Signals and Systems

Prof. Hae-Gon Jeon

Programing Assignment

(1) 2D Discrete Fourier Transform.

(2) 2D Inverse Fourier Transform.

(3) Correlation.

(4) Report

Specific Objectives:

- Implementation of whole pipeline for simplified visual tracking
- Understanding one of concepts of computer vision techniques, based on Signals and Systems knowledge
- Practice your programing skill

Evaluation

Mid term exam (25%)

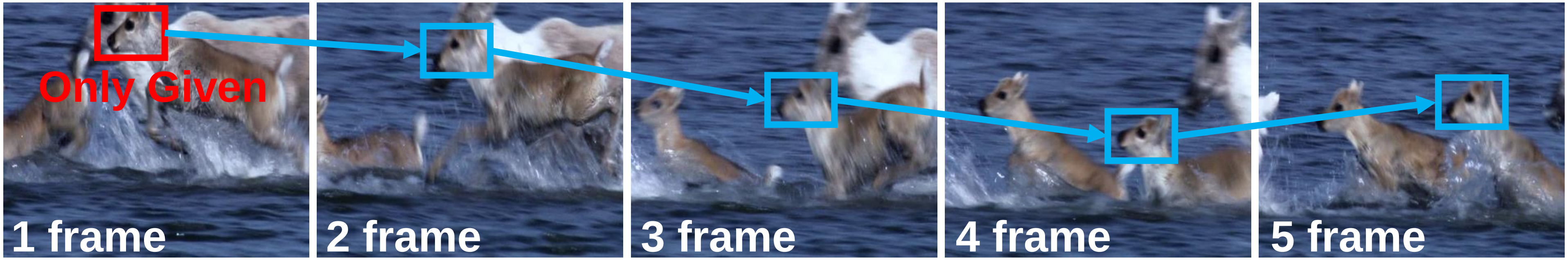
Final term exam (35%)

Homework (10%) : Upload answers with your derivations for problems in the textbook in GEL site.

Programing project (20%) : Any programing language is available. Upload your report and source codes in GEL site.

Class participation (10%)

Introduction



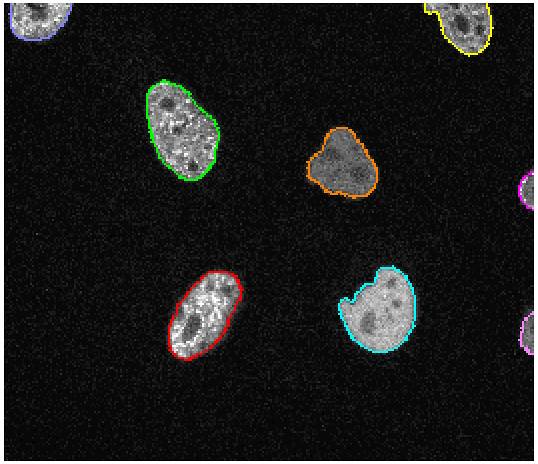
Track the target only given in the first frame of the scene

- Model-free: The target can be very diverse
- It is impossible to pre-train the tracker for each target.
- From the given target and the tracked result, the tracker should be updated.

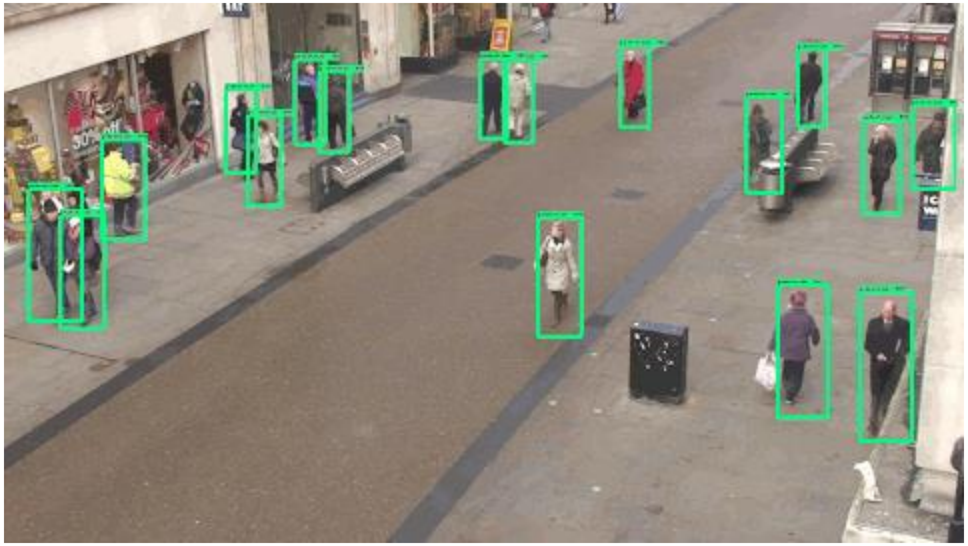
Introduction

Application Examples

- Robotics / Drone
- CCTV Surveillance Camera
- Medical Imaging



Microscopic Cell Tracking

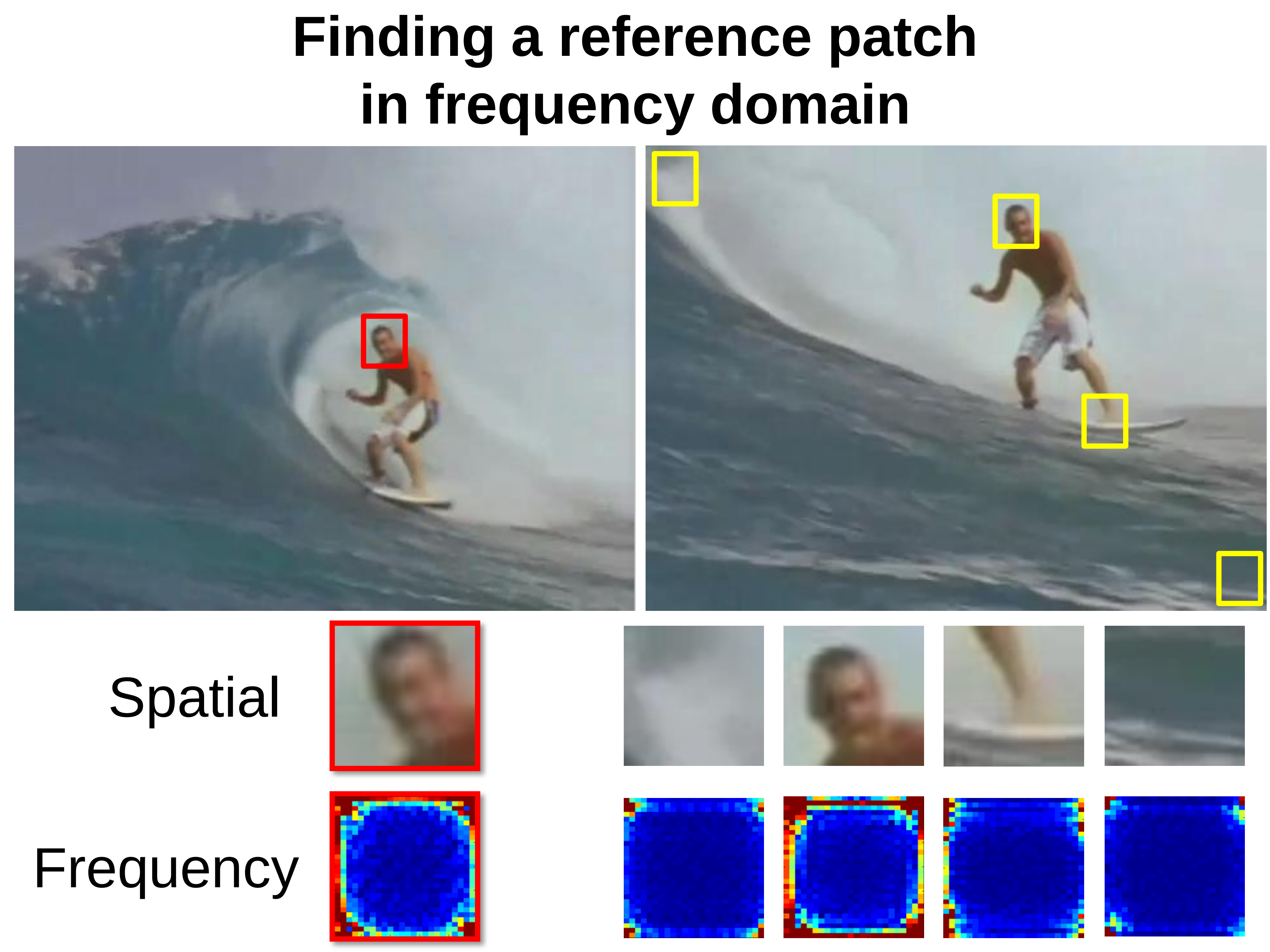


CCTV Surveillance

Autonomous Driving

Visual Tracking

Finding a reference patch in frequency domain


Finding a reference patch
in frequency domain
Spatial
Frequency

Task1 - 2D Fourier [4pts] and inverse Fourier Transform [4pts]

Convolution

1D: $y[n] = x[n] * h[n] = \sum_{k=-\infty}^{\infty} x[k] \cdot h[n-k]$

2D: $y[m,n] = x[m,n] * h[m,n] = \sum_{j=-\infty}^{\infty} \sum_{i=-\infty}^{\infty} x[i,j] \cdot h[m-i, n-j]$

Fourier Transform

1D: $F(k) \equiv \sum_{n=0}^{N-1} f(n)\, e^{\frac{-2\pi i k n}{N}}$

2D: $$F(u,v) = \frac{1}{MN} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} f(m,n) \exp\left[-2\pi i \left(\frac{mu}{M} + \frac{nv}{N}\right)\right] ,$$

$$u = 0, 1, \ldots, M-1 , \qquad v = 0, 1, \ldots, N-1 ,$$

Inverse Fourier Transform

1D: $f(n) \equiv \frac{1}{N} \sum_{k=0}^{N-1} F(k)\, e^{\frac{2\pi i k n}{N}}$

2D: $$f(m,n) = \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} F(u,v) \exp\left[2\pi i \left(\frac{mu}{M} + \frac{nv}{N}\right)\right] ,$$

$$m = 0, 1, \ldots, M-1 , \qquad n = 0, 1, \ldots, N-1 .$$

Task1 - 2D Fourier [4pts] and inverse Fourier Transform [4pts]

Implementation details

$$F(u,v) = \frac{1}{MN} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} f(m,n) \exp\left[-2\pi i \left(\frac{mu}{M} + \frac{nv}{N}\right)\right] ,$$

$$u = 0, 1, \ldots, M-1 , \qquad v = 0, 1, \ldots, N-1 ,$$

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$$m = 0, 1, \ldots, M-1 , \qquad n = 0, 1, \ldots, N-1 .$$

Task2 – Phase Correlation [4pts]

Cross-Correlation

In signal processing, cross-correlation is **a measure of similarity of two series** as a function of the displacement of one relative to the other. This is also known as a sliding dot product or sliding inner-product. It is commonly used for <u>searching a long signal for a shorter, known feature</u>. It has applications in pattern recognition, single particle analysis, electron tomography, averaging, cryptanalysis, and neurophysiology. The cross-correlation is similar in nature to the convolution of two functions. In an **autocorrelation**, which is the **cross-correlation of a signal with itself**, there will always be a peak at a lag of zero, and its size will be the signal energy.

Phase-Correlation

Phase correlation is an approach to **estimate the relative translative offset between two similar images** (<u>digital image correlation</u>) or other data sets. It is commonly used in image registration and relies on <u>a frequency-domain representation of the data</u>, usually calculated by fast Fourier transforms. The term is applied particularly to a subset of cross-correlation techniques that isolate the phase information from the Fourier-space representation of the cross-correlogram.

By Wikipedia

Task2 – Phase Correlation [4pts]

$$\mathbf{G}_a = \mathcal{F}\{g_a\},\ \mathbf{G}_b = \mathcal{F}\{g_b\}$$

Fourier transform of each patch

Complex conjugate

$$R = \frac{\mathbf{G}_a \circ \mathbf{G}_b^*}{|\mathbf{G}_a \circ \mathbf{G}_b^*|}$$

Element-wise multiplication

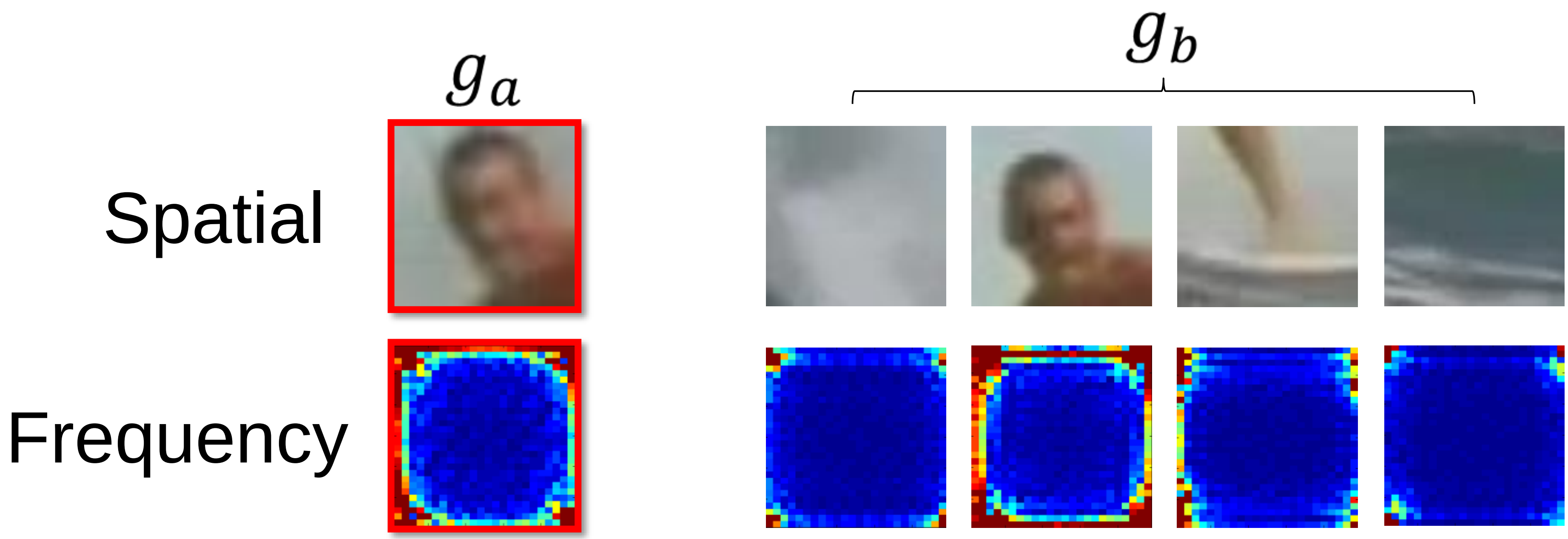
Compute correlation in frequency domain

$$r = \mathcal{F}^{-1}\{R\}$$

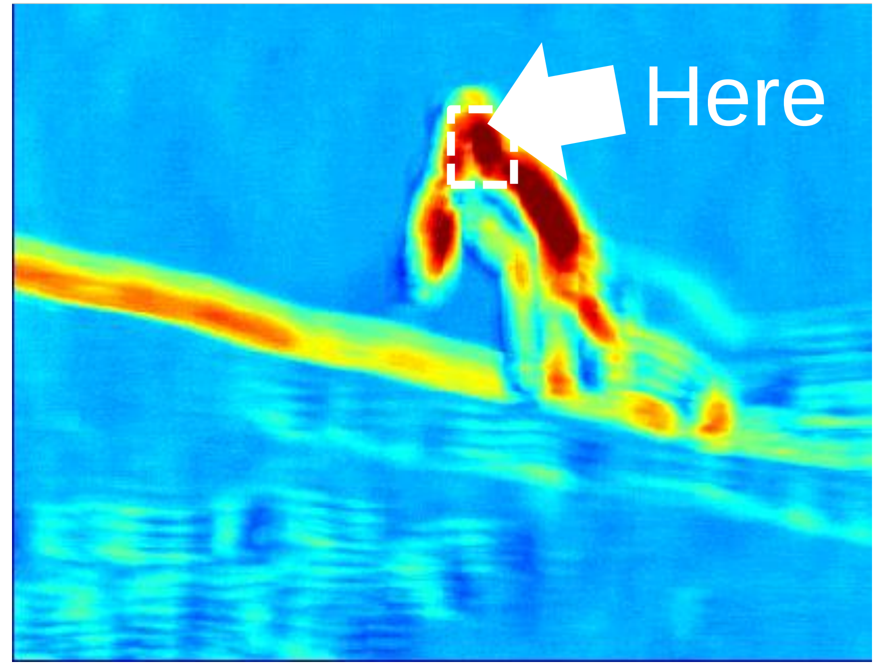
Inverse Fourier transform

$$\hat{r}(m,n) = \max_{(m,n)} r$$

Take maximum phase value in the local patch $\boldsymbol{r}$



Task3 - Example of output [3pts]



1. Compute phase correlation for each patch in the target image

2. Make an activation map

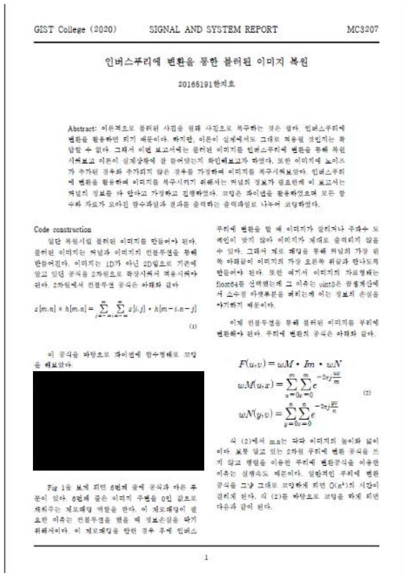
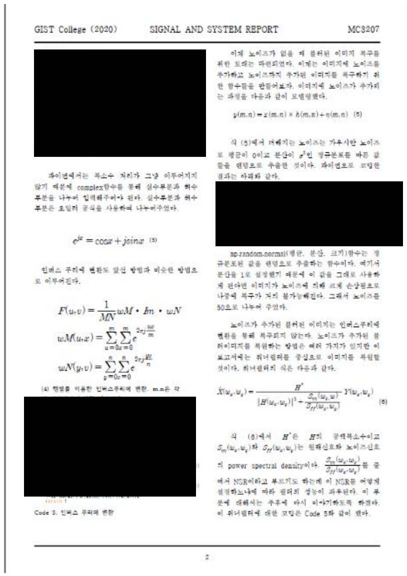
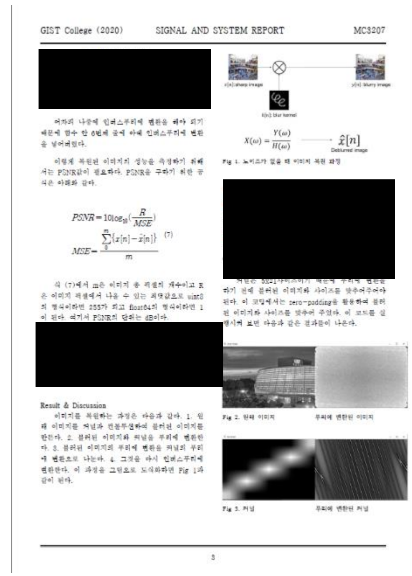
3. Find a point with a maximum correlation value

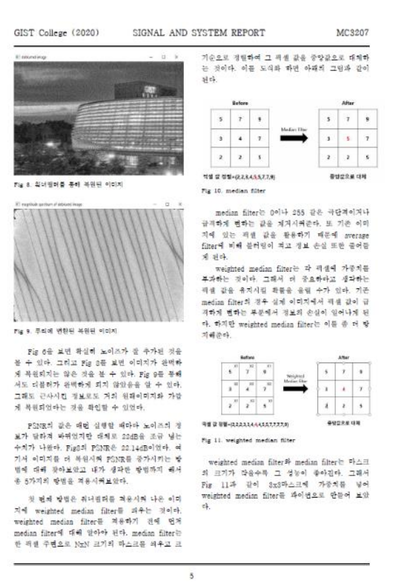
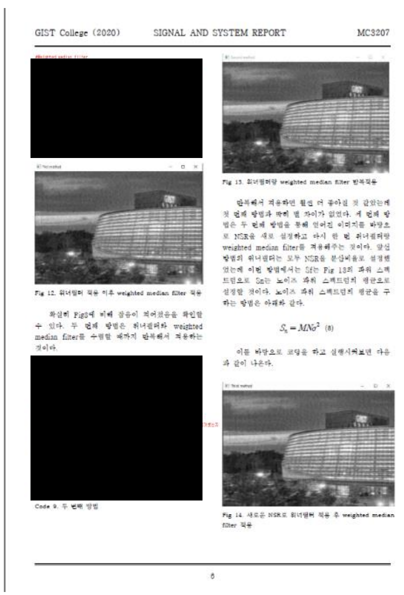
4. Draw the bounding box which has a same size of the reference patch

Task3 - Example of output [3pts]

Image size: 360*480
Reference patch size: 24*29
Computation time per an image: 66 sec.
Program language: MATLAB 2014a

Task4 - Write your report well [3pts]

Description of the background and your implementation with parts of source codes and images

Analysis your result based on your knowledge of your signals and systems.

If you want to get additional scores (maximum 2pts), you have to make better performances or a faster algorithm than that of professor's one.

Deliverable and Cautions

Submit your source codes and a report including results in GEL site

You can use any programing languages

Due date: 11:59PM at 6/4 (Friday)

NEVER use any function SUCH AS fft and xcorr etc, except for data load and display. If you use any publicly available function, your score is zero!

No delay is allowed

Never copy source codes of your friends and online.
If your copy is observed, your credit for this course is definitely

F!!