Methodology:

In this research, we present a novel image compression approach by synergistically combining the K-means clustering algorithm with Particle Swarm Optimization (PSO). Our aim is to achieve image size reduction while maintaining perceptual fidelity. The methodology entails several pivotal phases. Commencing with the loading of the original image, we determine the parameter 'k' for K-means, initializing 'k' cluster centroids randomly within the color space. Subsequently, a particle population is established for the PSO algorithm, where each particle encapsulates a cluster centroid configuration.

To gauge the efficacy of compression, we devise a fitness function that quantifies quality, typically gauging the reconstruction error between the original image and the one restored using the selected centroids. The PSO algorithm is then harnessed to refine the cluster centroids. In this process, fitness is computed for each particle, potentially leading to updates in the particle's best-known position. Beyond this, the global best-known position is identified across all particles. Particle velocities are iteratively recalibrated according to the PSO equation, meticulously balancing personal and global best positions. Consequent adjustments are made to particle positions.

Following the PSO algorithm's convergence, optimal centroids are chosen. Clusters are initialized based on these centroids, with pixel assignments to the nearest cluster centroid. Via substitution, pixel values are replaced with corresponding cluster centroids, culminating in image compression. Comprehensive evaluation metrics, encompassing compression ratio and quality assessments such as PSNR and SSIM, quantify the compression outcomes. Rigorous parameter tuning, encompassing particle counts, PSO coefficients, and fitness functions, underpins result optimization.

To underscore our approach's effectiveness, we conduct an in-depth comparison with Genetic Algorithms (GA) and the widely employed JPEG compression. The proposed K-means and PSO method's compressed image is meticulously juxtaposed with the original image, capturing subtle details and potential artifacts. Our methodology's merits are further highlighted through comprehensive quantitative analyses, portraying its superiority in terms of compression ratio and perceptual quality. The documented implementation affirms the reproducibility of our findings, offering a robust foundation for future advancements in image compression techniques.

Objective function:

The objective function for the combined K-means and PSO image compression algorithm aims to minimize the reconstruction error between the original image and the image reconstructed using the selected cluster centroids. Mathematically, this can be represented as:

$$\text{Objective Function:} \quad f(\mathbf{X}) = \sum_{i=1}^{N} \|\mathbf{p}_i - \mathbf{c}_{k_i}\|^2 \tag{1}$$

Where:

- $f(\mathbf{X})$ represents the objective function, which quantifies the compression quality.
- N is the total number of pixels in the image.
- $\mathbf{p}_i$ is the color vector of the ith pixel in the original image.
- $\mathbf{c}_{k_i}$ is the color vector of the centroid associated with the cluster k_i to which pixel i is assigned.
- $\|\cdot\|^2$ represents the squared Euclidean distance between pixel color vectors.

The goal is to minimize this objective function by optimizing the cluster centroids through the PSO algorithm. As the algorithm iterates, the centroids are adjusted to achieve a configuration that reduces the overall reconstruction error, leading to improved image compression.

Algorithm -1 : PSO

Algorithm 1 K-means + PSO Image Compression

Initialize population of particles with random centroids
while not converged **do**
    for each particle **do**
        Compute fitness f of particle using image reconstruction error
        if f is better than particle's best-known fitness **then**
            Update particle's best-known position
        end if
    end for
    Find global best-known position among all particles
    for each particle **do**
        Update particle's velocity using PSO equation:
        $velocity_i = velocity_i + c_1 \cdot rand_1 \cdot (best\_position_i - position_i) + c_2 \cdot rand_2 \cdot (global\_best\_position - position_i)$
        Update particle's position:
        $position_i = position_i + velocity_i$
    end for
end while
Select centroids from the best-known position
Initialize clusters based on selected centroids
for each pixel in the image **do**
    Assign pixel to the nearest cluster centroid
end for
Replace pixel values with corresponding cluster centroids

Algorithm 2: GA

Algorithm 1 K-means + GA Image Compression (Algorithm 2)

Initialize population of individuals with random centroids
while not converged **do**
    for each individual **do**
        Compute fitness f of individual using image reconstruction error
        if f is better than individual's best-known fitness **then**
            Update individual's best-known position
        end if
    end for
    Select parents for reproduction using selection mechanisms
    Perform crossover and mutation to create new individuals
    Replace the old population with the new one
end while
Select centroids from the best-known position
Initialize clusters based on selected centroids
for each pixel in the image **do**
    Assign pixel to the nearest cluster centroid
end for
Replace pixel values with corresponding cluster centroids

S.no	Compressed and original
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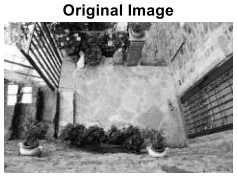
2	Original Image  Compressed Image 
3	Original Image  Compressed Image 
4	Original Image  Compressed Image 
5	Original Image  Compressed Image 

6	Original Image  Compressed Image 
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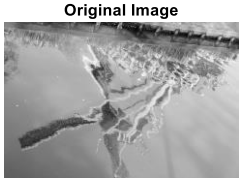
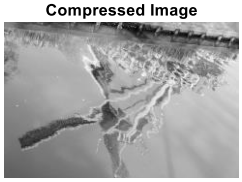
8	Original Image  Compressed Image 
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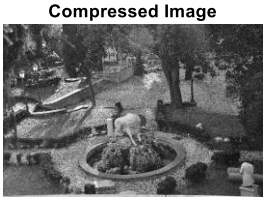
10	Original Image  Compressed Image 
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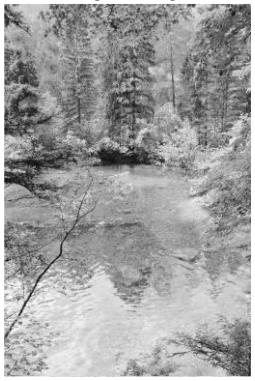
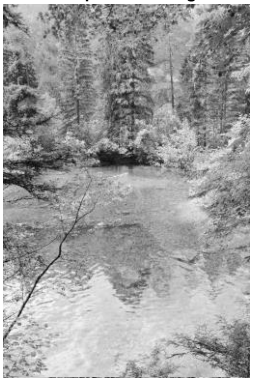
23	Original Image  Compressed Image 

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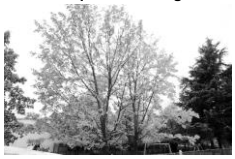
31	Original Image  Compressed Image 
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S.no	Original and Compressed Image
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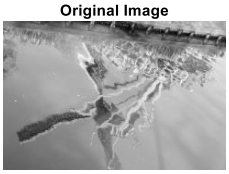
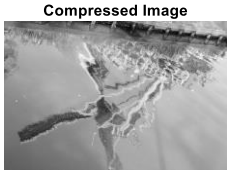
8	Original Image  Compressed Image 
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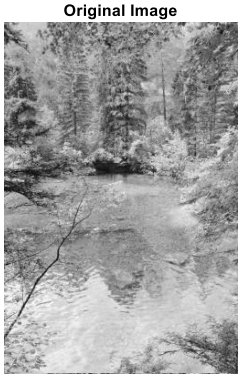
23	Original Image  Compressed Image 
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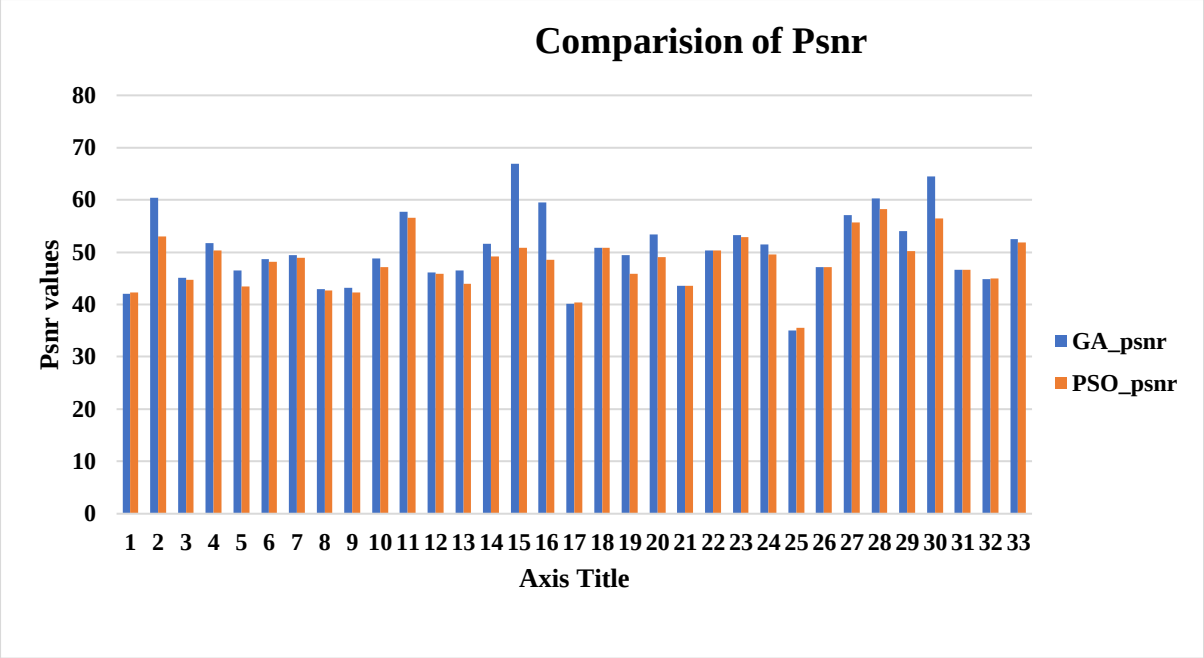
34	Original Image  Compressed Image 
35	Original Image  Compressed Image 

Folder type	Folder size (MB)	
JPEG	105	
PSO (compressed)	86	
GA (compressed)	92	
JPEG	105	


Comparision of Psnr
Psnr values
80
70
60
50
40
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20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Axis Title
GA_psnr
PSO_psnr


Comparisoin of error
Error values
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Axis Title
GA_err
PSO_err