FACIAL EXPRESSION MANIPULATION USING RADIAL BASIS FUNCTIONS
Computer Vision - Final Project Report

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Motivation:

The motivation behind this project was to understand different radial basis functions and their subsequent effect on manipulating facial expressions. Image warping being used in the context of manipulating facial expressions presents several differences based on the Radial Basis Functions used and the parameters used in those Radial Basis Functions.

Approach:

For the purpose of this application, front-facing facial images were selected. The landmarks (anchor points) in the source image were selected along with the corresponding points in the target image. A non-linear transformation was applied on the image using various Radial Basis Functions.

Based on the distance from the origin/centre, Radial Basis Functions calculates values for each point on a Euclidean Space. These functions are radially symmetric functions of distance to the landmarks. This calculated potential value is maximum at the landmarks themselves and decreases with respect to distance from the landmarks.

The different Radial Basis Functions used in this project were -

Gaussian : $\varphi(r) = e^{-(\varepsilon r)^2}$

Quadratic : $\varphi(r) = 1 + (\varepsilon r)^2$

Inverse multiquadric : $$\varphi(r) = \frac{1}{\sqrt{1 + (\varepsilon r)^2}}$$

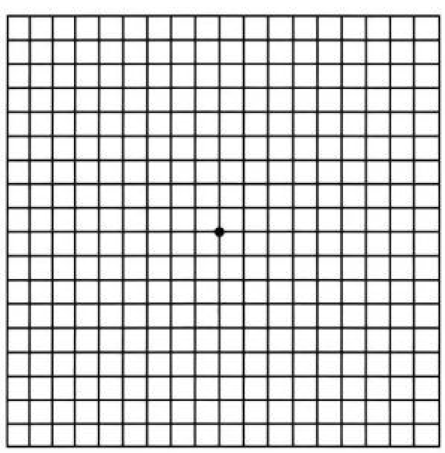
The parameter, $\sigma = 1/\varepsilon$ can be used to vary the radius of influence in the resulting warping.
2-D Mapping was carried out from the source to the target image. This mapping was based on the coordinates of the landmarks selected. For this 2-D Mapping, backward transformation was used from the target image to the source image using Bilinear Interpolation.

Linear interpolation uses linear polynomials as a method of curve fitting to construct new data points in the range of existing data points. It explores four neighbouring points for the point (x,y) and makes the assumption that the brightness function is linear in this neighbourhood. For interpolating functions of two variables (x and y) on a grid, bilinear interpolation applies linear interpolation in one direction and once more in the other direction.

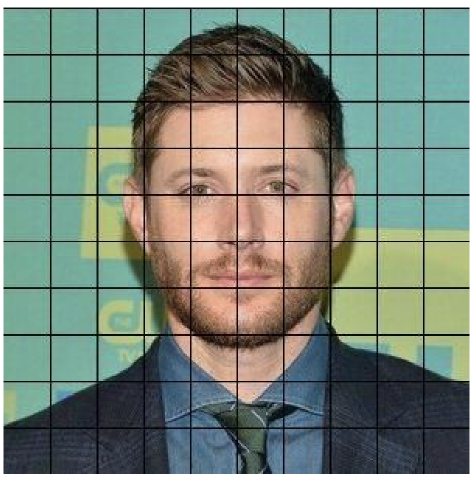
Data Used:

In this project, full front-facing facial images were used to understand the effects of various radial basis functions. The effects of the functions were also observed on a simple grid, to show the image warping. A grid overlay was used on one of the front-facing images to elucidate the outcome of the image warping

The following are the images used -



The second image was overlaid with a grid to demonstrate the effectiveness of the radial basis function -



Results :

Three different radial basis functions were used in this project -

1. Gaussian
2. Inverse Multiquadric
3. Quadratic

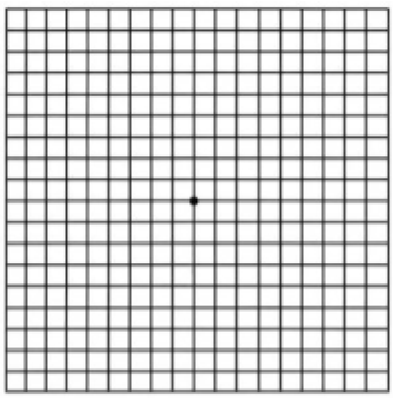
Three different values for $\sigma = 1/\varepsilon$ were also used -

1. $\sigma = 50$
2. $\sigma = 25$
3. $\sigma = 12.5$

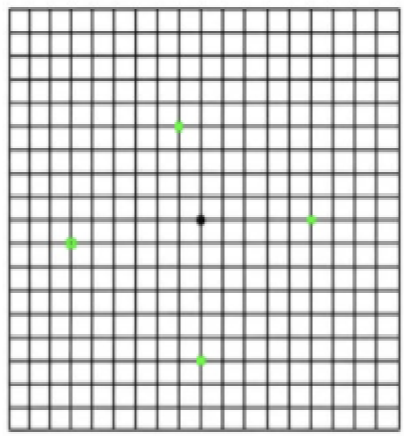
For each of the images, the different radial basis functions were applied and for each of the radial basis functions, the parameter $\sigma = {}^{1}/_{\varepsilon}$ varied.

The first image -

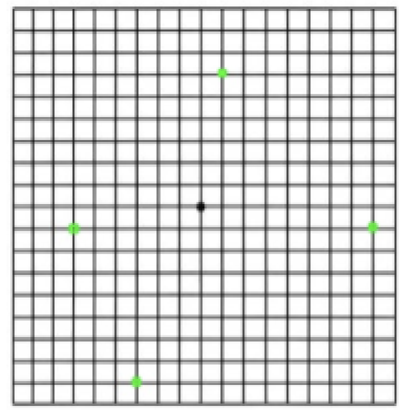
4 landmarks have been selected in the source and target images.



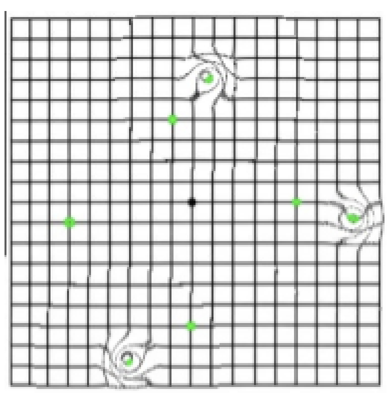
Original Image



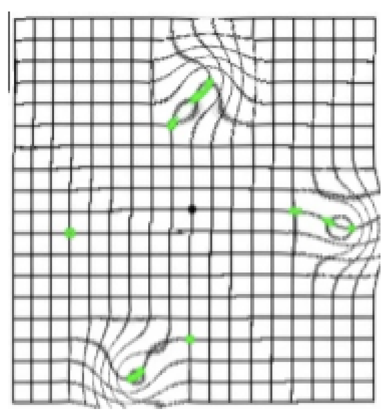
Source Landmarks



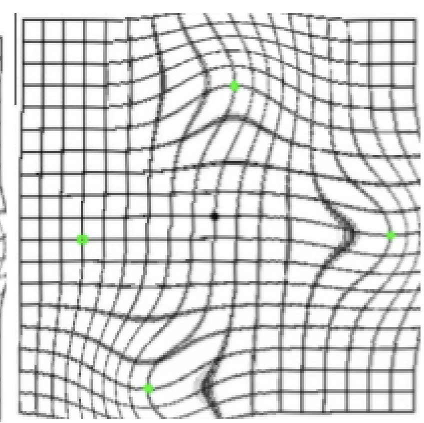
Target Landmarks



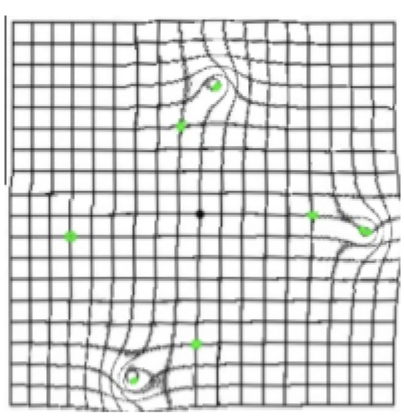
Gaussian Sigma = 12.5



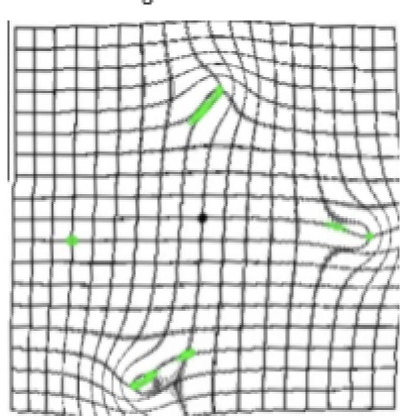
Gaussian Sigma = 25



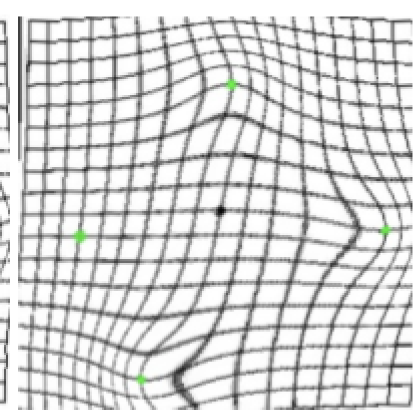
Gaussian Sigma = 50



Quadratic Sigma = 12.5

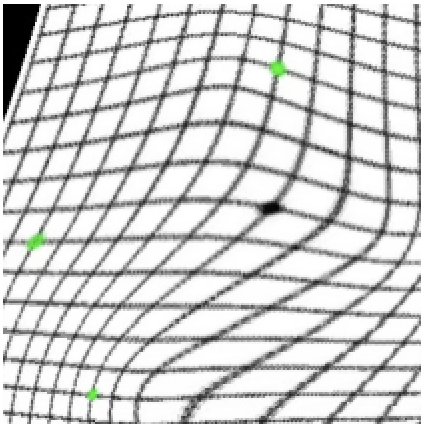


Quadratic Sigma = 25

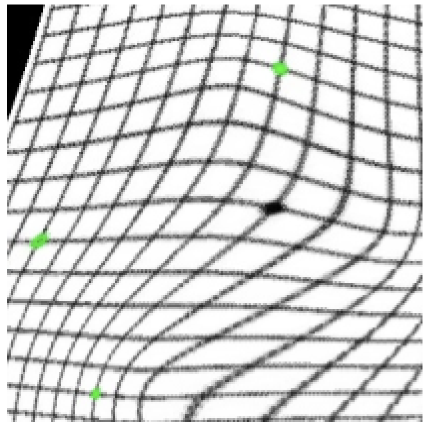


Quadratic Sigma = 50

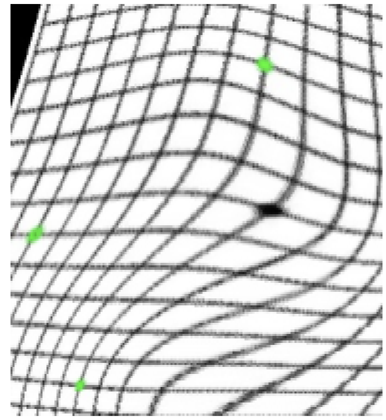
Higher σ values cause the result warping to be felt at a greater radius from the origin



Inverse Multiquadric
Sigma= 12.5



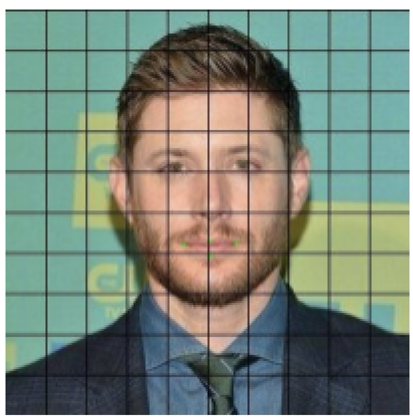
Inverse Multiquadric
Sigma = 25



Inverse Multiquadric
Sigma = 50

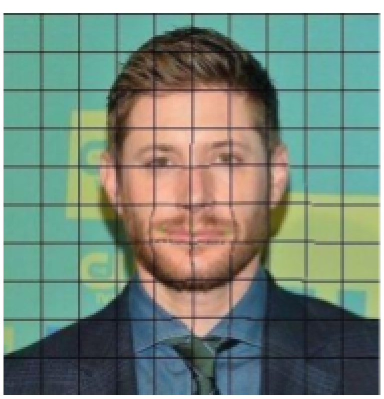
The second image -
4 landmarks have been selected in the lips, with the lips endpoints of the lips (far left and far right points) being stretched to achieve a smiling effect in the image.

Original Image

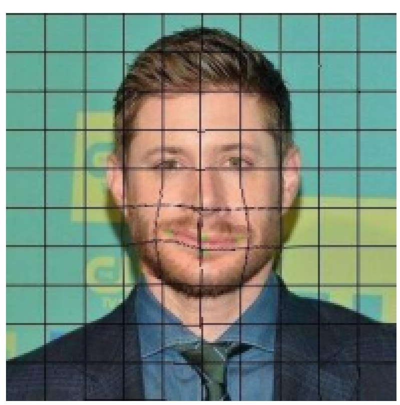


Source - Landmarks

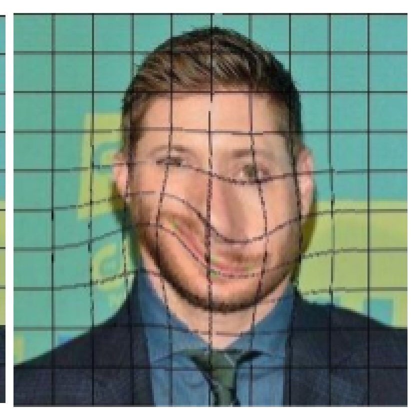
Target Landmarks



Gaussian, Sigma = 12.5



Gaussian, Sigma = 25



Gaussian Sigma = 50

Quadratic Sigma = 12.5

Quadratic Sigma = 25

Quadratic Sigma = 50

Inverse Multiquadric
Sigma = 12.5

Inverse Multiquadric
Sigma =25

Inverse Multiquadric
Sigma = 50

For the third image -

5 landmarks have been selected in the lips with the endpoints of the lips (far left and far right points being stretched downwards) to achieve a frown expression.

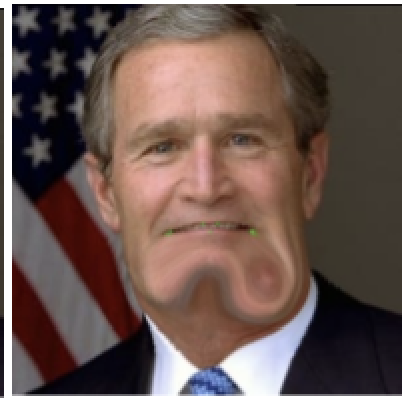
Original Image

Source Landmarks

Target Landmarks

Gaussian Sigma = 12.5

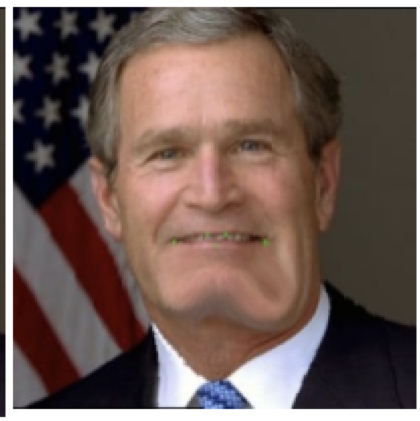
Gaussian Sigma = 25



Gaussian Sigma = 30

Quadratic Sigma = 12.5

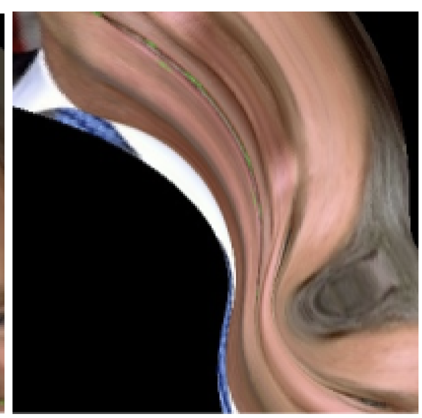
Quadratic Sigma = 25



Quadratic Sigma = 30

Inverse Multiquadric
Sigma = 12.5

Inverse Multiquadric
Sigma = 25



Inverse Multiquadric
Sigma = 30

Critical Discussion of the Obtained Results :

The lips were selected as the landmarks for the source and target image and as the basis for manipulating the facial expression(moving the landmarks in the lips can cause significant change in the expression of an individual, as observed in the results).

The different radial basis functions and the different values of σ used produced notable differences of manipulated facial image expression.

The larger the value of σ used, the larger the radius of effect of the radial basis function. When the value of σ is smaller, the effect of the radial basis function is felt locally around the landmarks (anchor points) selected. As the value of σ increases, the effect is spread more globally around the radius of the anchor points selected.

The Gaussian and the Quadratic functions resulted in desirable image warpings for the application of facial expression manipulation. The difference between the two functions can be observed with the same σ value. The Quadratic function produces an elongated local effect, whereas the Gaussian function produces a more circular local effect, which is clearly visible from the effect on the jawline in the image of George Bush for the same value of σ . The Inverse Multiquadric function however, produced a convex effect after warping - like a distorted funhouse mirror.

For targeted image warping - as in this application of facial expression manipulation, the larger the number of landmarks, the more controlled the output will be. The higher number of landmarks present an over constrained problem which provides a higher amount of control in localised warping. Smaller values of σ are better for targeted image warping.

In the specific application of facial expression manipulation, the higher the number of landmarks selected in the source and target image, the better the output of the image warping. Since facial expression manipulation is a targeted, controlled image warping technique, the effect of the radial basis function needs to be constrained locally. To prevent the distortion of certain facial features, stationary landmarks must be selected in both the source and target image (without any variation in landmark positions in the source and target images).

The application particularly favours front-facing images with neutral expressions to obtain desirable results. If the image is not front-facing, the precision with which the landmarks are selected might be compromised therefore compromising the overall image warping thus not producing the desired change in the facial expression, which is a shortcoming of this approach.

When an image without a neutral expression is used (as can be seen from the image of George Bush), the warped image that is meant to manipulate the expression doesn’t produce desirable results - if the warping is applied on the lips alone(a frown is visible from the lips for σ=12.5, however this expression does not go together with the expression of the eyes and cheeks which resemble a smiling person). Other facial features, like the eyes and the cheeks must also be warped to manipulate the overall expression consistently.

Future Work :

The shortcoming of this project is the precision in which landmarks must be selected in order to accurately manipulate facial expressions. In the possible future work of this project, the landmarks in the source image and the target image can be selected automatically using facial features detection techniques.

To manipulate facial expressions, common anchor points such as those in the lips and the eyes and several more in the cheek can be detected and moved to the target positions based on the facial symmetry and orientation to generate the required expression transformation. An optimal value of σ can thenxs be calculated based on the source and the target landmarks for the best possible image morphing.

INSTRUCTIONS TO RUN THE CODE

Python3.7 version was used with the following libraries:
Matplotlib, Numpy, CV2, Sys
3 RADIAL BASIS FUNCTIONS have been implemented:

1) Gaussain function can be run by running the file **gaussian.py**
2) Inverse Multi Quadric function can be run by running the file **inverse_multi_quadric.py**
3) Quadratic function can be run by running the file **quadratic.py**

To **run all the 3 functions together** on an image run the file : **all_in_one.py**

Steps :

1) Choose corresponding landmark pairs in the source and target images, if unequal landmarks are chosen, the program displays an error and exits.

2) Use mouse click action to select the landmarks, mouse click will be activated after the first click of the mouse. Each point selected will appear as a green dot in the image.

3) Click any key when finished selecting the landmarks in the source image, now select the landmarks in the target image based on where you want to move the points to , in order to alter the facial expression.

(eg. Stretching the ends of the lips slightly up/ down can cause smile or frown effects)

4) Results will be displayed for the **default sigma value =12.5, sigma value can be altered by changing the "par" variable in the potential(phi2) functions**. Instruction is mentioned in the function (phi2)

CONTRIBUTION OF TEAM MEMBERS:

1) Prasanna Surianarayanan - ps3703 : Implemented the function get_landmarks to calculate the parameters required for determining the Affine homogeneous matrix by solving the system of equations involving source and target landmark points.

2) Dipika Rajesh - dr2898 : Implemented the function to perform bilinear interpolation during the inverse mapping procedure at each individual pixel in the target image. This involved the calculation of the effect of the warp at each point in the image.

The process of writing the report based on the inferences from the project were carried out by both the team members having a fruitful discussion and each providing their insights into how the chosen landmarks and the warping function is affecting the target image.