Amirkabir University of Technology
(Tehran Polytechnic)

# Assignment 4
## Digging Into World War II Through Image Processing Techniques

### Homeworks Guidelines and Policies

- ***What you must hand in.*** It is expected that the students submit an assignment report (HW4_[student_id].pdf) as well as required source codes (.m or .py) into an archive file (HW4_[student_id].zip).
- ***Pay attention to problem types.*** Some problems are required to be solved *by hand* (shown by the icon), and some need to be implemented (shown by the icon).
  Please don't use implementation tools when it is asked to solve the problem by hand, otherwise you'll be penalized and lose some points.
- ***Don't bother typing!*** You are free to solve by-hand problems on a paper and include picture of them in your report. Here, cleanness and readability are of high importance. Images should also have appropriate quality.
- ***Reports are critical.*** Your work will be evaluated mostly by the quality of your report. Don't forget to explain what you have done, and provide enough discussions when it's needed.
- ***Appearance matters!*** In each homework, 5 points (out of a possible 100) belongs to compactness, expressiveness and neatness of your report and codes.
- ***Python is also allowable.*** By default, we assume you implement your codes in MATLAB. If you're using Python, you have to use equivalent functions when it is asked to use specific MATLAB functions.
- ***Be neat and tidy!*** Your codes must be separated for each question, and for each part. For example, you have to create a separate .m file for part b. of question 3. Please name it like p3b.m.
- ***Use bonus points to improve your score.*** Problems with bonus points are marked by the icon. These problems usually include uncovered related topics or those that are only mentioned briefly in the class.
- ***Moodle access is essential.*** Make sure you have access to Moodle because that's where all assignments as well as course announcements are posted on. Homework submissions are also done through Moodle.

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- ***Assignment Deadline.*** Please submit your work **before the end of July 2nd**.
- ***Delay policy.*** During the semester, students are given 7 free late days which they can use them in their own ways. Afterwards there will be a 25% penalty for every late day, and no more than three late days will be accepted.
- ***Collaboration policy.*** We encourage students to work together, share their findings and utilize all the resources available. However you are not allowed to share codes/answers or use works from the past semesters. Violators will receive a zero for that particular problem.
- ***Any questions?*** If there is any question, please don't hesitate to contact me through **ali.the.special@gmail.com**.

## 1. The Magnificent Eleven: Restoration of the Photographs of the Horrific D-Day (18 Pts.)

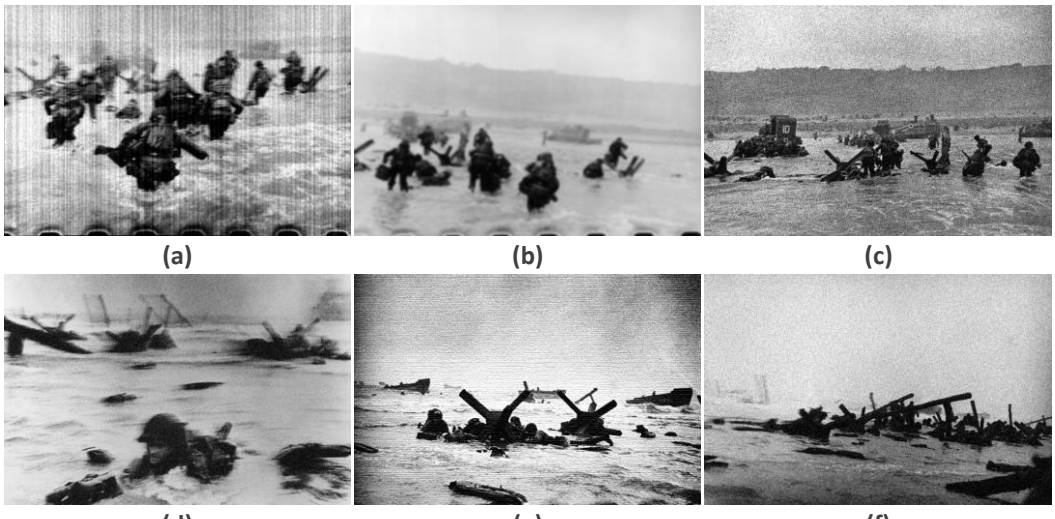
**Keywords**: *Image Enhancement, Image Restoration*

The *Normandy Landings*, aka the *D-Day*, were the landing operations conducted by the Allied during the invasion of Normandy in World War II. Being the largest seaborne invasion in history, this operation is known to be an iconic moment in the history of WW2, leading to the creation of numerous movies, books, songs, and video games.

*Figure 1 One of the most well-known photographs of the World War II, named "Into the Jaws of Death", taken from U.S. Army's soldiers moments before their landings on Omaha Beach. The majority of soldiers seen in the picture were likely be dead minutes later, as some Allied units suffered over 75% casualty rate during the first hour.*

Among one of the earliest waves of troops was Polish photographer Robert Capa. While under heavy fire, Capa managed to take 106 pictures, yet all but eleven of which were destroyed. The surviving photos, known as *the Magnificent Eleven*, have been widely celebrated since then, and Steven Spielberg is said to have been inspired by them when filming *Saving Private Ryan*.

Since Capa's hands were shaking in the excitement of the moment, most of the photos were slightly out of focus, and some contained additive artifacts, e.g., noise of various types. Your task is to utilize different image enhancement and restoration techniques on these photos, and obtain relatively higher quality images suitable to be published in a well-known history magazine.



**(a)** **(b)** **(c)**

**(d)** **(e)** **(f)**

*Figure 2 Six photographs from the collection "the Magnificent Eleven", each with various degradation.*

**Note 1:** Your attempts must considerably improve the quality of the input images. In other words, applying various techniques blindly without a noticeable effect will not be of much worth.

**Note 2:** Include all intermediate results in your report.

**Note 3:** You are free to make use of all methods you have learnt in this course.

**Note 4:** All functions and libraries are allowed to be used

## 2. Wait for Me, Daddy: Resolution Enhancement of a Dramatic Photograph (23 Pts.)

**Keywords**: *Image Interpolation, Image Super-Resolution, Nearest-Neighbor Interpolation, Bilinear Interpolation, Nearest Neighbor Value Interpolation, Non-uniform Interpolation*

When a large group of Canadian soldiers were marching towards a waiting ship to be sent to their destination on October 1, 1940, photographer Claude P. Dettloff positioned himself to take a photograph of the whole column. As he was getting ready, he saw a young boy run out onto the road, yelling "*Wait for Me, Daddy!*". He captured the image of the boy, named Warren Bernard, while he was running out of his mother's grasp to his father. This iconic picture received extensive exposure and became one of the most significant images in the history of Canada.

**(a)** **(b)**

*Figure 3 The globally famous photograph "Wait for Me, Daddy!" was captured when a five-year-old boy suddenly decided to reach his father moments before his departure to the battlefield. (a) The original photo. (b) The boy and his father after the war finished.*

The purpose of the problem is for you to enhance the resolution of a low-quality version of this image and resize it by the factor of 2. To achieve this goal, you will have to implement four different interpolation-based approaches as follows:

a. Nearest-neighbor interpolation.
b. Bilinear interpolation.
c. Nearest neighbor value interpolation.
   **Hint:** In this method, the missing pixel value is estimated by the nearest value rather than the distance. In other words, the nearest neighbor value interpolation considers the four pixels directly surrounding the empty location, and selects the one whose value is almost equal to the value obtained by bilinear interpolation method.
   **Useful Links**: [1], [2]
d. Non-uniform interpolation.
   **Hint:** Four low-resolution images of the same scene, each with a subpixel shift with respect to each other, are given. The resampling must be performed using these images and the shift information presented in Figure 4. Although this is considered to be an image super-resolution technique, the procedure is very similar to the prior interpolation methods.
   **Note:** The name of each low-resolution image file ends with its pixel displacements.
e. Calculate and compare PSNR of the results obtained in the previous parts using the given ground truth image. Also, comment on the visual appearance of the results.

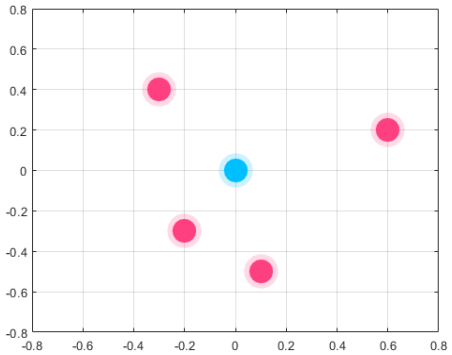



*Figure 4 The position of the pixels of the low-resolution images (red) with respect to the pixels of the main low-resolution image (blue).*

**Note:** The four main approaches are expected to be implemented by the students.

**Allowed MATLAB functions**: `size()`, `ceil()`, `meshgrid()`, `psnr()`

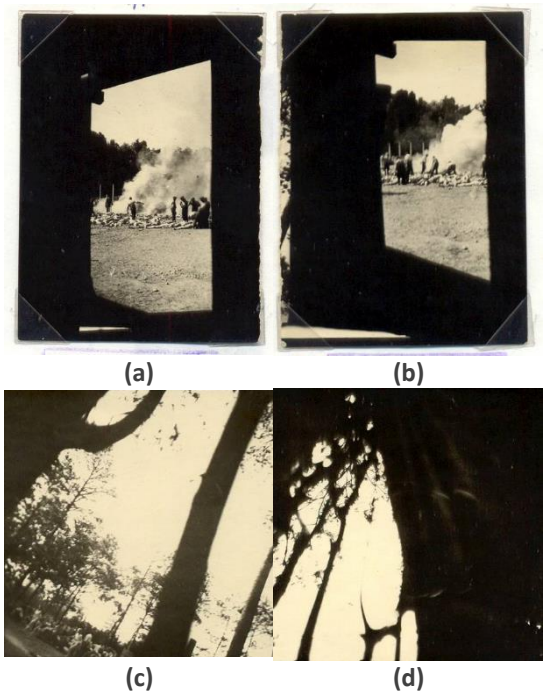
## 3. Sonderkommando Photographs: Recovering the Evidence of Nazi Crimes (22 Pts.)

**Keywords**: *Image Transformation, Image Alignment, Geometric Transformation, Image Enhancement, Image Restoration*

Despite the difficulty of acquiring evidence of Nazi crimes in Auschwitz concentration camp, there are still few reliable documents concerning the dreadful events inside the camp. Among them are *the Sonderkommando photographs*, which are four blurred photographs taken furtively in August 1944 inside the Auschwitz camp, known to be the only existing images of events surrounding the gas chambers.

The photographs were taken by a Jewish prisoner from Greece who was forced to work in and around the gas chambers. He took two shots from inside one of the gas chambers, and two outside. The film was later smuggled out of the camp by the Polish resistance in a toothpaste tube.

Since the images were taken in a secretive manner, they suffer from noticeable degradations. In this problem, you are required to restore the two photographs which were taken from the inside of the gas chambers (images (a) and (b) in Figure 5). These two images show the burning of corpses in a fire pit, and shot through a black frame of the gas chamber's doorway or window, hence are needed to be initially transformed to an appropriate frame (Figure 6) before being recovered using image restoration techniques.



**(a)** **(b)** **(c)** **(d)**

*Figure 5 Sonderkommando photographs were numbered 280 to 283 by the Auschwitz Museum. (a)-(b) No. 280 and 281, views from the inside of the gas chambers showing dead bodies burning. (c) No. 281, showing naked women seconds before entering the gas chamber and being executed. (d) No. 283, in which the camera was aimed too high as the photographer had to shoot from his hip.*

a. Find the geometric transformation needed to align each image.
   **Note:** The images must be transformed to a new frame in a way that the outside view forms a separate aligned image, similar to Figure 6. The size of the target images must be selected meticulously.
b. Apply the geometric transformations obtained in the previous part to the corresponding images and transform them to the new frameworks.
c. Restore the transformed images and enhance their visual quality.

**Note:** Using built-in functions and libraries is allowed.

**(a)** **(b)**

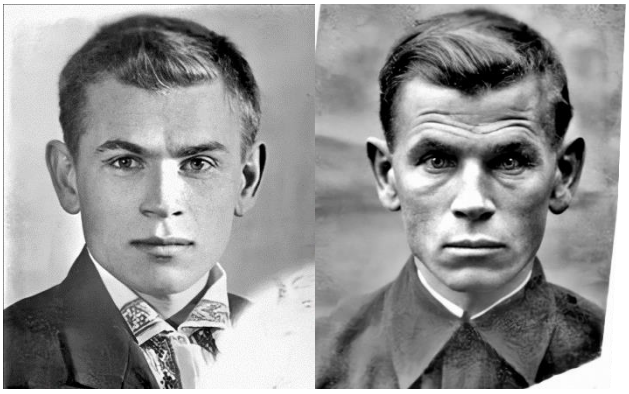
*Figure 6 The restored photographs corresponding to those taken from the inside of the gas chambers. (a) Aligned version of photograph 280. (b) Aligned version of photograph 281.*

## 4. The Impacts of War: Analyzing A Soldier's Face Before and After WWII (22 Pts.)

**Keywords**: *Image Morphing, Facial Morphing, Facial Features, Cross Dissolve Method, Delaunay Triangulation, Affine Transformation*

The dire impacts of World War II on people were far beyond what the most dramatic movies could depict. With an estimate total of 70-85 million deaths (approximately 3% of the 2.3 billion people on Earth in 1940) and hundreds of millions of injured and maimed, the war significantly influenced the life of the majority of people in the world.

In this problem, we aim to investigate the impacts of World War II on the face of Evgeny Kobytev, who was a Russian artist, writer, and teacher, before the Nazis invaded the Soviet Union and he forced to become a private gunner. Two photographs of Kobytev, one taken in 1941 when he was 31, and the other taken after the war ended in 1945, clearly shows how devastating his experience was.



**(a)** **(b)**

*Figure 7 A soldier's face after four years of war. (a) The day when he was sent to the front line in 1941. (b) The day when he returned in 1945.*

To better analyze the changes in his appearance, we are going to make use of image morphing. The technique, which was first became popular after it was used at the end of Michael Jackson's *Black or White* music video, is known to be a fun way to convert one face (or even object) to another, and can be performed through various approaches. Here, we first introduce a naïve way to handle the problem, and then define an algorithm based on geometric transformation, which successfully overcomes the first method's deficiency.

### I. Naïve Method

The first idea which may come to the mind is to simply interpolate whole images. Assuming $M$ as the initial image and $N$ as the target image, each pixel in the morphed image $I$ can be interpolated as follows:

$$I(i,j) = (1-\alpha)\cdot M(i,j) + \alpha \cdot N(i,j), \quad 0 \le \alpha \le 1$$

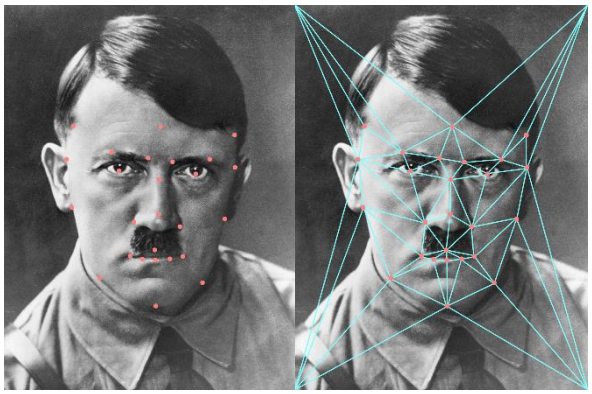
where $\alpha$ controls the gradual transformation from $M$ to $N$. This technique is known as *cross-dissolve* in the film industry, and is able to balance coloration in the middle frames. However, it leaves a "ghosting" effects in the intermediate images, especially if the two faces aren't perfectly aligned.

### II. Triangulation Method

In the previous method, only the "photometric" side of the transformation was addressed, and the "geometric" side was ignored. We therefore need to find a one-to-one correspondence between certain parts of the two images (e.g. lips, eyes, nose, etc.), so as to know which part of the initial image should be morphed into which part of the target image. This can be done through a new algorithm, which is defined in the following steps:

**i. Finding corresponding points.** First, a set of corresponding keypoints must be extracted from each images. These keypoints play a major role in highlighting prominent facial features so as the interpolation becomes more specific. Here, we perform this step manually, using the reference

image shown in Figure 8. In this image, 26 facial feature points are highlighted with red dots. In order to include the background into the morphing frames, at least 4 additional points (corners) must also be selected. Let $P_M = \{p_M^1, p_M^2, \dots, p_M^k\}$ and $P_N = \{p_N^1, p_N^2, \dots, p_N^k\}$ be the two set of points extracted from images $M$ and $N$, respectively.



**(a)** **(b)**

*Figure 8 The process of face triangulation. (a) Specific landmarks are detected, denoting important regions of the face. (b) Triangulation algorithm is performed.*

**ii. Delaunay Triangulation.** Next, a weighted mean of the points in the two sets must be calculated. More precisely, using $P_M$ and $P_N$, we obtain another set of points $P_I = \{p_I^1, p_I^2, \dots, p_I^k\}$ in which

$$p_I^j = (1-\alpha)\, p_M^j + \alpha\, p_N^j$$

These points are the corresponding features in the intermediate image, and will be used later to apply the triangulation to the set $P_I$.

Triangulation operation divides the plane of the image into small triangles (Figure 8), using the points of the set $P_I$ as vertices. We opt to use *Delaunay Triangulation*, since it does not produce overly skinny triangles. The triangulation should be performed for all the sets $P_M$, $P_N$ and $P_I$, giving a one-to-one correspondence between triangles in the images $M$, $N$ and $I$. We now have three sets of corresponding triangles, $T_M = \{t_M^1, t_M^2, \dots, t_M^l\}$, $T_N = \{t_N^1, t_N^2, \dots, t_N^l\}$ and $T_I = \{t_I^1, t_I^2, \dots, t_I^l\}$.

**iii. Affine transformation.** Now, we select a triangle $t_M^j$ from the image $M$ as well as its corresponding triangle $t_I^j$ from the image $I$, and calculate the affine transform which converts the triangle $t_M^j$ to $t_I^j$. Similarly, we calculate the transformation matrix of the corresponding triangle $t_N^j$ in the image $N$ to the triangle $t_I^j$. Then we apply the obtained transformations to all the triangles of both images $M$ and $N$, and obtain warped images $M'$ and $N'$. Finally, we calculate the intermediate image $I$ by using the same equation in the naïve method:

$$I(i,j) = (1-\alpha)\cdot M'(i,j) + \alpha \cdot N'(i,j), \quad 0 \le \alpha \le 1$$

Hence, a series of intermediate images based on different values of $\alpha$ will be obtained. When shown in rapid succession, these images gives the effect of one image being converted into the other.

Considering the image taken at the end of the war as the target image, perform the following steps on the given images:

a. Use the naïve method to convert the initial image to the target one. Calculate and display 10 intermediate images. Comment on the results.
b. Manually select keypoints in two images. Display the detected points.
c. Apply triangulation to both images, and display the results.
d. Calculate the transformations, and display 10 intermediate images. Compare the results with part (a).
e. Generate a two-second animation containing 61 frames. Frame 0 must be identical to the initial image, and frame 60 must be identical to the target image. In the video, each frame will be displayed for 1/30 of a second.

**Note 1:** The transition between frames should be smooth and the intermediate frames must be as realistic as possible.

**Note 2:** There is no restriction on the usage of built-in functions and libraries.

**Recommended MATLAB functions**: `cpselect()`, `ginput()`, `delaunay()`, `imtransform()`, `cp2tform()`, `maketform()`, `tsearch()`, `interp2()`, `VideoWriter()`, `writeVideo()`

## 5. Some Explanatory Questions (10 Pts.)

Please answer the following questions as clear as possible:

a. Write an appropriate transformation matrix for a transformation consisting of a horizontal scaling of 3x, a clockwise rotation by 30 degrees, and a vertical translation by 20 pixels.
b. Why does the last column of an affine transformation matrix consist of two '0's and a '1'?
c. Imagine we continuously upscale and downscale an image by the factor of $s$ and $s^{-1}$, respectively. Does this process converge to a certain state? Justify your answer.
d. Is image geometric transformation a reversible process? Why?
e. Is periodic noise additive or quantitative? What about salt-and-pepper noise? Explain.

*Good Luck!*
*Ali Abbasi*