Table of Contents


```
% This main fucntion tests the new idea for handling noise by using
 the
% distribution as a priori known information
%
clear;
clc;
close all;
```

Add file dependencies

```
addpath ../../../rvctools/robot
addpath ../../../rvctools/common
addpath ../../../kinematics/kinematics/screws
addpath ../../../kinematics/kinematics/util
addpath ../../../kinematics/kinematics/lie_group
addpath ../../../axxb_calibration/matlab/new_mean/codegen/mex/
distibutionPropsMex
```

Initialize Parameters

```
num = 50; % number of samples in a cloud

gmean = [0;0;0;0;0;0]; %Gaussian Noise Mean

cov = eye(6,6);

std = 0.1;    % std for generating the noise-free sample cloud

ratio_std = 0.005:0.005:0.05; % noise level 0.5% - 5% on std

nstd = ratio_std*std; % Gaussian Noise standard deviation Range

n_trials = 2; %60

x = randn(6,1); x = x./norm(x); X = expm(se3_vec(x)); % Generate a
 Random X

noiseModel = 2; % Select the noise model which has zero mean and nstd
 as the
% standard deviation on lie aglebra
```

```
optPDF = 1; % Select the distribution for generating {A} and {B}
 sample cloud.
% They will have zero mean and std as the standard deviation in
% lie algebra
```

Data Initialization

For simplicity, we only apply noise onto {A}

```
A_noise = zeros(4, 4, num); % A with noise
B = zeros(4, 4, num);       % B will be kept noise free
Ainv_noise = zeros(4, 4, num); % Calculate {A^-1}

rotErr1 = [];
tranErr1 = [];
covErr1 = [];
covErr1Rot = [];

rotErr2 = [];
tranErr2 = [];
covErr2 = [];
covErr2Rot = [];

covX1Err = [];
meanX1Err = [];
```

Apply noise on Ai only

```
for m = 1:length(nstd)

    for k = 1: 200

        % Generate num samples of A and B given the ground truth X,
        % type of distribution optPDF, mean gmean and covariance
 std*cov
        [A, B] = generateAB(num, optPDF, X, gmean, std*cov);

        % Apply noise onto A
        A_noise = sensorNoise(A, gmean, nstd(m), noiseModel);

        % Compute the mean and covariance of A_noise
        [a1,a2,a3]  = size(A_noise);
        A_mex = reshape(A_noise, a1, a2*a3);
        [MeanA_noise, SigA_noise] = distibutionPropsMex_mex(A_mex);

        % Compute the mean and covariance of noise-free B
        B_mex = reshape(B, a1, a2*a3);
        [MeanB, SigB] = distibutionPropsMex_mex(B_mex);

        % Compute adjoint matrix of Xinv and MeanBinv
        adXinv = SE3inv_Ad(X);
        adBinv = SE3inv_Ad(MeanB);
```

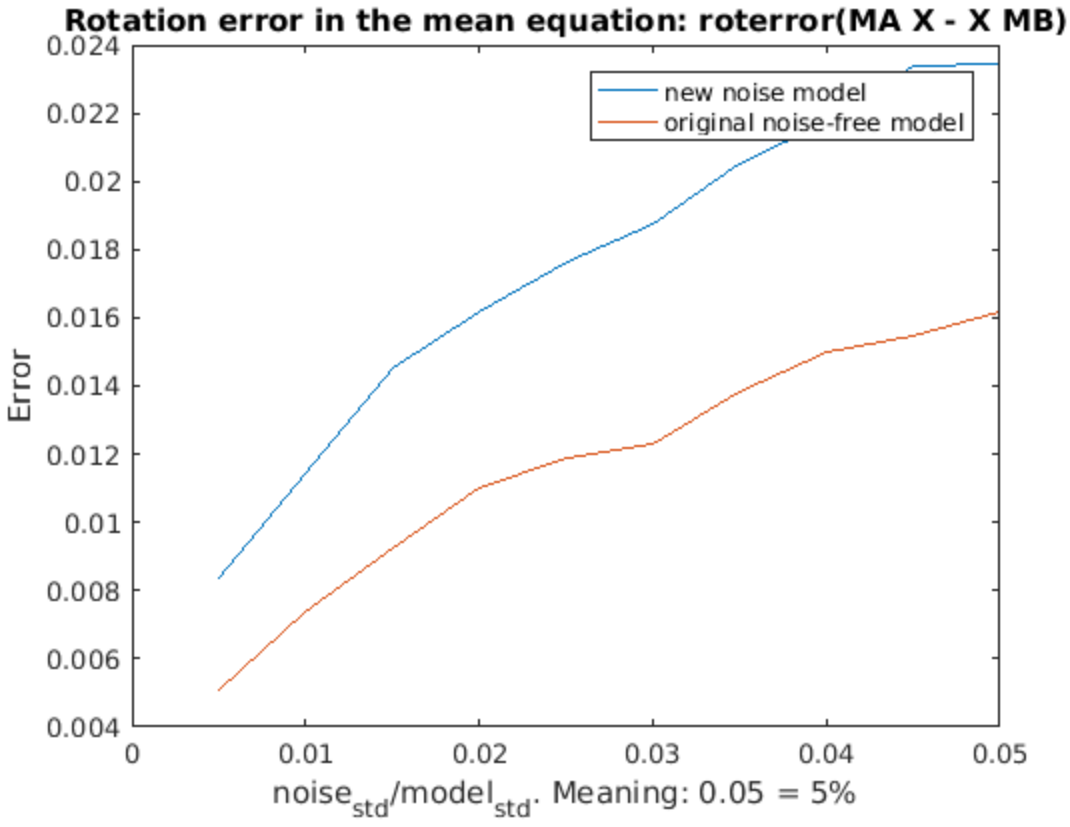
```
        % Lie algebra basis
        E1(:,:,1)=[0 0 0 0; 0 0 -1 0; 0 1 0 0; 0 0 0 0];
        E1(:,:,2)=[0 0 1 0; 0 0 0 0; -1 0 0 0; 0 0 0 0];
        E1(:,:,3)=[0 -1 0 0; 1 0 0 0; 0 0 0 0; 0 0 0 0];
        E1(:,:,4)=[0 0 0 1; 0 0 0 0; 0 0 0 0; 0 0 0 0];
        E1(:,:,5)=[0 0 0 0; 0 0 0 1; 0 0 0 0; 0 0 0 0];
        E1(:,:,6)=[0 0 0 0; 0 0 0 0; 0 0 0 1; 0 0 0 0];

        % ------ Compute the covariance of the noise correcting term
------
        % n_A_prime namely,  { exp(\sum (nj Ai Ej Ai^-1)) }
        N_A_prime = zeros(4, 4, num);
        for i = 1:a3

            temp_se3 = zeros(4,4);

            % Generate a sample of Lie algebra using zero mean and
nstd(m)*cov
            % as the covariance
            lie_algebra = mvg(gmean, nstd(m)*cov, 1);

            % Assume the noise is really small and use measured data
            % A_noise to replace the noise-free data A
            for j = 1:6
                temp_se3 = temp_se3 +
lie_algebra(j)*A_noise(:,:,i)*E1(:,:,j)/A_noise(:,:,i);
            end

            N_A_prime(:,:,i) = expm(temp_se3);
        end
        %
-------------------------------------------------------------------

        % Calculate the mean and covariance of the noise correcting
term
        N_A_mex = reshape(N_A_prime, a1, a2*a3);
        [MeanN_A_prime, SigN_A_prime] =
distibutionPropsMex_mex(N_A_mex);

        % Compute the mean and covariance of the inverse of A_noise
        for s = 1: a3
            Ainv_noise(:,:,s) = inv(A_noise(:,:,s));
        end
        Ainv_mex = reshape(Ainv_noise, a1, a2*a3);
        [MeanAinv_noise, SigAinv_noise] =
distibutionPropsMex_mex(Ainv_mex);
```

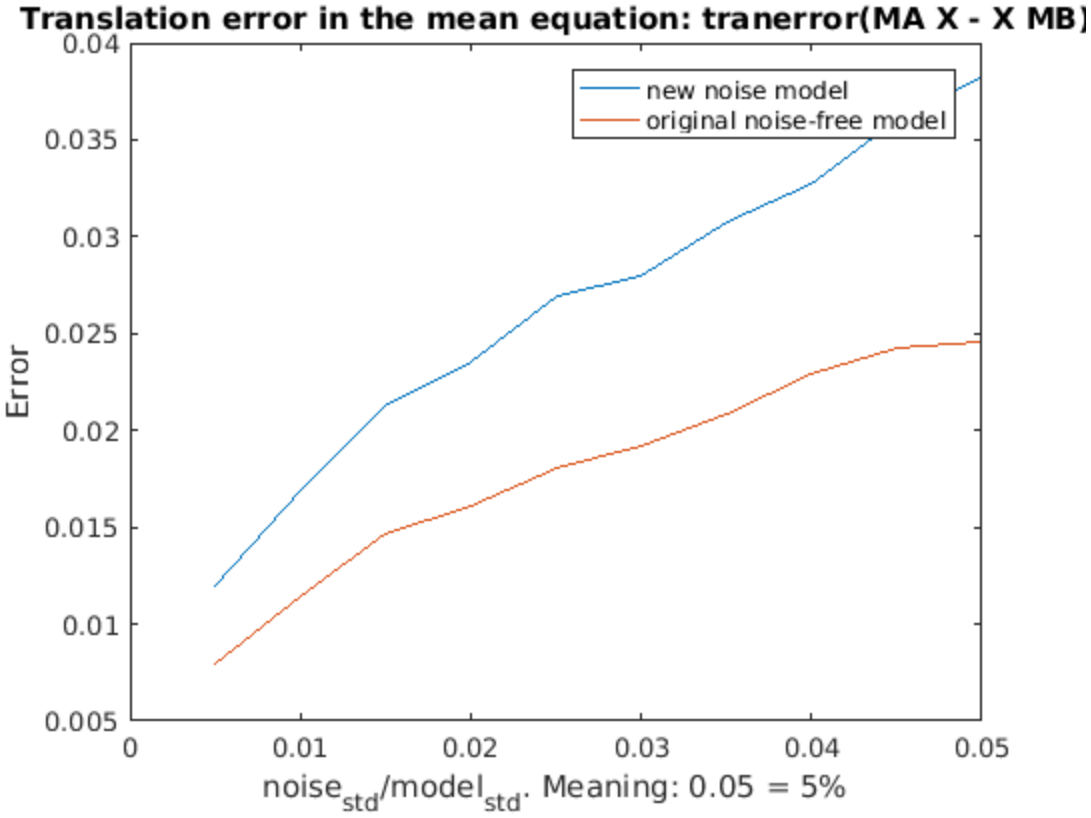
Verification of the mean and covariance equations

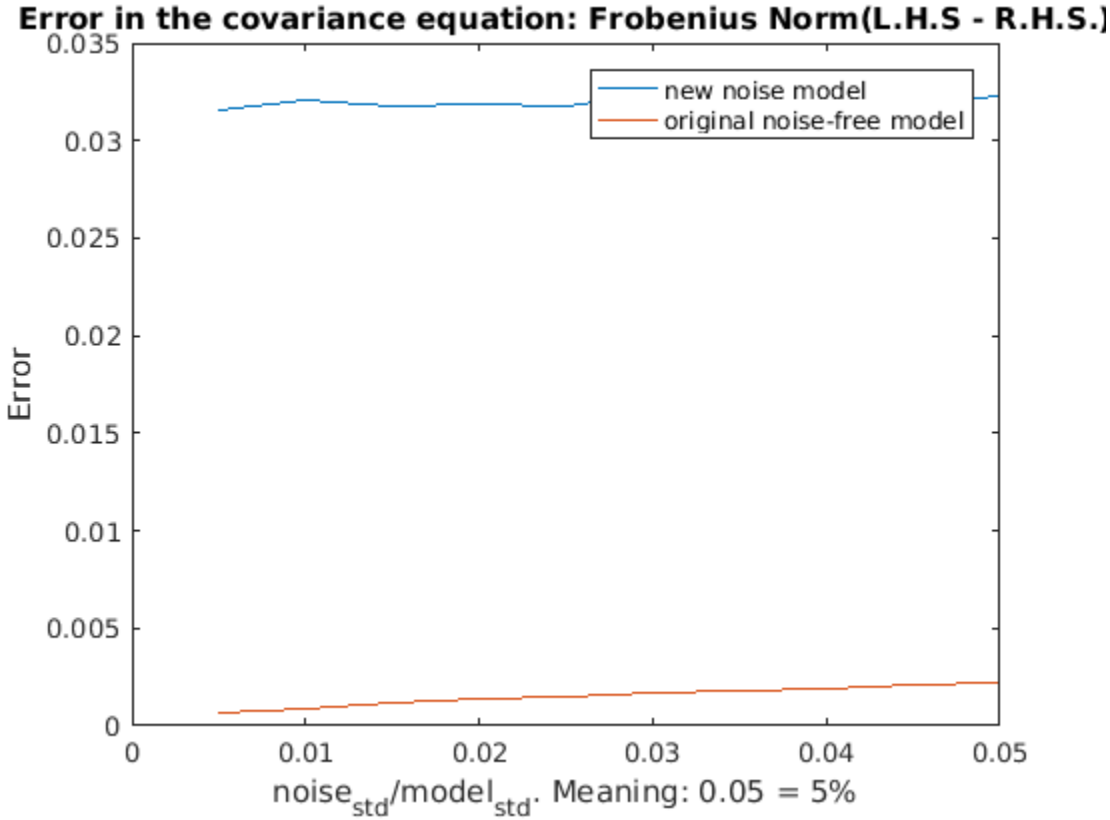
------- Mean Equation Error Analysis ------- % Rotation error of the new model

```
        rotErr1(k,m) = roterror(MeanA_noise*X, MeanN_A_prime*X*MeanB);
        % Translation error of the new model
        tranErr1(k,m) = tranerror(MeanA_noise*X,
 MeanN_A_prime*X*MeanB);
        % Rotation error of the no-noise model
        rotErr2(k,m) = roterror(MeanA_noise*X, X*MeanB);
        % Translation error of the no-noise model
        tranErr2(k,m) = tranerror(MeanA_noise*X, X*MeanB);

        % ------- Covariance Equation Error Analysis ------- %
        % Covariance error of the new model
        covDiff1 = adXinv*SigA_noise*adXinv' -
 adBinv*adXinv*SigN_A_prime*adXinv'*adBinv' + SigB;
        covErr1(k,m) = norm(covDiff1, 'fro');

        % Covariance error of the noise-free model
        covDiff2 = adXinv*SigA_noise*adXinv' - SigB;
        covErr2(k,m) = norm(covDiff2, 'fro');

%         covX1 = adBinv*adXinv*SigAinv_noise*adXinv'*adBinv' + SigB;
%         covX1Err(k,m) = norm(covX1, 'fro');
%
%         meanX1 = X - MeanAinv_noise*X*MeanB;
%         meanX1Err(k,m) = norm(meanX1, 'fro');
        % covariance

    end

end

figure
plot(ratio_std, mean(rotErr1, 1))
hold on
plot(ratio_std, mean(rotErr2, 1))
legend('new noise model','original noise-free model')
xlabel('noise_{std}/model_{std}. Meaning: 0.05 = 5%')
ylabel('Error')
title('Rotation error in the mean equation: roterror(MA X - X MB)')

figure
plot(ratio_std, mean(tranErr1, 1))
hold on
plot(ratio_std, mean(tranErr2, 1))
legend('new noise model','original noise-free model')
xlabel('noise_{std}/model_{std}. Meaning: 0.05 = 5%')
ylabel('Error')
title('Translation error in the mean equation: tranerror(MA X - X
 MB)')

figure
plot(ratio_std, mean(covErr1, 1))
hold on
plot(ratio_std, mean(covErr2, 1))
legend('new noise model','original noise-free model')
```

```
xlabel('noise_{std}/model_{std}. Meaning: 0.05 = 5%')
ylabel('Error')
title('Error in the covariance equation: Frobenius Norm(L.H.S -
 R.H.S.)')
```




Translation error in the mean equation: tranerror(MA X - X MB)
new noise model
original noise-free model
Error
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0.01
0.02
0.03
0.04
0.05
noise_std/model_std. Meaning: 0.05 = 5%


Error in the covariance equation: Frobenius Norm(L.H.S - R.H.S.)
new noise model
original noise-free model
Error
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0.01
0.02
0.03
0.04
0.05
noise_std/model_std. Meaning: 0.05 = 5%

```
fprintf('Rotation error of the noise correction method is %d \n',
 mean(rotErr1, 1));
fprintf('Translation error of the noise correction method is %d \n',
 mean(tranErr1, 1));
fprintf('Rotation error of the normal method is %d \n', mean(rotErr2,
 1));
fprintf('Translation error of the normal method is %d \n',
 mean(tranErr2, 1));
fprintf('##------------------------------------------------------##
 \n')
fprintf('Norm of covariance difference for the noise correction method
 is %d \n', mean(covErr1, 1));
fprintf('Norm of covariance difference is %d \n', mean(covErr2, 1));
fprintf('##------------------------------------------------------##
 \n')
```

```
Rotation error of the noise correction method is 8.371782e-03
Rotation error of the noise correction method is 1.143928e-02
Rotation error of the noise correction method is 1.455468e-02
Rotation error of the noise correction method is 1.615432e-02
Rotation error of the noise correction method is 1.764864e-02
Rotation error of the noise correction method is 1.873176e-02
Rotation error of the noise correction method is 2.053063e-02
Rotation error of the noise correction method is 2.175096e-02
Rotation error of the noise correction method is 2.339144e-02
Rotation error of the noise correction method is 2.346845e-02
Translation error of the noise correction method is 1.194809e-02
Translation error of the noise correction method is 1.691069e-02
Translation error of the noise correction method is 2.124092e-02
Translation error of the noise correction method is 2.355741e-02
Translation error of the noise correction method is 2.689050e-02
Translation error of the noise correction method is 2.802291e-02
Translation error of the noise correction method is 3.075630e-02
Translation error of the noise correction method is 3.275546e-02
Translation error of the noise correction method is 3.605628e-02
Translation error of the noise correction method is 3.815180e-02
Rotation error of the normal method is 5.113696e-03
Rotation error of the normal method is 7.353492e-03
Rotation error of the normal method is 9.269465e-03
Rotation error of the normal method is 1.100755e-02
Rotation error of the normal method is 1.190257e-02
Rotation error of the normal method is 1.232588e-02
Rotation error of the normal method is 1.384659e-02
Rotation error of the normal method is 1.501813e-02
Rotation error of the normal method is 1.545986e-02
Rotation error of the normal method is 1.616257e-02
Translation error of the normal method is 7.951532e-03
Translation error of the normal method is 1.148834e-02
Translation error of the normal method is 1.461834e-02
Translation error of the normal method is 1.615011e-02
Translation error of the normal method is 1.807446e-02
Translation error of the normal method is 1.922490e-02
Translation error of the normal method is 2.087193e-02
Translation error of the normal method is 2.291674e-02
```

```
Translation error of the normal method is 2.427169e-02
Translation error of the normal method is 2.457653e-02
##------------------------------------------------------##
Norm of covariance difference for the noise correction method is
 3.154595e-02
Norm of covariance difference for the noise correction method is
 3.203019e-02
Norm of covariance difference for the noise correction method is
 3.177044e-02
Norm of covariance difference for the noise correction method is
 3.188783e-02
Norm of covariance difference for the noise correction method is
 3.177975e-02
Norm of covariance difference for the noise correction method is
 3.233529e-02
Norm of covariance difference for the noise correction method is
 3.184455e-02
Norm of covariance difference for the noise correction method is
 3.183831e-02
Norm of covariance difference for the noise correction method is
 3.182366e-02
Norm of covariance difference for the noise correction method is
 3.230454e-02
Norm of covariance difference is 6.272265e-04
Norm of covariance difference is 9.208384e-04
Norm of covariance difference is 1.140903e-03
Norm of covariance difference is 1.344139e-03
Norm of covariance difference is 1.503661e-03
Norm of covariance difference is 1.715285e-03
Norm of covariance difference is 1.841207e-03
Norm of covariance difference is 1.941624e-03
Norm of covariance difference is 2.120168e-03
Norm of covariance difference is 2.252124e-03
##------------------------------------------------------##
```

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