Advanced Spectral Imaging: Homework 3

Yuya Haga

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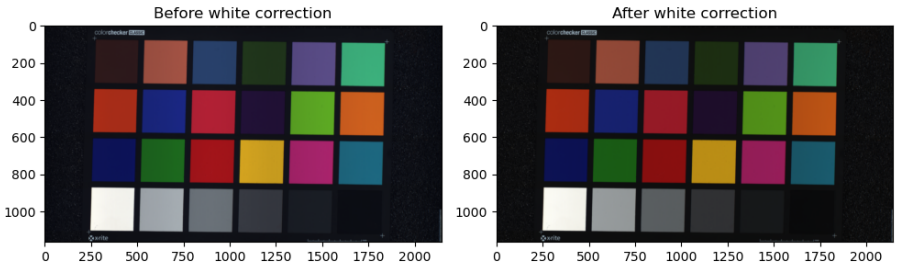
1 Tasks #1. White correction

1.1 Colorchecker [from Specim scanner]

White correction of specim scanner is shown in Figure 1. The white correction is done by using a white reference and a dark reference.

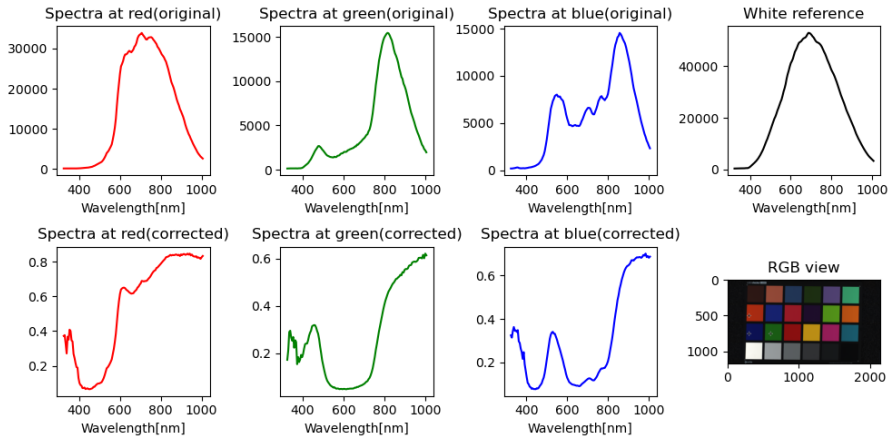
Script for white correction is shown in Code 1.

Figure 1: White correction of specim scanner



Spectra of white corrected image is shown in Figure 2.

Figure 2: Spectra of white corrected image

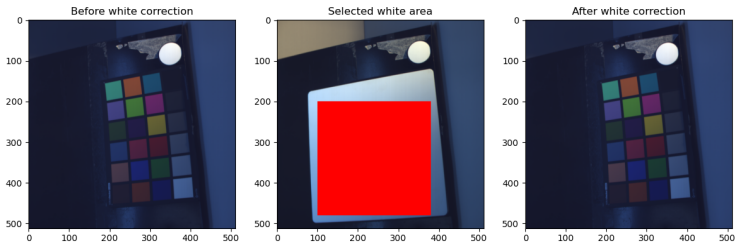


1.2 Color Checker 2 lamps + White Sample 2 lamps

1.2.1 SpecimIQ

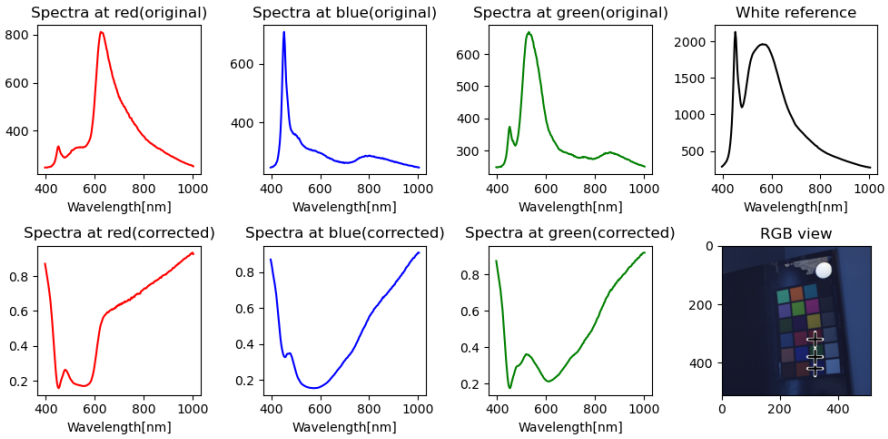
White correction of SpecimIQ is shown in Figure 3.

Figure 3: White correction of SpecimIQ with large reference



Spectra of white corrected image is shown in Figure 4.

Figure 4: Spectra of white corrected image

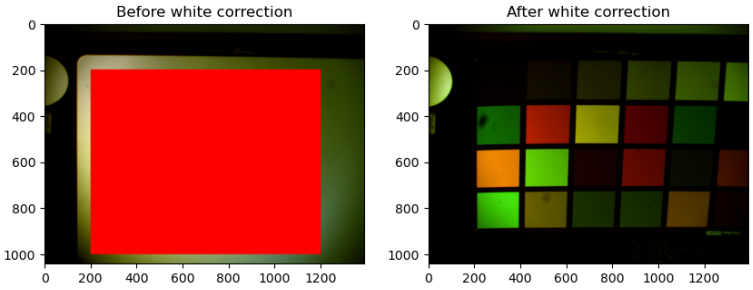


Figures were generated with the script shown in Code 7.

1.2.2 Nuance camera

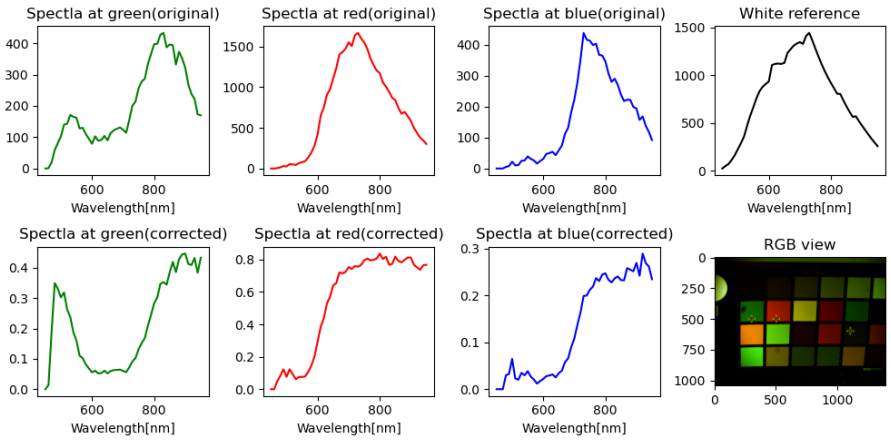
White correction of nuance camera is shown in Figure 5.

Figure 5: White correction of nuance camera with large reference



Spectra of white corrected image is shown in Figure 6.

Figure 6: Spectra of white corrected image



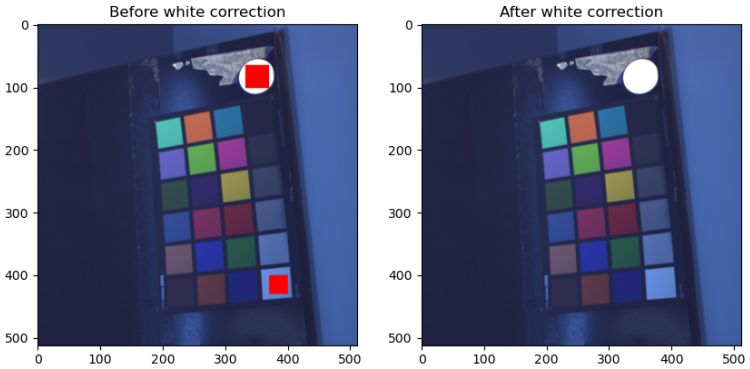
Nuance image was loaded with the script shown in Code 4. Figures were generated with the script shown in Code 3.

1.3 Color Checker 2 lamps using left and right white samples inside the image

1.3.1 SpecimIQ

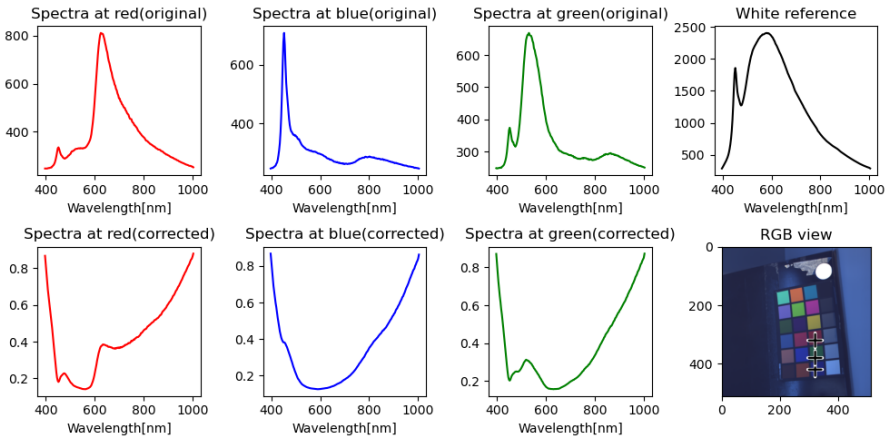
White correction of SpecimIQ is shown in Figure 7.

Figure 7: White correction of SpecimIQ



Spectra of white corrected image is shown in Figure 8.

Figure 8: Spectra of white corrected image

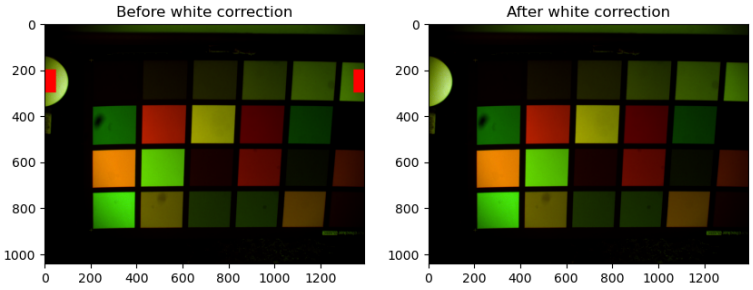


Figures were generated with the script shown in Code 6.

1.3.2 Nuance camera

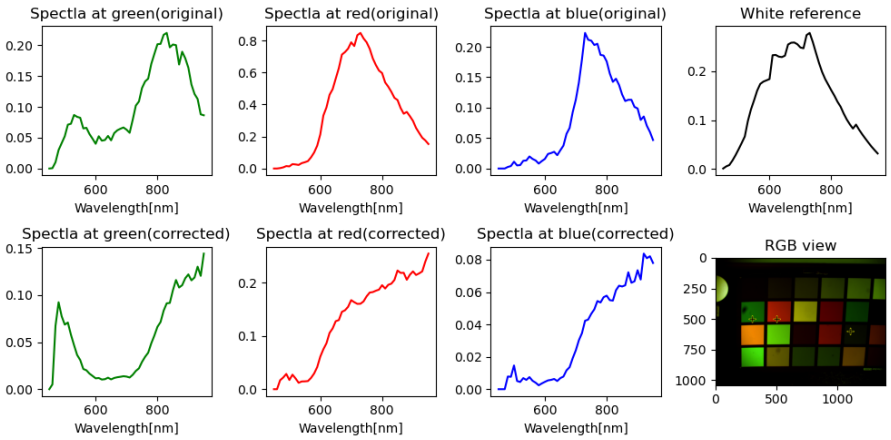
White correction of nuance camera is shown in Figure 9.

Figure 9: White correction of nuance camera



Spectra of white corrected image is shown in Figure 10.

Figure 10: Spectra of white corrected image

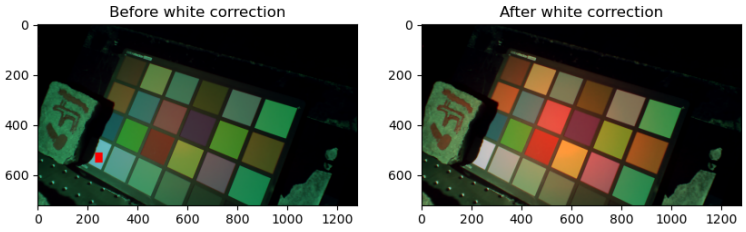


Nuance image was loaded with the script shown in Code 4. Figures were generated with the script shown in Code 2.

1.4 Tunable light source

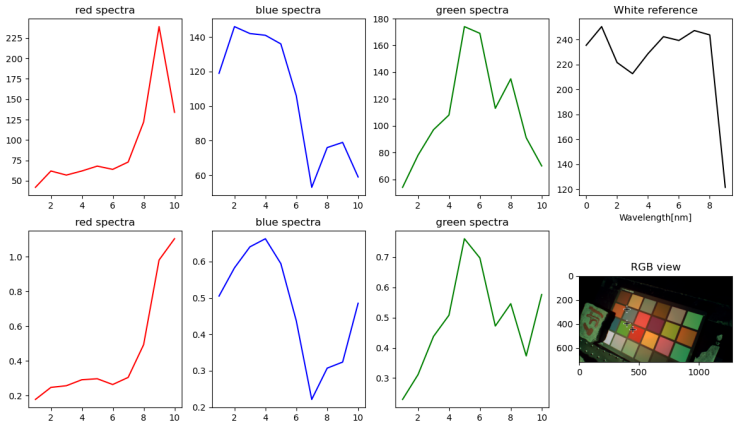
White correction of tunable light camera is shown in Figure 11.

Figure 11: White correction of tunable light source



Spectra of white corrected image is shown in Figure 12

Figure 12: Spectra of white corrected image



Nuance image was loaded with the script shown in Code 8. Figures were generated with the script shown in Code 9.

2 Tasks #2. Nuance camera

3 Tasks #3. Build ENVI spectral image from Tunable light source

4 Code

```
import matplotlib.pyplot as plt

from asi import path_config
from asi.draw import draw_multi_crosss, reconstruct_rgb_envi
from asi.io.load_envi import load_spectral_image
```

```
from asi.preprocess import load_white_corrected
from asi.utils import get_wavelengths

session1_root = path_config.measurements / "Session1"
spec_path = session1_root / "Specim scanner/Color_checker_8_binning/capture"

fig, axes = plt.subplots(1, 2, figsize=(10, 5))

colorchecker_path = spec_path / "solutions_scan_0110"
whiteref_path = spec_path / "WHITEREF_solutions_scan_0110"
darkref_path = spec_path / "DARKREF_solutions_scan_0110"

spectral_image, envi_header = load_spectral_image(colorchecker_path)
rgb_view = reconstruct_rgb_envi(spectral_image, envi_header)
axes[0].imshow(rgb_view)
axes[0].set_title("Before white correction")

spectral_image, envi_header = load_white_corrected(
    colorchecker_path,
    whiteref_path,
    darkref_path,
)
rgb_view = reconstruct_rgb_envi(spectral_image, envi_header)

axes[1].imshow(rgb_view)
axes[1].set_title("After white correction")
plt.show()

# Show spectra
colors = ["r", "g"]
positions = [(300, 500), (400, 1000)]
canvas = draw_multi_crosss(rgb_view, positions)

plt.rcParams["figure.dpi"] = 100
fig, axes = plt.subplots(1, 3, figsize=(10, 5), tight_layout=True)

wavelength = get_wavelengths(envi_header)
for pos, color, ax in zip(positions, colors, axes[:2]):
    ax.plot(wavelength, spectral_image[pos[1], pos[0], :], color=color)
    ax.set_title(f"Spectrum at {pos[0]}th pixel")
    ax.set_xlabel("Wavelength[nm]")

axes[2].imshow(canvas)
axes[2].set_title("RGB view of spectral image")

plt.show()
```

Code 1: White correction for Specium Scanner

```
import numpy as np
from matplotlib import pyplot as plt

from asi import path_config
from asi.draw import draw_multi_crosss, reconstruct_rgb, select_area
from asi.io.load_nuance import load_nuance_image

session1 = path_config.measurements / "session1"
nuance = session1 / "Nuance"
```

```

# White correction with small reference

fig, axes = plt.subplots(1, 2, figsize=(10, 5))
root = nuance / "colorchecker 2lights"

white_pos_list = [
    (slice(200, 300), slice(0, 50)),
    (slice(200, 300), slice(-50, -1)),
]


spectral_image, wavelengths = load_nuance_image(root)
spectral_image = spectral_image.astype(np.float64)
spectral_image /= spectral_image.max()

original_rgb = reconstruct_rgb(spectral_image, wavelengths)
for white_pos in white_pos_list:
    original_rgb = select_area(original_rgb, white_pos)
original_rgb /= original_rgb.max()
original_rgb = original_rgb.clip(0, 1)
axes[0].imshow(original_rgb)
axes[0].set_title("Before white correction")

white_sq_list = []

# White correction with selected area
for white_pos in white_pos_list:
    white_sq = spectral_image[white_pos]
    a, b, band = white_sq.shape
    white_sq = white_sq.reshape(a * b, band)

    # replace nonzero elements with minimum value
    nonzero_elements = white_sq[white_sq != 0]
    min_elm = nonzero_elements.min()
    white_sq_list.append(white_sq)

white_sq = np.vstack(white_sq_list)
whiteref = white_sq.mean(axis=0)

# spectral_image *= 1.5
# spectral_image = spectral_image.clip(0, 1)
white_corrected = spectral_image / whiteref
white_corrected /= white_corrected.max()
white_corrected = white_corrected.clip(0, 1)
del original_rgb

white_corrected_rgb_view = reconstruct_rgb(white_corrected, wavelengths)
axes[1].imshow(white_corrected_rgb_view)
axes[1].set_title("After white correction")

plt.show()

# Show spectra
colors = ["g", "r", "b"]
color_names = ["green", "red", "blue"]
positions = [(300, 500), (500, 500), (1100, 600)]
```

```

plt.rcParams["figure.dpi"] = 100
fig, axes = plt.subplots(2, 4, figsize=(10, 5), tight_layout=True)
print(axes)

axes1, axes2 = axes
for pos, color, color_name, ax in zip(positions, colors, color_names, axes2):
    print(ax)
    ax.plot(wavelengths, white_corrected[pos[1], pos[0], :], color=color)
    ax.set_title(f"Spectla at {color_name}(corrected)")
    ax.set_xlabel("Wavelength[nm]")

for pos, color, color_name, ax in zip(positions, colors, color_names, axes1):
    print(ax)
    ax.plot(wavelengths, spectral_image[pos[1], pos[0], :], color=color)
    ax.set_title(f"Spectla at {color_name}(original)")
    ax.set_xlabel("Wavelength[nm]")


axes1[-1].plot(wavelengths, whiteref, color="k")
axes1[-1].set_title("White reference")
axes1[-1].set_xlabel("Wavelength[nm]")

canvas = draw_multi_crosss(white_corrected_rgb_view, positions)
axes2[-1].imshow(canvas)
axes2[-1].set_title("RGB view")

plt.show()
```

Code 2: White correction for Nuance Cmaera with small reference

```
import numpy as np
from matplotlib import pyplot as plt

from asi import path_config
from asi.draw import draw_multi_crosss, reconstruct_rgb, select_area
from asi.io.load_nuance import load_nuance_image

session1 = path_config.measurements / "session1"
nuance = session1 / "Nuance"

# White correction with large reference

# load white image

root = nuance / "white 2lights"

white_image, wavelengths = load_nuance_image(root)
white_image = white_image.astype(np.float64)


fig, axes = plt.subplots(1, 2, figsize=(10, 5))

white_pos = (slice(200, 1000), slice(200, 1200))


white_rgb = reconstruct_rgb(white_image, wavelengths)
```

```
white_rgb = select_area(white_rgb, white_pos)
white_rgb /= white_rgb.max()
white_rgb = white_rgb.clip(0, 1)
axes[0].imshow(white_rgb)
axes[0].set_title("Before white correction")


# White correction with selected area
white_sq = white_image[white_pos]

# replace nonzero elements with minimum value
nonzero_elements = white_sq[white_sq != 0]
min_elm = nonzero_elements.min()
white_sq = white_sq.clip(min_elm, None)


# load spectral image
root = nuance / "colorchecker 2lights"
spectral_image, wavelengths = load_nuance_image(root)

# apply white correction
whiteref = white_sq.mean((0, 1))
white_corrected = spectral_image / whiteref
white_corrected /= white_corrected.max()
white_corrected = white_corrected.clip(0, 1)
del white_rgb

white_corrected_rgb_view = reconstruct_rgb(white_corrected, wavelengths)
axes[1].imshow(white_corrected_rgb_view)
axes[1].set_title("After white correction")

plt.show()

# Show spectra
colors = ["g", "r", "b"]
color_names = ["green", "red", "blue"]
positions = [(300, 500), (500, 500), (1100, 600)]


plt.rcParams["figure.dpi"] = 100
fig, axes = plt.subplots(2, 4, figsize=(10, 5), tight_layout=True)
print(axes)

axes1, axes2 = axes
for pos, color, color_name, ax in zip(positions, colors, color_names, axes2):
    print(ax)
    ax.plot(wavelengths, white_corrected[pos[1], pos[0], :], color=color)
    ax.set_title(f"Spectla at {color_name}(corrected)")
    ax.set_xlabel("Wavelength[nm]")

for pos, color, color_name, ax in zip(positions, colors, color_names, axes1):
    print(ax)
    ax.plot(wavelengths, spectral_image[pos[1], pos[0], :], color=color)
    ax.set_title(f"Spectla at {color_name}(original)")
    ax.set_xlabel("Wavelength[nm]")


axes1[-1].plot(wavelengths, whiteref, color="k")
```

```
axes1[-1].set_title("White reference")
axes1[-1].set_xlabel("Wavelength[nm]")

canvas = draw_multi_crosss(white_corrected_rgb_view, positions)
axes2[-1].imshow(canvas)
axes2[-1].set_title("RGB view")

plt.show()
```

Code 3: White correction for Nuance Cmaera with large reference

```
from pathlib import Path

import numpy as np
import tifffile as tiff
from natsort import natsorted


def load_nuance_image(tiff_root: Path) -> tuple[np.ndarray, list[float]]:
    wavelengths: list[float] = []
    imgs = []
    tiff_list = list(tiff_root.glob("*.tif"))
    tiff_list = natsorted(tiff_list, reverse=False)
    for tiff_path in tiff_list:
        img = tiff.imread(tiff_path)
        wavelength = float(tiff_path.stem.split("_")[-1])
        imgs.append(img)
        wavelengths.append(wavelength)

    spectral_image = np.stack(imgs, axis=-1)
    spectral_image = spectral_image.astype(np.float64)
    return spectral_image, wavelengths
```

Code 4: Load Nuance Cmaera

```
from pathlib import Path

import numpy as np


def parse_envi_header(lines: list) -> dict[str, str]:
    """
    Parses ENVI file content into a structured dictionary
    This code was written with Github Copilot
    """
    envi_data = {}
    in_block_key = None

    for line_org in lines:
        line = line_org.strip()

        # Skip empty lines
        if not line:
            continue

        # Handle multiline blocks
        if in_block_key:
            if line.endswith("}"):
```

```
                # Closing multiline
                envi_data[in_block_key] += line[:-1].strip()
                in_block_key = None
            else:
                # Continue multiline
                envi_data[in_block_key] += line
            continue

        # Key-value pair parsing
        if "=" in line:
            key, value = map(str.strip, line.split("=", 1))
            key = key.lower().replace(" ", "_")  # Normalize key format

            # Handle block values
            if value.startswith("{"):
                # Handle multiline block
                in_block_key = key
                # Remove opening '{'
                value = value[1:].strip()
                if value.endswith("}"):
                    # Single-line block
                    envi_data[key] = value[:-1]
                    in_block_key = None
                else:
                    # Start multiline block
                    envi_data[key] = value
            else:
                # Single-line value
                envi_data[key] = value
    return envi_data


def load_envi_header(hdr_file: Path) -> dict[str, str]:
    """Loads ENVI header file."""
    with hdr_file.open(encoding="utf-8") as f:
        header_content = f.readlines()
    envi_header = parse_envi_header(header_content)
    return envi_header


def load_spectral_image(file_stem: Path) -> tuple[np.ndarray, dict[str, str]]:
    """Loads spectral image from ENVI format."""
    # Load ENVI header
    hdr_file = file_stem.with_suffix(".hdr")
    envi_header = load_envi_header(hdr_file)

    # Load parameters
    interleave = str(envi_header["interleave"])
    lines = int(envi_header["lines"])
    samples = int(envi_header["samples"])
    bands = int(envi_header["bands"])
    data_type = int(envi_header.get("data type", 12))

    # Map ENVI data type to NumPy dtype
    data_type_map = {
        1: np.uint8,
        2: np.int16,
        3: np.int32,
```

```
        4: np.float32,
        5: np.float64,
        6: np.complex64,
        9: np.complex128,
        12: np.uint16,
        13: np.uint32,
        14: np.int64,
        15: np.uint64,
    }

    if data_type not in data_type_map:
        msg = f"Unsupported data type: {data_type}"
        raise ValueError(msg)

    dtype = data_type_map[data_type]

    # Load raw data
    raw_file = file_stem.with_suffix(".raw")
    with open(raw_file, "rb") as f:
        raw = np.fromfile(f, dtype=dtype)

    # define shape and transpose order by interleave method
    if interleave.upper() == "BIL":
        new_shape = (lines, bands, samples)
        axis_order = (0, 2, 1)
    elif interleave.upper() == "BIP":
        new_shape = (lines, samples, bands)
        axis_order = (0, 1, 2)
    elif interleave.upper() == "BSQ":
        new_shape = (bands, samples, lines)
        axis_order = (0, 2, 1)
    else:
        msg = f"Interleave {interleave} not supported."
        raise ValueError(msg)

    spectral_image = raw.reshape(new_shape)
    # change axis order to 'lines, samples, bands'
    spectral_image = np.transpose(spectral_image, axis_order)

    return spectral_image, envi_header
```

Code 5: Load ENVI format images

```
import numpy as np
from matplotlib import pyplot as plt

from asi import path_config
from asi.draw import draw_multi_crosss, reconstruct_rgb_envi, select_area
from asi.io.load_envi import load_spectral_image
from asi.preprocess import load_white_corrected
from asi.utils import get_wavelengths

specim_iq_root = path_config.measurements / "Session1" / "SpecimIQ"

path_404 = specim_iq_root / "404" / "capture"


# White correction with small reference
```

```
fig, axes = plt.subplots(1, 2, figsize=(10, 5))

image_path = path_404 / "404"
spectral_image, envi_header = load_spectral_image(image_path)


white_pos_list = [
    (slice(65, 102), slice(332, 370)),
    (slice(400, 430), slice(370, 400)),
]

original_rgb = reconstruct_rgb_envi(spectral_image, envi_header)
for white_pos in white_pos_list:
    original_rgb = select_area(original_rgb, white_pos)

original_rgb *= 1.5
original_rgb = original_rgb.clip(0, 1)

axes[0].imshow(original_rgb)
axes[0].set_title("Before white correction")

# White correction with selected area
white_sq_list = []
for white_pos in white_pos_list:
    white_sq = spectral_image[white_pos]
    a, b, band = white_sq.shape
    white_sq = white_sq.reshape(a * b, band)

    # replace nonzero elements with minimum value
    nonzero_elements = white_sq[white_sq != 0]
    min_elm = nonzero_elements.min()
    white_sq_list.append(white_sq)

white_sq = np.vstack(white_sq_list)
whiteref = white_sq.mean(axis=0)

white_corrected = spectral_image / whiteref

white_corrected_rgb_view = reconstruct_rgb_envi(white_corrected, envi_header)
white_corrected_rgb_view *= 1.5
white_corrected_rgb_view = white_corrected_rgb_view.clip(0, 1)


axes[1].imshow(white_corrected_rgb_view)
axes[1].set_title("After white correction")

plt.show()

# Show spectra
colors = ["r", "b", "g"]
color_names = ["red", "blue", "green"]
positions = [(320, 320), (320, 420), (320, 380)]

wavelengths = get_wavelengths(envi_header)


fig, axes = plt.subplots(2, 4, figsize=(10, 5), tight_layout=True)

```

```
axes1, axes2 = axes
for pos, color, color_name, ax in zip(positions, colors, color_names, axes2):
    ax.plot(wavelengths, white_corrected[pos[1], pos[0], :], color=color)
    ax.set_title(f"Spectra at {color_name}(corrected)")
    ax.set_xlabel("Wavelength[nm]")

for pos, color, color_name, ax in zip(positions, colors, color_names, axes1):
    ax.plot(wavelengths, spectral_image[pos[1], pos[0], :], color=color)
    ax.set_title(f"Spectra at {color_name}(original)")
    ax.set_xlabel("Wavelength[nm]")


axes1[-1].plot(wavelengths, whiteref, color="k")
axes1[-1].set_title("White reference")
axes1[-1].set_xlabel("Wavelength[nm]")

canvas = draw_multi_crosss(white_corrected_rgb_view, positions)
axes2[-1].imshow(canvas)
axes2[-1].set_title("RGB view")

plt.show()
```

Code 6: White correction for SpecimIQ with small reference

```
from matplotlib import pyplot as plt

from asi import path_config
from asi.draw import draw_multi_crosss, reconstruct_rgb_envi, select_area
from asi.io.load_envi import load_spectral_image
from asi.utils import get_wavelengths

specim_iq_root = path_config.measurements / "Session1" / "SpecimIQ"


# White correction with small reference
fig, axes = plt.subplots(1, 3, figsize=(15, 5))

image_path = specim_iq_root / "404" / "capture" / "404"
spectral_image, envi_header = load_spectral_image(image_path)


original_rgb = reconstruct_rgb_envi(spectral_image, envi_header)

# original_rgb *= 1.5
# original_rgb = original_rgb.clip(0, 1)


axes[0].imshow(original_rgb)
axes[0].set_title("Before white correction")

white_path = specim_iq_root / "405" / "capture" / "405"
white_image, white_envi_header = load_spectral_image(white_path)

white_pos = (slice(200, 480), slice(100, 380))
white_rgb_view = reconstruct_rgb_envi(white_image, white_envi_header)
white_rgb_view = select_area(white_rgb_view, white_pos)

axes[1].imshow(white_rgb_view)
```

```
axes[1].set_title("Selected white area")

white_sq = white_image[white_pos]

# White correction with selected area
whiteref = white_sq.mean(axis=(0,1))

white_corrected = spectral_image / whiteref

white_corrected_rgb_view = reconstruct_rgb_envi(white_corrected, envi_header)
# white_corrected_rgb_view *= 2.5
# white_corrected_rgb_view = white_corrected_rgb_view.clip(0, 1)


axes[2].imshow(white_corrected_rgb_view)
axes[2].set_title("After white correction")

plt.show()

# Show spectra
colors = ["r", "b", "g"]
color_names = ["red", "blue", "green"]
positions = [(320, 320), (320, 420), (320, 380)]

wavelengths = get_wavelengths(envi_header)


fig, axes = plt.subplots(2, 4, figsize=(10, 5), tight_layout=True)

axes1, axes2 = axes
for pos, color, color_name, ax in zip(positions, colors, color_names, axes2):
    ax.plot(wavelengths, white_corrected[pos[1], pos[0], :], color=color)
    ax.set_title(f"Spectra at {color_name}(corrected)")
    ax.set_xlabel("Wavelength[nm]")

for pos, color, color_name, ax in zip(positions, colors, color_names, axes1):
    ax.plot(wavelengths, spectral_image[pos[1], pos[0], :], color=color)
    ax.set_title(f"Spectra at {color_name}(original)")
    ax.set_xlabel("Wavelength[nm]")


axes1[-1].plot(wavelengths, whiteref, color="k")
axes1[-1].set_title("White reference")
axes1[-1].set_xlabel("Wavelength[nm]")

canvas = draw_multi_crosss(white_corrected_rgb_view, positions)
axes2[-1].imshow(canvas)
axes2[-1].set_title("RGB view")

plt.show()
```

Code 7: White correction for SpecimIQ with large reference

```
from pathlib import Path

import cv2
import numpy as np

```

```python
# CONSTS
MAX_PIXEL_VALUE = 255
MIN_PIXEL_VALUE = 0


def parse_png_path(path: Path) -> tuple[str, int, float]:
    # parse path of tunable files
    path_parts = path.stem.split(",")
    name = path_parts[0]
    ch_info = path_parts[1]
    exp_info = path_parts[2]
    ch_id = int(ch_info.strip().split(" ")[1])
    exp_id = float(exp_info.strip().split(" ")[1])
    return name, ch_id, exp_id


def gen_template(name: str, ch: int) -> str:
    return f"{name}, ch {ch}, exp * ms.png"


def get_score(im: np.ndarray) -> int:
    nb_max = (im == MAX_PIXEL_VALUE).sum()
    nb_min = (im == MIN_PIXEL_VALUE).sum()
    return nb_max + nb_min


def load_tunable_image(
    tunable_root: Path, name: str, white_pos: tuple[slice, slice]
) -> tuple[np.ndarray, list[int]]:
    png_list = list(tunable_root.glob("*.png"))
    channels = {parse_png_path(p)[1] for p in png_list}
    channels = sorted(channels)
    imgs = []
    # chose minimum score image
    for ch in channels:
        best_im = None
        best_score = 1e9
        template = gen_template(name, ch)
        for png_path in tunable_root.glob(template):
            # Select minimum score image. Score is calculated from number of unvalid pixels
            im = cv2.imread(str(png_path), cv2.IMREAD_GRAYSCALE)
            if im[white_pos].max() == MAX_PIXEL_VALUE:
                continue
            score = get_score(im)
            if score < best_score:
                best_score = score
                best_im = im
        if best_im is None:
            msg = f"Channel {ch} not found."
            raise ValueError(msg)
        imgs.append(best_im)

    spectral_image = np.stack(imgs, axis=-1)
    return spectral_image, channels
```

Code 8: Load Tunable Light Sources images

```python
import matplotlib.pyplot as plt
import numpy as np

from asi import path_config
from asi.draw import draw_multi_crosss, select_area
from asi.io import load_tunable_image

# Configurations
WHITE_POS = (slice(510, 550), slice(230, 260))
SELECT_CHANNELS = [9, 4, 0]
# LOAD IMAGE
session1 = path_config.measurements / "session1"
tunable_root = session1 / "Tunable light sorces" / "ImagesASI"

spectral_image, channels = load_tunable_image(
    tunable_root, name="colorchecker", white_pos=WHITE_POS
)
spectral_image = spectral_image.astype(np.float64)

# Make RGB view
rgb_view = spectral_image[..., SELECT_CHANNELS]
# Postprocess for preview
rgb_view /= rgb_view.max()
rgb_view *= 0.8
rgb_view = rgb_view.clip(0, 1)

# Select white area for correction
rgb_view = select_area(rgb_view, WHITE_POS)

# Apply white correction
white_sq = spectral_image[WHITE_POS]
whiteref = white_sq.mean(axis=(0, 1))
white_corrected = spectral_image / whiteref

# RGB view after white correction
white_corrected_rgb_view = white_corrected[..., SELECT_CHANNELS]
white_corrected_rgb_view /= white_corrected_rgb_view.max()
white_corrected_rgb_view *= 1.2
white_corrected_rgb_view = white_corrected_rgb_view.clip(0, 1)


# Plot images
fig, axes = plt.subplots(1, 2, figsize=(10, 5))
axes[0].imshow(rgb_view)
axes[0].set_title("Before white correction")

axes[1].imshow(white_corrected_rgb_view)
axes[1].set_title("After white correction")

plt.show()

# show spectra
red_pos = (450, 450)
blue_pos = (400, 280)
green_pos = (400, 400)


pos_list = (red_pos, blue_pos, green_pos)
```

```
colors = ["r", "b", "g"]
color_names = ["red", "blue", "green"]

fig, axes = plt.subplots(2, 4, figsize=(15, 8))

org_axes, white_axes = axes
for axes, image in zip([org_axes, white_axes], [spectral_image, white_corrected
    ]):
    for pos, color_name, color, ax in zip(pos_list, color_names, colors, axes):
        ax.plot(channels, image[pos[1], pos[0], :], color=color)
        ax.set_title(f"{color_name} spectra")


org_axes[-1].plot(whiteref, color="k")
org_axes[-1].set_title("White reference")
org_axes[-1].set_xlabel("Wavelength[nm]")

canvas = draw_multi_crosss(white_corrected_rgb_view, pos_list)
white_axes[-1].imshow(canvas)
white_axes[-1].set_title("RGB view")

plt.show()
```

Code 9: White correction for Tunable Light Sources with small white reference