

(a)

```
bruin = imread("UCLA_Bruin.jpg");  
image(bruin);
```



```
n = size(bruin, 1);  
m = size(bruin, 2);
```

(b)

```
K = 4;  
mu = zeros(K, 3);  
mu(1,:) = bruin(1,1,:);  
  
for k = 2:K  
    maxd = -1;  
    for x = 1:n  
        for y = 1:m  
            mind = 1e9;  
            cxy = zeros(1, 3);  
            cxy(:) = bruin(x,y,:);  
            for kp = 1:(k-1)  
                mind = min(norm(cxy - mu(kp,:))^2, mind);  
            end  
            if (maxd < mind)  
                maxd = mind;  
                mu(k,:) = cxy(:);  
            end  
        end  
    end  
end
```

```

        end
    end
end
mu

```

```

mu = 4x3
    147    200    250
         0         0
    137    141     57
     31     70    125

```

```

r = zeros(300, 400, K);
J = zeros(10, 1);
for iter = 1:10
    for x = 1:n
        for y = 1:m
            cxy = cast(squeeze(bruin(x,y,:)), 'double');
            mind = 1e9;
            mink = 0;
            for kp = 1:K
                dist = norm(cxy - mu(kp,:));
                if (mind > dist)
                    mind = dist;
                    mink = kp;
                end
            end
            for kp = 1:K
                r(x, y, kp) = 0;
            end
            r(x, y, mink) = 1;
        end
    end
    for k = 1:K
        mean = zeros(1, 3);
        count = 0;
        for x = 1:n
            for y = 1:m
                cxy = cast(squeeze(bruin(x,y,:)), 'double');
                mean = mean + r(x, y, k) * cxy';
                count = count + r(x, y, k);
            end
        end
        mu(k,:) = mean / count;
    end
    sum = 0;
    for x = 1:n
        for y = 1:m
            cxy = cast(squeeze(bruin(x,y,:)), 'double');
            for k = 1:K
                sum = sum + r(x, y, k) * norm(cxy - mu(k,:))^2;
            end
        end
    end
    J(iter) = sum;
end
end

```

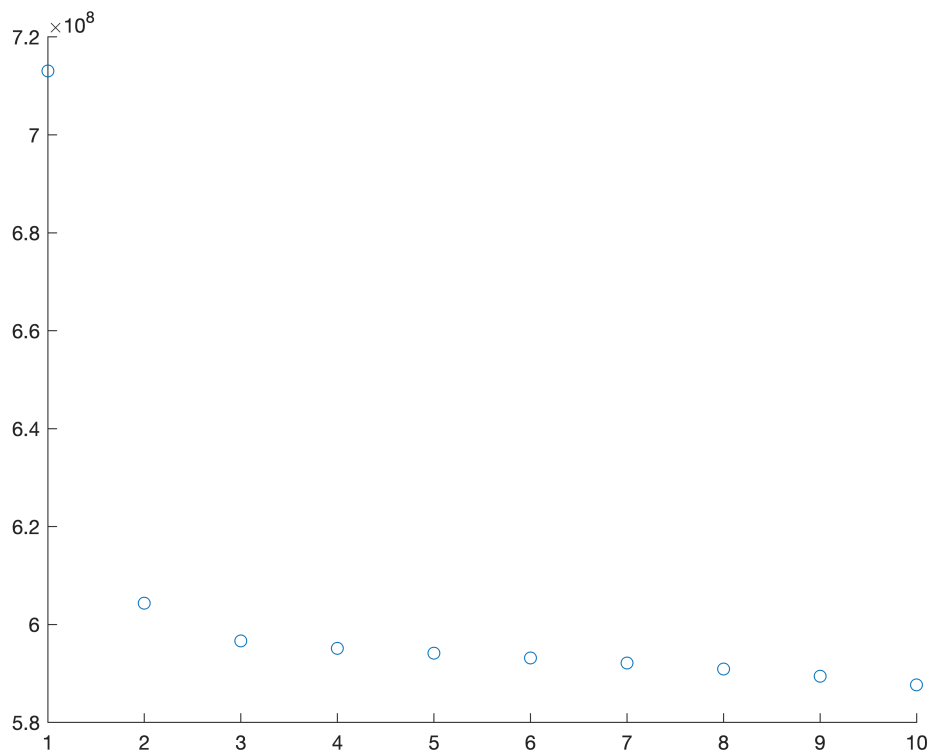
J(10)

```
ans = 5.8770e+08
```

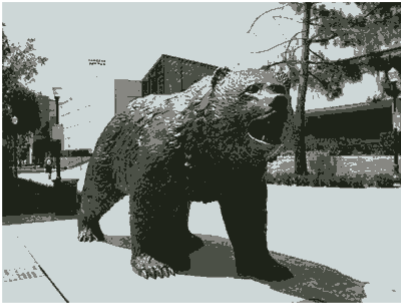
mu

```
mu = 4x3
    205.3092    218.2813    218.4876
     33.6186     36.2153     27.3633
    134.5668    136.7124    130.2239
     77.8911     83.4243     72.4920
```

```
newbruin = bruin;
for x = 1:n
    for y = 1:m
        kp = 0;
        for k = 1:K
            if r(x, y, k) == 1
                newbruin(x, y, :) = mu(k, :);
            end
        end
    end
end
scatter(1:10, J);
```



```
imshow(newbruin);
```



(c)

```
K = 8;
mu = zeros(K, 3);
mu(1,:) = bruin(1,1,:);

for k = 2:K
    maxd = -1;
    for x = 1:n
        for y = 1:m
            mind = 1e9;
            cxy = zeros(1, 3);
            cxy(:) = bruin(x,y,:);
            for kp = 1:(k-1)
                mind = min(norm(cxy - mu(kp,:))^2, mind);
            end
            if (maxd < mind)
                maxd = mind;
                mu(k,:) = cxy(:);
            end
        end
    end
end
end
mu
```

```
mu = 8x3
    147    200    250
         0         0         0
    137    141     57
     31     70    125
    251    214    159
    109    139    165
     69     81     0
    242    255    255
```

```
r = zeros(300, 400, K);
J = zeros(10, 1);
for iter = 1:10
    for x = 1:n
        for y = 1:m
```

```

        cxy = cast(squeeze(bruin(x,y,:)), 'double');
        mind = 1e9;
        mink = 0;
        for kp = 1:K
            dist = norm(cxy - mu(kp,:));
            if (mind > dist)
                mind = dist;
                mink = kp;
            end
        end
        for kp = 1:K
            r(x, y, kp) = 0;
        end
        r(x, y, mink) = 1;
    end
end
for k = 1:K
    mean = zeros(1, 3);
    count = 0;
    for x = 1:n
        for y = 1:m
            cxy = cast(squeeze(bruin(x,y,:)), 'double');
            mean = mean + r(x, y, k) * cxy';
            count = count + r(x, y, k);
        end
    end
    mu(k,:) = mean / count;
end
sum = 0;
for x = 1:n
    for y = 1:m
        cxy = cast(squeeze(bruin(x,y,:)), 'double');
        for k = 1:K
            sum = sum + r(x, y, k) * norm(cxy - mu(k,:))^2;
        end
    end
end
J(iter) = sum;
end
J(10)

```

```
ans = 4.7337e+08
```

```
mu
```

```
mu = 8x3
    168.8847    217.7350    250.7417
     22.0897     25.8861     19.4480
    105.9684    111.8957    105.6784
     78.3522     84.3161     72.1193
    207.4103    199.6460    179.9658
    153.6260    155.0707    150.9627
     53.1262     54.7085     42.1512
    235.8857    228.0374    209.6141

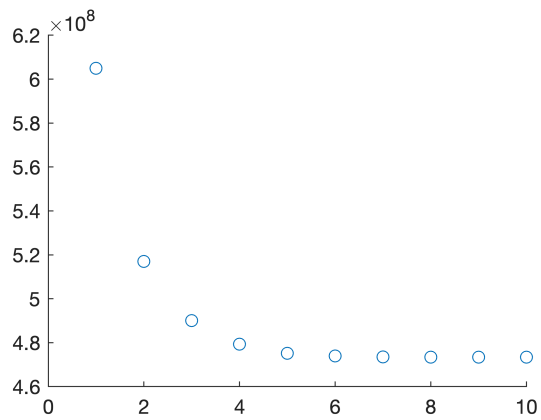
```

```
newbruin = bruin;
```

```

for x = 1:n
    for y = 1:m
        kp = 0;
        for k = 1:K
            if r(x, y, k) == 1
                newbruin(x, y, :) = mu(k,:);
            end
        end
    end
end
end
scatter(1:10, J);

```



```

imshow(newbruin);

```



```

K = 16;
mu = zeros(K, 3);
mu(1,:) = bruin(1,1,:);

for k = 2:K
    maxd = -1;
    for x = 1:n
        for y = 1:m
            mind = 1e9;
            cxy = zeros(1, 3);
            cxy(:) = bruin(x,y,:);
            for kp = 1:(k-1)

```

```

        mind = min(norm(cxy - mu(kp,:))^2, mind);
    end
    if (maxd < mind)
        maxd = mind;
        mu(k,:) = cxy(:);
    end
end
end
end
mu

```

```

mu = 16x3
    147    200    250
         0         0
    137    141     57
     31     70    125
    251    214    159
    109    139    165
     69     81     0
    242    255    255
    196    144    130
     96     69     76
     ⋮
     ⋮

```

```

r = zeros(300, 400, K);
J = zeros(10, 1);
for iter = 1:10
    for x = 1:n
        for y = 1:m
            cxy = cast(squeeze(bruin(x,y,:)), 'double');
            mind = 1e9;
            mink = 0;
            for kp = 1:K
                dist = norm(cxy - mu(kp,:)');
                if (mind > dist)
                    mind = dist;
                    mink = kp;
                end
            end
            for kp = 1:K
                r(x, y, kp) = 0;
            end
            r(x, y, mink) = 1;
        end
    end
end
for k = 1:K
    mean = zeros(1, 3);
    count = 0;
    for x = 1:n
        for y = 1:m
            cxy = cast(squeeze(bruin(x,y,:)), 'double');
            mean = mean + r(x, y, k) * cxy';
            count = count + r(x, y, k);
        end
    end
end

```

```

        mu(k,:) = mean / count;
    end
    sum = 0;
    for x = 1:n
        for y = 1:m
            cxy = cast(squeeze(bruin(x,y,:)), 'double');
            for k = 1:K
                sum = sum + r(x, y, k) * norm(cxy - mu(k,:))^2;
            end
        end
    end
    J(iter) = sum;
end
J(10)

```

```
ans = 4.4759e+08
```

```
mu
```

```

mu = 16x3
    169.4358    218.6251    251.6993
     17.7295     21.7464     16.2366
    109.1421    109.8681     70.8890
     63.4478     77.9096     86.0944
    233.2694    222.1816    198.6191
    129.6679    146.0076    157.9573
     58.2489     58.8509     45.5631
    238.0500    234.0214    221.4212
    188.7162    172.5177    152.1534
     81.2063     81.7605     58.6404
     ⋮
     ⋮

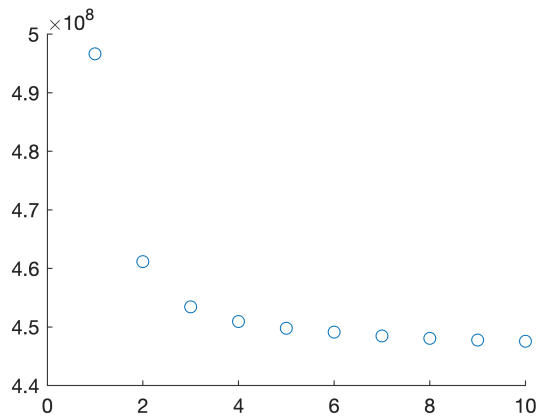
```

```

newbruin = bruin;
for x = 1:n
    for y = 1:m
        kp = 0;
        for k = 1:K
            if r(x, y, k) == 1
                newbruin(x, y, :) = mu(k,:);
            end
        end
    end
end
end
scatter(1:10, J);

```





```
imshow(newbruin);
```



(d)

The original image is  $300 * 400 * 3 * 8 = 2880000$  bits needed. After the K-means algorithm the image is compressed and only relates to the size of the  $r$  matrix and the number of centers.

$K = 4$  needs  $4 * 3 * 8$  for the 4 centers, and  $300 * 400 * 2 = 240000$  bits approximately. The compression ratio is about 12:1

$K = 8$  needs approximately  $300 * 400 * 3 = 360000$  bits. The compression ratio is about 8:1

$K = 16$  needs approx  $300 * 400 * 4 = 480000$  bits. The compression ratio is about 6:1.