



PROJECT

Extended Kalman Filters

A part of the Self Driving Car Engineer Nanodegree Program

PROJECT REVIEW

CODE REVIEW 9

NOTES

▼ using_cmake/src/FusionEKF.cpp 4

```

1 #include "FusionEKF.h"
2 #include "tools.h"
3 #include "Eigen/Dense"
4 #include <iostream>
5
6 using namespace std;
7 using Eigen::MatrixXd;
8 using Eigen::VectorXd;
9 using std::vector;
10
11 /*
12  * Constructor.
13  */
14 FusionEKF::FusionEKF() {
15     is_initialized_ = false;
16
17     previous_timestamp_ = 0;
18
19     // initializing matrices
20     R_laser_ = MatrixXd(2, 2);
21     R_radar_ = MatrixXd(3, 3);
22     H_laser_ = MatrixXd(2, 4);
23     Hj_ = MatrixXd(3, 4);
24     //add
25     ekf_.P_ = MatrixXd(4, 4);
26     ekf_.F_ = MatrixXd(4, 4);
27     ekf_.Q_ = MatrixXd(4, 4);
28     //add
29
30     //measurement covariance matrix - laser
31     R_laser_ << 0.0225, 0,
32         0, 0.0225;
33
34     //measurement covariance matrix - radar
35     R_radar_ << 0.09, 0, 0,
36         0, 0.0009, 0,
37         0, 0, 0.09;
38
39     /**
40     TODO:
41     * Finish initializing the FusionEKF.
42     * Set the process and measurement noises
43     */
44     //measurement matrix - laser
45     H_laser_ << 1, 0, 0, 0,
46         0, 1, 0, 0;
47
48     //jacobian matrix - radar
49     Hj_ << 1, 0, 0, 0,
50         0, 1, 0, 0,
51         0, 0, 1, 0;
52
53     // state covariance matrix P
54     ekf_.P_ << 1, 0, 0, 0,
55         0, 1, 0, 0,
56         0, 0, 1000, 0,
57         0, 0, 0, 1000;

```



AWESOME

Good job!

```

59
60 // state transition matrix F
61
62 ekf_.F_ << 1, 0, 1, 0,
63         0, 1, 0, 1,
64         0, 0, 1, 0,
65         0, 0, 0, 1;
66
67 // process noise covariance matrix Q
68 ekf_.Q_ << 0, 0, 0, 0,
69         0, 0, 0, 0,
70         0, 0, 0, 0,
71         0, 0, 0, 0;
72
73 // Initialize ekf state
74 ekf_.x_ = VectorXd(4);
75 ekf_.x_ << 1, 1, 1, 1;
76
77 noise_ax = 5;
78 noise_ay = 5;

```

REQUIRED

Changes Required

Revert this back to 9!

```

79
80 }
81
82 /**
83 * Destructor.
84 */
85 FusionEKF::~FusionEKF() {}
86
87 void FusionEKF::ProcessMeasurement(const MeasurementPackage &measurement_pack) {
88
89
90     /*****
91     * Initialization
92     *****/
93     if (!is_initialized_) {
94         /**
95         TODO:
96         * Initialize the state ekf_.x_ with the first measurement.
97         * Create the covariance matrix.
98         * Remember: you'll need to convert radar from polar to cartesian coordinates.
99         */
100         // first measurement
101         cout << "EKF: " << endl;
102         ekf_.x_ = VectorXd(4);
103         ekf_.x_ << 1, 1, 1, 1;
104
105         if (measurement_pack.sensor_type_ == MeasurementPackage::RADAR) {
106             /**
107             Convert radar from polar to cartesian coordinates and initialize state.
108             */
109             float rho = measurement_pack.raw_measurements_(0);
110             float phi = measurement_pack.raw_measurements_(1);
111             float dot_rho = measurement_pack.raw_measurements_(2);
112
113             float px = rho * cos(phi);
114             float py = rho * sin(phi);
115             float vx = dot_rho * cos(phi);
116             float vy = dot_rho * sin(phi);

```

SUGGESTION

This is something that a lot of students get it wrong, phi is the direction of the object relative to our car. It's not the direction in which the object is heading (i.e. heading, which is introduced in UKF) to compute vx and vy. So even from radar measurement, we can only compute px and py. Hope that made sense. This [discussion](#) explain:

```

117
118     ekf_.x_ << px, py, vx, vy;
119 }
120 else if (measurement_pack.sensor_type_ == MeasurementPackage::LASER) {
121     /**
122     Initialize state.
123     */
124     float px = measurement_pack.raw_measurements_(0);
125     float py = measurement_pack.raw_measurements_(1);
126     float vx = 0, vy = 0;
127     // Initialize state
128     ekf_.x_ << px, py, vx, vy;
129 }
130
131 // done initializing, no need to predict or update
132 is_initialized_ = true;
133 return;
134 }
135
136 /*****

```

```

137 * Prediction
138 *****/
139
140 /**
141 TODO:
142 * Update the state transition matrix F according to the new elapsed time.
143   - Time is measured in seconds.
144 * Update the process noise covariance matrix.
145 * Use noise_ax = 9 and noise_ay = 9 for your Q matrix.
146 */
147 float dt = (measurement_pack.timestamp_ - previous_timestamp_) / 1000000.0; // dt - expressed in seconds
148 previous_timestamp_ = measurement_pack.timestamp_;
149
150 float dt_2 = dt * dt;
151 float dt_3 = dt_2 * dt;
152 float dt_4 = dt_3 * dt;
153
154 //Modify the F matrix so that the time is integrated
155 ekf_.F_(0, 2) = dt;
156 ekf_.F_(1, 3) = dt;
157
158 //set the process covariance matrix Q
159 ekf_.Q_ << dt_4 / 4 * noise_ax, 0, dt_3 / 2 * noise_ax, 0,
160          0, dt_4 / 4 * noise_ay, 0, dt_3 / 2 * noise_ay,
161          dt_3 / 2 * noise_ax, 0, dt_2*noise_ax, 0,
162          0, dt_3 / 2 * noise_ay, 0, dt_2*noise_ay;
163
164 // todo end
165
166
167 ekf_.Predict();

```

SUGGESTION

If dt is 0 (simultaneous measurements), you need not and should not predict again. So it's better to check if dt is above a certain threshold before predicting. Note tha

```

168
169 *****/
170 * Update
171 *****/
172
173 /**
174 TODO:
175 * Use the sensor type to perform the update step.
176 * Update the state and covariance matrices.
177 */
178
179 if (measurement_pack.sensor_type_ == MeasurementPackage::RADAR) {
180   // Radar updates
181   ekf_.H_ = tools.CalculateJacobian(ekf_.x_);
182   ekf_.R_ = R_radar_;
183   ekf_.UpdateEKF(measurement_pack.raw_measurements_);
184 } else {
185   // Laser updates
186   ekf_.H_ = H_laser_;
187   ekf_.R_ = R_laser_;
188   ekf_.Update(measurement_pack.raw_measurements_);
189 }
190
191 // print the output
192 cout << "x_ = " << ekf_.x_ << endl;
193 cout << "P_ = " << ekf_.P_ << endl;
194 }
195

```

► using_cmake/src/kalman_filter.cpp 3

► using_cmake/src/tools.cpp 2

► using_eclips_oxygen/src/Eigen/src/plugins/BlockMethods.h

► using_eclips_oxygen/src/Eigen/src/plugins/ArrayCwiseUnaryOps.h

► using_eclips_oxygen/src/Eigen/src/plugins/ArrayCwiseBinaryOps.h

► using_eclips_oxygen/src/Eigen/src/misc/blas.h

► using_eclips_oxygen/src/Eigen/src/misc/SparseSolve.h

► using_eclips_oxygen/src/Eigen/src/misc/Solve.h

► using_eclips_oxygen/src/Eigen/src/misc/Kernel.h

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- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_pruneL.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_pivotL.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_panel_dfs.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_panel_bmod.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_kernel_bmod.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_heap_relax_snode.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_gemm_kernel.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_copy_to_ucol.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_column_dfs.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_column_bmod.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_Utils.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_SupernodalMatrix.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_Structs.h
- using_eclips_oxygen/src/Eigen/src/SparseLU/SparseLU_Memory.h
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- using_eclips_oxygen/src/Eigen/src/SparseLU/CMakeLists.txt
- using_eclips_oxygen/src/Eigen/src/SparseCore/TriangularSolver.h

- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseView.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseVector.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseUtil.h
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- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseTranspose.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseSparseProductWithPruning.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseSelfAdjointView.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseRedux.h
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- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparsePermutation.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseMatrixBase.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseMatrix.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseFuzzy.h
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- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseDiagonalProduct.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseDenseProduct.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseCwiseUnaryOp.h
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- ▶ using_eclips_oxygen/src/Eigen/src/SparseCore/SparseColEtree.h
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- ▶ using_eclips_oxygen/src/Eigen/src/SparseCholesky/SimplicialCholesky_impl.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCholesky/SimplicialCholesky.h
- ▶ using_eclips_oxygen/src/Eigen/src/SparseCholesky/CMakeLists.txt
- ▶ using_eclips_oxygen/src/Eigen/src/SVD/UpperBidiagonalization.h
- ▶ using_eclips_oxygen/src/Eigen/src/SVD/JacobiSVD_MKL.h
- ▶ using_eclips_oxygen/src/Eigen/src/SVD/JacobiSVD.h
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- ▶ using_eclips_oxygen/src/Eigen/src/SPQRSupport/SuiteSparseQRSupport.h
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- ▶ using_eclips_oxygen/src/Eigen/src/QR/FullPivHouseholderQR.h
- ▶ using_eclips_oxygen/src/Eigen/src/QR/ColPivHouseholderQR_MKL.h
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- using_eclips_oxygen/src/Eigen/src/Core/util/Memory.h

- ▶ using_eclips_oxygen/src/Eigen/src/Core/util/Macros.h
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- ▶ using_eclips_oxygen/src/Eigen/src/Core/products/SelfadjointMatrixVector_MKL.h
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- ▶ using_eclips_oxygen/src/Eigen/src/Core/products/SelfadjointMatrixMatrix_MKL.h
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- using_eclips_oxygen/src/Eigen/src/Core/GlobalFunctions.h
- using_eclips_oxygen/src/Eigen/src/Core/GenericPacketMath.h
- using_eclips_oxygen/src/Eigen/src/Core/GeneralProduct.h
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- using_eclips_oxygen/src/Eigen/src/Core/Dot.h
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- using_cmake/src/Eigen/src/QR/ColPivHouseholderQR_MKL.h
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- using_cmake/src/Eigen/src/Eigen2Support/Geometry/Translation.h
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