Assignment 1 - Report

Image Signal Processing (ISP) Tool

Introduction

The code implements an **Image Signal Processing (ISP) Tuning Tool** that allows users to process and optimize 12-bit RAW Bayer images interactively. Built using OpenCV and Streamlit, the tool offers a graphical interface for performing various ISP tasks like demosaicing, white balancing, denoising, gamma correction, and sharpening. This report discusses the design and approach of the system.

Core Design Principles

1. **Modular Architecture**:
   - The ImageSignalProcessor class encapsulates key ISP functionalities, promoting reusability and clarity.
2. **User Interactivity**:
   - The Streamlit-based GUI provides real-time control over ISP parameters and predefined combinations, enhancing user engagement.
3. **Scalability**:
   - The modular pipeline design supports easy extension for future ISP features or custom processing needs.

Pipeline Design

The processing pipeline consists of the following sequential steps:

1. **RAW Image Loading**:
   - The tool accepts 12-bit Bayer pattern images in .raw or .bin format. The load_raw_image function reshapes the input into a 2D array based on the image dimensions.
2. **Demosaicing**:
   - Converts the Bayer pattern into an RGB image using OpenCV's cv2.COLOR_BayerGR2RGB. It assumes a GRBG pattern but can be adjusted for other configurations.
   - Output: A float32 RGB image for consistency across processing steps.
3. **White Balancing**:
   - Implements the Gray World algorithm, which adjusts channel gains to achieve a neutral white balance.
4. **Denoising**:
   - Applies Gaussian smoothing with tunable kernel size and standard deviation. Conversion between 12-bit and 8-bit ensures compatibility with OpenCV functions.
5. **Gamma Correction**:

    - Normalizes the image to a [0, 1] range, applies gamma adjustment, and scales it to an 8-bit range for display.
6. **Sharpening**:
    - Utilizes an unsharp mask to enhance image edges. The sharpening strength and blur radius are configurable.
7. **Normalization for Display**:
    - Scales the pixel intensities between 0 and 1 for consistent visualization in Streamlit.

Interactive Tuning

The interactive mode allows users to:

- Configure parameters for white balancing, denoising, gamma correction, and sharpening using a Streamlit sidebar.
- View intermediate results after each processing step for better understanding and tuning.

Predefined Combinations

For convenience, the tool provides predefined processing pipelines, including:

- Demosaic + Gamma
- Demosaic + White Balance + Gamma
- Demosaic + White Balance + Denoise + Gamma
- Demosaic + White Balance + Denoise + Gamma + Sharpen

These options streamline processing for common use cases.

Code Organization

1. **Class Design**:
    - ImageSignalProcessor encapsulates processing logic, ensuring separation of concerns.
2. **Streamlit Integration**:
    - GUI logic and parameter controls are defined in the main() function.
    - File handling and temporary storage are managed efficiently using Python's tempfile module.

Error Handling and Cleanup

The tool ensures robust error handling:

- Safely deletes temporary files after processing to avoid resource leaks.
- Handles invalid inputs or processing errors gracefully.

Potential Enhancements

1. **Support for Additional Formats**:
    - Extend compatibility to more RAW formats (e.g., .dng).
2. **Real-Time Feedback**:
    - Use Streamlit's st.progress for visualizing processing status.

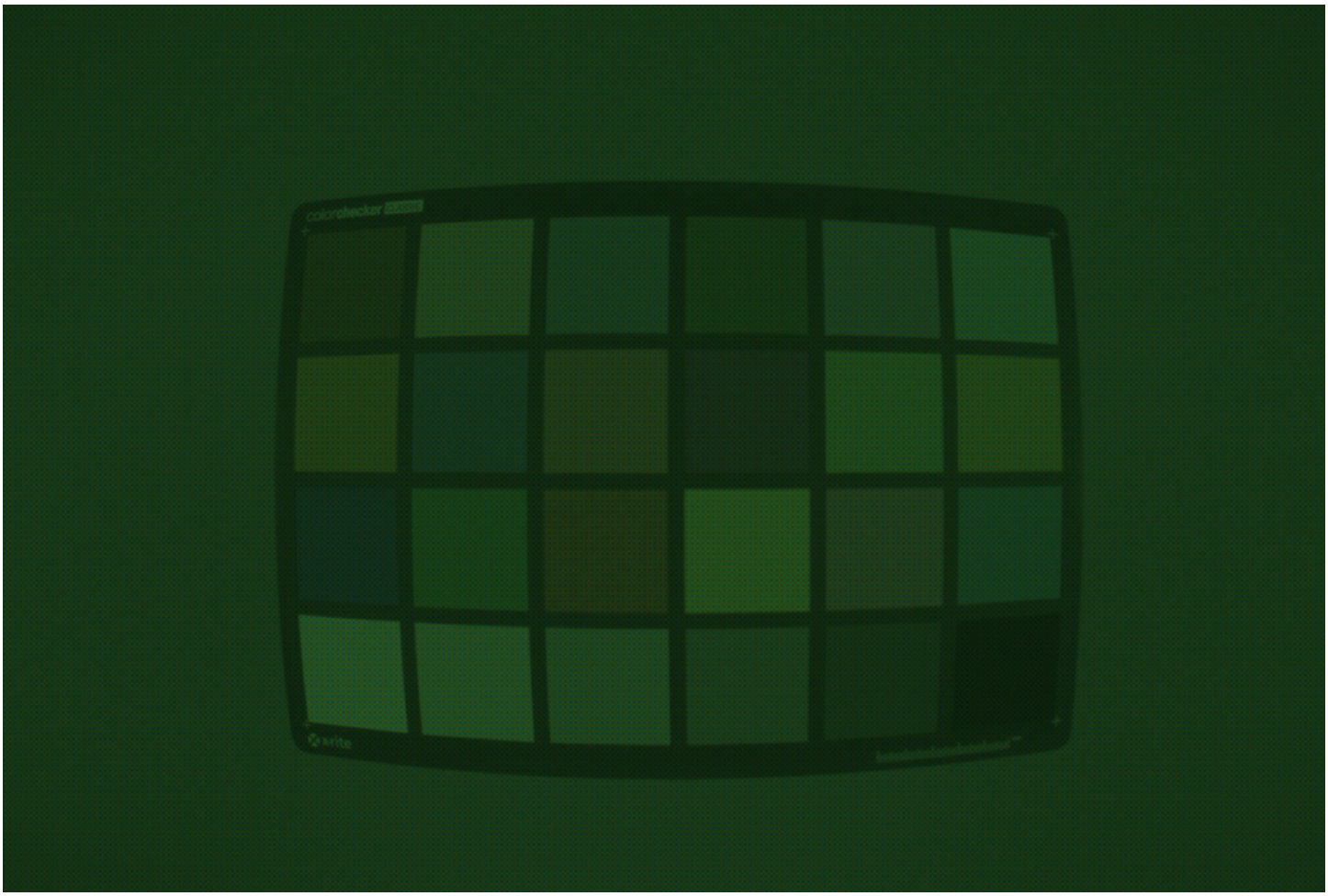
3. **Advanced ISP Techniques**:
    - Include tone mapping, chromatic aberration correction, and HDR processing.

Conclusion

This ISP Tuning Tool demonstrates an efficient and user-friendly approach to RAW image processing. Its modular design and interactive interface make it an excellent foundation for exploring advanced ISP tasks.

Observations

- **Original 12bit Bayer Raw image (Input):**



1920x1280x12bitsxGRBG_6500K_2000Lux.raw in PixelViewer

---

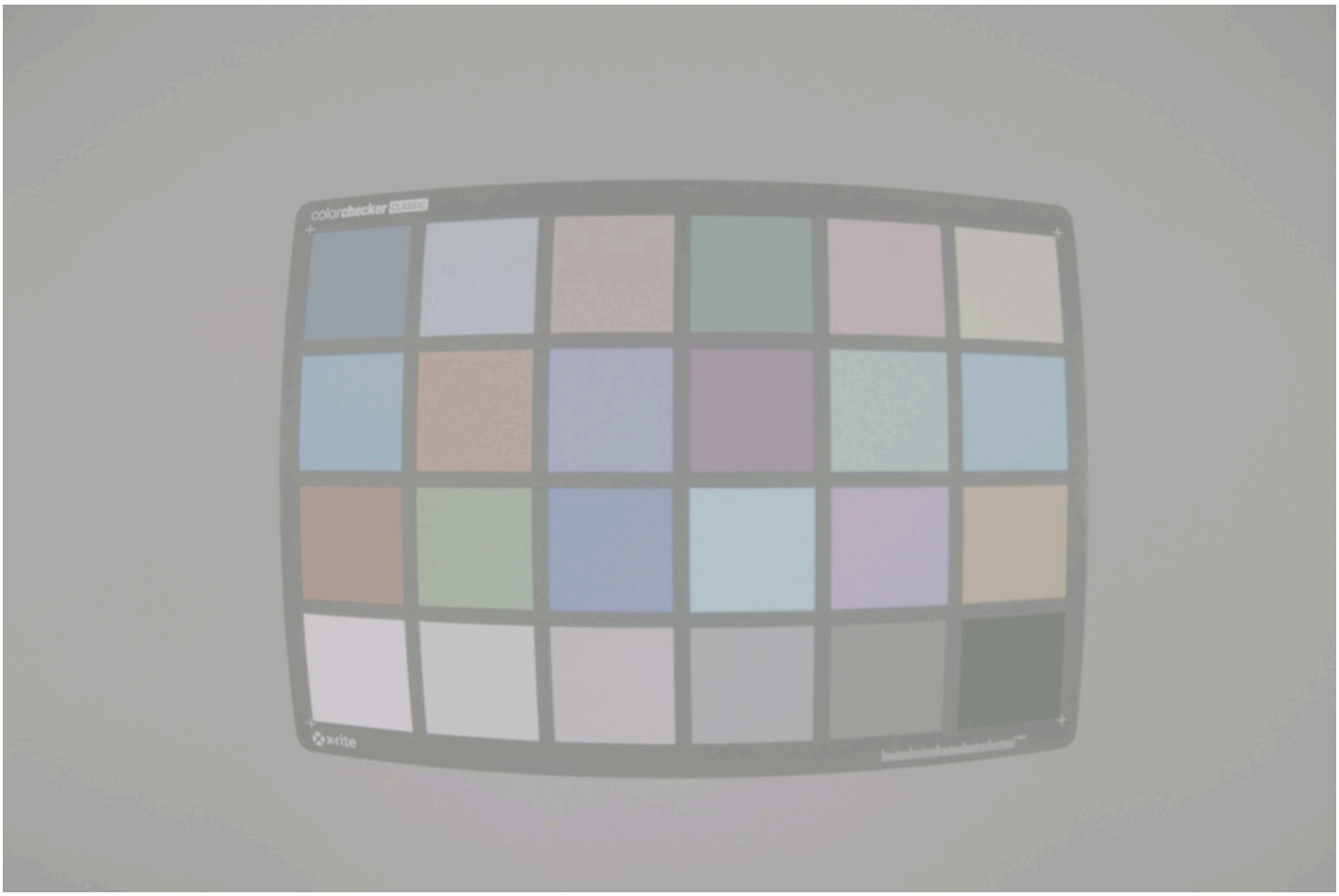
1. **Demosaic + Gamma**

- **Process**: The raw Bayer image is demosaiced into an RGB image, then gamma correction is applied to adjust the brightness and contrast.
- **Outcome**: The image appears with better color representation due to demosaicing, and gamma correction will improve the tonal balance of the image.
- **Summary Observation**: This combination should give a clearer, more balanced image, especially in terms of contrast, but the image might still lack some refinement like denoising and sharpening.

Demosaic + Gamma

2. Demosaic + White Balance + Gamma

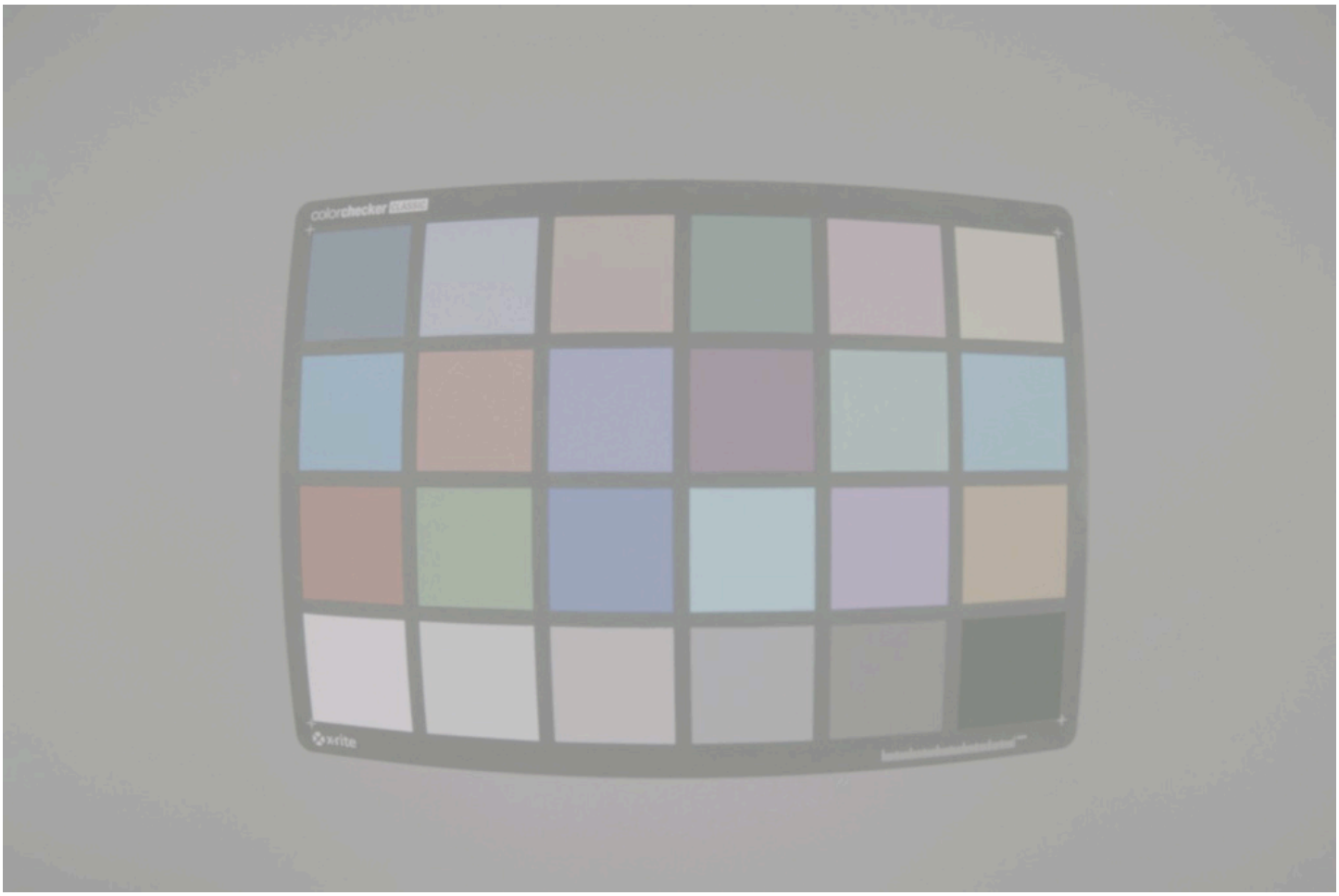
- **Process:** After demosaicing, the image undergoes white balance adjustment based on the Gray World algorithm, followed by gamma correction.
- **Outcome:** This combination corrects color casts, making the image more natural in terms of color temperature, while gamma correction adjusts brightness.
- **Summary Observation:** The image should look more balanced in terms of both color and tonal range. White balance can significantly improve the color accuracy, and gamma will ensure proper exposure.



Demosaic + White Balance + Gamma

3. **Demosaic + White Balance + Denoise + Gamma**

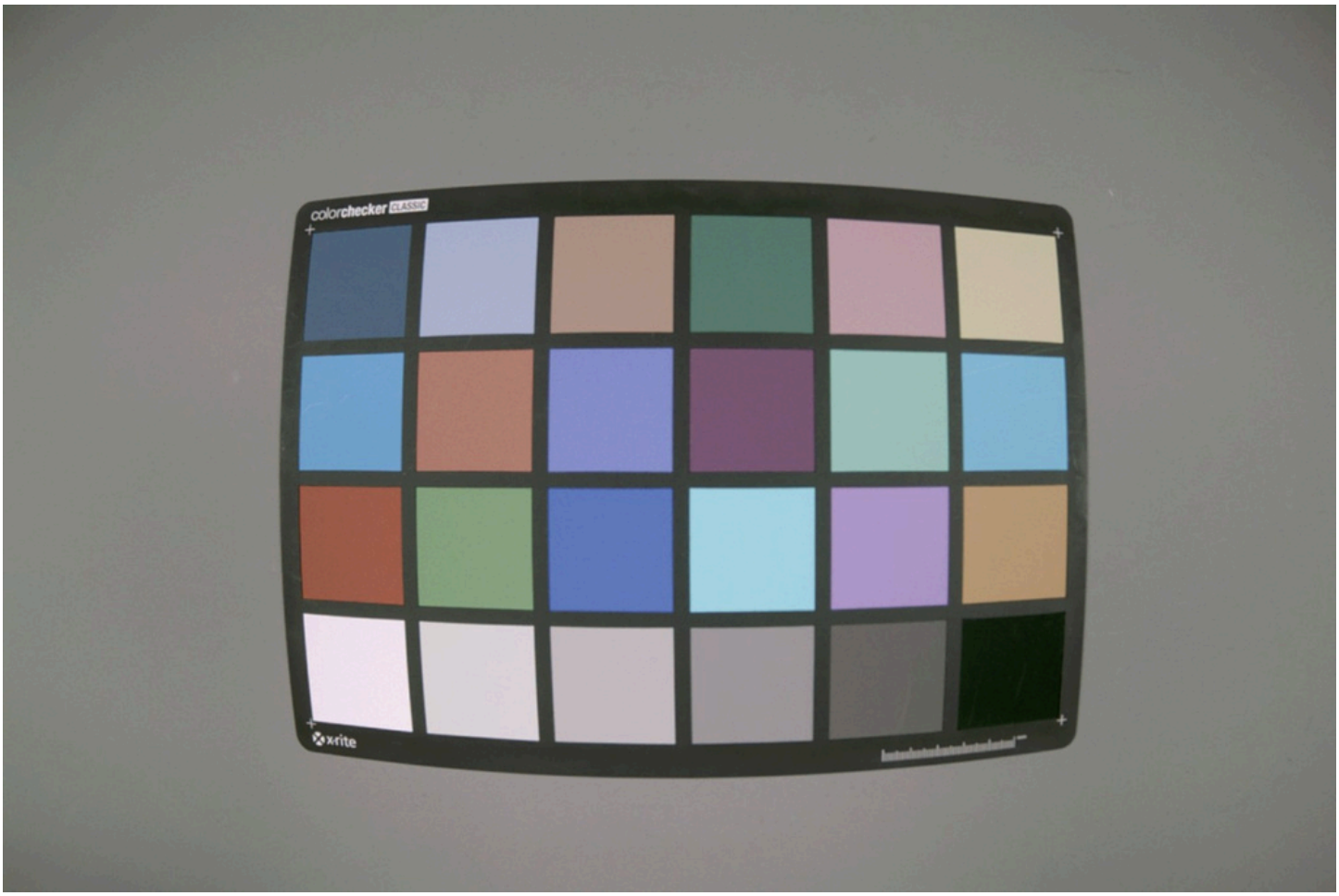
- **Process**: This sequence first demosaics the image, then adjusts white balance, applies denoising, and finally applies gamma correction.
- **Outcome**: The denoising step smooths out any remaining noise, making the image clearer, and the other steps will ensure proper color and tonal balance.
- **Summary Observation**: This should produce a smoother, more professional-looking image with better color accuracy and reduced noise, as well as appropriate contrast and brightness.



Demosaic + White Balance + Denoise + Gamma

4. **Demosaic + White Balance + Denoise + Gamma + Sharpen**

- **Process**: After demosaicing, the image will undergo white balance, denoising, gamma correction, and finally sharpening.
- **Outcome**: The image will have the most refined quality, with better color accuracy, reduced noise, proper contrast, and enhanced sharpness.
- **Summary Observation**: This combination will result in the sharpest and clearest image with the most balanced colors and reduced noise. However, sharpening may introduce artifacts if overdone.



Demosaic + White Balance + Denoise + Gamma + Sharpen