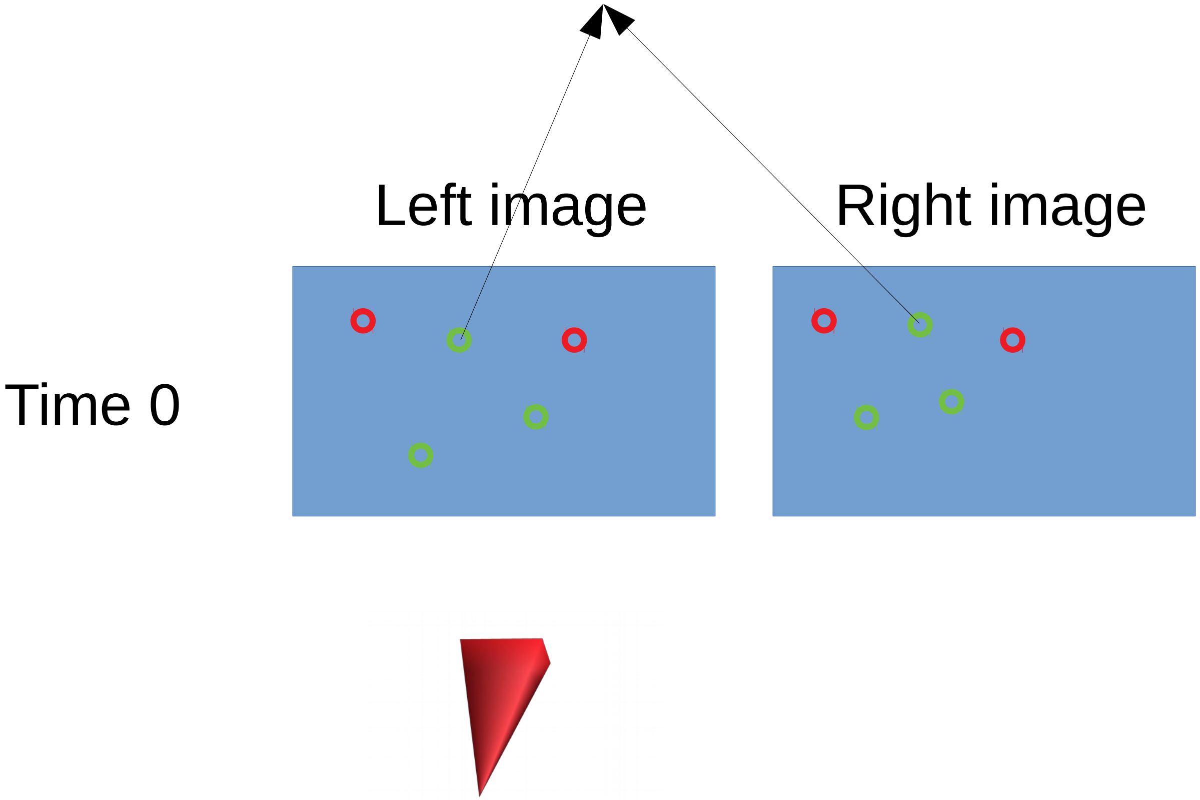
Right image

Time 0

1 Introduction

1.2 Project pipeline: first key frame

Step 5: triangulate landmarks



Left image

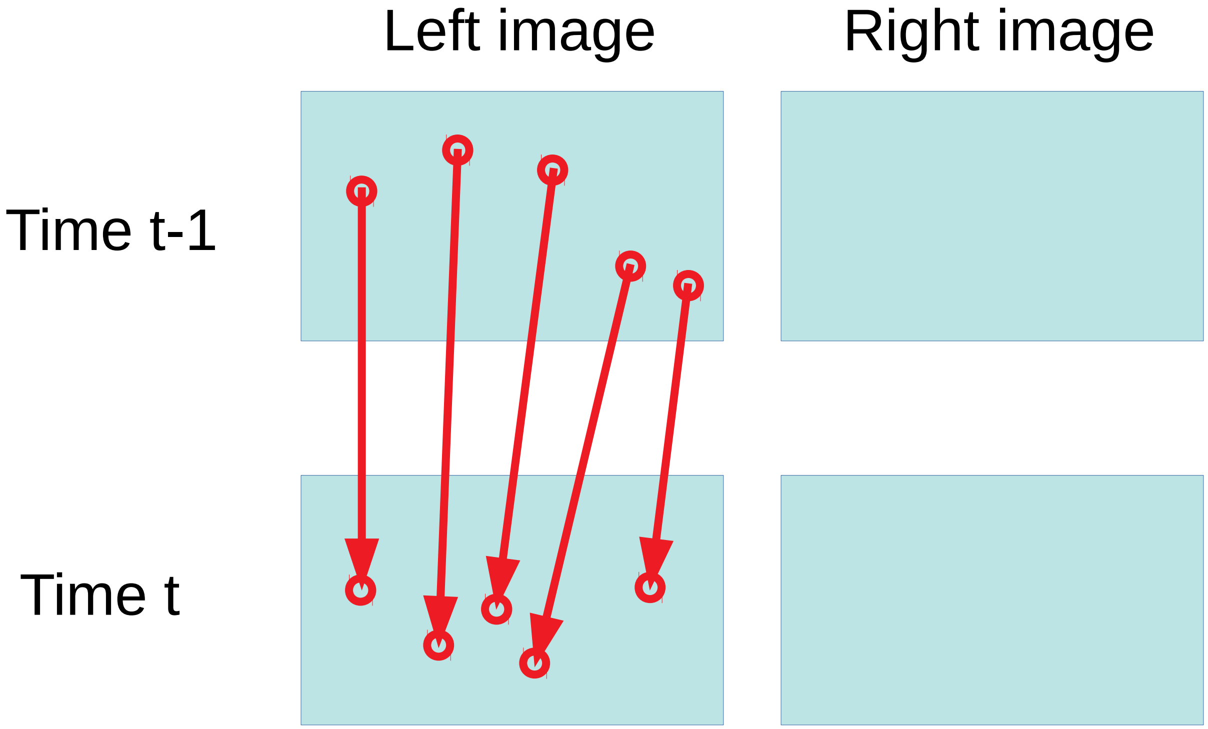
Right image

Time 0

1 Introduction

1.2 Project pipeline: second and later key frame

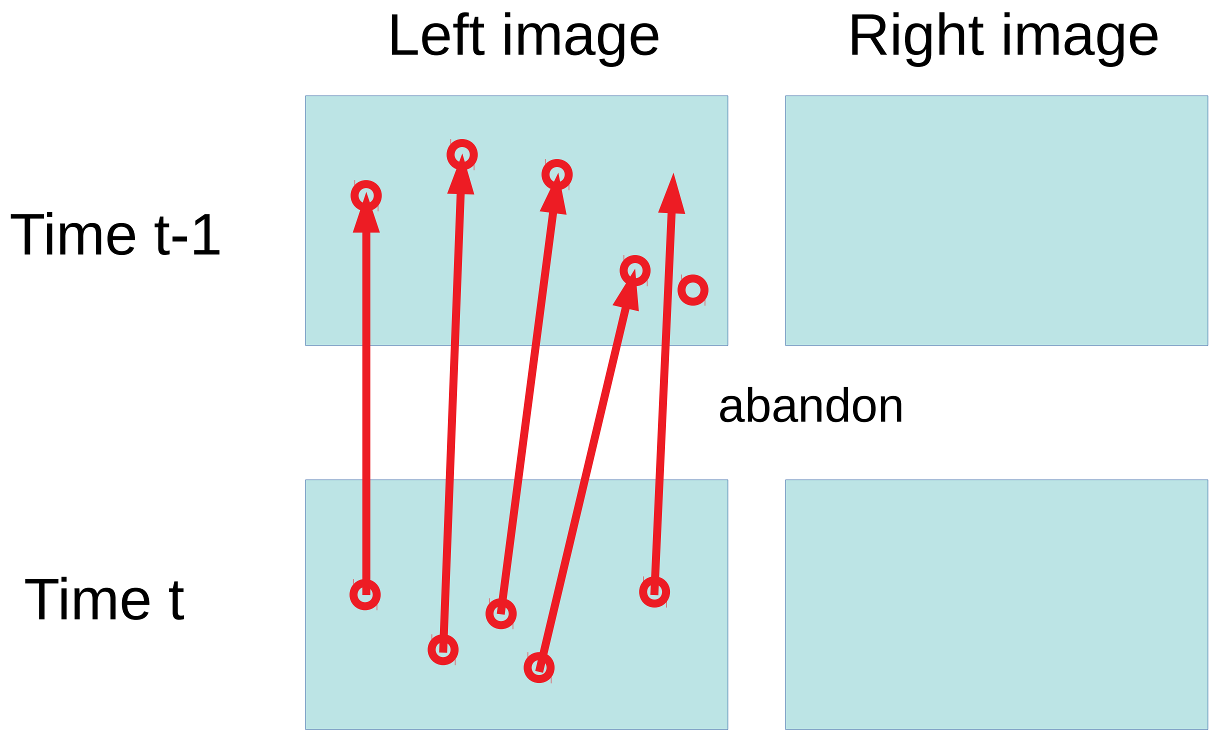
Step 1: optical flow to next left frame



1 Introduction

1.2 Project pipeline: second and later key frame

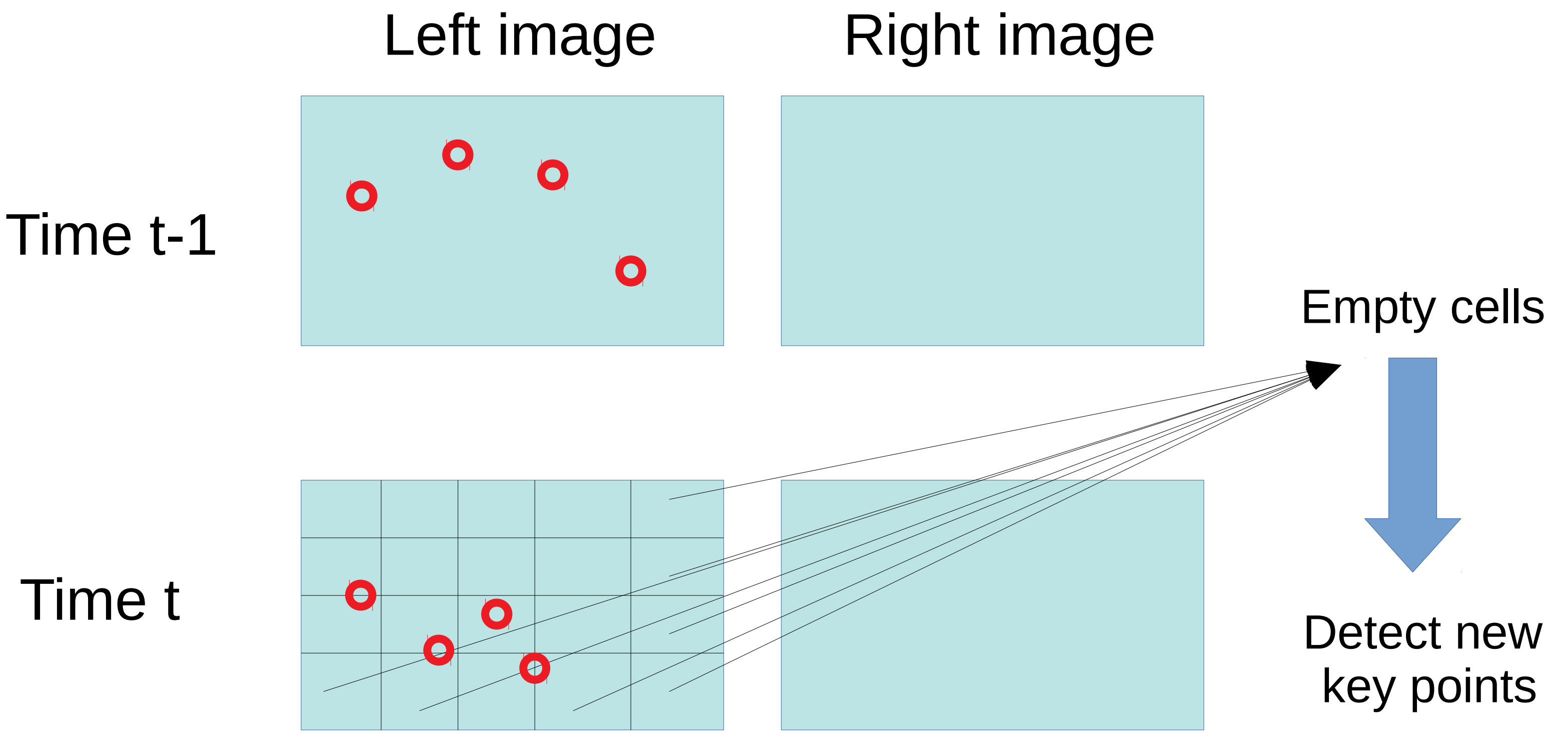
Step 1: optical flow: backward check



1 Introduction

1.2 Project pipeline: second and later key frame

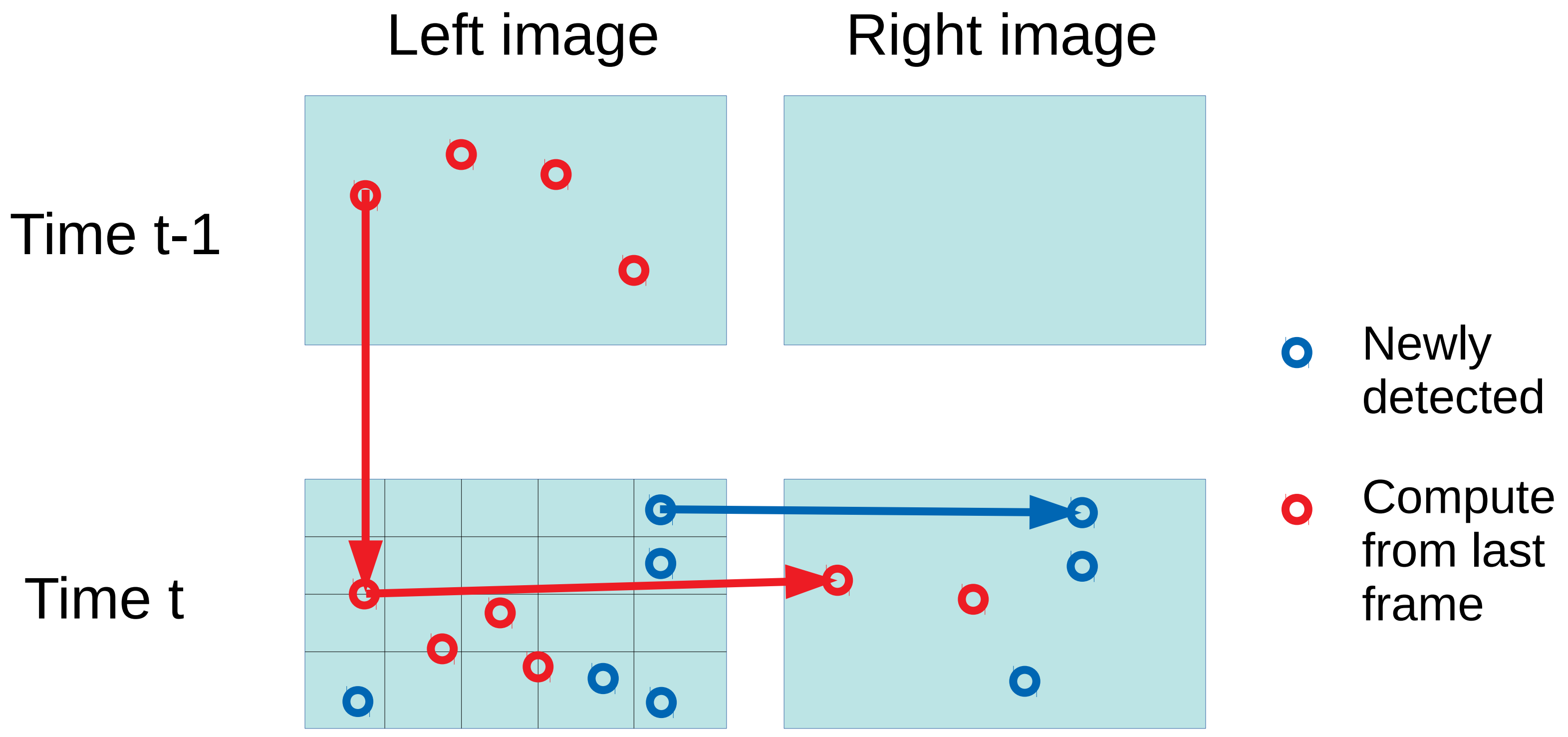
Step 2: make grid & detect key points in empty cells



1 Introduction

1.2 Project pipeline: second and later key frame

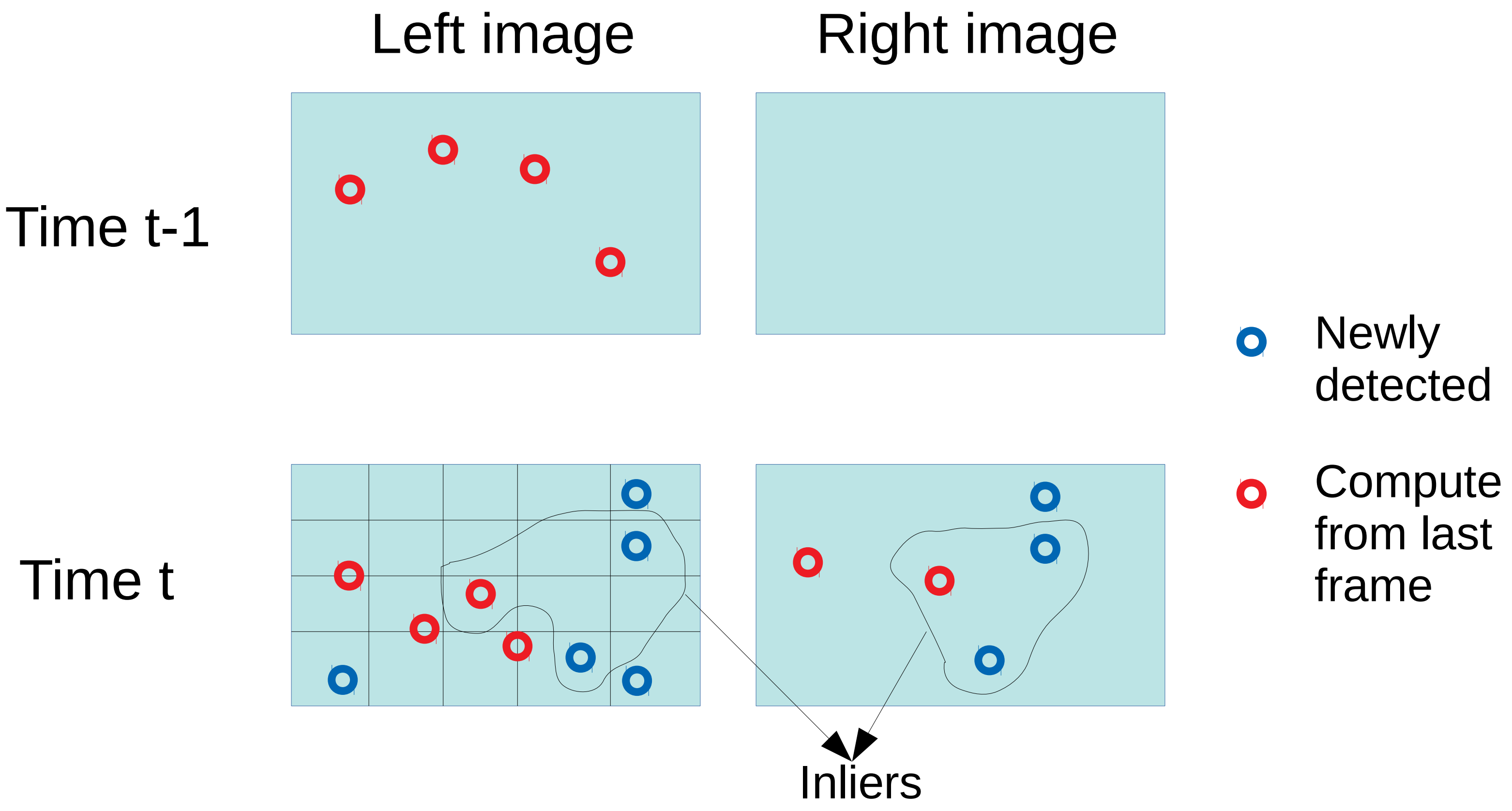
Step 3: optical flow to the right image



1 Introduction

1.2 Project pipeline: second and later key frame

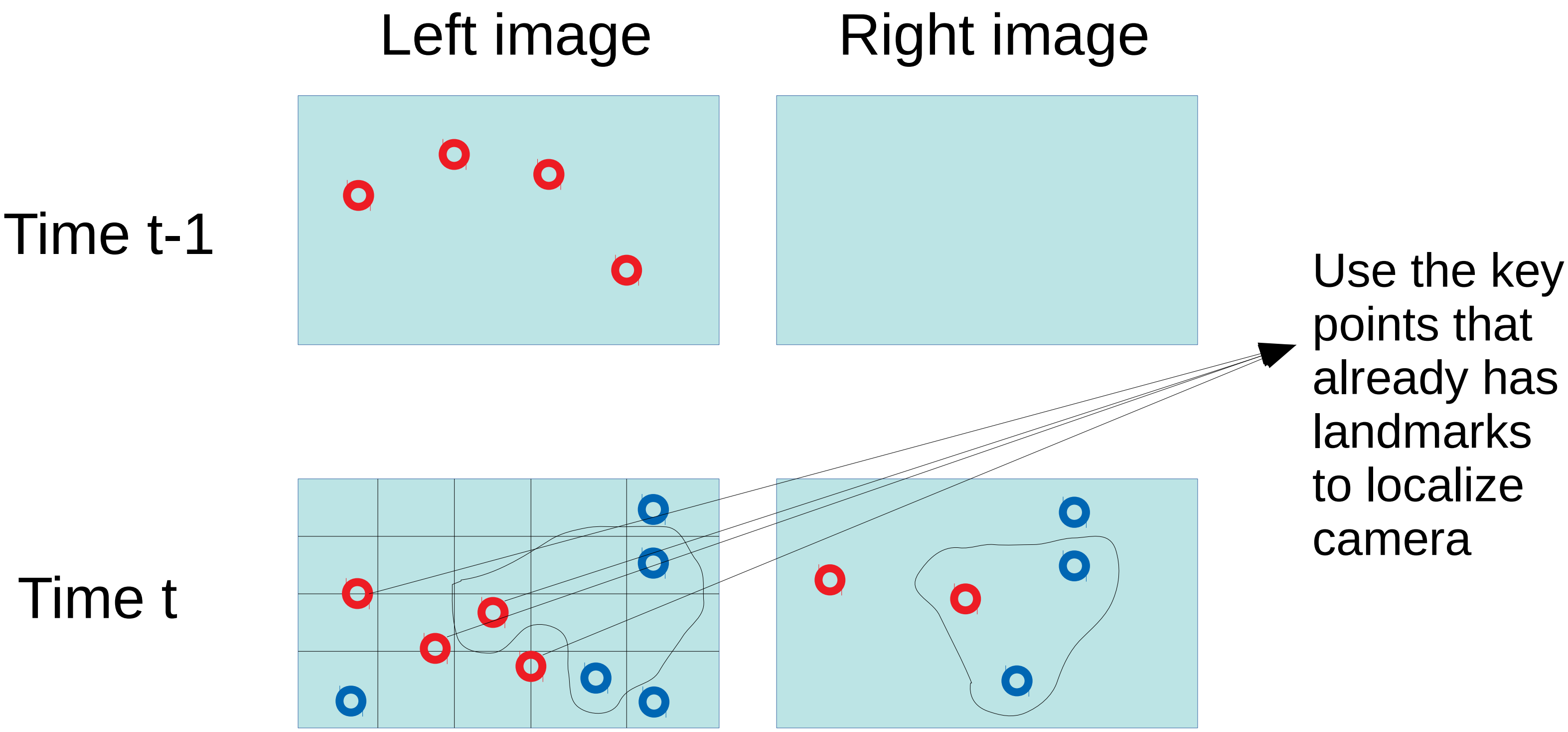
Step 4: use epipolar constraint to find inliers



1 Introduction

1.2 Project pipeline: second and later key frame

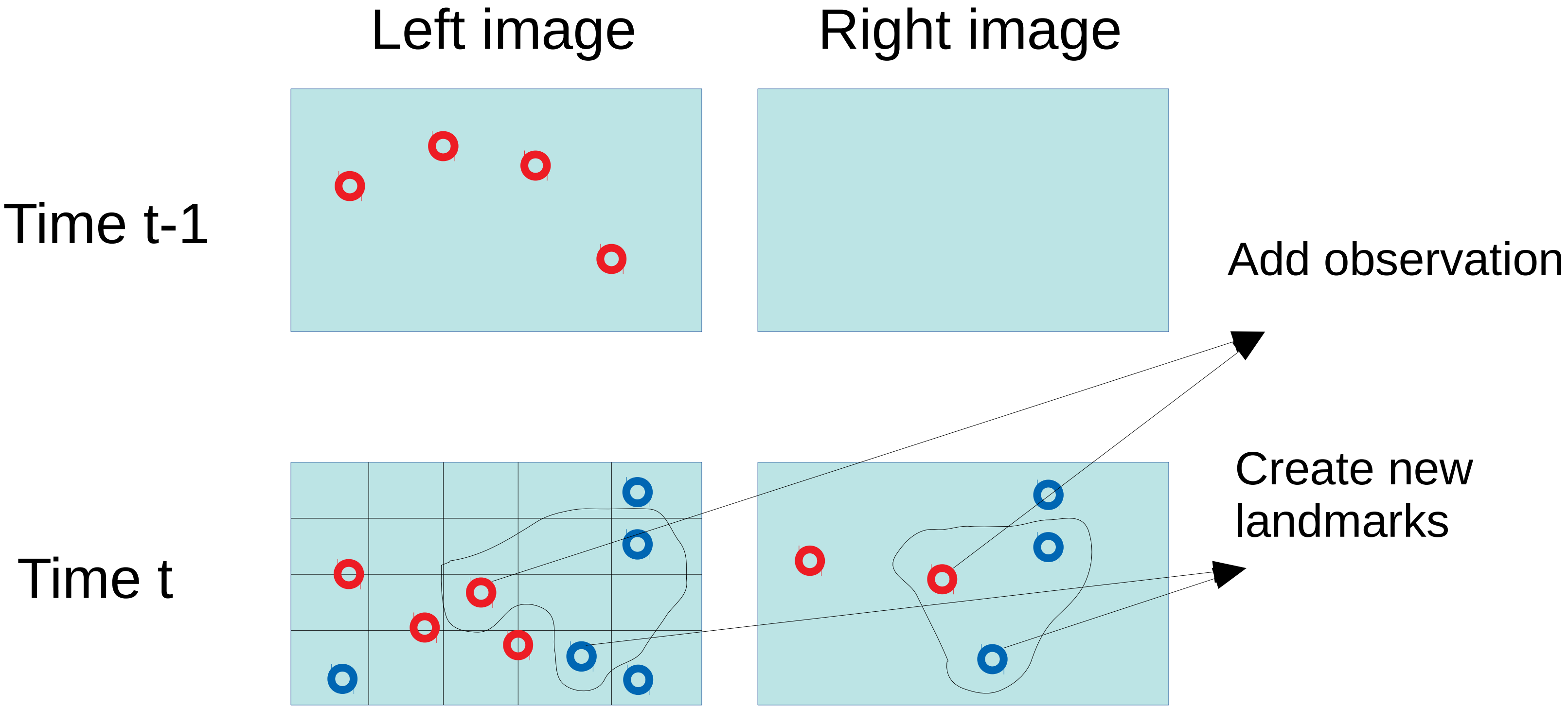
Step 5: localize camera


Left image
Right image
Time t-1
Time t
Use the key points that already has landmarks to localize camera

1 Introduction

1.2 Project pipeline: second and later key frame

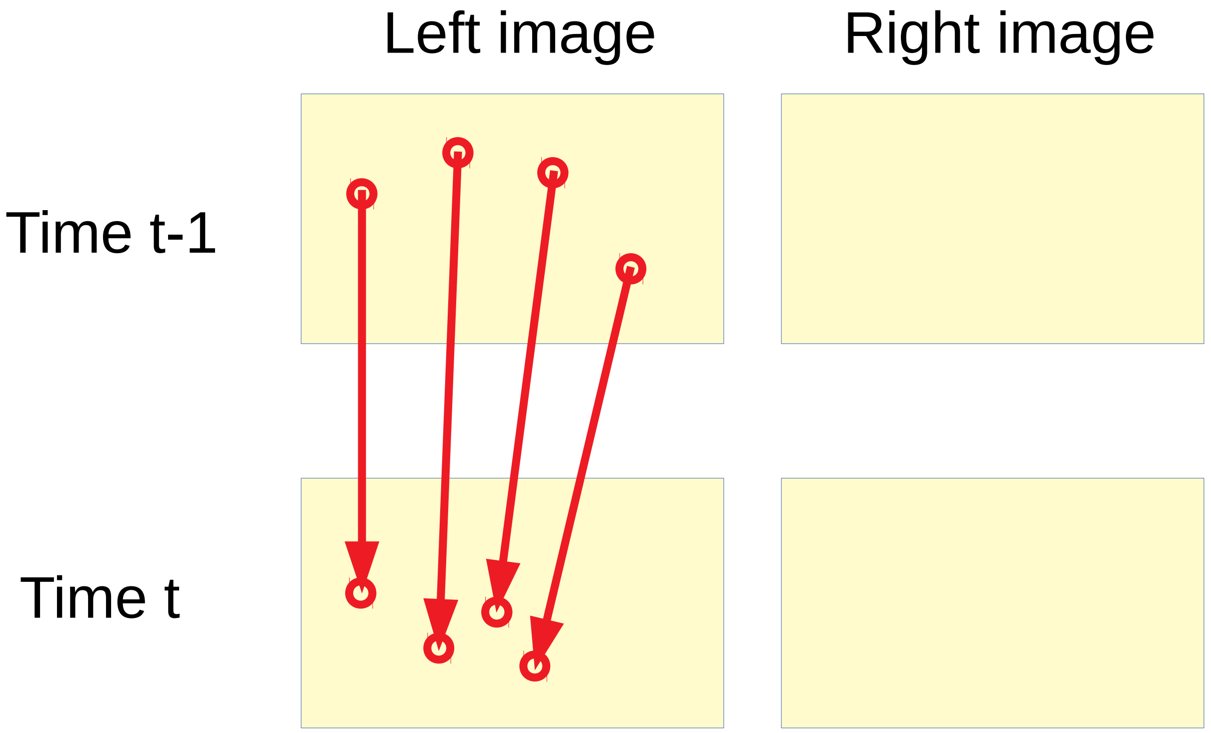
Step 6: add observation and create landmarks



1 Introduction

1.2 Project pipeline: non key frame

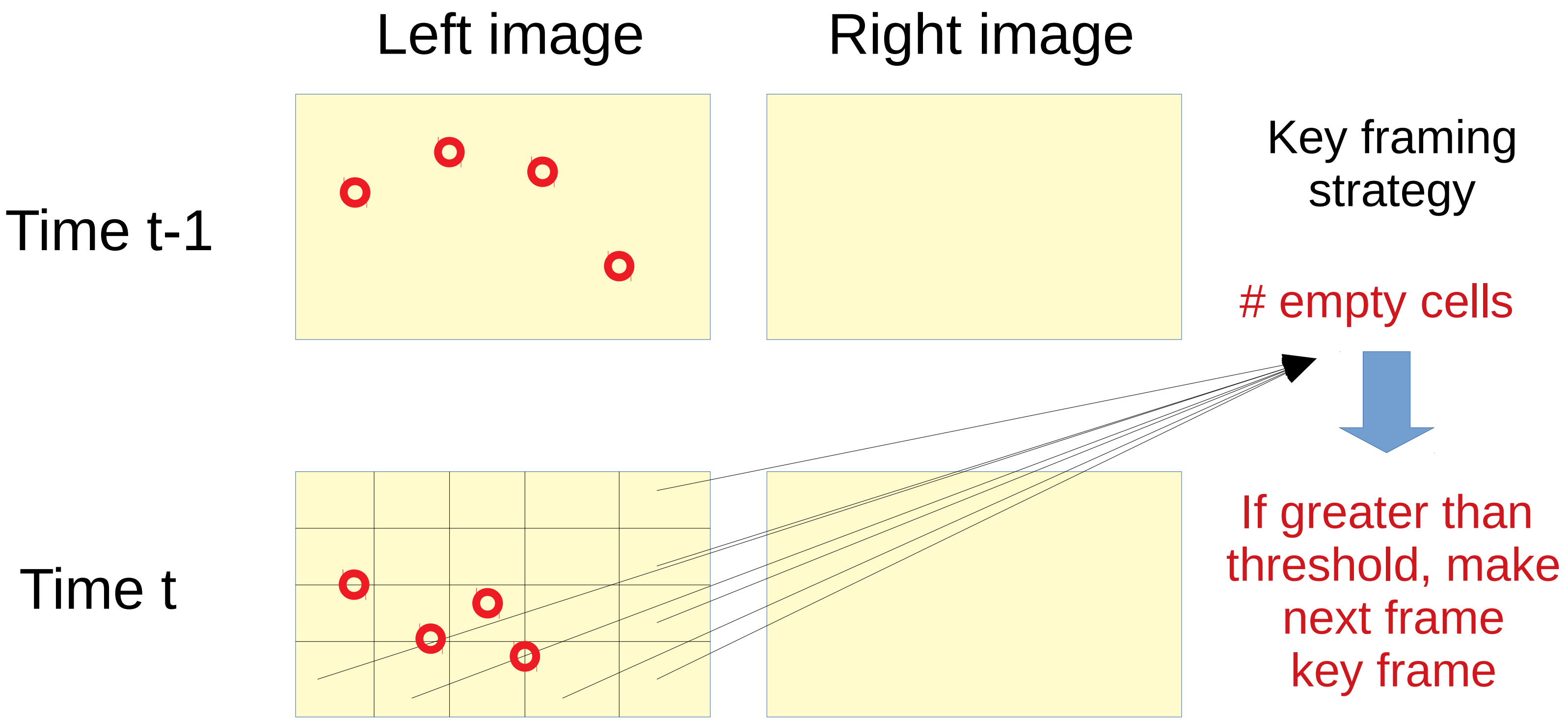
Step 1: optical flow to next frame



1 Introduction

1.2 Project pipeline: non key frame

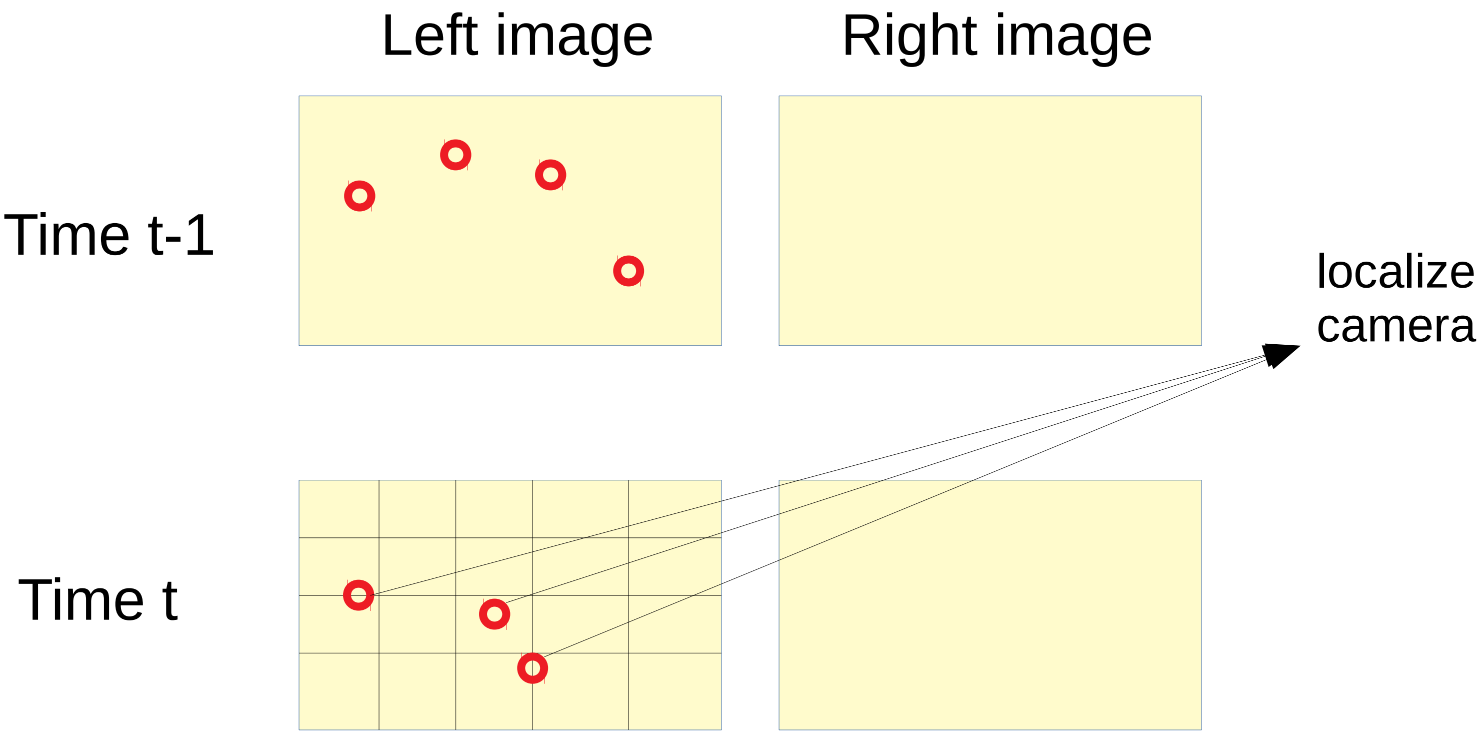
Step 2: make grid & count empty cells



1 Introduction

1.2 Project pipeline: non key frame

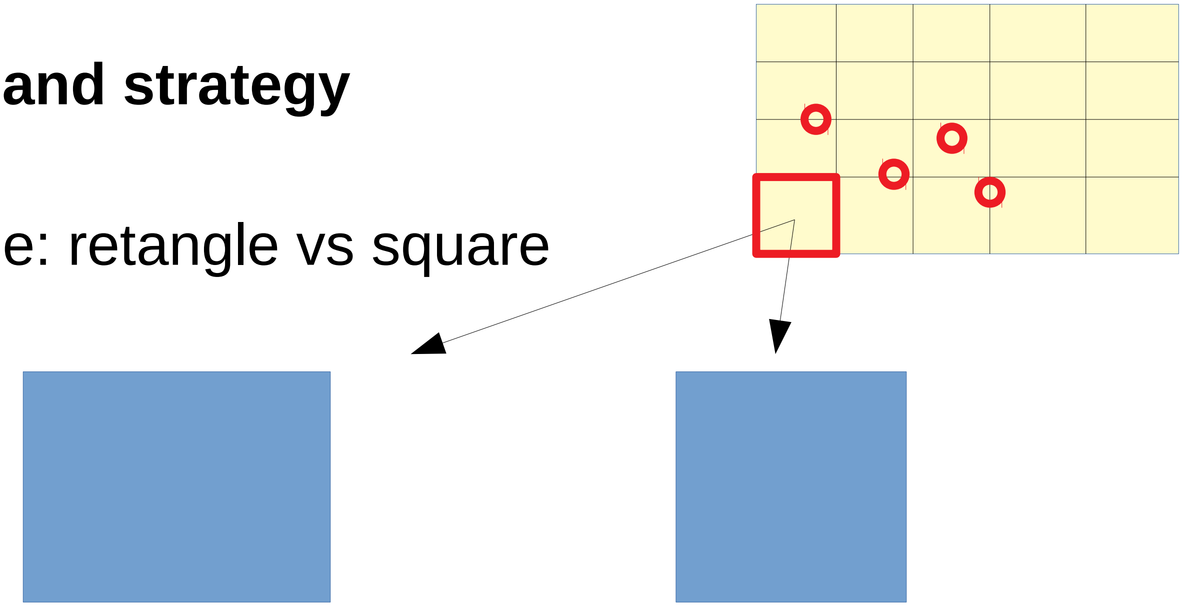
Step 3: localize camera



1 Introduction

1.3 Parameter and strategy

1.3.1 Grid shape: retangle vs square



pixel x pixel	30 x 47	32 x 32
rmse	0.14	0.11

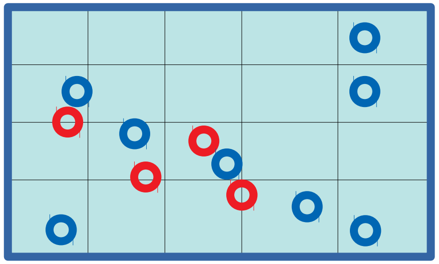
1 Introduction

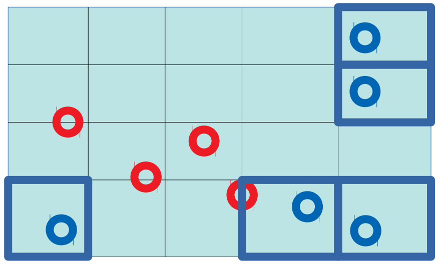
1.3 Parameter and strategy

1.3.2 Key points detection: in whole image vs in each cell

Detect in whole image

Then only keep key points in empty cells





Detect in empty cells respectively

rmse	0.1139	0.1116

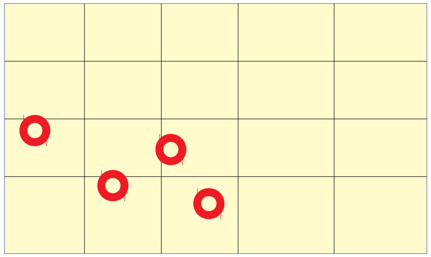
1 Introduction

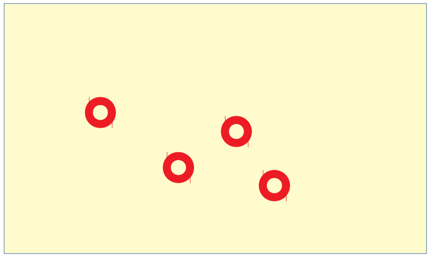
1.3 Parameter and strategy

1.3.3 Key framing: use grid vs use only inliers number

# empty cells

If greater than threshold, make next frame key frame





# localization inliers

If smaller than threshold, make next frame key frame

rmse	0.11	0.43

2 Evaluation

2 Evaluation

2.1 Precision comparison

Basic parameters

image height (pixel)	image width (pixel)	grid size (pixel x pixel)
480	752	32 x 32

Strategy

1. Square grid

2. Key points detection only in empty cell

3. Use number of empty cells to decide key frame

2 Evaluation

2.1 Precision comparison

Variation parameters: maximum empty cells percentage*

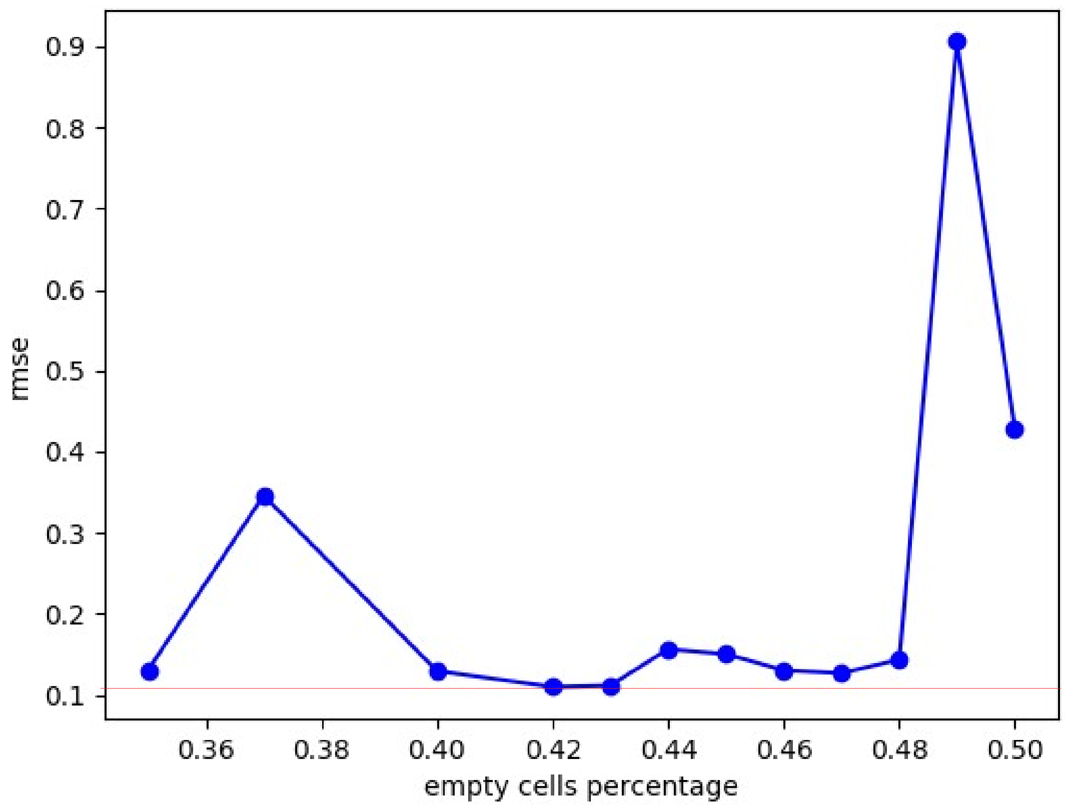
Max empty cells	35%	40%	42%	44%	46%	Exercise 5
rmse	0.1303	0.1295	**0.1099**	0.1563	0.1304	**0.1012**

*maximum empty cells percentage: when the empty cells percentage exceeds this value and optimization is finished, make next frame key frame

2 Evaluation

2.1 Precision comparison

empty cells percentage vs rmse



2 Evaluation

2.2 Execution time comparison

2.2.1 Detection time

Max empty cells	35%	40%	42%	44%	46%	Exercise 5
detection time (seconds)	3.03643	2.73232	2.43286	2.62328	2.26326	**44.0214**

2 Evaluation

2.2 Execution time comparison

2.2.2 Optimization time

Max empty cells (%)	0.42	Exercise 5
Opt. time(s)	305.043	**65.8619**
# landmarks	290657	**221886**
# observation	1939460	**559563**
# keyframe	414	**170**

2 Evaluation

2.2 Execution time comparison

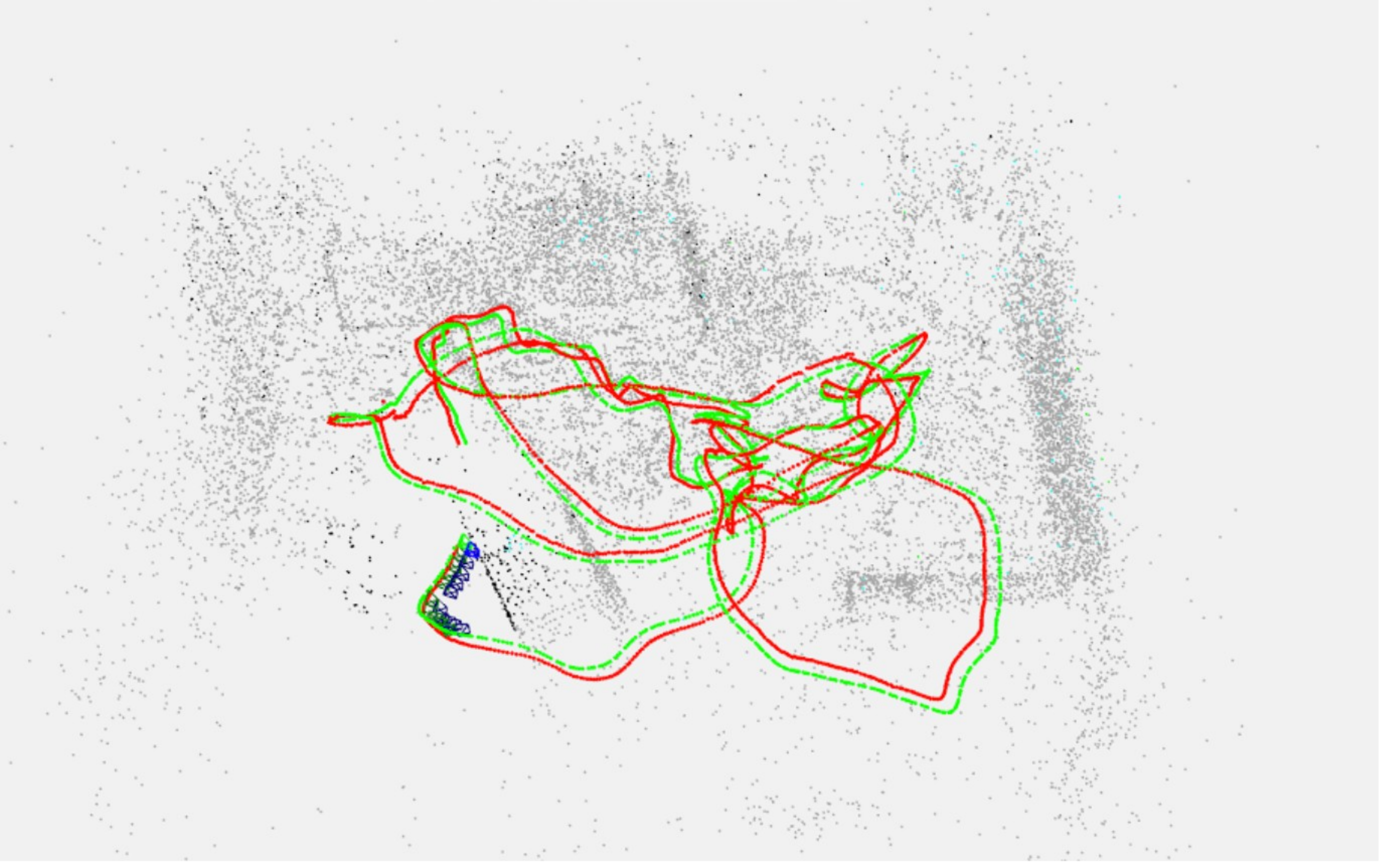
2.2.3 Frame to frame (f2f) optical flow time

Ex. 5 Feature Matching time(s)	5.79
f2f optical flow time(s)	117.4~143.1

2 Evaluation

2.3 Visualization comparison

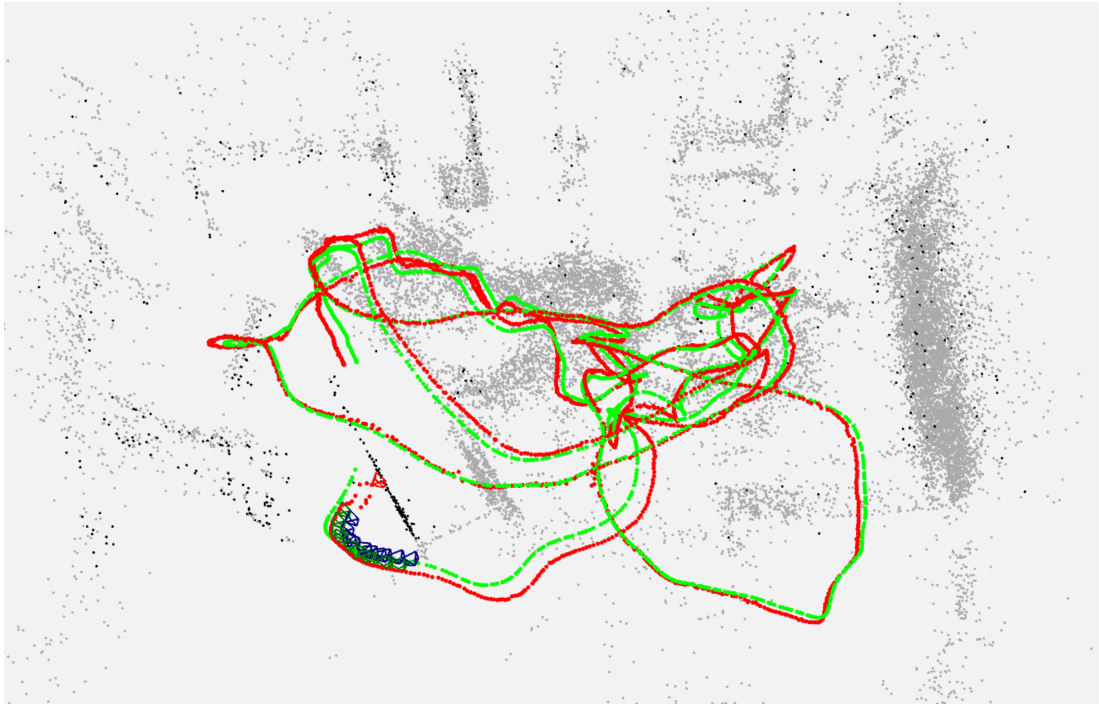
Maximum empty cells percentage: 42%



2 Evaluation

2.3 Visualization comparison

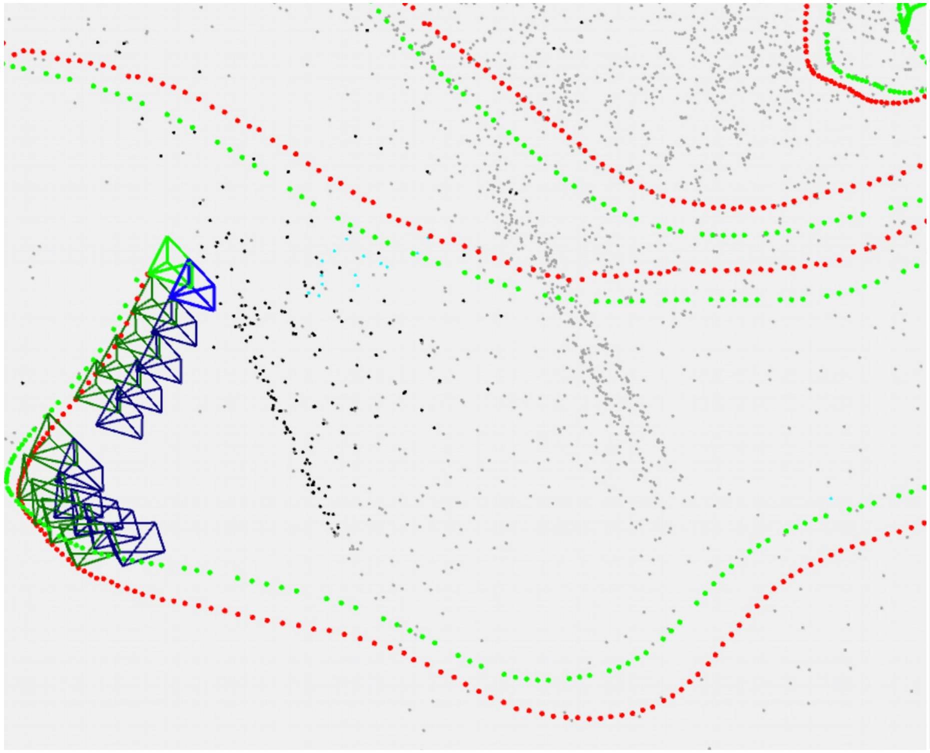
Exercise 5



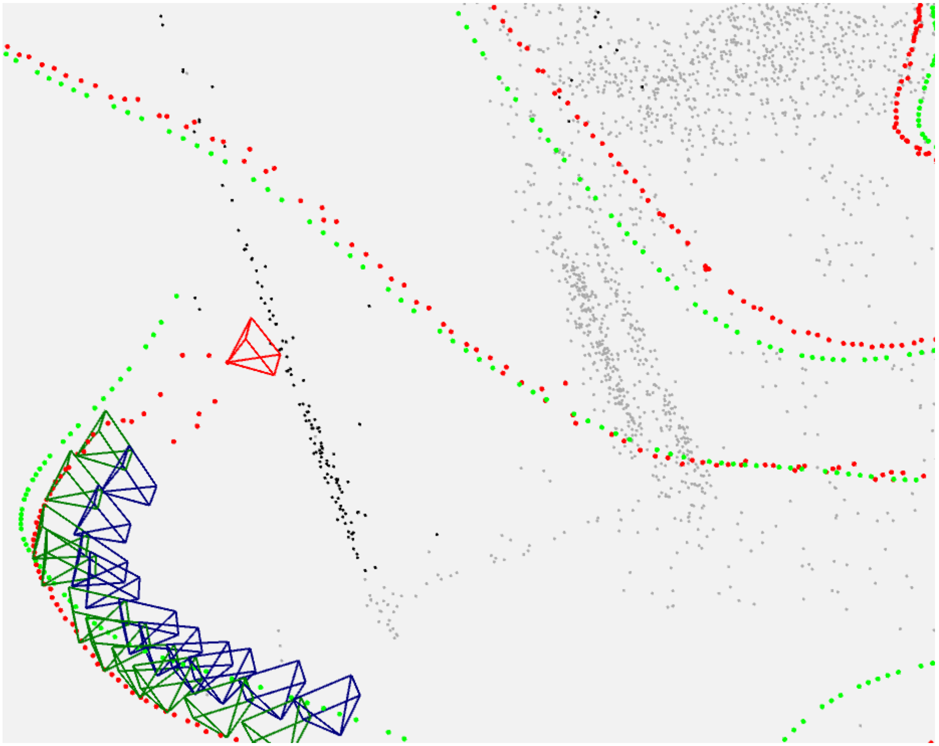
2 Evaluation

2.3 Visualization comparison

Maximum empty cells percentage: 42%



Exercise 5



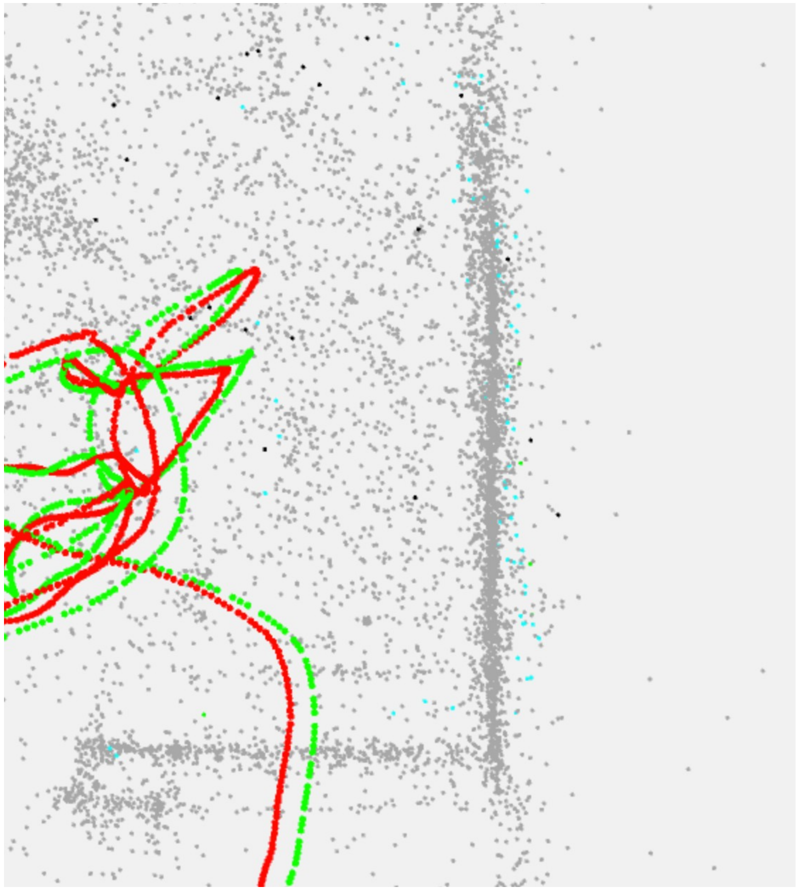
2 Evaluation

2.3 Visualization comparison

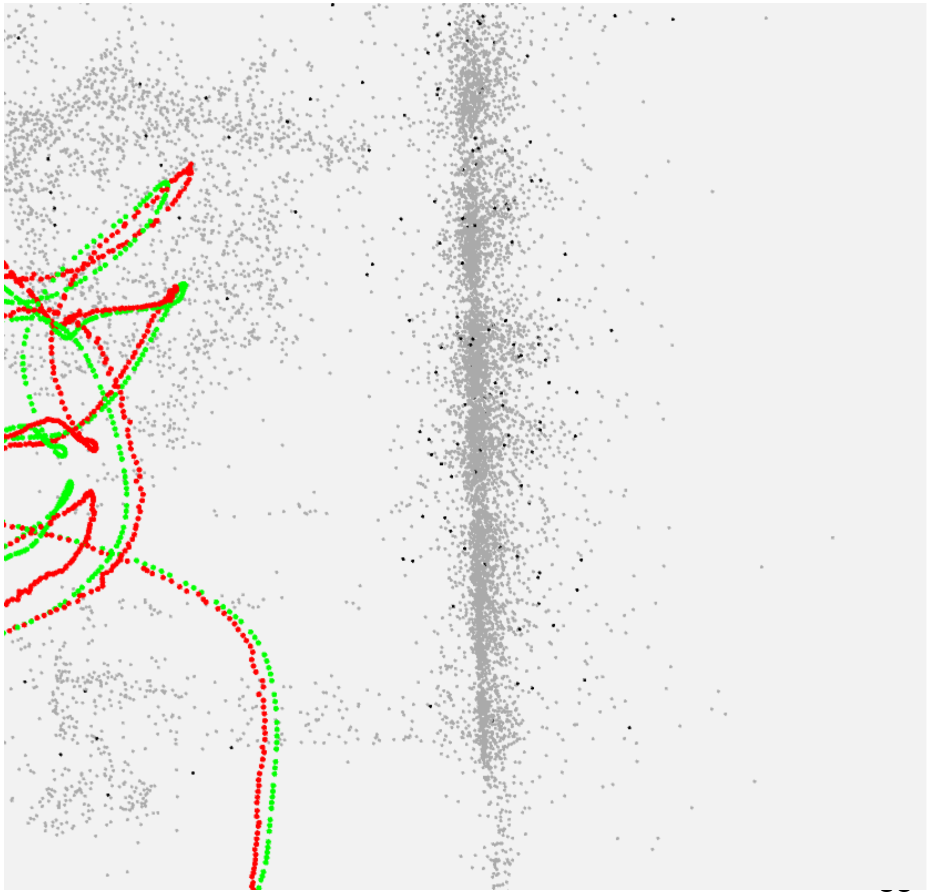
2 Evaluation

2.3 Visualization comparison

Maximum empty cells percentage: 42%



Exercise 5



3 Conclusion

1. Use Lucas and Kanade Optical Flow method to replace normal feature matching.
2. Try different key framing strategies: use grid or only inliers.
3. Try different configurations (e.g. shape of grid, key points detection strategies)
4. Visualize the ground truth and estimated trajectories of camera
5. Evaluation

Q&A

Any question?

Thank you for your attention!