

Practical Course: Vision-based Navigation (IN2106)

Exercise 2

Introduction to SLAM and Lie Groups

By

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11.11.2018

Exercise 1: Camera Models

1. What exactly test/src/test_ex2.cpp tests?

Answer:

It tests four (Pinhole, Extended Unified, Double Sphere and Kannala-Brandt) camera model's projection and unprojection functions and the subspace of points that result in valid projection.

Excise 2: Optimization

1. What is the difference between these curve fitting and robust curve fitting?

Answer:

The data we are given could have some outliers. For these noisy data, robust curve fitting gives us more accurate result, closer to ground truth.

Exercise 3: Camera Calibration

1. What are the command line parameters that src/calibration.cpp uses?

Answer:

- a. --show-gui (Default true)
- b. --dataset-path (Required)
- c. --cam-model (Possible values: pinhole, ds, eucm, kb4. Default: ds.)

2. Provide Summary and Analysis of the calibration result.

Answer:

From the result below we can be sure that the pinhole needs more time and more number of iteration than others. So the overall cost is high. Other three has similar cost.

Result

w0031@atcremers50:/work/w0031/visnav_ws18\$./build/calibration --show-gui 0

--dataset-path data/euroc_calib/ --cam-model pinhole

Loaded 104 poses

Loaded 104 corners

Loaded camera

into the optimize function

Solver Summary (v

1.14.0-eigen-(3.3.90)-lapack-suitesparse-(4.4.6)-cxsparse-(3.1.4)-eigensparse-no
_openmp-tbb-(4.4))

	Original	Reduced
Parameter blocks	56	55
Parameters	394	387
Effective parameters	340	334
Residual blocks	12442	12442
Residuals	24884	24884

Minimizer TRUST_REGION

Sparse linear algebra library SUITE_SPARSE

Trust region strategy LEVENBERG_MARQUARDT

	Given	Used
Linear solver	SPARSE_NORMAL_CHOLESKY	
SPARSE_NORMAL_CHOLESKY		
Threads	1	1
Linear solver ordering	AUTOMATIC	55

Cost:

Initial 1.795667e+07

Final 1.565735e+05

Change 1.780009e+07

Minimizer iterations 16

Successful steps 16

Unsuccessful steps 0

Time (in seconds):

Preprocessor 0.004606

Residual only evaluation	0.100279 (16)
Jacobian & residual evaluation	1.595493 (16)
Linear solver	0.134324 (16)
Minimizer	1.856005

Postprocessor	0.000453
Total	1.861064

Termination: CONVERGENCE (Function tolerance reached.
|cost_change|/cost: 2.191522e-13 <= 1.000000e-12)

```
{
  "value0": {
    "cam.T_i_c": [
      {
        "px": 0.0,
        "py": 0.0,
        "pz": 0.0,
        "qx": 0.0,
        "qy": 0.0,
        "qz": 0.0,
        "qw": 1.0
      },
      {
        "px": 0.10960220177714075,
        "py": -0.00010490052806700287,
        "pz": 0.0037400002055084206,
        "qx": 0.005389357928739971,
        "qy": -0.0381800849875592,
        "qz": 0.003278934586413812,
        "qw": 0.9992509617305538
      }
    ],
    "cam.intrinsics": [
      {
        "cam_type": "pinhole",
        "fx": 546.2147378586982,
        "fy": 551.5811503832609,
        "cx": 399.0884109494396,
        "cy": 208.37160821353988,
        "p1": 0.0,
        "p2": 0.0,

```

```

        "p3": 0.0,
        "p4": 0.0
    },
    {
        "cam_type": "pinhole",
        "fx": 547.2084958014367,
        "fy": 550.3778903534299,
        "cx": 368.8628411405755,
        "cy": 215.16198122823909,
        "p1": 0.0,
        "p2": 0.0,
        "p3": 0.0,
        "p4": 0.0
    }
]
}

```

}into the save_calib function

Saved camera calibration

w0031@atcremers50:/work/w0031/visnav_ws18\$./build/calibration --show-gui 0

--dataset-path data/euroc_calib/ --cam-model ds

Loaded 104 poses

Loaded 104 corners

Loaded camera

into the optimize function

Solver Summary (v

1.14.0-eigen-(3.3.90)-lapack-suitesparse-(4.4.6)-cxsparse-(3.1.4)-eigensparse-no
_openmp-tbb-(4.4))

	Original	Reduced	
Parameter blocks	56	55	
Parameters	394	387	
Effective parameters	340		334
Residual blocks	12442	12442	
Residuals	24884	24884	

Minimizer TRUST_REGION

Sparse linear algebra library SUITE_SPARSE

Trust region strategy LEVENBERG_MARQUARDT

Given

Used

Linear solver	SPARSE_NORMAL_CHOLESKY		
SPARSE_NORMAL_CHOLESKY			
Threads	1	1	
Linear solver ordering	AUTOMATIC		55

Cost:	
Initial	5.353182e+06
Final	1.627482e+02
Change	5.353019e+06

Minimizer iterations	15
Successful steps	13
Unsuccessful steps	2

Time (in seconds):	
Preprocessor	0.004165

Residual only evaluation	0.095083 (15)
Jacobian & residual evaluation	1.348467 (13)
Linear solver	0.125547 (15)
Minimizer	1.591064

Postprocessor	0.000468
Total	1.595697

Termination: CONVERGENCE (Parameter tolerance reached.
Relative step_norm: 6.648840e-09 <= 1.000000e-08.)

```
{
  "value0": {
    "cam.T_i_c": [
      {
        "px": 0.0,
        "py": 0.0,
        "pz": 0.0,
        "qx": 0.0,
        "qy": 0.0,
        "qz": 0.0,
        "qw": 1.0
      },
      {
        "px": 0.11002674958788153,
        "py": -0.0002891377986657835,
```

```

        "pz": 0.00024662504992001955,
        "qx": 0.007123658988065932,
        "qy": 0.0006289220700000715,
        "qz": 0.001077495211590841,
        "qw": 0.9999738481299002
    },
    ],
    "cam.intrinsics": [
    {
        "cam_type": "ds",
        "fx": 351.0372832168706,
        "fy": 350.0074555977391,
        "cx": 365.8880973548213,
        "cy": 249.34573836993602,
        "p1": -0.23853128172699096,
        "p2": 0.5678694845290959,
        "p3": 0.0,
        "p4": 0.0
    },
    {
        "cam_type": "ds",
        "fx": 362.9532887030654,
        "fy": 361.8568553744133,
        "cx": 379.35501913798887,
        "cy": 256.03924167771847,
        "p1": -0.21063783723054917,
        "p2": 0.5776109411992839,
        "p3": 0.0,
        "p4": 0.0
    }
    ]
}

```

}into the save_calib function

Saved camera calibration

w0031@atcremers50:/work/w0031/visnav_ws18\$./build/calibration --show-gui 0

--dataset-path data/euroc_calib/ --cam-model eucm

Loaded 104 poses

Loaded 104 corners

Loaded camera

into the optimize function

Solver Summary (v
 1.14.0-eigen-(3.3.90)-lapack-suitesparse-(4.4.6)-cxsparse-(3.1.4)-eigensparse-no
 _openmp-tbb-(4.4))

	Original	Reduced
Parameter blocks	56	55
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Minimizer TRUST_REGION

Sparse linear algebra library SUITE_SPARSE
 Trust region strategy LEVENBERG_MARQUARDT

	Given	Used
Linear solver	SPARSE_NORMAL_CHOLESKY	
Threads	1	1
Linear solver ordering	AUTOMATIC	55

Cost:
 Initial 5.353182e+06
 Final 1.627604e+02
 Change 5.353019e+06

Minimizer iterations	7
Successful steps	7
Unsuccessful steps	0

Time (in seconds):
 Preprocessor 0.004192

Residual only evaluation	0.046948 (7)
Jacobian & residual evaluation	0.719952 (7)
Linear solver	0.063987 (7)
Minimizer	0.842480

Postprocessor	0.000386
Total	0.847058

Termination: CONVERGENCE (Parameter tolerance reached.
Relative step_norm: 2.527948e-09 <= 1.000000e-08.)

```
{
  "value0": {
    "cam.T_i_c": [
      {
        "px": 0.0,
        "py": 0.0,
        "pz": 0.0,
        "qx": 0.0,
        "qy": 0.0,
        "qz": 0.0,
        "qw": 1.0
      },
      {
        "px": 0.11002631815223638,
        "py": -0.00028908964378219533,
        "pz": 0.000246181144400511,
        "qx": 0.007123595350702436,
        "qy": 0.0006300007991473259,
        "qz": 0.0010774305748141595,
        "qw": 0.9999738479738503
      }
    ],
    "cam.intrinsics": [
      {
        "cam_type": "eucm",
        "fx": 460.97949866208639,
        "fy": 459.62650958263296,
        "cx": 365.8867492896416,
        "cy": 249.346486044204,
        "p1": 0.5916648096407773,
        "p2": 1.1241125399441319,
        "p3": 0.0,
        "p4": 0.0
      },
      {
        "cam_type": "eucm",
        "fx": 459.79606434876208,
        "fy": 458.4063095857847,
        "cx": 379.3544250501397,
        "cy": 256.0400994980228,
```

```

        "p1": 0.6060839010938548,
        "p2": 1.088350919730381,
        "p3": 0.0,
        "p4": 0.0
    }
]
}

```

}into the save_calib function

Saved camera calibration

w0031@atcremers50:/work/w0031/visnav_ws18\$./build/calibration --show-gui 0

--dataset-path data/euroc_calib/ --cam-model kb4

Loaded 104 poses

Loaded 104 corners

Loaded camera

into the optimize function

Solver Summary (v

1.14.0-eigen-(3.3.90)-lapack-suitesparse-(4.4.6)-cxsparse-(3.1.4)-eigensparse-no
_openmp-tbb-(4.4))

	Original	Reduced
Parameter blocks	56	55
Parameters	394	387
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Minimizer TRUST_REGION

Sparse linear algebra library SUITE_SPARSE

Trust region strategy LEVENBERG_MARQUARDT

	Given	Used
Linear solver	SPARSE_NORMAL_CHOLESKY	
SPARSE_NORMAL_CHOLESKY		
Threads	1	1
Linear solver ordering	AUTOMATIC	55

Cost:

Initial 5.788049e+06

Final 1.619844e+02

Change 5.787887e+06

Minimizer iterations	8
Successful steps	8
Unsuccessful steps	0

Time (in seconds):

Preprocessor	0.004850
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Residual only evaluation	0.058969 (8)
Jacobian & residual evaluation	0.840666 (8)
Linear solver	0.069336 (8)
Minimizer	0.981935

Postprocessor	0.000318
Total	0.987103

Termination: CONVERGENCE (Parameter tolerance reached.
Relative step_norm: 1.775294e-10 <= 1.000000e-08.)

```
{
  "value0": {
    "cam.T_i_c": [
      {
        "px": 0.0,
        "py": 0.0,
        "pz": 0.0,
        "qx": 0.0,
        "qy": 0.0,
        "qz": 0.0,
        "qw": 1.0
      },
      {
        "px": 0.11002263076486116,
        "py": -0.0002883117629450844,
        "pz": 0.0002519373817561351,
        "qx": 0.0071296487226686689,
        "qy": 0.0006308484199464338,
        "qz": 0.0010771978182017289,
        "qw": 0.9999738045490108
      }
    ],
    "cam.intrinsics": [
      {
```

```

        "cam_type": "kb4",
        "fx": 461.15819016326057,
        "fy": 459.80802859479726,
        "cx": 365.8972386901174,
        "cy": 249.35492318319,
        "p1": -0.004593052532206329,
        "p2": 0.027532432037032769,
        "p3": -0.03697767177100388,
        "p4": 0.01861021724557171
    },
    {
        "cam_type": "kb4",
        "fx": 459.74480686519805,
        "fy": 458.3535053463388,
        "cx": 379.363961495464,
        "cy": 256.04352542706246,
        "p1": 0.004549588612678704,
        "p2": 0.002485490491611451,
        "p3": -0.010601348784735579,
        "p4": 0.010781041140897625
    }
]
}

```

}into the save_calib function
 Saved camera calibration