Northeastern University

Computer Vision I [EECE 5639]
Project 3
Shah, Romil [shah.romil@husky.neu.edu]
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Project 3
TARGET TRACKING

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Acknowledgement

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We would also like to thank our **TA Shuhui Jiang** for her constant support and guidance throughout the program and betterment of the ideas implemented throughout the project.

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1. Abstract

A technique for Target Tracking of the moving objects with and without Occlusions is proposed in the project. The project incorporates use of Circular matrix for the tracking and it is further complemented by the use of Kalman Filters for tracking the object during the occlusion of object during motion. The proposed algorithm is tested on numerous videos examples as referred to in the project guideline. Corresponding results are analysed with the correlation plot between the actual motion of the object and its tracked trajectory, the graph shown in results is plotted between Precision and Threshold. The results are then summed up in the final report.

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2. Introduction

Our algorithm incorporated the use of the resultant Circulant Matrix to do the Target Tracking (as prescribed in the reference research paper - High-Speed Tracking with Kernelized Correlation Filters by João F. Henriques). A circulant matrix is a Toeplitz Matrix in which the row vector is rotated on element to the right with respect to the previous row vector. As these matrices are diagonalized by Discrete Fourier Transfomr (DFT), they are significant and hence can be quickly solved using Fast Fourier Transform (FFT). This comes in very handy as the computation time is reduced by several order of magnitude.

$$C = \begin{bmatrix} c_0 & c_{n-1} & \cdots & c_2 & c_1 \\ c_1 & c_0 & c_{n-1} & & c_2 \\ \vdots & c_1 & c_0 & \ddots & \vdots \\ c_{n-2} & & \ddots & \ddots & c_{n-1} \\ c_{n-1} & c_{n-2} & \cdots & c_1 & c_0 \end{bmatrix} \qquad f(x) = c_0 + c_1 x + \ldots + c_{n-1} x^{n-1}$$

We have further improved this reference approach for the area where it lacked – Occlusion detection. We have fused the use of Kalman Filter with this to track the object when it is occluded.

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3. Description of algorithm

We are using the discrete Kalman Filter that follows the following formula:

$$\hat{x}_k(+) = K'_k \hat{x}_k(-) + K_k y_k$$

$$\boxed{\hat{x}_k(+) = \underbrace{\hat{x}_k(-)}_{\text{Previous estimate}} + K_k \underbrace{[y_k - M_k \hat{x}_k(-)]}_{\text{Measurement Residual}}}$$

Between the measurements:

$$\begin{aligned} \hat{x}_k(-) &= D_k \hat{x}_{k-1}(+) \\ P_k(-) &= \Sigma_{dk} + D_k P_{k-1}(+) D_k \end{aligned}$$

Across the measurements:

$$\begin{aligned} K_k &= P_k(-) M_k^T [M_k P_k(-) M_k^T + \Sigma_{mk}]^{-1} \\ \hat{x}_k(+) &= \hat{x}_k(-) + K_k [y_k - M_k \hat{x}_k(-)] \\ P_k(+) &= [I - K_k M_k] P_k(-) \end{aligned}$$

Thus based on this Kalman algorithm, the occluded frame is detected as per Constant velocity.

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4. Experiments

The devised algorithm gives good results on tis applications on all the tester videos as given in the project question. We have experimented by changing the Threshold values for each of the image sequence.

5. Values of Parameters

Kalman Filter:

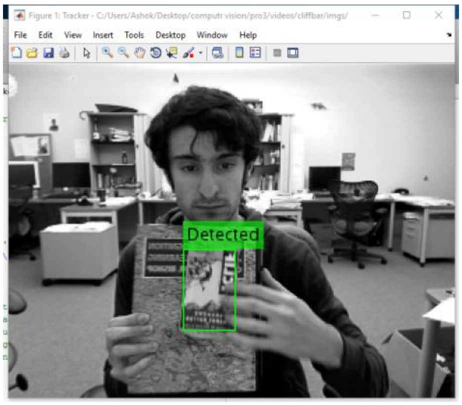
Motion Model = 'ConstantVelocity';
Initial Location = [0 0];
Initial Estimate Error = 1E5 * ones(1, 3);
Motion Noise = [25, 10, 1];
Measurement Noise = 25;
Segmentation Threshold = 0.05;

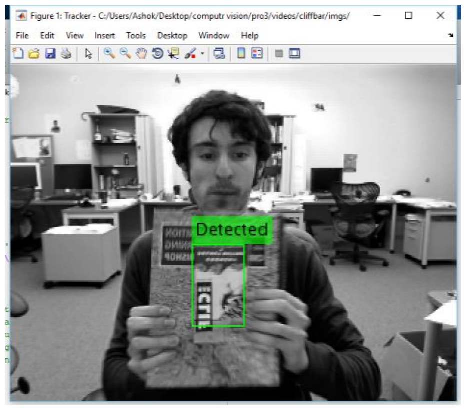
Threshold values:

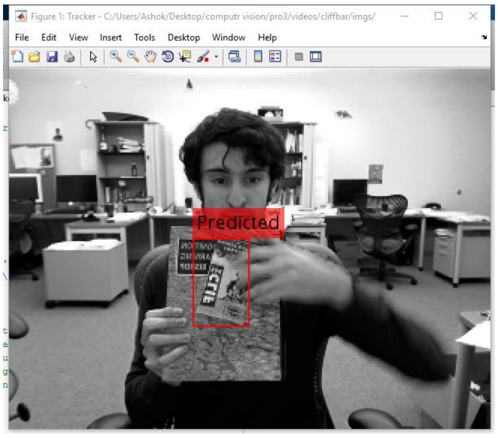
Sr.No.	Databse	PSR-Threshold
1.	tiger1	15
2.	dollar	35
3.	tiger2	11.5
4.	twinnings	17
5.	faceocc	40
6.	cliffbar	27
7.	sylv	35
8.	coke11	15
9.	david	16

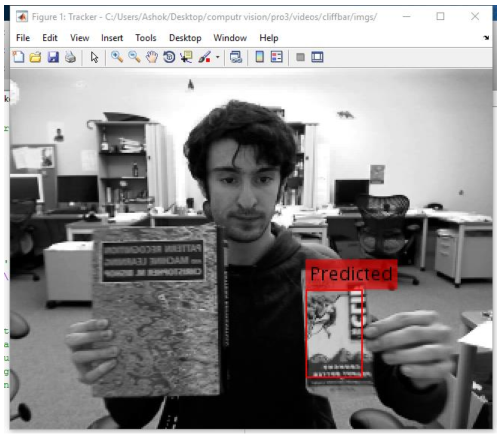
6. Results:

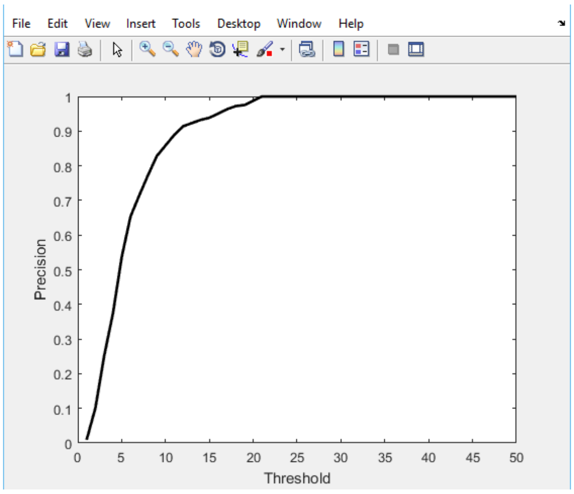
6.1 Cliffbar:

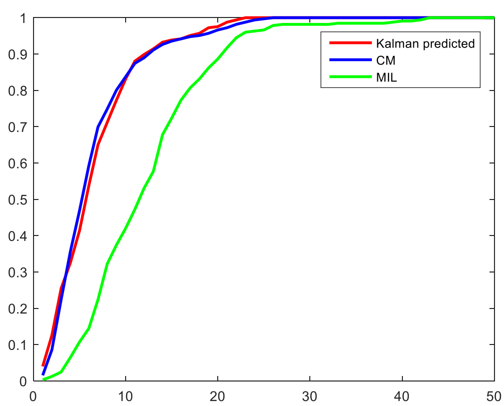












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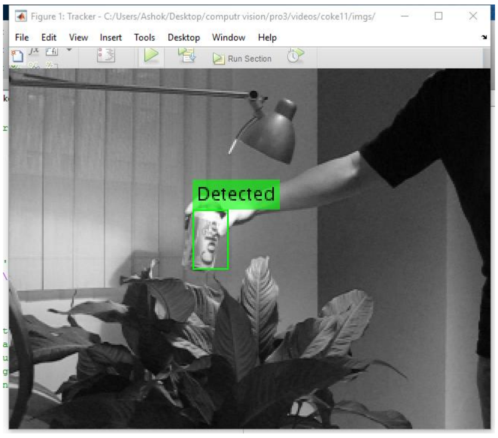
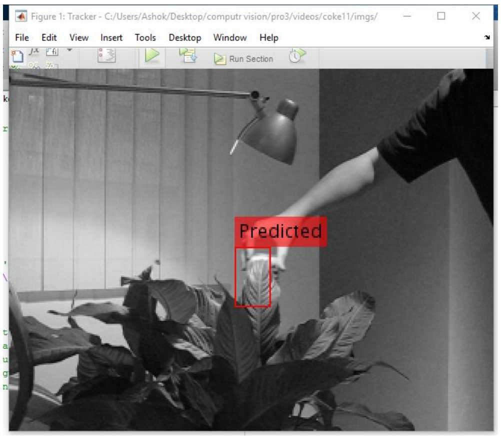
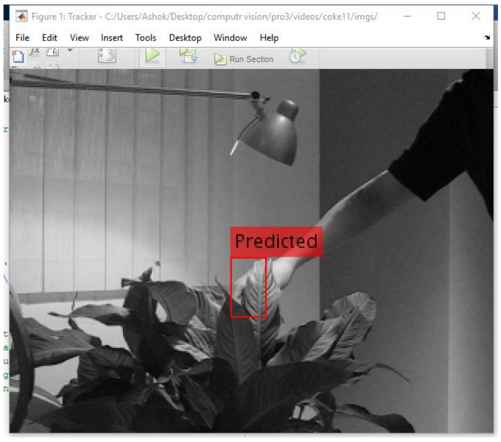
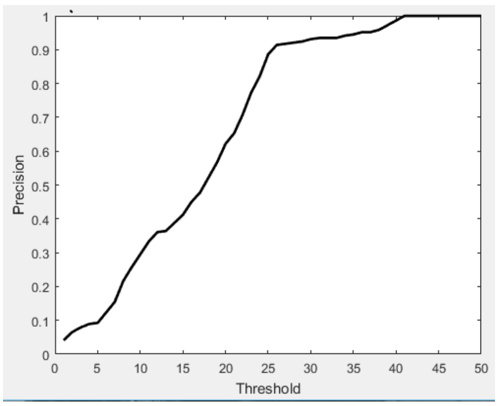
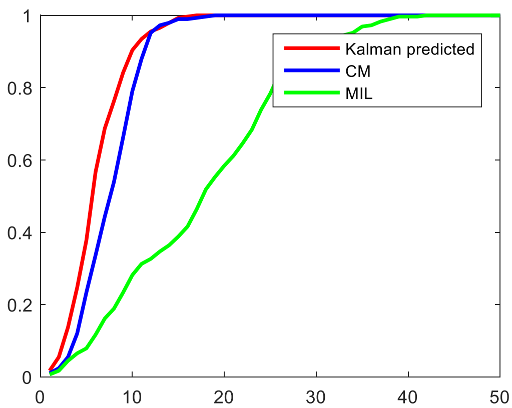
6.2 Coke11:











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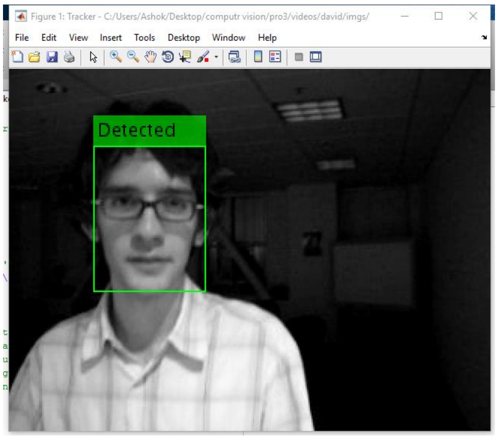
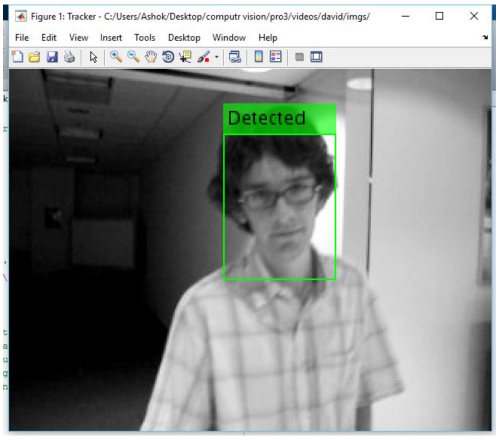
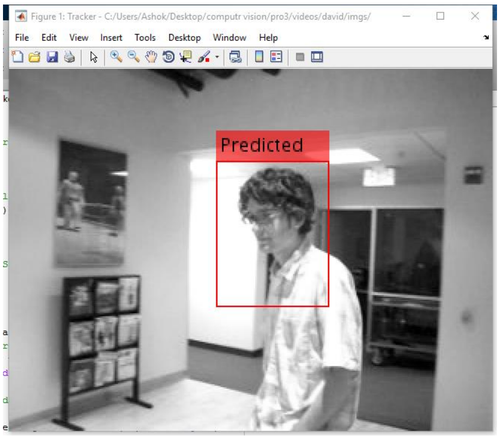
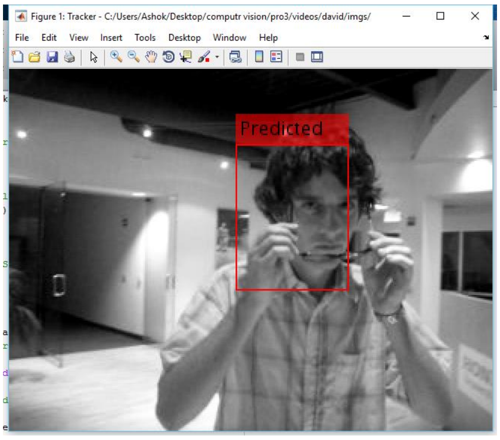
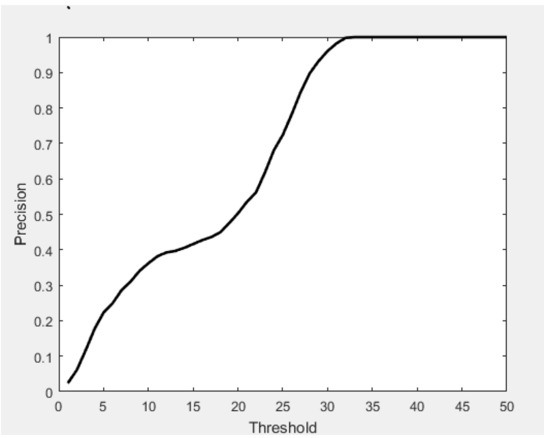
6.3 David:

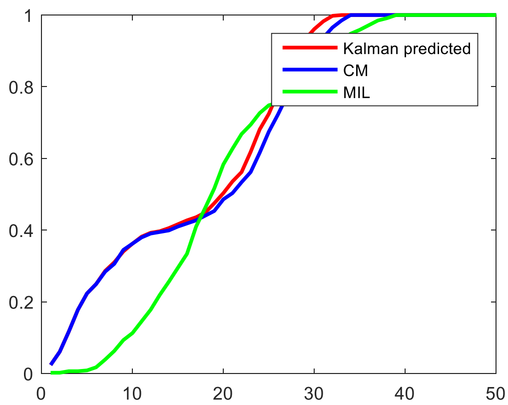












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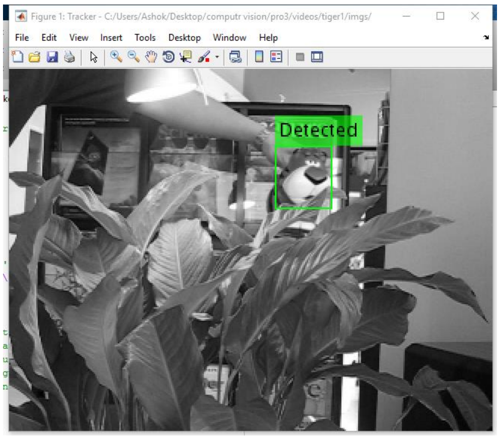
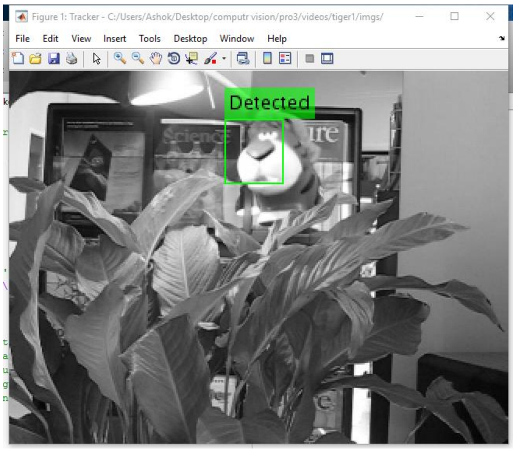
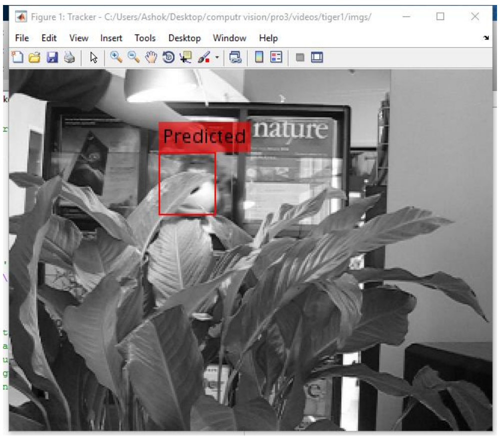
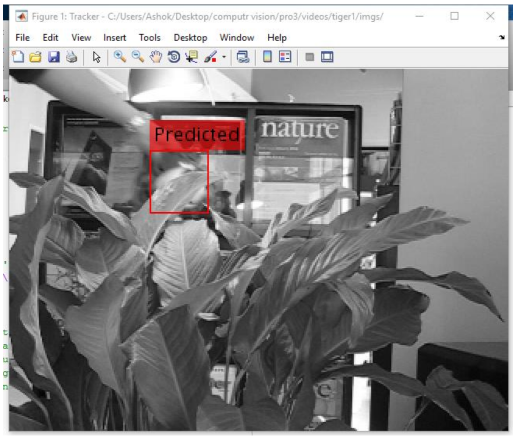
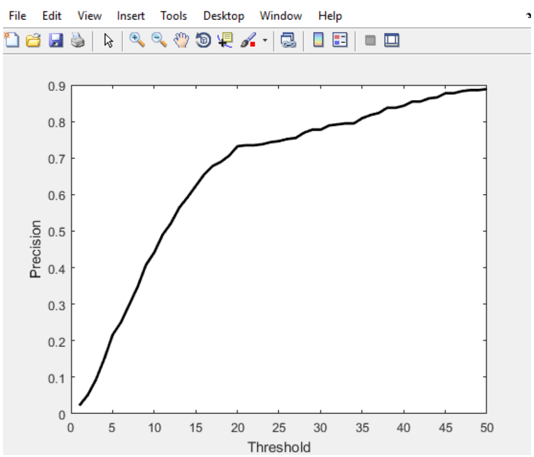
6.4 Tiger1:

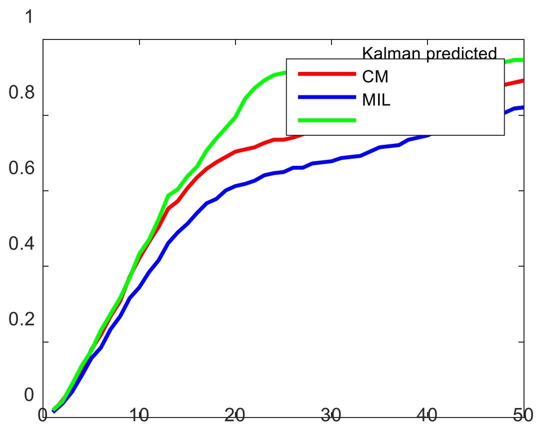












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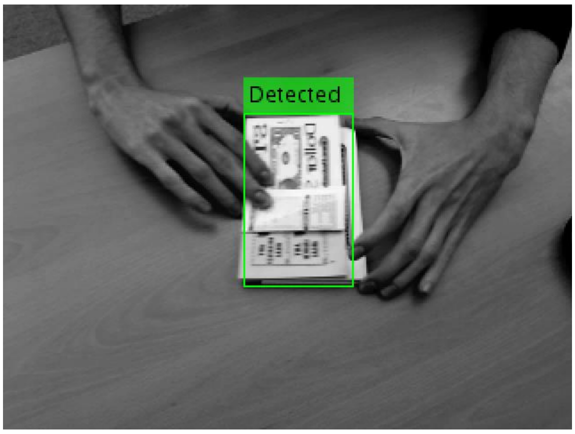
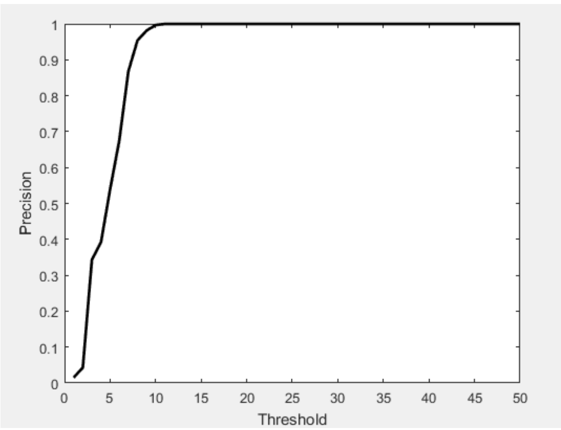
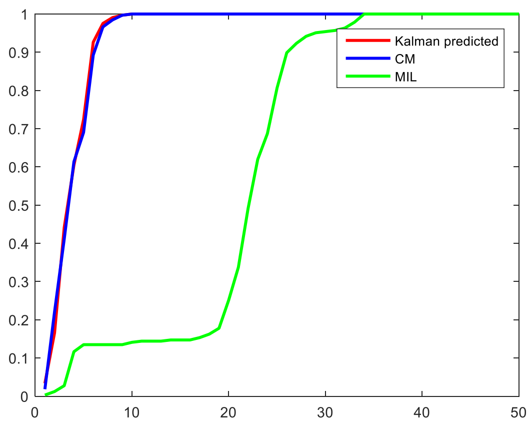
6.5 Dollar:







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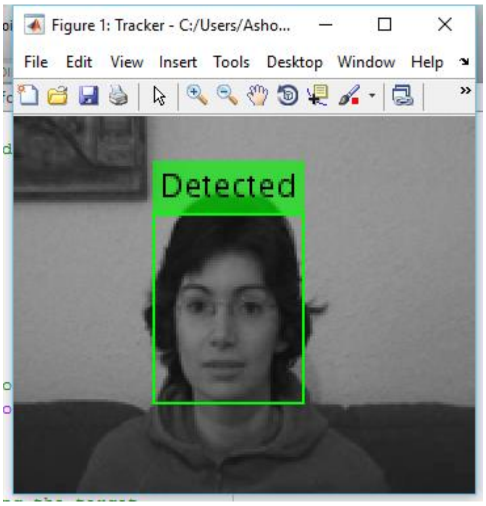
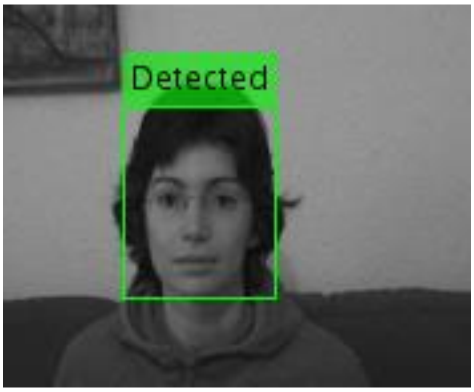
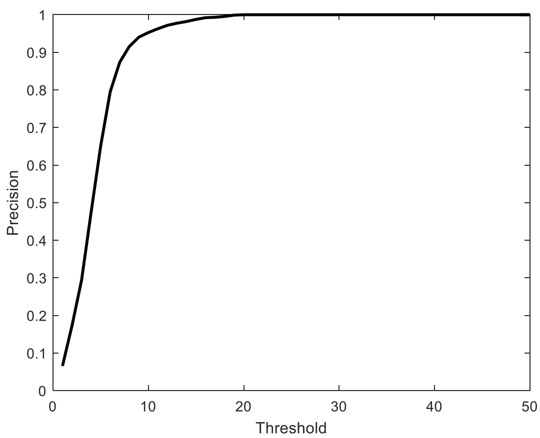
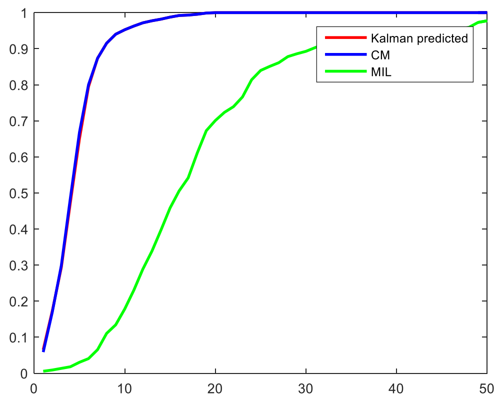
6.6 FaceOcc:









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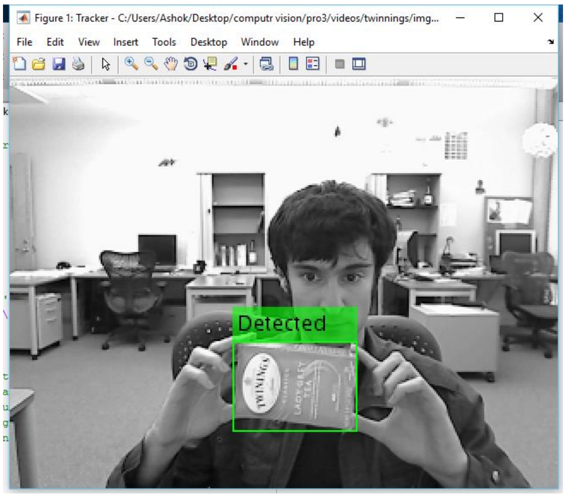
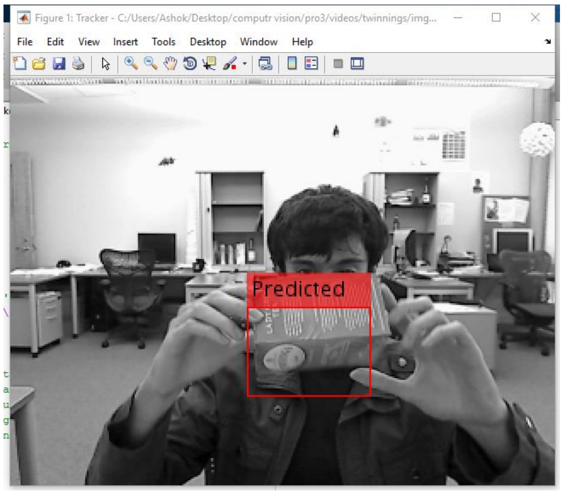
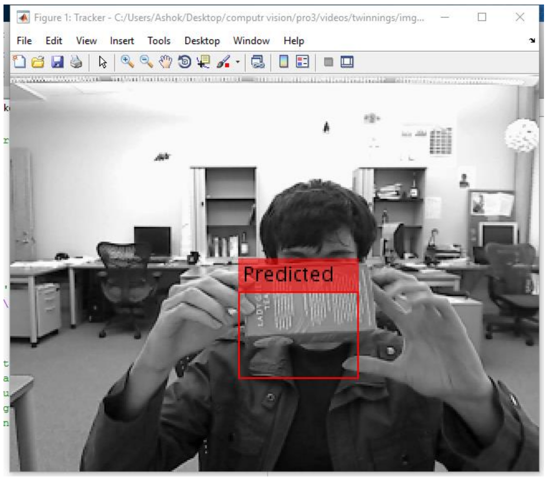
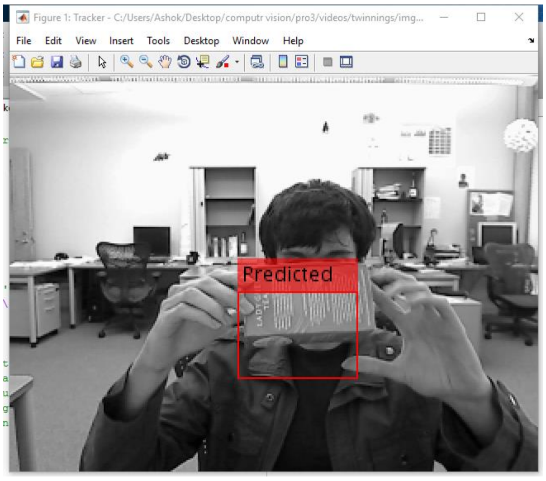
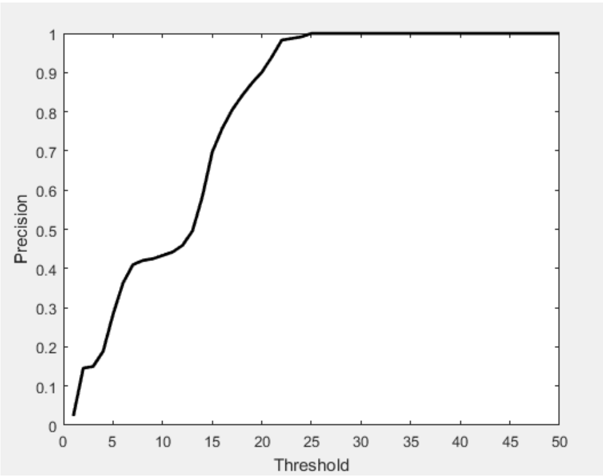
6.7 Twinnings:

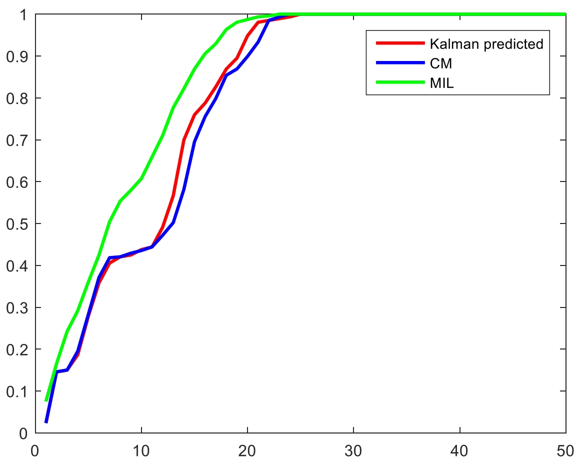












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7. Conclusion

The image frames were analysed with videos of 7 given scenarios and applied upon with the object tracking algorithm. The devised algorithm showed decent results with each of the given video situation. The occluded object was accurately predicted and tracked upon. The Precision vs thresholding graph showed desired results in sync with the visual analysis. Some of the image sequences where there was instantaneous change in acceleration in dynamics there was difficulty in object tracking, as the Kalman filter incorporates constant velocity motion model. We introduced new element of the object tracking in the Algorithm which displayed detection and prediction with green and red colors respectively in writing gave a clear picture of the effective working of the algorithm.

8. Future Scope

- Integration of this system with Hankel Matrix Approach

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9. Appendix (MATLAB Code)

9.1 Main Code:

```
clear all
clc

run_tracker;
precisions1 = show_precision(positions, ground_truth, '');

run_tracker_1;
precisions2 = show_precision(positions, ground_truth, '');

f =
fopen('C:\Users\rams1\Desktop\Spring2016\CV\Projects\Project_3\Videos\twi
nnings\twinings_MIL_TR004.txt');
f = textscan(f,'%f,%f,%f,%f'); fpos = [f{2} f{1}]; hw = [f{4} f{3}];
fpos = fpos + hw/2;
precisions3 = show_precision(fpos, ground_truth, '');

figure(4);
plot(1:length(precisions1),precisions1,'r',1:length(precisions2),precisio
ns2,'b',1:length(precisions3),precisions3,'g','LineWidth',2);
legend('Kalman predicted','CM','MIL');
```

```
%  Exploiting the Circulant Structure of Tracking-by-detection with
Kernels
%
%  Main script for tracking, with a gaussian kernel.
%
%  João F. Henriques, 2012
%  http://www.isr.uc.pt/~henriques/
%%Modifications performed as per requirement of the project by us%%

clear all
clc
close all
%choose the path to the videos (you'll be able to choose one with the
GUI)
base_path = 'C:\Users\Ashok\Desktop\computr vision\pro3\videos\';


%parameters according to the paper
padding = 1;                    %extra area surrounding the target
output_sigma_factor = 1/16;     %spatial bandwidth (proportional to
target)
sigma = 0.2;                    %gaussian kernel bandwidth
lambda = 1e-2;                  %regularization
```

```
interp_factor = 0.075;          %linear interpolation factor for
adaptation



%notation: variables ending with f are in the frequency domain.

%ask the user for the video
video_path = choose_video(base_path);
video_path = strcat(video_path,'imgs/');
if isempty(video_path), return, end  %user cancelled
[img_files, pos, target_sz, resize_image, ground_truth, video_path] = ...
    load_video_info(video_path);


%window size, taking padding into account
sz = floor(target_sz * (1 + padding));

%desired output (gaussian shaped), bandwidth proportional to target size
output_sigma = sqrt(prod(target_sz)) * output_sigma_factor;
[rs, cs] = ndgrid((1:sz(1)) - floor(sz(1)/2), (1:sz(2)) -
floor(sz(2)/2));
y = exp(-0.5 / output_sigma^2 * (rs.^2 + cs.^2));
yf = fft2(y);

%store pre-computed cosine window
cos_window = hann(sz(1)) * hann(sz(2))';


time = 0;  %to calculate FPS
positions = zeros(numel(img_files), 2);  %to calculate precision

for frame = 1:numel(img_files),
    %load image
    im = imread([video_path img_files{frame}]);
    if size(im,3) > 1,
        im = rgb2gray(im);
    end
    if resize_image,
        im = imresize(im, 0.5);
    end

    tic()

    %extract and pre-process subwindow
    x = get_subwindow(im, pos, sz, cos_window);

    if frame > 1,
        %calculate response of the classifier at all locations
        k = dense_gauss_kernel(sigma, x, z);
        response = real(ifft2(alphaf .* fft2(k)));   %(Eq. 9)
        [YN,psr(frame-1),psr0(frame-1)] = PSR(response);
        psr(frame-1)
```

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```
        if frame>3
            if YN==1
                pos = kalmanpredict(oldpos(frame-1,:),oldpos(frame-2,:));
            end
        end
        %target location is at the maximum response
        [row, col] = find(response == max(response(:)), 1);
        pos = pos - floor(sz/2) + [row, col];
    end

    %get subwindow at current estimated target position, to train
classifer
    x = get_subwindow(im, pos, sz, cos_window);

    %Kernel Regularized Least-Squares, calculate alphas (in Fourier
domain)
    k = dense_gauss_kernel(sigma, x);
    new_alphaf = yf ./ (fft2(k) + lambda);   %(Eq. 7)
    new_z = x;

    if frame == 1,  %first frame, train with a single image
        alphaf = new_alphaf;
        z = x;
    else
        %subsequent frames, interpolate model
        alphaf = (1 - interp_factor) * alphaf + interp_factor *
new_alphaf;
        z = (1 - interp_factor) * z + interp_factor * new_z;
    end

    %save position and calculate FPS
    positions(frame,:) = pos;
    time = time + toc();

    %visualization
    rect_position = [pos([2,1]) - target_sz([2,1])/2, target_sz([2,1])];
    if frame == 1,  %first frame, create GUI
        figure('Name',['Tracker - ' video_path])
        im_handle = imshow(im, 'Border','tight', 'InitialMag',200);
    else
        try  %subsequent frames, update GUI
            if YN == 1
                combinedImage = insertObjectAnnotation(im,
'rectangle',...
                    rect_position, {'Predicted'}, 'Color', 'red');
            else
                combinedImage = insertObjectAnnotation(im,
'rectangle',...
                    rect_position, {'Detected'}, 'Color', 'green');
            end
            im_handle = imshow(combinedImage, 'Border','tight',
'InitialMag',200);

        catch  %#ok, user has closed the window
            return
```

```
        end
    end

    drawnow
    %pause(0.05)  %uncomment to run slower
    oldpos = positions;
end

if resize_image, positions = positions * 2; end

disp(['Frames-per-second: ' num2str(numel(img_files) / time)])

%show the precisions plot
show_precision(positions, ground_truth, video_path);
```

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```
      9.2 PSR
function [YN,psr,psr0] = PSR(response)

oldres = response;
[idx,idy]=find(response==max(max(response)));
[m,n]=size(response);
gmax = response(idx,idy);

if idx<6
    if idy<6
        wind = response(1:idx+5,1:idy+5);
        response(1:idx+5,1:idy+5) =
zeros(size(response(1:idx+5,1:idy+5)));
    elseif idy>n-5
        wind = response(1:idx+5,idy-5:end);
        response(1:idx+5,idy-5:end) = zeros(size(response(1:idx+5,idy-
5:end)));
    else
        wind = response(1:idx+5,idy-5:idy+5);
        response(1:idx+5,idy-5:idy+5) = zeros(size(response(1:idx+5,idy-
5:idy+5)));
    end
elseif idx>m-5
    if idy<6
        wind = response(idx-5:end,1:idy+5);
        response(idx-5:end,1:idy+5) = zeros(size( response(idx-
5:end,1:idy+5)));
    elseif idy>n-5
        wind = response(idx-5:end,idy-5:end);
        response(idx-5:end,idy-5:end) = zeros(size(response(idx-
5:end,idy-5:end)));
    else
        wind = response(idx-5:end,idy-5:idy+5);
        response(idx-5:end,idy-5:idy+5) = zeros(size(response(idx-
5:end,idy-5:idy+5)));
    end
else
    if idy<6
        wind = response(idx-5:idx+5,1:idy+5);
        response(idx-5:idx+5,1:idy+5) = zeros(size(response(idx-
5:idx+5,1:idy+5)));
    elseif idy>n-5
        wind = response(idx-5:idx+5,idy-5:end);
        response(idx-5:idx+5,idy-5:end) = zeros(size(response(idx-
5:idx+5,idy-5:end)));
    else
        wind = response(idx-5:idx+5,idy-5:idy+5);
        response(idx-5:idx+5,idy-5:idy+5) = zeros(size(response(idx-
5:idx+5,idy-5:idy+5)));
    end
end

response(idx,idy) = gmax;
u0 = mean2(oldres);
sig0 = std2(oldres);
```

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Sharma, Shivam [sharma.s@husky.neu.edu]

```
psr0 = (gmax-u0)/sig0;
u = mean2(response);
sig = std2(response);
psr = (gmax-u)/sig;

if psr < 15
    YN = 1;
else
    YN = 0;
End

      9.3 Kalman Predict

function pos = kalmanpredict(oldpos1,oldpos2)

param = getDefaultParameters();
param.initialEstimateError = param.initialEstimateError(1:2);
param.motionNoise          = param.motionNoise(1:2);
initialLocation = oldpos2;
kalmanFilter = configureKalmanFilter(param.motionModel, ...
          initialLocation, param.initialEstimateError, ...
          param.motionNoise, param.measurementNoise);
predict(kalmanFilter);
pos = correct(kalmanFilter, oldpos1);

end

function param = getDefaultParameters()
  param.motionModel           = 'ConstantVelocity';
  param.initialLocation       = [0 0];
  param.initialEstimateError  = 1E5 * ones(1, 3);
  param.motionNoise           = [25, 10, 1];
  param.measurementNoise      = 25;
  param.segmentationThreshold = 0.05;
end
```

OUTPUT of COORDINATES OF BOUNDING BOX WITH WIDTH AND HEIGHT:

```
outtxt_1,outtxt_2,outtxt_3,outtxt_4
125.5,164.5,73,53
125.5,164.5,73,53
125.5,164.5,73,53
125.5,164.5,73,53
125.5,164.5,73,53
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Computer Vision I [EECE 5639]
Project 3
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Computer Vision I [EECE 5639]
Project 3
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Computer Vision I [EECE 5639]
Project 3
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Sharma, Shivam [sharma.s@husky.neu.edu]

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Key Frames:

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