Rebecca May
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Homework 2 - Chroma Subsampling
Due: 3/27/25

Observations/Comparisons

4:4:4

The original images for the assignment.

4:2:2

The RGB colors on this image seem very similar to 4:4:4's coloring. The range of colors is not noticeably decreased even though they have been, due to the subsampling. Overall, the RGB has maintained its quality well here. In the grayscale image of the Cr layer, there are obvious differences from the original, aside from the fact that it is grayscale. The objects within the photo are mostly outlines, especially the pills photo. The only time a person can see any difference is when zooming in very closely to the same part of the image for the 4:4:4 and 4:2:2, and this shows subtle discrepancies in coloring of the image content's outlines (for example, the flower petals may look more smooth in 4:4:4 sampling and more rigid in 4:2:2). The grayscale images for the Cr layer compared to the 4:4:4 image or RGB of the 4:2:2 barely show the rough image contents, and without knowing the image before subsampling, a person may not be able to decipher what the image contents are.

4:2:0

This subsampling had more obvious differences for the RGB images than in the 4:2:2 subsampling. When zoomed in on the pills and flower, compared to the 4:4:4 and 4:2:2, one can see there's more blockiness in the 4:2:0 than either of the other two when an object border is looked at (for example, the edges of pill casings or the end of the flower petals). The RGB images look almost the same when not zoomed in for the 4:2:2 and 4:4:4 RGBs as well. For the grayscale images, when compared to the 4:2:2, there are slight changes where one can see the block outlines are slightly larger than the other one, most likely due to a decrease in precision. The grayscale images overall look very similar to the 4:2:2 grayscale.

Conclusions

From experimenting with the different subsampling types, we noticed that every pixel has its own unique color and brightness compared to the original image. The subsampling can be very useful for transferring high-quality images without the need for high bandwidth to broadcast

them, or space to store the picture data. Some good use cases to use the 4:4:4 sampling would be high-end film production, color grading, or visual effects. Use cases for the 4:2:2 subsampling would also be broadcasting or video recording to maintain good quality while decreasing the file size. As for the 4:2:0 subsampling, it would best be used for streaming, DVDs, or Blu-rays for the efficient compression of the picture. For the Y (Luma) component, the resolution is not touched by the subsampling algorithm, thus making it full resolution for the images even after computation. However, for the CbCr (Chroma) component, the resolution is reduced by computing the subsampling algorithm. Although the chroma channel loses resolution, it is very minor to the naked eye.

Subsampling Output Images

4:4:4 - RGB

Original Image - Tulips

Original Image - Pills

4:2:2 - RGB

Tulips

Pills

4:2:0 - RGB

Tulips

Pills

4:2:2 - Grayscale

Tulips

Pills

4:2:0 - Grayscale

Tulips

Pills

Block-Wise Output Comparisons

4:2:2

Tulips

```
 101    93    83    82    86    86    87    88
  86    86    84    82    83    86    86    91
  85    85    83    83    86    87    89    89
  81    86    85    85    86    86    86    84

 101    91    83    81    86    86    87    88
  86    85    84    81    83    86    86    90
  85    83    83    83    86    87    89    88
  81    85    85    84    86    85    86    83
```

Pills

```
 166   161   159   158   158   157   153   152
 162   162   161   159   160   157   156   154
 164   164   161   159   159   156   157   153
 165   163   162   160   158   157   155   152

 166   160   159   159   158   157   153   152
 162   162   161   160   160   157   156   154
```

164	164	161	159	159	156	157	153
165	163	162	160	158	159	155	152

4:2:0

Tulips

101	93	83	82	86	86	87	88
88	88	85	83	84	87	87	91
85	85	83	83	86	87	89	89
82	87	85	85	87	87	89	87

101	91	83	81	86	86	87	88
86	85	84	81	83	86	86	90
85	83	83	83	86	87	89	88
81	85	85	84	86	85	86	83

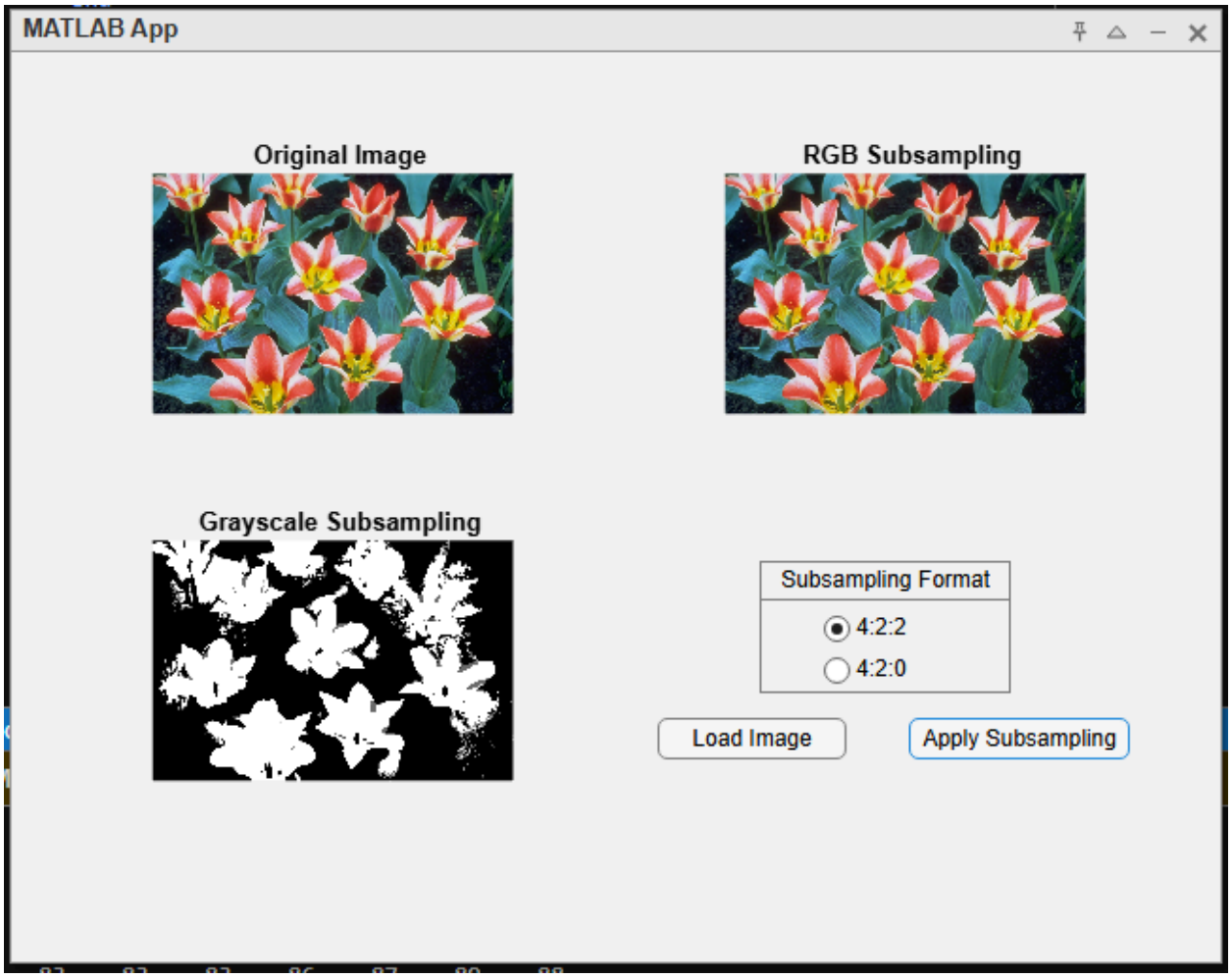
Pills

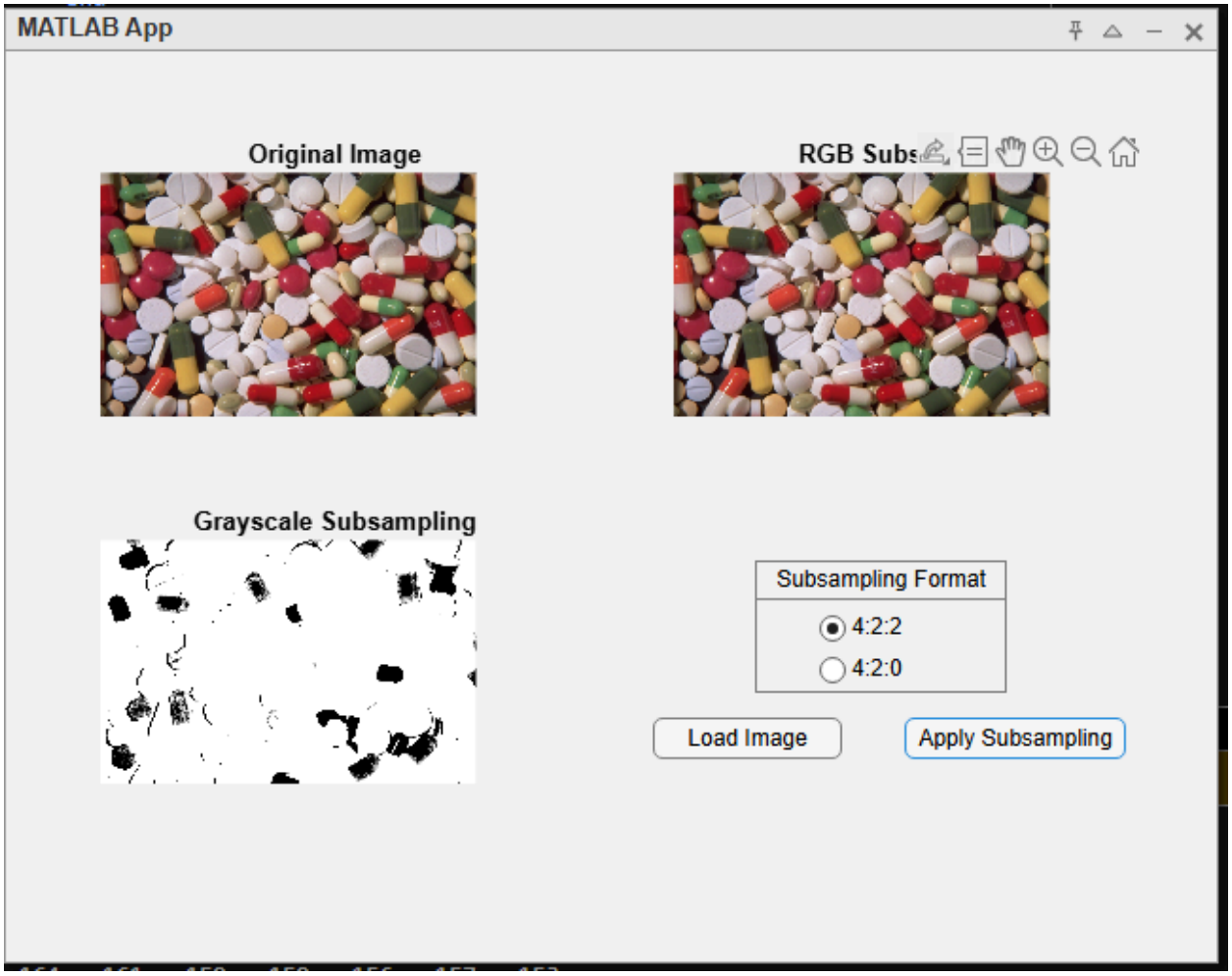
166	161	159	158	158	157	153	152
163	163	161	159	160	157	156	154
164	164	161	159	159	156	157	153
165	163	162	160	159	158	155	152

166	160	159	159	158	157	153	152
162	162	161	160	160	157	156	154
164	164	161	159	159	156	157	153
165	163	162	160	158	159	155	152

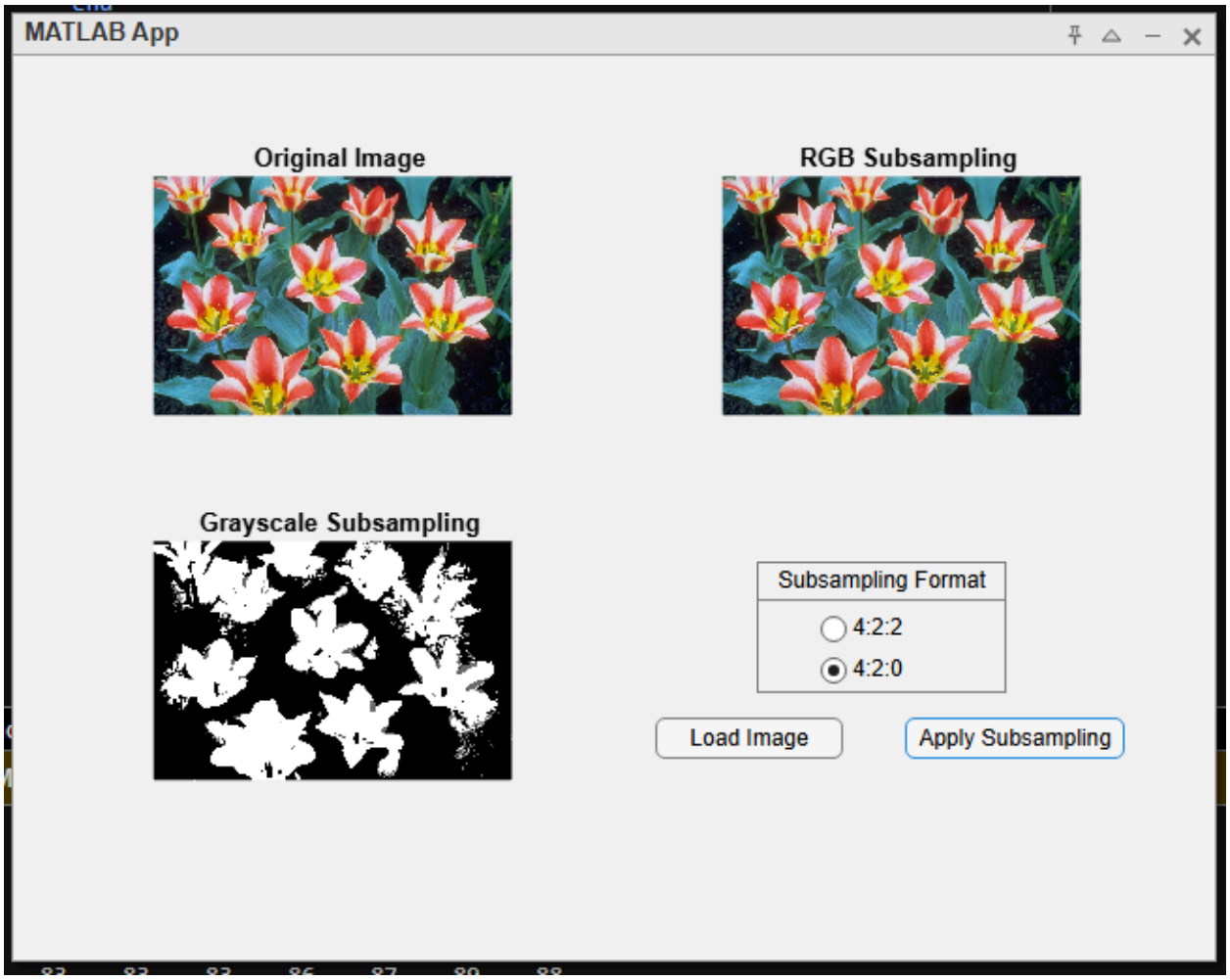
GUI Screenshots

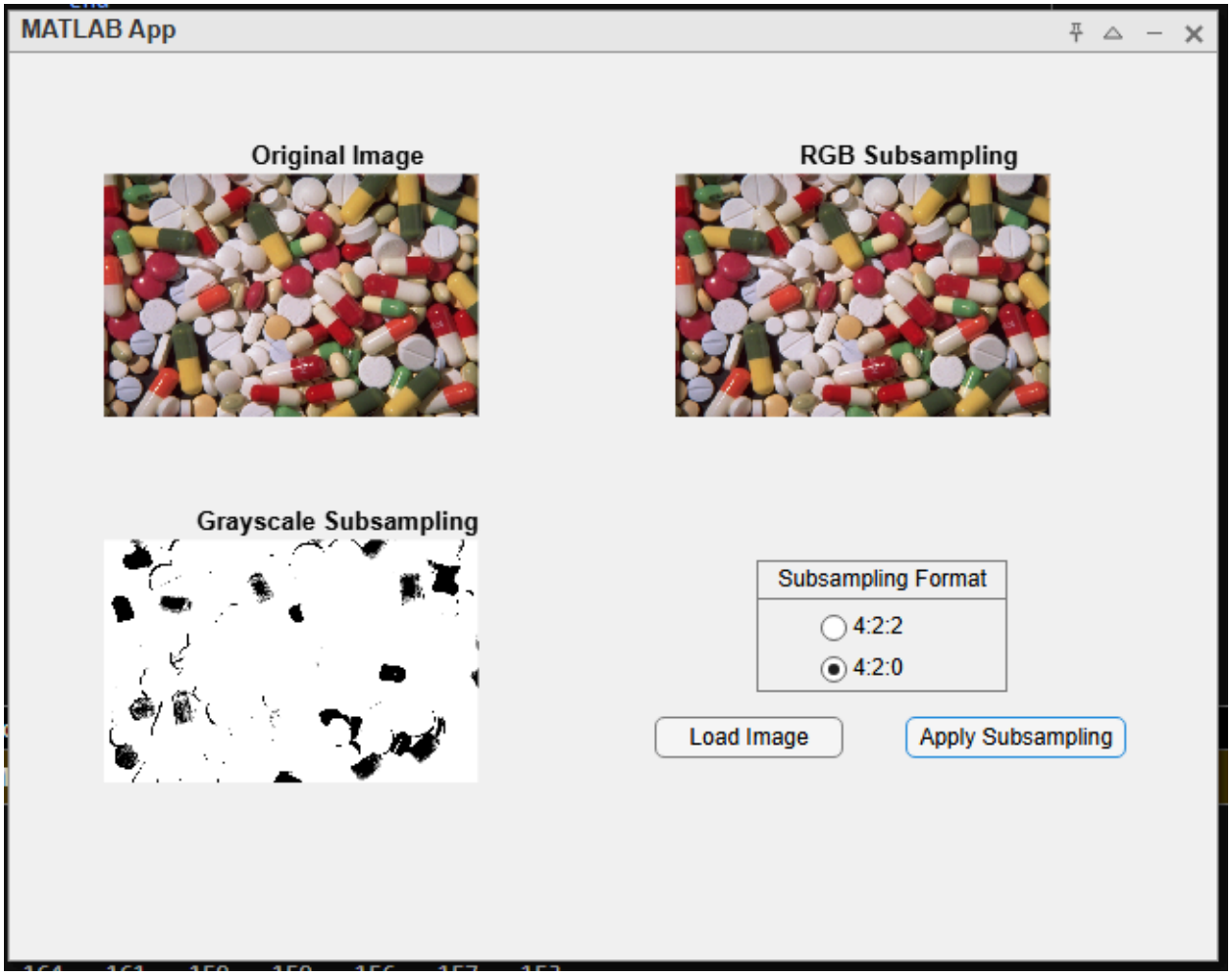
4:2:2


MATLAB App
Original Image
RGB Subsampling
Grayscale Subsampling
Subsampling Format
4:2:2
4:2:0
Load Image
Apply Subsampling


MATLAB App
Original Image
RGB Subs
Grayscale Subsampling
Subsampling Format
4:2:2
4:2:0
Load Image
Apply Subsampling

4:2:0


MATLAB App
Original Image
RGB Subsampling
Grayscale Subsampling
Subsampling Format
4:2:2
4:2:0
Load Image
Apply Subsampling



MatLab Source Code

MatLab App Code:

```
classdef subsampling < matlab.apps.AppBase
    % Properties that correspond to app components
    properties (Access = public)
        UIFigure                        matlab.ui.Figure
        SubsamplingFormatButtonGroup    matlab.ui.container.ButtonGroup
        Button_2                        matlab.ui.control.RadioButton
        Button                          matlab.ui.control.RadioButton
        ApplySubsamplingButton          matlab.ui.control.Button
        LoadImageButton                 matlab.ui.control.Button
        ImageGray                       matlab.ui.control.UIAxes
        ImageRGB                        matlab.ui.control.UIAxes
        ImageOriginal                   matlab.ui.control.UIAxes
    end
```

```
 % Callbacks that handle component events
methods (Access = private)
    % Button pushed function: ApplySubsamplingButton
    function apply(app, event)
        % See which subsampling option is selected
        config = false;
        if (app.Button.Value == true)
            % subsampling 4:2:2 chosen
            % call function and apply
            config = true;
        end

        % Call the function that handles subsampling
        [RGB, Gray] = subsample(app.ImageOriginal.UserData, config);

        % display the RGB image on app
        % rgb = imread(RGB);
        axis(app.ImageRGB, 'off');
        set(app.ImageRGB, 'UserData', RGB);
        imshow(RGB, 'Parent', app.ImageRGB);

        % display the grayscale image on app
        % gray = imread(Gray);
        axis(app.ImageGray, 'off');
        set(app.ImageGray, 'UserData', Gray);
        imshow(Gray, 'Parent', app.ImageGray);
    end
    % Button pushed function: LoadImageButton
    function loadImage(app, event)
        [f, p] = uigetfile({'*.jpg; *.png; *.gif', 'All Image Files'});
        if (ischar(p))
            fname = [p f];
            im = imread(fname);
            axis(app.ImageOriginal, 'off');
            set(app.ImageOriginal, 'UserData', im);
            imshow(im, 'Parent', app.ImageOriginal);
        end
    end
end
% Component initialization
methods (Access = private)
    % Create UIFigure and components
    function createComponents(app)
        % Create UIFigure and hide until all components are created
        app.UIFigure = uifigure('Visible', 'off');
        app.UIFigure.Position = [100 100 640 480];
        app.UIFigure.Name = 'MATLAB App';
        % Create ImageOriginal
        app.ImageOriginal = uiaxes(app.UIFigure);
```

```
            title(app.ImageOriginal, 'Original Image')
            app.ImageOriginal.PlotBoxAspectRatio = [2.07079646017699 1 1];
            app.ImageOriginal.XTick = [];
            app.ImageOriginal.YTick = [];
            app.ImageOriginal.Position = [23 263 304 172];
            % Create ImageRGB
            app.ImageRGB = uiaxes(app.UIFigure);
            title(app.ImageRGB, 'RGB Subsampling')
            app.ImageRGB.PlotBoxAspectRatio = [2.07079646017699 1 1];
            app.ImageRGB.XTick = [];
            app.ImageRGB.YTick = [];
            app.ImageRGB.Position = [326 263 304 172];
            % Create ImageGray
            app.ImageGray = uiaxes(app.UIFigure);
            title(app.ImageGray, 'Grayscale Subsampling')
            app.ImageGray.PlotBoxAspectRatio = [2.07079646017699 1 1];
            app.ImageGray.XTick = [];
            app.ImageGray.YTick = [];
            app.ImageGray.Position = [23 69 304 172];
            % Create LoadImageButton
            app.LoadImageButton = uibutton(app.UIFigure, 'push');
            app.LoadImageButton.ButtonPushedFcn = createCallbackFcn(app,
@loadImage, true);
            app.LoadImageButton.Position = [343 107 100 22];
            app.LoadImageButton.Text = 'Load Image';
            % Create ApplySubsamplingButton
            app.ApplySubsamplingButton = uibutton(app.UIFigure, 'push');
            app.ApplySubsamplingButton.ButtonPushedFcn = createCallbackFcn(app,
@apply, true);
            app.ApplySubsamplingButton.Position = [476 107 117 22];
            app.ApplySubsamplingButton.Text = 'Apply Subsampling';
            % Create SubsamplingFormatButtonGroup
            app.SubsamplingFormatButtonGroup = uibuttongroup(app.UIFigure);
            app.SubsamplingFormatButtonGroup.TitlePosition = 'centertop';
            app.SubsamplingFormatButtonGroup.Title = 'Subsampling Format';
            app.SubsamplingFormatButtonGroup.Position = [397 142 133 70];
            % Create Button
            app.Button = uiradiobutton(app.SubsamplingFormatButtonGroup);
            app.Button.Text = '4:2:2';
            app.Button.Position = [34 23 66 22];
            app.Button.Value = true;
            % Create Button_2
            app.Button_2 = uiradiobutton(app.SubsamplingFormatButtonGroup);
            app.Button_2.Text = '4:2:0';
            app.Button_2.Position = [34 1 66 22];
            % Show the figure after all components are created
            app.UIFigure.Visible = 'on';
        end
    end
```

```
    % App creation and deletion
    methods (Access = public)
        % Construct app
        function app = subsampling
            % Create UIFigure and components
            createComponents(app)
            % Register the app with App Designer
            registerApp(app, app.UIFigure)
            if nargout == 0
                clear app
            end
        end
        % Code that executes before app deletion
        function delete(app)
            % Delete UIFigure when app is deleted
            delete(app.UIFigure)
        end
    end
end
```

MatLab .m Code:

```
% Rebecca May, Paige Smith
% Homework 2
% Due: 3/27/25
% Create a MatLab function that converts an image's RGB values to
% YCbCr and applies subsampling to it.
% This function will be called in the MatLab subsampling application
function [outputImgRGB, outputImgGray] = subsample(inputImg, config)
    % Grab the image and put its values in a matrix
    OrigImage = double(inputImg);
    [row, col, layer] = size(OrigImage);
    % YCbCr Matrix (given in assignment)
    ConvertYCbCr = [0.299 0.587 0.114; -0.16874 -0.33126 0.5; 0.5 -0.41869
-0.08131];
    % Column YCbCr aid matrix (given in assignment)
    YCbCrAid = [0; 0.5; 0.5];

    % Convert to YCbCr
    ConvertedImage = zeros(row, col, layer);
    % Iterate through the rows and columns and convert to YCbCr
    for x = 1:row
            for y = 1:col
                % Separate the RGB layers and perform conversion
                OrgRGB = [OrigImage(x, y, 1); OrigImage(x, y, 2); OrigImage(x,
y, 3)];
                YCbCr = (ConvertYCbCr * OrgRGB) + YCbCrAid;
                % Put layers back in one matrix to apply subsampling later
```

```
            ConvertedImage(x, y, 1) = YCbCr(1, 1);
            ConvertedImage(x, y, 2) = YCbCr(2, 1);
            ConvertedImage(x, y, 3) = YCbCr(3, 1);
        end
end
% Perform subsambling
Subsampled = ConvertedImage;
% Determine which subsample was chosen
if (config)
    % 4:2:2 is chosen when true
    % Loop over the matrix in 2x4 blocks
    for r = 1:2:row
        for c = 1:4:col
            % Safe indexing to stay within bounds
            r2 = min(r+1, row);     % 2nd row
            c2 = min(c+1, col);     % 2nd column
            c3 = min(c+2, col);     % 3rd column
            c4 = min(c+3, col);     % 4th column

            % ===== Cb Layer =====
            % Copy cell with with into corresponding cells in 2x4
            Subsampled(r, c2, 2) = ConvertedImage(r, c, 2);
            Subsampled(r, c4, 2) = ConvertedImage(r, c3, 2);
            Subsampled(r2, c2, 2) = ConvertedImage(r2, c, 2);
            Subsampled(r2, c4, 2) = ConvertedImage(r2, c3, 2);

            % ===== Cr Layer =====
            % Copy cell with with into corresponding cells in 2x4
            Subsampled(r, c2, 3) = ConvertedImage(r, c, 3);
            Subsampled(r, c4, 3) = ConvertedImage(r, c3, 3);
            Subsampled(r2, c2, 3) = ConvertedImage(r2, c, 3);
            Subsampled(r2, c4, 3) = ConvertedImage(r2, c3, 3);
        end
    end
else
    %4:2:0 is chosen when false
    % Loop over the matrix in 2x4 blocks
    for  r = 1:2:row
        for c = 1:4:col
        % Compute safe indices within bounds
        r2 = min(r+1, row);         % 2nd row
        c2 = min(c+1, col);         % 2nd column
        c3 = min(c+2, col);         % 3rd column
        c4 = min(c+3, col);         % 4th column

        % ===== Cb Layer =====
        % Copy cell with with into corresponding cells in 2x4
        Subsampled(r, c2, 2) = ConvertedImage(r, c, 2);
        Subsampled(r2, c,  2) = ConvertedImage(r, c, 2);
```

```
            Subsampled(r2, c2, 2) = ConvertedImage(r, c, 2);
            Subsampled(r, c4, 2) = ConvertedImage(r, c3, 2);
            Subsampled(r2, c3, 2) = ConvertedImage(r, c3, 2);
            Subsampled(r2, c4, 2) = ConvertedImage(r, c3, 2);

            % ===== Cr Layer =====
            % Copy cell with with into corresponding cells in 2x4
            Subsampled(r, c2, 3) = ConvertedImage(r, c, 3);
            Subsampled(r2, c, 3) = ConvertedImage(r, c, 3);
            Subsampled(r2, c2, 3) = ConvertedImage(r, c, 3);
            Subsampled(r, c4, 3) = ConvertedImage(r, c3, 3);
            Subsampled(r2, c3, 3) = ConvertedImage(r, c3, 3);
            Subsampled(r2, c4, 3) = ConvertedImage(r, c3, 3);
            end
        end
    end
    % Make a copy of the YCbCr converted image for output2
    % Separate the layers from Cr subsampled image
    outputImgGray(:, :) = Subsampled(:, :, 3);
    % Save the grayscale output image
    imwrite(outputImgGray, "ouputImgGray.png");

    % RGB Matrix (given in assignment)
    ConvertRGB = [1 0 1.402; 1 -0.34414 -0.71414; 1 1.77200 0];
    outputImgRGB = zeros(row, col, layer);
    % Iterate through subsampled matrix and convert back to RGB values
    for x = 1:row
            for y = 1:col
                % Subtract 0.5 from Cb and Cr rows only
                RGBAid = [Subsampled(x, y, 1); Subsampled(x, y, 2)-0.5;
Subsampled(x, y, 3)-0.5];

                % Convert the subsampled matrix back to RGB Form
                RGB = (ConvertRGB)*(RGBAid);
                RGB = max(0, min(255, RGB));
                % Add R and G and B layers back
                outputImgRGB(x, y, 1) = RGB(1, 1);
                outputImgRGB(x, y, 2) = RGB(2, 1);
                outputImgRGB(x, y, 3) = RGB(3, 1);
            end
    end
    % Save RGB output image
    outputImgRGB = uint8(outputImgRGB);
    imwrite(outputImgRGB, "ouputImgRGB.png");
    % Display for .m running testing purposes
    disp(outputImgRGB(1:4, 1:8, 2))
    disp(OrigImage(1:4, 1:8, 2))
end
```