EE 610: Image Processing Final Project

Automatic Image Stitching

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Understanding the Problem

Why to stitch?

- matching of panoramic image - despite rotation, zoom and illumination

Problems of image Stitching:

- To Register images so their features align
- Matching different images to stitch into one
- Blending images to hide stitching marks

Algorithm: Panoramic Recognition

Input: n unordered images

I. Extract SIFT features from all n images

II. Find k nearest-neighbours for each feature using a k-d tree

III. For each image:
   (i) Select m candidate matching images (with the maximum number of feature matches to this image)
   (ii) Find geometrically conisistent feature matches using RANSAC to solve for the homography between pairs of images
   (iii) Verify image matches using probabilistic model

IV. Find connected components of image matches

V. For each connected component:
   (i) Perform bundle adjustment to solve for the rotation $\theta_1, \theta_2, \theta_3$ and focal length f of all cameras
   (ii) Render panorama using multi-band blending

Output: Panoramic image(s)

Feature Matching: SIFT

SIFT:

Extract and match SIFT [Low04] features between all of the images. Characteristic scale and orientation is established at each feature location

K-d tree:

Each feature is matched to its k nearest neighbours in feature space (we use k = 2)

$$\tilde{\mathbf{u}}_i = \mathbf{H}_{ij}\tilde{\mathbf{u}}_j$$

SIFT

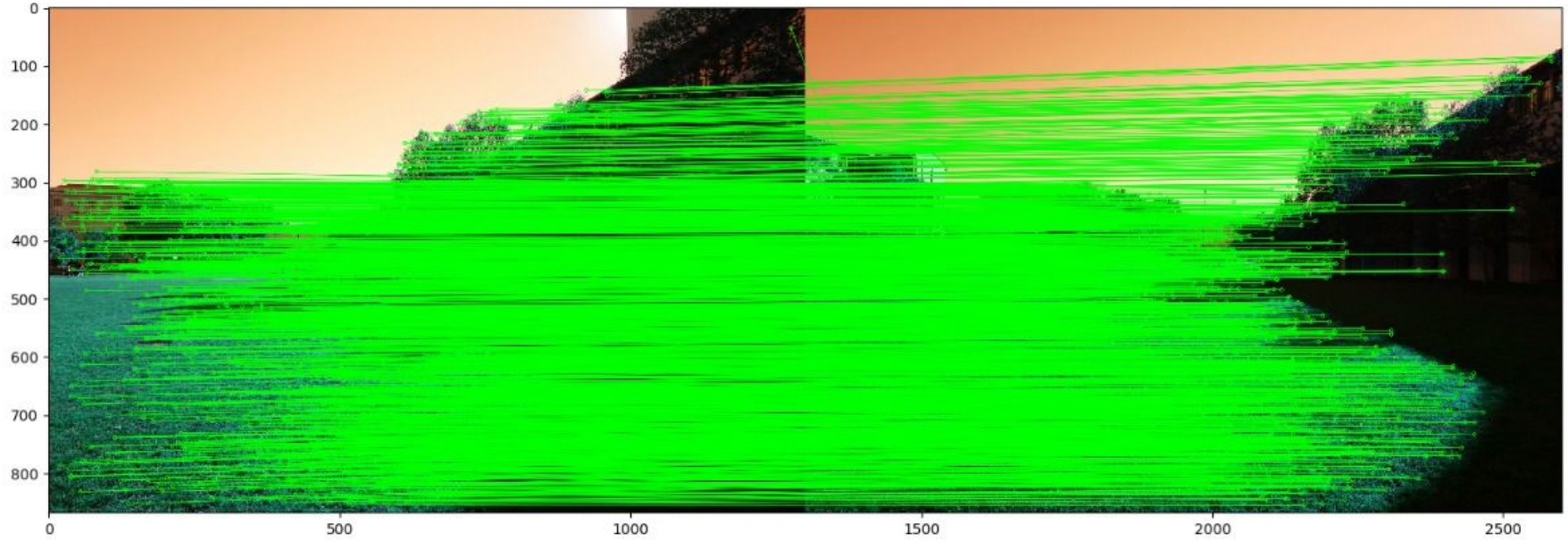


Image Matching - RANSAC

RANSAC is essentially a sampling approach to estimating H

$$p(\mathbf{H}\ is\ correct) = 1 - (1 - (p_i)^r)^n$$

N - no of trials
Pi - probability that a feature match is correct between a pair of matching images
R- feature correspondances(=2)

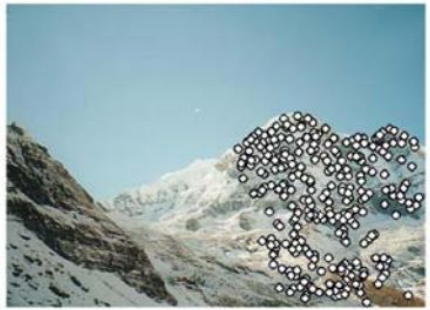
After 500 trials, p = 10^-14

(a) Image 1

(b) Image 2

(c) SIFT matches 1

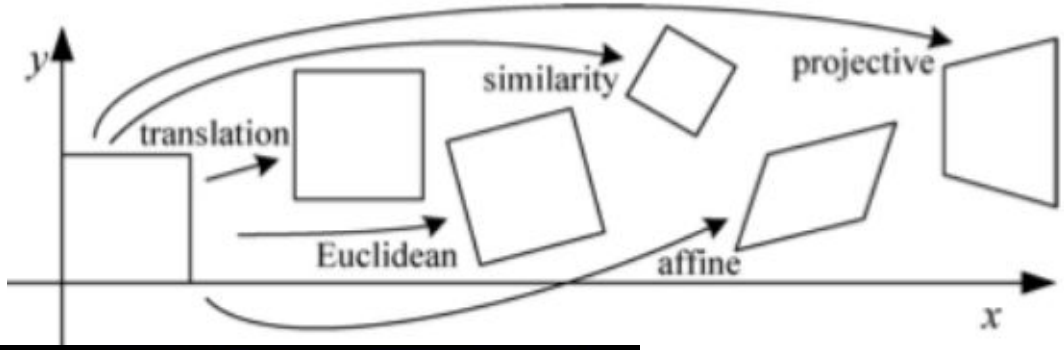
(d) SIFT matches 2



(e) RANSAC inliers 1

(f) RANSAC inliers 2

Homography


y
translation
similarity
projective
Euclidean
affine
x

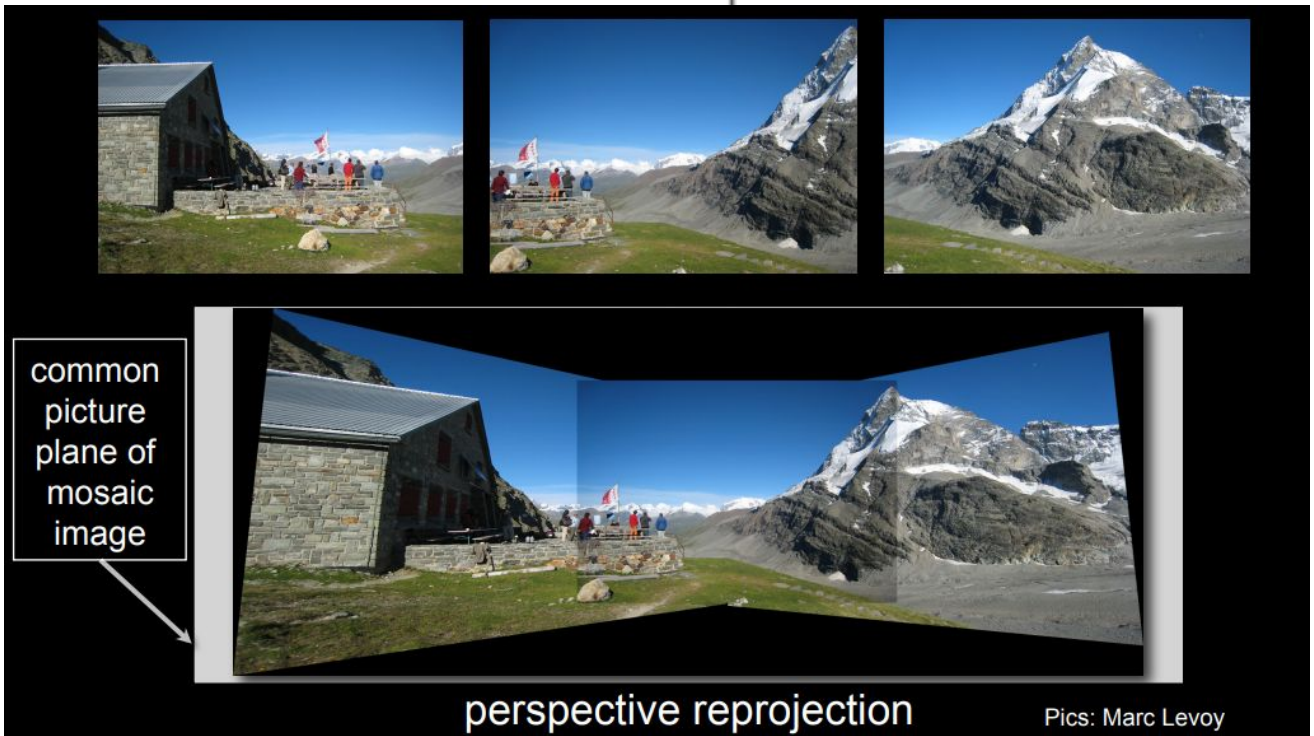

common picture plane of mosaic image
perspective reprojection
Pics: Marc Levoy

Image Matching - Probabilistic Model

Condition:

$$\frac{B(n_i; n_f, p_1)p(m=1)}{B(n_i; n_f, p_0)p(m=0)} \underset{reject}{\overset{accept}{\gtrless}} \frac{1}{\frac{1}{p_{min}} - 1}.$$

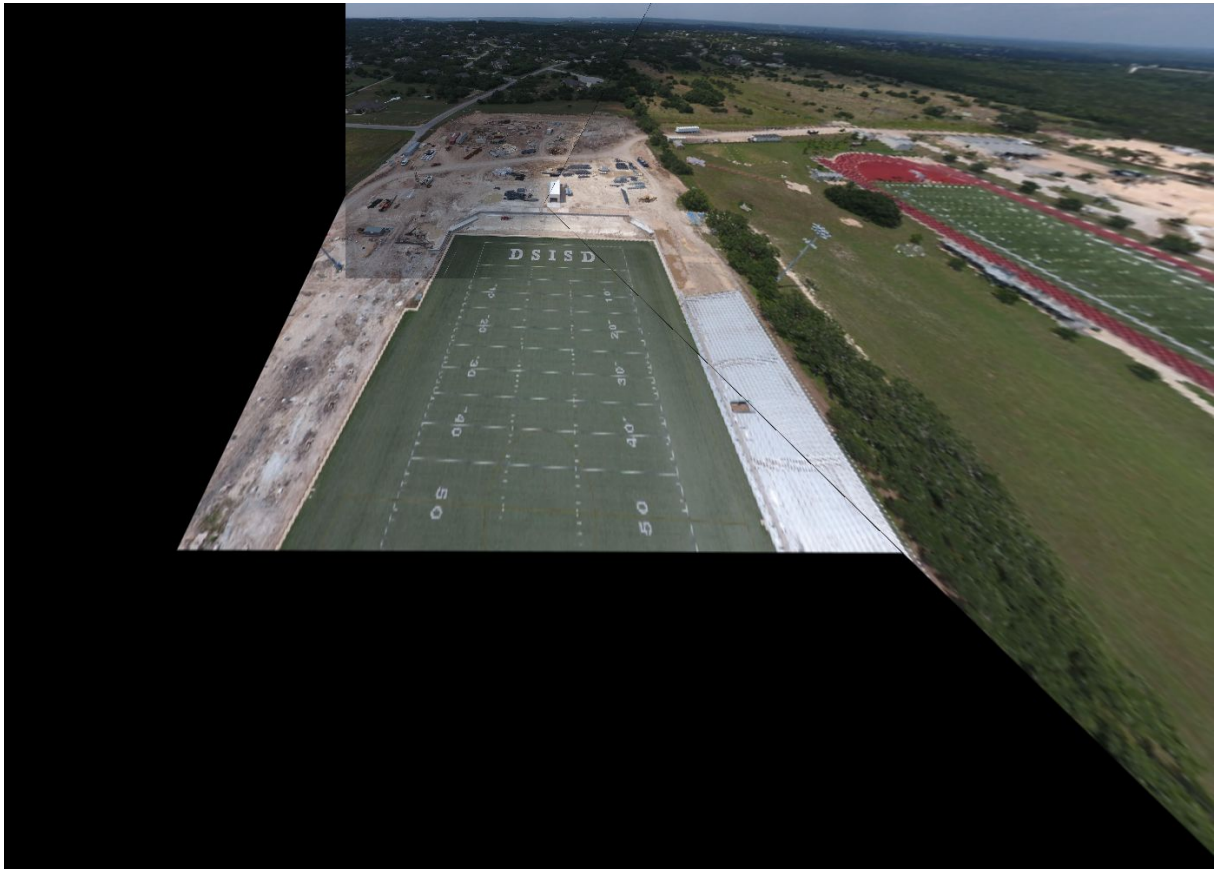
$$p\left(f^{(1:n_f)} \,\middle|\, m=1\right) = B(n_i; n_f, p_1)$$
$$p\left(f^{(1:n_f)} \,\middle|\, m=0\right) = B(n_i; n_f, p_0)$$

$$B(x; n, p) = \frac{n!}{x!(n-x)!} p^x (1-p)^{n-x}.$$

Choosing values $p(m = 1) = 10^{-6}$ and $p_{min} = 0.999$ gives the condition

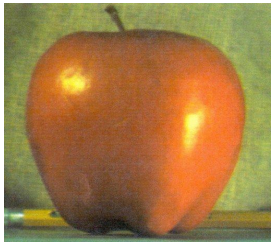
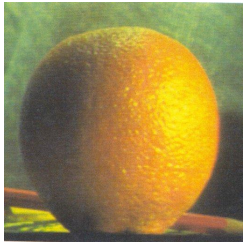
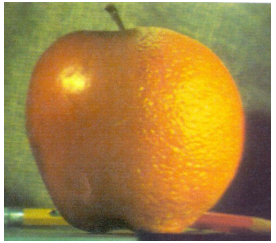
$$n_i > \alpha + \beta n_f \qquad (13)$$

for a correct image match, where $\alpha = 8.0$ and $\beta = 0.3$.


DSISD

Multi-band Blending

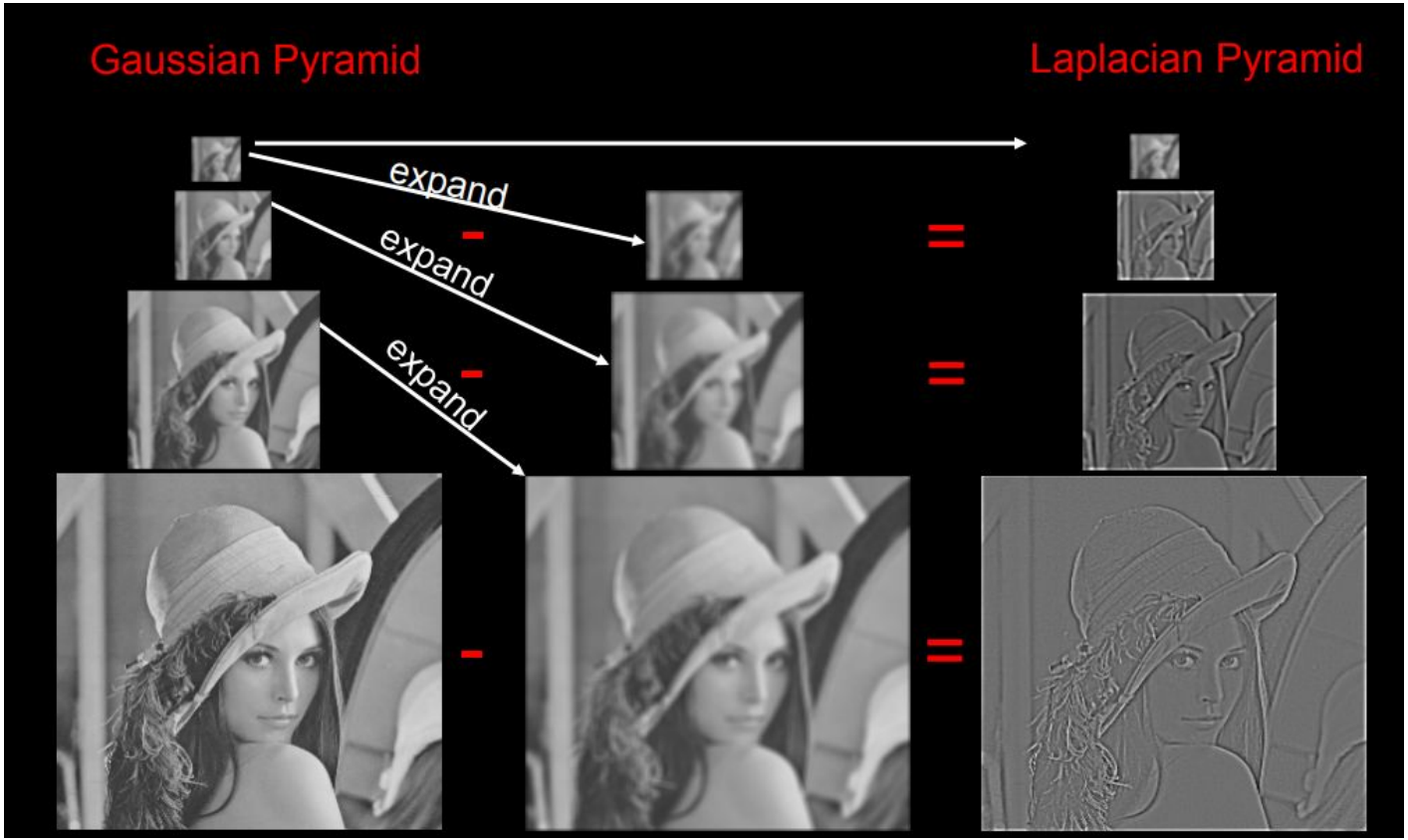
- Given two images we decide the overlapping regions.

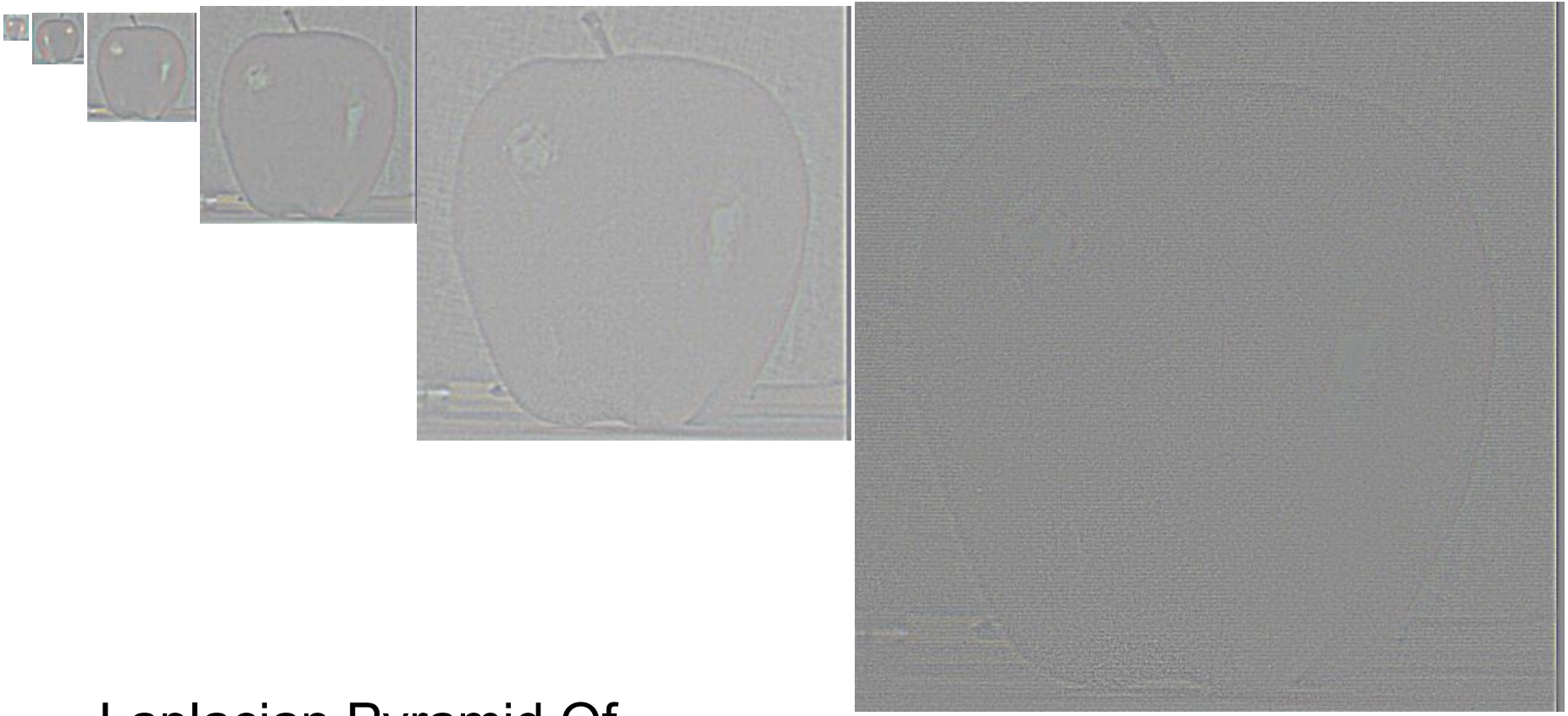

+

=


- Laplacian Pyramid is formed of the two images to be overlapped by finding the DoG

$$
\begin{aligned}
B^i_{(k+1)\sigma} &= I^i_{k\sigma} - I^i_{(k+1)\sigma} \\
I^i_{(k+1)\sigma} &= I^i_{k\sigma} * g_{\sigma'} \\
W^i_{(k+1)\sigma} &= W^i_{k\sigma} * g_{\sigma'}
\end{aligned}
\qquad
W^i_{max}(\theta,\phi) = \begin{cases} 1 & \text{if } W^i(\theta,\phi) = \arg\max_j W^j(\theta,\phi) \\ 0 & \text{otherwise} \end{cases}
$$

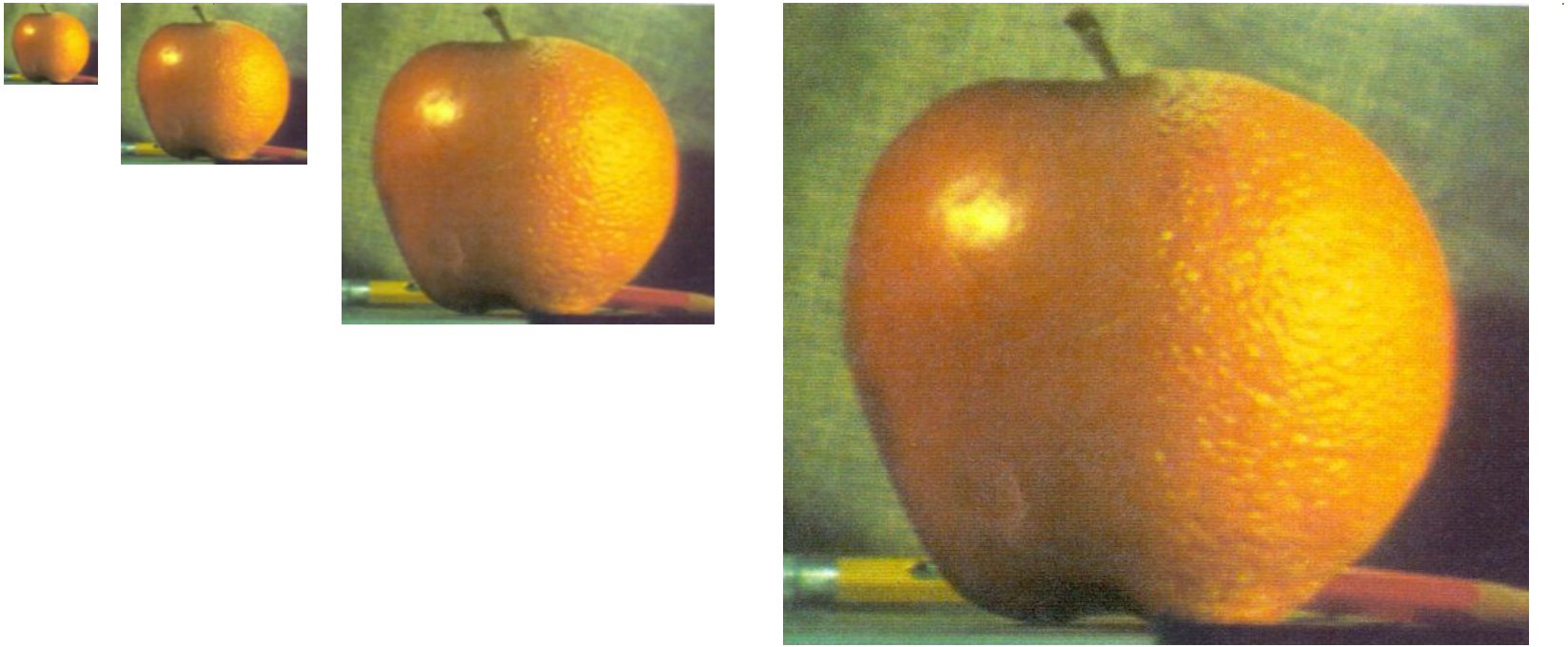
- Gaussian Pyramid of the mask is formed

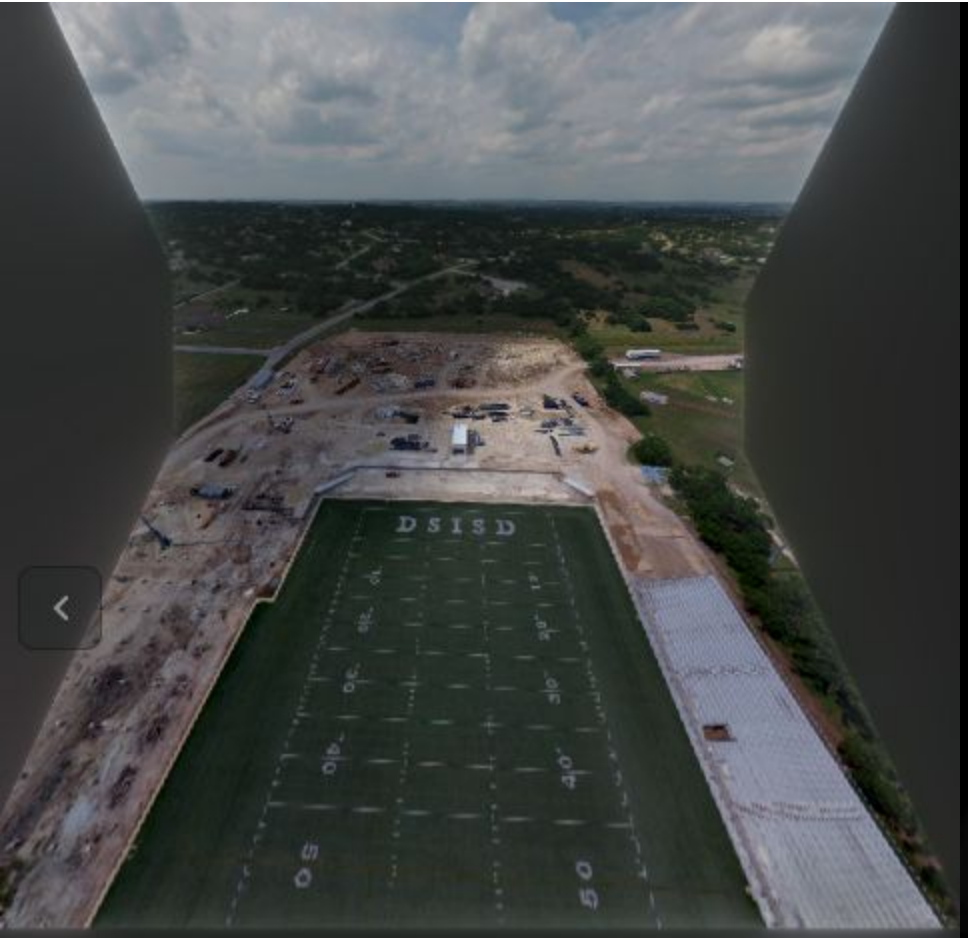

Gaussian Pyramid
Laplacian Pyramid
expand
expand
expand
-
-
-
=
=
=



Laplacian Pyramid Of Apple images

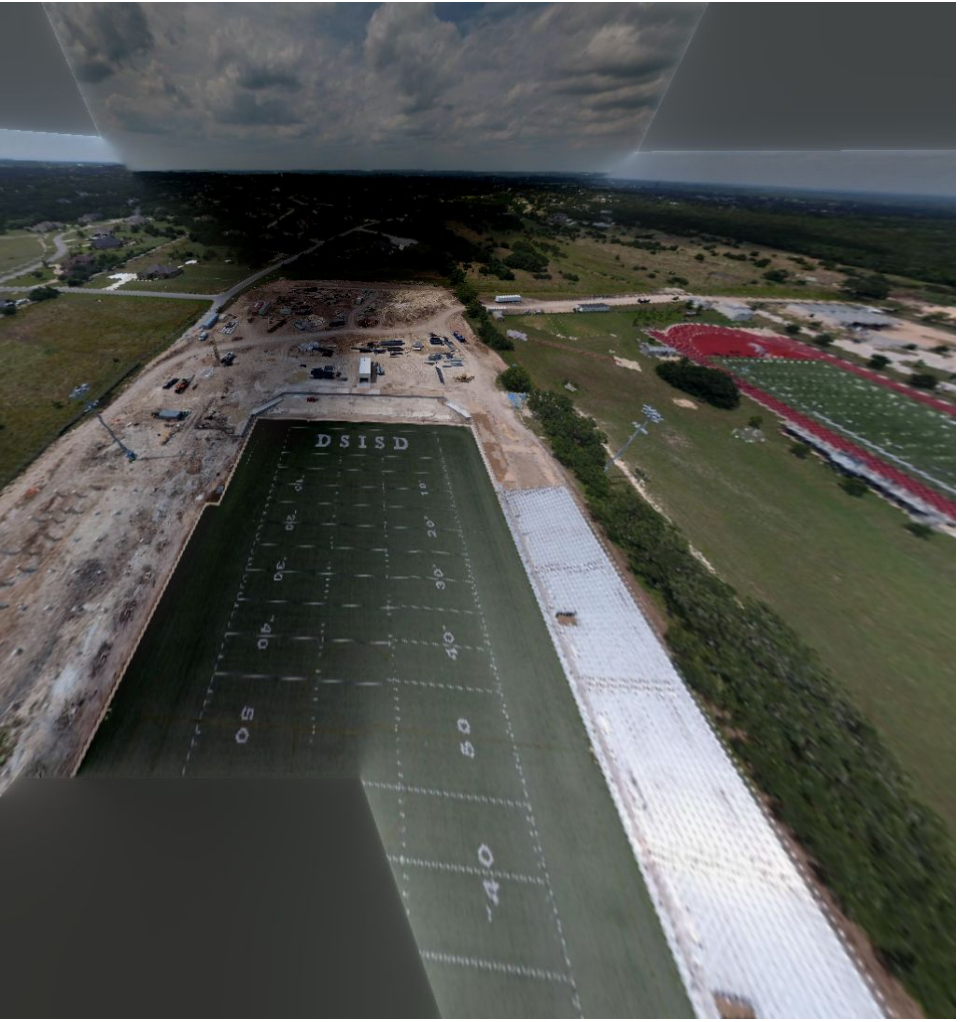
- Each pyramid is Blended by weighting the pyramids with the gaussian pyramids of the mask.
- Final image is formed by reconstructing the images from the pyramid.




DSISD

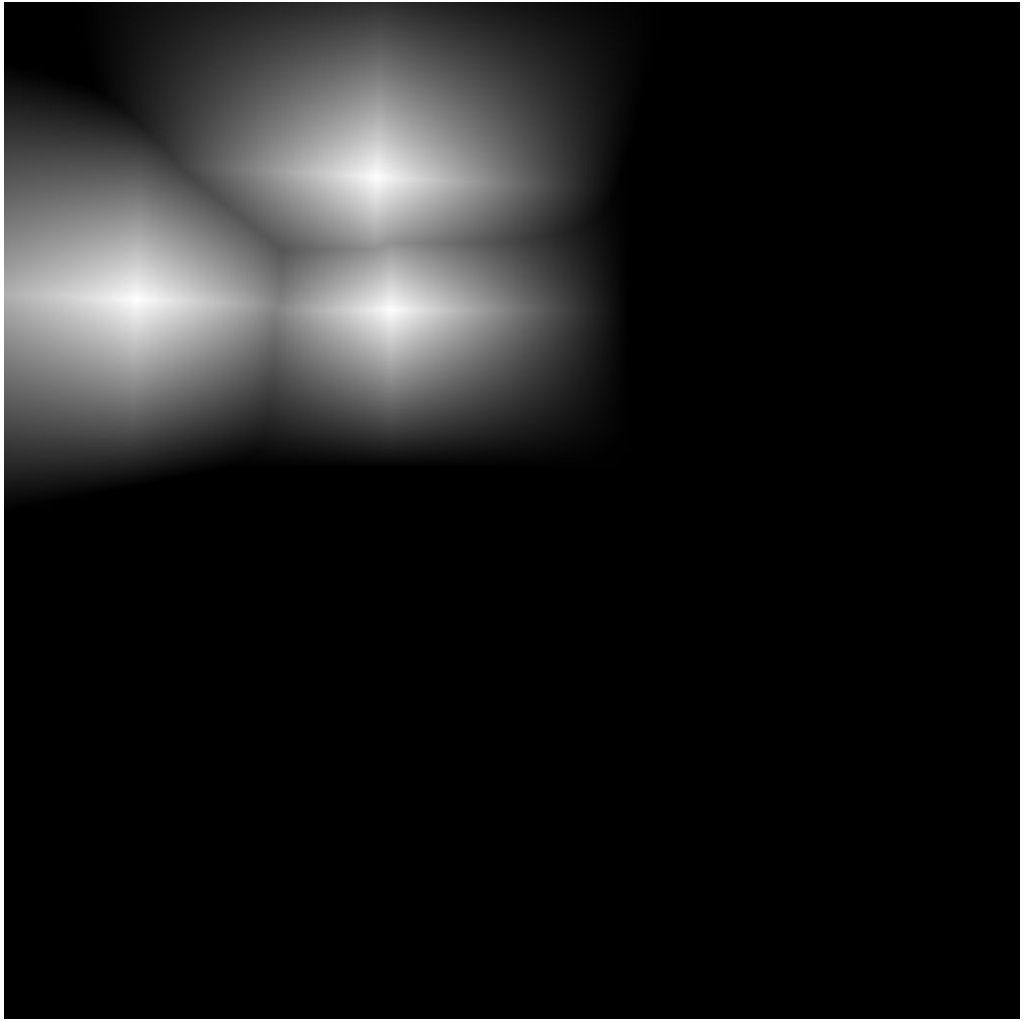

DSISD
50
50

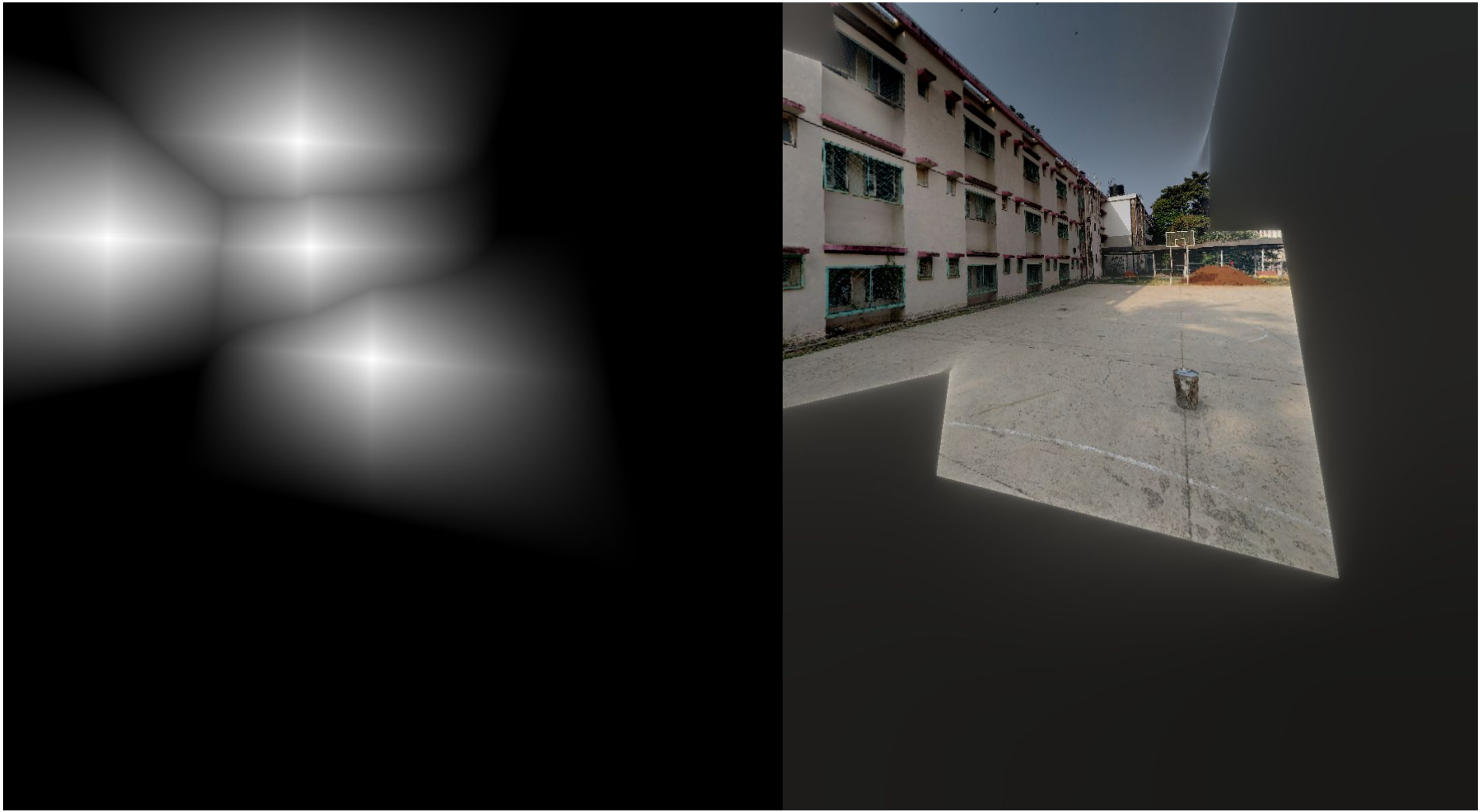

DSISD

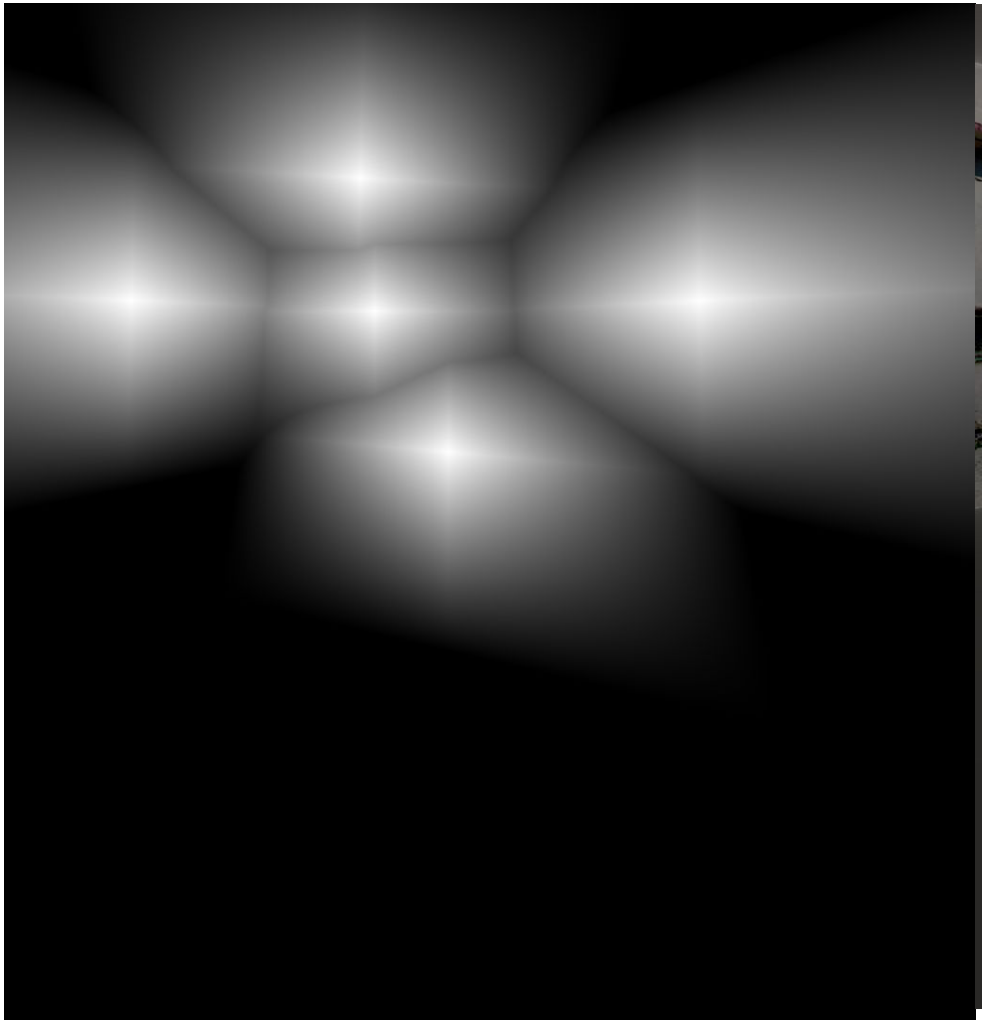

DSISD

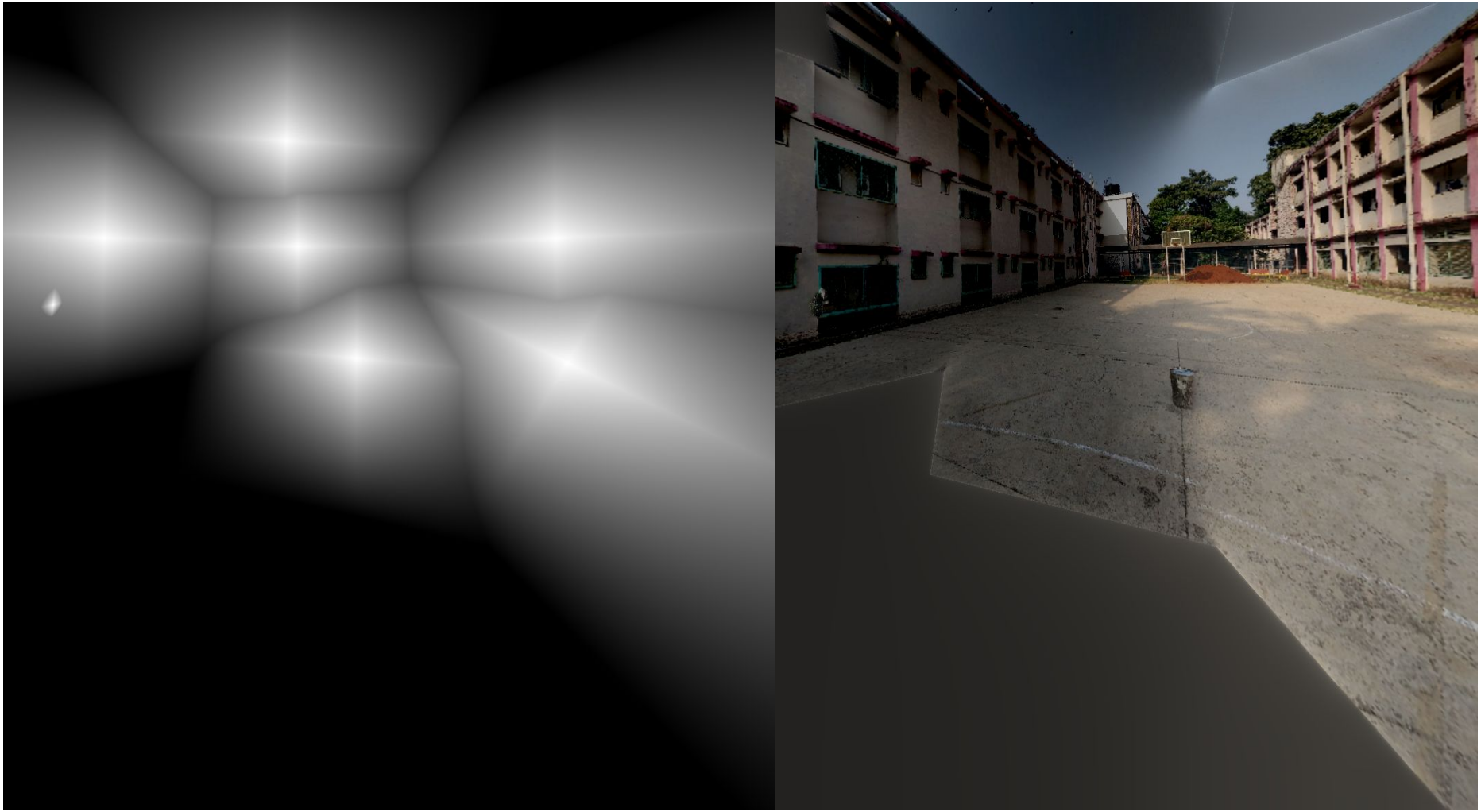

DSISD
50
40
30
20
10


DSISD



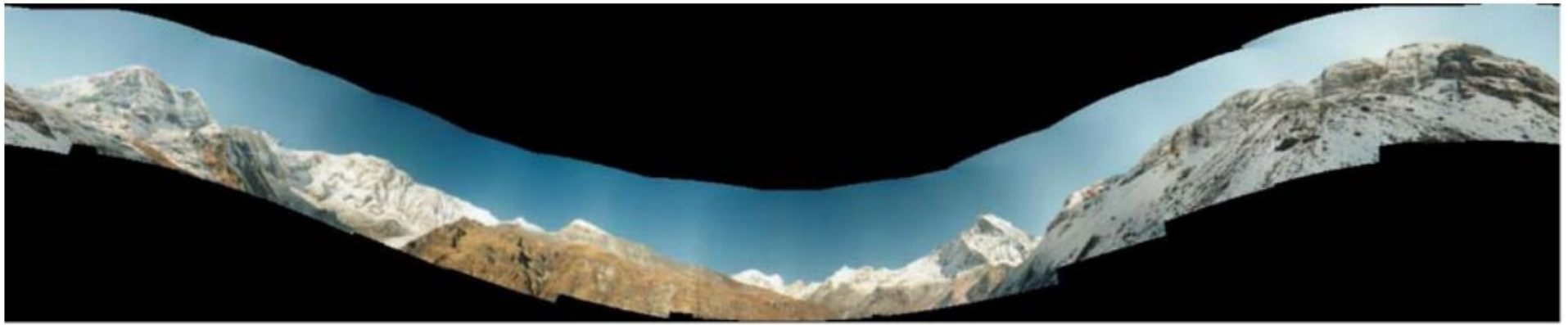






Future scope

- Scene motion
- Automatic panoramic straightening



- Photometric modelling (decrease in intensity towards image edges)

Learning Points

- Implemented theoretical concepts of image processing.
- Understanding papers and referencing multiple papers.
- Harnessing synergy of team members towards a common goal.

Thank You